Analysis of the causes of fracture of metal parts of 220KV transmission towers and protective measures

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Abstract. The corrosion causes of a 220kV transmission tower grounding flat steel were experimentally analyzed by macroscopic inspection, chemical composition analysis, microscopic structure inspection, corrosion product morphology and energy spectrum, galvanized layer thickness test, soil physical and chemical property analysis, and other test methods. The results indicate that the combined effect of chemical and electrochemical corrosion of the soil and stray current corrosion has resulted in the development of severe corrosion damage, which has ultimately led to the failure of the grounding flat steel. Furthermore, the requisite protective measures and recommendations are provided for the aforementioned scenarios.

1. Introduction

The transmission line is undoubtedly one of the core components of the power system, which plays an indispensable and key role in the transmission and distribution of electric energy. As the skeleton supporting transmission lines, the reliability of transmission towers is an important guarantee for the safe and stable operation of power grids. In a heavily industrialized and humid environment, the corrosion rate of the metal connectors of the transmission tower will be significantly accelerated. Once these metal components have been significantly corroded, the safety and stability of the transmission tower will be severely compromised, which will result in the occurrence of large-scale power outages and pose a significant security risk[1-3].

In the course of their inspection, the power supply bureau inspectors discovered that ground flat steel for 220 kV transmission pylons was corroded and fractured. In order to identify the root cause of corrosion and prevent similar failures from occurring again, this paper employs a multi-faceted approach, analyzing the corrosion mechanism and corrosion behavior of the failed grounding flat steel through a combination of physical and chemical testing methods. At the same time, the corresponding protective measures are proposed in order to provide technical support for the safe operation and maintenance of power grid equipment.

2. physical and chemical analysis

2.1. Macro inspection

Corrosion damage to the transmission tower grounding flat steel macroscopic morphology observation, found that the transmission tower grounding flat steel buried in the underground part of the surface of the galvanized layer has been completely peeled off and obvious corrosion thinning fracture, part of the region of the grounding flat steel has been serious crisping, perforation. The yellowish-brown corrosion products on the grounding flat steel surface are distributed in flakes, some of these corrosion products were missing and no significant mechanically damage or plastically deformation was detected. Grounding flat steel above ground part of the hot dip galvanizing combined with painting double anti-corrosion system, Surface of galvanized coating exhibits no obvious corrosion after measuring its thickness between 72.3 and 95.5 micrometers. The average galvanized layer thickness was found to be 87.5 μm, which is in accordance with the standard requirements (minimum galvanizing thickness ≥ 70 μm, average thickness of ≥ 85 μm). This is illustrated in Figure 1.
2.2. Morphology of corrosion products and energy spectra analyze

Scanning electron microscopy (SEM) was used to investigate the microscopic characteristics of corrosion products on the transmission tower grounding flat steel that had been subjected to corrosion damage. The results of the detection are presented in Figure 2. The corrosion products on the surface of the grounded flat steel exhibit a dense, lamellar structure, with the presence of lumpy particles of varying sizes.

Fig. 1. Macroscopic morphology of corrosion damaged tower grounding flat steel

Fig. 2. SEM morphology of corrosion products formed on grounding flat steel that has been damaged by corrosion.
An energy spectrum analyzer (EDS) was utilized to determine compositional characteristics of corrosion products on the transmission tower grounding flat steel that had been subjected to corrosion damage. The findings of the examination are presented in Figures 3 and Table 1. The corrosion products of grounding flat steel have been observed to be primarily composed of iron oxides and chlorides, in addition to sulfates. Additionally, it is evident that the majority of silicon is present in the form of silicon oxide on the surface of the grounding flat steel. This can be attributed to the adsorption of gravel particles on the steel's surface.

**Table 1.** The results of the analysis of the energy spectrum of corrosion products (wt%).

<table>
<thead>
<tr>
<th>Detecting Components</th>
<th>Fe</th>
<th>O</th>
<th>Si</th>
<th>S</th>
<th>Cl</th>
<th>Na</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured value</td>
<td>68.72</td>
<td>22.1</td>
<td>0.84</td>
<td>0.44</td>
<td>7.63</td>
<td>0.28</td>
</tr>
</tbody>
</table>

### 2.3. Physical and chemical analysis of soils

Soil samples were collected in the vicinity of the corrosion-damaged transmission tower grounding body and subjected to physicochemical property and ion content analysis. The results of this analysis are presented in Table 2. It can be found that the soil in the vicinity of the grounding body of the tower contains as much as 0.55g/kg of chloride ions, as much as 0.43g/kg of sulfur, with a conductivity of 1,373μs/cm and a pH of 8.95, which soil is classified as high-salinity alkaline.

**Table 2.** Results of physical and chemical properties and ion content of soil samples

<table>
<thead>
<tr>
<th>Detection items</th>
<th>Cl-/ (g/kg)</th>
<th>sulfur content (g/kg)</th>
<th>conductivity / (μs/cm)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured value</td>
<td>0.55</td>
<td>0.43</td>
<td>1373</td>
<td>8.95</td>
</tr>
</tbody>
</table>

### 2.4. Microstructure Inspection and Analysis

Corrosion damage to the transmission tower grounding flat steel samples for metallurgical microstructure analysis, It is evident that corrosion has occurred on the grounding flat steel matrix organization for a small amount of banded pearlite + block ferrite, surface of the flat steel there are varying depths of corrosion pits, and it has been observed that a significant number of corrosion holes have penetrated the grounding steel plate. This is illustrated in Figure 4.

![Microstructure Inspection and Analysis](image)

**Fig. 4.** Metallographic organization of corrosion damaged tower grounding flat steel

### 3. Analysis and discussion

A macro-physical analysis revealed that the underground portion of the corroded tower ground flat steel has completely lost its zinc coating and has obviously corroded and thinned. In addition, part of the region of the grounding flat steel has been seriously crispy,
perforation. The corrosion product is yellow-brown and distributed in layers on the metal surface. Furthermore, part of these corrosion products were missing and no significant mechanically damage or plastically deformation was detected.

The grounding flat steel that is exposed to the atmosphere has been subjected to a double anti-corrosion system comprising hot dip galvanizing and painting. No evidence of corrosion was observed, and thickness of zinc coating on metal surfaces was measured to be 72.3-95.5 μm, with an average thickness of 87.5 μm, which is consistent with the standard specifications. The metallographic analysis revealed that corrosion has occurred on the grounding flat steel matrix organization for a small amount of banded pearlite + block ferrite. The surface of the flat steel ground rod exhibits corrosion pits of varying depths. In some instances, the corrosion pits have penetrated the entire rod, forming corrosion holes.

The analysis of corrosion products revealed that the corrosion product on the surface of flat steel exhibits a dense and complex structure, presenting as deep ravines with attached particles of varying sizes. The primary components are iron oxide, chloride, and sulfate. The silicon present on the surface is predominantly in the form of silicon oxide, which can be identified as sand and gravel attached to the surface of the flat steel.

The physical and chemical properties of the soil revealed that the soil near the grounding body contains up to 0.55 g/kg of chloride ions, up to 0.43 g/kg of sulfur, a conductivity of 1373 μs/cm, and a pH of 8.95. The soil is alkaline and high in salt, which can exacerbate corrosion of the grounding metal material and thereby affect the safe operation of the power grid.

The Huanghe irrigation area is home to a transmission line, surrounded by cultivated land irrigated by the Yellow River, which is alkaline and highly saline. Tests have shown that the soil contains high levels of sulfate and chloride. Given their solubility in water, both substances decompose in water, producing chlorine and sulfate ions. This results in the corrosion of the surrounding soil. The degree of corrosion increases with the concentration of the substances present[4-5]. The specific reasons for this phenomenon are mainly reflected in the following aspects. Destruction of the passivation film: Chloride ions have a smaller radius and can easily penetrate the passivation film on the surface of the galvanized layer and adsorb on the metal surface, causing significant damage to the passivation film. In soil with a high sulfate content, the zinc coating is susceptible to corrosion, forming zinc sulfate, which is soluble and causes the hot-dip zinc coating to rapidly consume and eventually fail.[6-8] Conductivity. The ionic pathway is one of the necessary conditions for the formation of a corrosion cell. The presence of chloride and sulfate ions in the soil strengthens the ionic pathway, reducing the resistance of the cathode and anode, increasing the efficiency of the corrosion current, and ultimately accelerating electrochemical corrosion. Anodic depolarization. In the event that the generated ferrous iron ions are unable to diffuse into the soil in a timely manner and accumulate on the anode surface, the anodic reaction will be impeded. The chemical reaction between chloride ions and ferrous iron ions results in the formation of ferrous chloride, while the subsequent reaction between free chloride ions produces additional ferrous iron ions, thereby forming soluble products that can penetrate surface corrosion layer and base metal, accelerating the anodic process of metal corrosion[9-10].

4. Conclusion and preventive measures

In summary, the primary cause of corrosion damage to the 220 kV transmission tower ground flat steel is its location in the Yellow River irrigation area, which is a high-salinity region. The soil in this area contains elevated levels of chloride and sulfate ions. Over time, the transmission tower flat steel is continuously exposed to the combined effects of various corrosion mechanisms, including electrochemical, chemical, and stray current corrosion has resulted in the development of severe corrosion damage, which has ultimately led to the failure of the steel.

It is recommended that regular examination of the grounding of transmission towers in high-salinity areas, such as the Yellow River irrigation zone, be conducted with a view to identifying potential issues and implementing appropriate corrective measures. In the event that corrosion-reduced or broken flat steel grounding is identified, it is imperative that it be replaced in a timely manner. The newly replaced flat steel grounding should be subjected to the hot-dip galvanizing process, which will render it anti-corrosion. The minimum galvanizing thickness should not be less than 70μm, and the average thickness should not be less than 85μm. Secondly, given that transmission tower grounding device has been operating in high-salinity soil for a considerable period of time, it is possible to increase the cross-sectional area of the grounding body or to replace the material with copper/copper-clad steel, it can effectively improve corrosion resistance and prolong the service life of the grounding grid.

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References


