# Anti-Corrosion Design of Grounding Body in Power Transmission Line with Cathode Protection Method

Rui Liu[1,a], Peng Huang[1,b], Juan Mo[1,c]

[1]China Electric Power Research Institute, Beijing 100192, China

[a]email: liurui@epri.sgcc.com.cn

[b]email: huangp@epri.sgcc.com.cn

[c]email: mojuan@epri.sgcc.com.cn

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**Abstract:** The grounding body in the power transmission line engineering is buried underground for long term, which will be eroded by soil environment. If it passes by the DC grounding pole, corrosion will be aggravated. Aiming at the 220kV line engineering in 500kV Dongpo substation and the 110kV line engineering in the 220kV Yongfeng substation, this paper studies to apply sacrificial anode protection method to carry out anti-corrosion design of the grounding body in the line for existing corrosion in the grounding body in the line engineering.

## Preface

The grounding body in the power transmission line engineering which is buried under ground not only suffers chemical and electrical chemical corrosion in around soil environment but also suffers electricity corrosion caused by leakage current and connection of different materials. In case corrosion is serious that grounding resistance of the grounding body is higher than safety scope, even through it has not reached breakage degree, it is liable to cause accident, it evenly endanger safety of the grid and human body.

The DC grounding pole is essential composition part of the super-high voltage DC power transmission system. For the DC power transmission system with the single pole ground wire returning way, current in earth of its grounding pole is continuous DC current of engineering. When working current flows through ground through the DC grounding pole, current in earth of its grounding pole is DC current that the engineering is continuously in service. When working current flows into ground through the DC grounding pole, electricity corrosion will generate on the underground metal member around the grounding pole.

Both the 220kV line engineering in the 500kV Dongpo substation and the 110kV line engineering in the 220kV Yongfeng substation pass through the same power transmission corridor, resistance rate of soil is about 20Ω.m, and it passes through west side of the grounding pole at Guangzhou side of ±500kV Tianguang direct current. Carry out detection of the soil in the corridor which has middle and weak corrosion. When the ±500kV Tianguang DC line is considered to apply operation of the single pole, it may have corrosion on the grounding body around the line, therefore it is necessary to apply anti-corrosion design on the grounding body of the above line.

## Engineering conditions

The ±500kV Tianshengqiao ~ Guangzhou DC power transmission line starts from the Tianshengqiao current conversion station at boundary of Qian and Gui, it reaches Guangzhou current conversion station in Guangdong province at east. Whole length of the lien is 980km, current is 1800A and transmission power of the double poles is 1800MW, which is first long distance, large power and ultra-high voltage DC power transmission engineering in Southern Grid. The grounding pole at Guangzhou side of ±500kV Tianguang DC applies the concentric double ring structure, the diameters of the inner ring and the outer ring are 480m and 690m respectively, and bury depth is 3m.

Minimum distance between the long term standby 220kV Dongpo ~ Kangle double circuits of the 220kV line engineering in 500kV Dongpo substation is only about 4.5km. Minimum between the

 

110kV Yongfeng ~ Kangle A and B double lines, the 110kV Yongfeng ~ Xiaobian, Sanshui double circuit line, the 110kV Yongfeng ~ Datang, Kangle double circuit of the 220kV Yongfeng outgoing line engineering and the grounding pole is only about 6km.

According to regulations of 《Design technical regulations of high voltage DC power transmission ground returning system》[1]: "1) If the lightening proof line is set up in the whole line, the lightening proof wire close to the grounding pole (at least 10km long) must be effectively insulated; 2) For the line which is closed to the grounding pole 5km at least, the power transmission tower shall apply the single point grounding; 3) furthermore for the power transmission tower which is close to grounding less than 2km, the foundation to ground and the power transmission tower to ground shall be insulated (when the grounding lead wire is broken, contact resistance between the grounding device and the power transmission tower shall be greater than 500Ω)". It is specified in 《Design code for 110kV ~ 750kV overhead power transmission line》[2]:"When distance between the line and the DC power transmission engineering is less than 5km, the grounding wire (OPGW) shall be insulated, when it is greater or equals to 5km, the grounding wire (OPGW) is determined to be insulated or not through calculation".

After the grounding devices in the several existing lines around the grounding pole are detected for corrosion, there are corrosion conditions at different degree,which is shown in fig.1. Collect the soil sample, and the grounding lab of State Grid is entrusted to detect the soil sample, corrosion class of the soil is mainly middle and weak, which has certain corrosion influence on the foundation distribution bar and the grounding device.

Fig. 1 Grounding wires in No 35, 36 power transmission towers in 110kV Luliu line which are corroded.

## Cathode protection

The cathode protection technology is one of the electrical and chemical protection technology, which is earliest applied in the vessel, pipe transportation etc fields. It is gradually applied in anti-corrosion of the grounding network of the substation in recent years[3-6]. Its basic principle is the battery principle in electrochemistry, i.e., in the dielectric (sea water, fresh water and soil etc medium), the protected metal material is taken as cathode, and impose certain DC current on it, and it generate cathode polarization. When potential of the metal material is negative at some one potential value, electrochemical un-evenness on surface of this metal material is eliminated, solution process of the corroded cathode is inhibited effectively, and protection purpose is realized[7].

According to different way to provide cathode current, the cathode protection method consists of the sacrificial anode method and external current impose method two methods. Sacrificial anode method is to connect the protected metal by one more active metal or alloy, this alloy will continuously corrode current generated from solution so as to protect the protected metal. The material which can be used as the sacrificial anode consist of the zinc alloy, the magnesium alloy and the aluminium alloy etc. The external current impose method cathode protection technology is a method to provide cathode protection current to the grounding body through the external automatic control DC constant potential power supply. It conveys the demanded protection current to the grounding body metal as the cathode through the auxiliary anode which is embedded underground, and protection current is controlled through the electrochemical potential of the grounding network measured by a reference electrode. Current outputted by this method is great and adjustable. Potential can be artificially set, it is automatically traced and controlled, and service life is longer.

When the protected area is very small, the grounding network which resistance rate of soil is low and distribution is even shall apply the sacrificial anode cathode protection. When the grounding network which protected area is very great, resistance rate of soil is very high and distribution isn't even or the embedded metals in the whole plant are anti-corrosion protected, the external current imposing cathode protection [8] shall be applied.

Table 1 shows the cathode protection method is better than other anti-corrosion method [9] in technology and economy.

Table 1 Technical and economic comparison of several anti-corrosion methods

| | Steel galvanized | Copper | Cathode protection |
|---|---|---|---|
| Conductivity | Very good | Good | Good |
| Anti-corrosion | Low | Middle | High |
| Grounding resistance | Very small | Small | Small |
| Comparison of initial investment | 1.0 | 1.9-2.5 | 1.5-1.9 |
| Construction and maintenance difficulty | Difficult | Difficult | Easy |
| Comparison of maintenance cost | 1.0 | 0.83 | 0.083 |
| Service life/a | 5-10 | 10-20 | 20-30 |

## Design of cathode protection

According to engineering conditions, carry out sacrificial anode cathode protection design on the power transmission tower foundation and the grounding device which distance between the matched 220kV and 110kV lines and the grounding poles don't exceed 7km.

### Protection potential

At present, potential for the cathode protection in the engineering is mainly determined according to experience, which is lack of tight theoretical basis. The cathode potential of the grounding network is -850 mV at least (corresponding to $Cu/CuSO_4$ saturated pole), or make nature corrosion potential of the grounding network negatively shift 250 ~ 300mV, and maximum protection potential isn't more negative than -1500 mV(corresponding to $Cu/CuSO_4$ saturated pole). When cathode protection is implemented, more is cathode polarization current and more obvious is potential negative shift, greater is reduction degree of corrosion speed of the metal. But following continuous negative shift of potential , reduction amplitude of corrosion speed is reduced gradually, and hydrogen evaluation speed of the cathode is greater and greater, which may bring hydrogen bubble of the coating, hydrogen brittle of the base metal etc, and more protection current will be consumed at same time. Therefore selection of proper cathode protection potential is very important to guarantee protection effect, prevent over protection and save energy resource. Research shows the optimum cathode protection potential selected according to the lad shall be located at -100 ~ -300mV of cathode polarization.

### Protection current density

Protection current density is protection current demanded by unit area of the protected object, which is determined by category of the protection metal, composition of corrosive medium, resistance rate of soil and features of the surface coating. DL/T 5394-2007《Technical guide for anti-corrosion of underground metal building in power engineering》[7] requires protection current density shall be greater than 20mA/$m^2$ when resistance rate of soil is 20Ω.m and below. Protection current density of the concrete steel bar foundation shall be calculated as 2.0mA/$m^2$; protection current density of the grounding device shall be calculated as 20 mA/$m^2$ [10].

### Calculation of protection current

$$I = i \cdot S \tag{1}$$

In Eq.1: $I$ is the protection current, $A$; $i$ is the Protection current density, $A/m^2$; $S$ is the protection area, $m^2$. Steel bar concrete foundation: $I_1 = 0.002 \times 248.4 = 0.5A$; Grounding device: $I_2 = 0.02 \times 4.38 = 0.09A$ .

**Grounding resistance of anode**

When resistance rate of soil is 10Ω·m and above, magnesium alloy is applied, type is 1524×(87+106)×106 and weight is 27.2kg.

$$R = \frac{\rho}{2\pi L}\left[\ln\frac{2L}{D_1}\left(1+\frac{\frac{L_1}{4t}}{\ln^2\frac{L_1}{D_1}}+\frac{\rho_1}{\rho}\ln\frac{D_1}{D}\right)\right] \quad (2)$$

In Eq.2: $L$ is the Length of anode, 1.524 $m$ ; $L_1$ is the length of filler package, 1.724 $m$ ; $D$ is the equivalent diameter of anode, 0.13 $m$ ; $D_1$ is the diameter of filler package, 0.23 $m$ ; $\rho$ is the resistance rate of soil, 20 $\Omega\cdot m$ ; $\rho_1$ is the resistance rate of filler material, 1 $\Omega\cdot m$ ; $t$ is the bury depth between ground to centre of anode, 0.8 $m$ ; $R=5.72\Omega$.

**Generation current calculation of sacrificial anode**

$$I_f = \frac{\Delta E}{R} \quad (3)$$

In Eq.3: $I_f$ is the generation current of every anode, $A$; $\Delta E$ is the driving potential of anode, $V$ ; $I_f = 0.11 A$.

**Average generation current calculation of every anode**

$$I_m = 0.7 I_f \quad (4)$$

In Eq.4: $I_m$ is the average generation current of every anode, $A$; $I_m = 0.08 A$.

**Service life calculation of sacrificial anode**

$$Y = \frac{1000 Q\cdot G}{8760 I_m}\cdot\frac{1}{K} \quad (5)$$

In Eq.5: $Y$ is the service life of anode, $a$ ; $Q$ is the actual capacitance quantity of anode, $A\cdot h/kg$ ; $G$ is the weight of every anode, $kg$ ; $1/K$ is the utilization coefficient of anode, take 0.85 ; $Y = 37\,a$ .

**Number calculation of sacrificial anode**

$$N = \frac{I}{I_f} \quad (6)$$

In Eq.6: $N$ is the quantity of sacrificial anode, piece; Number of Magnesium alloy anode demanded by foundation steel bar: $N_1 = 5$ pieces ; Number of Magnesium alloy anode demanded by grounding device: $N_2 = 1$ piece

The design quantity of the sacrificial cathode protection demanded by the power transmission tower in 110kV Yongfeng ~ Kangle A and B connection part is listed in table 2, other lines can be calculated as the same method.

Table 2 Sacrificial anode quantity of a part of power transmission tower in 110kV Yongfeng ~ Kangle A and B connection part

| Tower number | Type of pouring pile | Type of grounding device | Total area of pouring pile/m$^2$ | Area of grounding device /m$^2$ | Quantity of Magnesium anode /piece | |
|---|---|---|---|---|---|---|
| | | | | | Pouring pile | Grounding device |
| D12 | 72508D16Z | FC16-1 | 330.08 | 5.08 | 6 | 1 |
| D13 | 62304D12Z | FC10-1 | 229.64 | 4.03 | 5 | 1 |
| D14 | 43238R2 | FC8-1 | 78.20 | 3.68 | 2 | 1 |
| D15 | 62204E12Z | FC10-1 | 239.72 | 4.03 | 5 | 1 |
| D16 | 43440R2 | FC8-1 | 95.36 | 3.68 | 2 | 1 |
| D17 | 62504D12Z | FC10-1 | 248.44 | 4.03 | 5 | 1 |
| D18 | 72808D14Z | FC12-1 | 332.40 | 4.38 | 6 | 1 |
| D19 | 61604D10Z | FC12-1 | 143.12 | 4.38 | 3 | 1 |
| D20 | 71754D16Z | FC10-1 | 232.88 | 4.03 | 5 | 1 |
| 1D1 | 72858E14Z | FC10-1 | 367.64 | 4.03 | 7 | 1 |

## Arrangement and installation of sacrificial anode

(1) The sacrificial anode shall be arranged evenly at same distance along the grounding body at horizontal direction.

(2)The cable connection shall be applied between the sacrificial anode and the protection grounding body, the cable shall be welded reliably with the steel core of the anode, and certain tolerance shall be reserved for length of the cable.

(3) The sacrificial anode shall apply the horizontal slotting to bury, distance to the horizontal grounding body shall not be less than 500mm. Bury dept at top of the anode to ground shall not be less than 1m buried at same elevation with the horizontal grounding body, water shall be sufficiently poured during burying, and back fill after it is saturated.

## Conclusion

(1) The DC grounding pole will cause electrochemical corrosion of the foundation distribution bar and the grounding device of the around power transmission line, and soil at some area also has corrosion, anti-corrosion design shall be carried out on the foundation and grounding device of the power transmission line.

(2) The protected area of the power transmission tower foundation and the grounding device are very small, and resistance rate of soil is 20Ω·m, Magnesium alloy sacrificial anode cathode protection method is applied for anti-corrosion design of the power transmission tower foundation and the grounding device.

(3) Considering technical and economic factors, it is testified through practice that the grounding body of the power transmission line engineering applies the traditional steel structure in combination with cathode protection design is more economic, feasible and free of danger corrosion control and anti-accident measures.

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