THE Simulation Study of DC Grounding Electrode Based on CDEGS and ANSYS

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Abstract. When the UHVDC project was put into operation, grounding electrode grounding current may affect the transformer in the substation near the pole, it will cause transformer DC bias saturation, which leads to higher transformer temperature rise, too high harmonic and reactive power consumption, which will cause transformer damage or power grid blackout. The earth resistivity model of grounding pole is not accurate enough and the calculation of surface potential distribution is not accurate enough, which will cause the deviation between the evaluation and actual damage degree before and after the project put into operation. In order to simulate the grounding potential distribution directly after grounding, the simulation analysis with different methods can be checked with each other, and the related design units used CDEGS to simulate the earth potential rise. In this paper, the influence of DC transmission grounding electrode on the distribution of ground surface potential is analyzed, and the calculation method of DC grounding electrode current field is deduced. The 6 layers earth soil model was established. CDEGS and ANSYS were applied. The earth potential rise distribution in the 0~100 km radius of the earth electrode was calculated respectively. In this paper, the results of the earth potential distribution in the 0~50 km range of the two schemes were compared and analyzed. The results show that the calculation results of ANSYS were slightly smaller than those calculated by CDEGS, and the difference was about 0.6 V. The calculation results of the two schemes could provide reference for field practical monopole operation and commissioning.

1. Introduction
The development of ultra high voltage AC / DC power transmission is in line with national conditions, and it is an important measure to prevent and control air pollution. The HVDC project is designed to form a circuit and set a potential reference point. It is necessary to set the DC ground electrode [1]. In the initial stage of completion and the operation mode transformation phase during the operation process, the operation mode of monopole earth loop will be used. Up to thousands of ampere currents flow into the earth through the earth’s pole. And generally it will last for a long time at the ground pole. A series of hazards may be induced [2].

With the construction of UHVDC converter station, it is revealed that the grounding electrode has more and more influence on the surrounding AC power system. The normal alternating current magnetic field of a power transformer is biased by the impact of the intrusions of DC current. The power transformers with DC bias become the harmonic power and reactive power of the AC power...
grid. A large number of harmonic currents can cause the relay protection to be misoperated or rejected. The phenomenon of a large number of transformers in the power grid with DC bias will cause the system's reactive power fluctuation and voltage drop. When the phenomenon of DC bias is serious, it can cause permanent damage to the transformer body. Therefore, the analysis and grasp of the DC bias of the power transformer is also the basis for the rational assessment of the influence of DC bias and the necessary measures to be taken [3-4].

The key problem at the design stage is the accuracy of the geodetic potential distribution around the ground polar site. This problem plays an important role in evaluating the direct current derived disasters. This paper provides a certain theoretical reference for the calculation of the ground potential distribution in HVDC transmission project. Combined with the earth pole project of the Northern Shaanxi converter station, the soil resistivity model of multi-layer soil near ground pole is simulated by using CDEGS and ANSYS. The simulation results show the distribution of the surface potential near the ground pole. The CDEGS calculation data and the ANSYS simulation data are compared and analyzed. The research work depends on the grounding pole engineering of the existing North Shaanxi ±800 kV UHVDC converter station, and carries out the calculation and study of the grounding electrode. The calculation is carried out in this paper so that the designer can fully grasp the design scheme of the grounding electrode and the calculation of the influence of the earth potential rise.

2. Basic Equation and Boundary Condition of Geoelectric Field

2.1. Basic Equation
When the DC transmission lines operate in the monopole circuit and the bipolar unbalance earth return line operation, the current is in the way of the earth, and a direct current potential will be generated on the surface of the earth [5]. The structure of the monopole earth line and the structure diagram of the operation mode of the bipolar unbalance earth line are as shown in Figure 1 and Figure 2:

![Figure 1. Ground return operation mode of HVDC transmission system Monopole ground return model.](image1)

![Figure 2. Ground return operation mode of HVDC transmission system Bipolar unbalanced earth loop operation.](image2)

2.2. Boundary Condition
Assuming that a DC grounding current \( I \) nearby the grounding electrode. In the ground 5 meters underground within the scope of the regional point current source is \( I \), the unit point charge density function is defined as a formula (1).

\[
\rho(x) = \delta(x - x')
\]

(1)

where, \( \delta(x - x') \) is defined as the unit point charge density, at the point \( x' \).

\[
\delta(x) = \begin{cases} 
0 & x \neq 0 \\
1 & x = 0
\end{cases}
\]

\[\delta(x)dv = \begin{cases} 
0 & x \neq 0 \\
1 & x = 0
\end{cases}
\]

(2)

It can be seen that the point charge is the limit of a charged ball with a small volume and a large charge density, distributed within a small volume \( \Delta V \). When \( \Delta V \to 0 \), \( \rho \to \infty \). The values of \( \nabla \cdot \vec{J} \) with current source are derived by formula (3) and formula (4):
3. MT Measurement of Earth Resistivity of Grounding Electrode in North Shaanxi Converter Station

3.1. Engineering Survey
The rated transmission capacity of 10000 MW is ± 800 kV Shaanxi Lake UHVDC transmission project. The connection of the valve group of the rectifier station is a bipolar connection. The connection of the valve group of the inverter station is also a bipolar connection. And the double 12 pulsating valve group is used for each connection. The sending end station grounding engineering is an important part of Shaanxi Lake UHVDC project.

According to the information of the system, the construction scale of the transfer station of this project is as follows: The DC current is rated 6250 A, and the transmission capacity is rated 10000 MW. According to the recommendation of the site selection of the transfer station in the feasibility study report of the Shaanxi Lake project, the sending end station grounding electrode site recommends alternative for Fugu site. This project is located in the Loess Plateau. The landform is gently sloping and sloping. The terrain breakage unit is complex. On the whole, the soil structure and its topography are more complex.

3.2. Ground Pole Soil Parameters
In this project, the resistivity of shallow soil has been surveyed in the research stage. In addition to conventional resistivity measurements, the MT is also used to detect the deep electrical structure characteristics of the recommended polar site. After the systematic analysis and processing of the interpretation results of magnetotelluric sounding data, the electrical parameters have been obtained about Yan site of Daliushu village, the multi-layer soil model is shown in Figure 3.

According to the surface soil resistivity and the deep soil resistivity measured by magnetotelluric method, the surface soil resistivity and the magnetotelluric method are measured. The soil structure model near the ground pole site was studied. On the basis of determining the accurate soil model, ANSYS finite element analysis software and CDEGS software are applied to model the resistivity structure around the pole. The simulation calculation is carried out. The potential rise of various substations is obtained. Based on the CDEGS software and the ANSYS software, the design department can be calculated and analyzed.

4. Results and Comparison

4.1. Calculation Results by CDEGS
The geodetic potential of the earthing pole is up to 532 V. Geodetic potential of the 16km rises to less than 6.9 V. The potential of the 33km rises to less than 3 V.

It can be seen from the Fugu Yan village site of Daliushu substation and power plant within 50 km, except the 330 kV Hao Jia substation, the current of the other main transformer core does not exceed the allowable range.
4.2. Calculation Results by ANSYS

The earth potential rise data curve in the 0–100 km range of the ground electrode in Figure 4, and the 0–50 km range earth potential rise curve is shown in Figure 5. The 0–10 km range earth potential rise data curve is calculated by ANSYS as shown in Figure 6, and the 0–5 km range earth potential rise curve is shown in Figure 7.

Through ANSYS calculation and analysis, in conjunction with Fig. 4, Fig. 5, Fig. 6, fig 7, the geodetic potential rise curve within the range of 100 km of the polar address of the ground pole is connected to the range of the polar address of the ground pole. It can be seen that the trend of the geodetic potential rise is decreasing. The fastest range of reduction is 2 km of the earth's polar square. The problem of ground potential distribution in the 2 km range of the earth's polar square should be taken into consideration. The effect of the ground potential is faster and the ground potential gradient is large, and the effect on the ground artificial system is greater. The land into the earth is deep in the depths of the earth. The current density on the surface gradually decreases as it is far away from the ground pole.

4.3. Results Comparison

The comparison between the results of ANSYS software and the results of CDEGS can be seen. The calculated results of ANSYS are slightly less than the CDEGS results, and the difference is about 0.6 V. According to the results of this calculation, the potential difference between the nodes calculated by CDEGS and ANSYS is basically no difference. Therefore, the application of electric network theory and the analysis of node voltage method can be found. The calculated current value of the DC current flowing through the neutral points of each transformer should be basically the same.

The result of ANSYS calculation is slightly lower than that of CDEGS. The authors believe that the ANSYS finite element analysis software is used to calculate the distribution of the geodetic potential in large scale structures of the earth. The CDEGS software package calculates the geodetic potential rise, and the results of the ANSYS calculation are slightly lower than the results of the CDEGS software package.

However, the real geodetic structure is more complex. In this paper, the 6 layer earth resistivity data of magnetotelluric sounding in the field of MT method is adopted by the relevant design institutes. The model is built on horizontal uniform layered structure. The effects of actual breakage, lateral difference and coastal effect are not considered. So this paper simulates the basic data used in simulation. There is a great difference from the actual geoelectric structure. The 0-5 km range geodetic elevation data curve of the distance to the ground pole address of Figure 7 shows that, when the distance to the ground pole is above 2 km, the decrease of the surface potential slows down. And we
should focus on the surface potential distribution of the ground polar square 2 km, as described in the previous article. The construction of related power facilities and oil and gas pipelines should be avoided in the square circle. This result can also provide reference for the initial site selection of DC transmission project, and away from the related facilities in the near area. At the same time, the damage prevention and control of the built power facilities and oil and gas pipelines should be strengthened.

5. Conclusion
(1) For the surface potential distribution, in this paper, the 6 layer soil resistivity model measured by MT method is used to calculate the CDEGS software and the ANSYS software. The calculation results show that the distance from the ground to ground electrode decreases gradually. And two methods are both low and fast in the nearer ground potential.
(2) The results are calculated according to the ground potential rise of two kinds of software. The difference between the potential differences between the nodes calculated by CDEGS and ANSYS is smaller. Therefore, the application of electrical network theory analysis shows that The two kinds of software calculated by the neutral point of each transformer should be basically the same.

6. References
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