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DC Bias Risk Assessment of Power Grid Based on Extreme Value Estimation

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DC Bias Risk Assessment of Power Grid Based on Extreme Value Estimation

WU Weili, Jiang Lin

YiLi Normal University, YiNing XinJiang, 835000

wwllxm@163.com

Abstract. The HVDC single-pole operation mode gives the Hami grid be in the risk of DC bias. Grasp the DC bias level of AC power in extreme cases can provide a basis for the defense system failure risk. In this paper, the DC bias risk assessment method of Hami power grid based on extreme value theory is put forward. Firstly, the method of continental plate and soil is analyzed. Secondly, the DC bias risk evaluation index for the power grid is constructed. Finally, the risk level of DC bias of Hami power grid is assessed. The results can provide a theoretical reference for defusing the DC bias risk caused by DC transmission.

1. Introduction

UHVDC transmission has caused a large number of DC bias events in AC system transformers. In order to better prevent and mitigate grid operation accidents caused by DC bias of transformers, it is necessary to evaluate the DC bias of transformers in the most extreme conditions.

At present, there are few researches on the risk of DC bias of transformers caused by HVDC transmission. However, the assessment of grid accident risk caused by geomagnetic storm, another cause of DC bias of transformers, has been made. Literature [1] established Based on the generalized Pareto distribution model of the geomagnetic horizontal field rate of change, the geomagnetic revision rate (nT / min) in the 52 ° N-63 ° N region is estimated at 200 years from 28 geomagnetic observational data in Europe. [2] proposed the geoelectric field conditional probability model for Dst index. Reference [3] combined with the plane wave theory (PWM), using the geomagnetic statistics in the high latitudes to estimate the geoelectric field extremum, quantified Points out the differences of the electric field in the high and low resistivity regions under the same geomagnetic disturbance level. The above study shows that the electrical structure of the earth is also another important factor that determines the electric field [4]. In addition, literature [5] proposed the power system fault risk index considering the cause of geomagnetic storms and quantified the severity of power system faults under extreme magnetic storms. These results provide some references for studying the risk of DC bias in AC / DC hybrid systems.

Therefore, a risk assessment model of DC bias for power system considering the cause of HVDC transmission in Hami power grid is proposed. Based on the bias current model under extreme conditions, a risk assessment index is put forward and the specific grid parameters are used Verify in order to provide a theoretical reference for resisting and preventing the risk of DC bias.

2. DC bias current magnetic bias model

2.1. Earth resistivity model

The earth resistivity information mainly comes from geological prospecting literature [6] and geodetic literature [7, 8], covering 15 areas such as Xinjiang, Tibet, Jiangsu, Luxi and Yangtze areas. The geological components are igneous, Sedimentary rocks and metamorphic rocks.

First of all, according to the geological components of the grid area along the transformer substation distribution and transmission line to the horizontal surface of the regional division.

Second, the vertical stratification of each partition is calculated. By analyzing the geological structure and the electrical structure of the earth, a three-dimensional earth resistivity model can be used. Taking the earth's surface as the xy plane and the z-axis pointing to the geocentric center. The conductivities of the layers corresponding to the n-layer earth resistivity model are respectively for, $\sigma_1, \sigma_2, \dots, \sigma_n$ and $h_1, h_2, \dots, h_{n-1}, h_n \rightarrow \infty$, The method of literature [9] can be used to calculate the equivalent surface resistance of the earth.

2.2. Biasing current impact factor analysis

Factors determining the level of bias current include, the distribution of the electric field around the grounding current, and the structure and parameters of the AC power grid. Using the bias voltage (U_{im}) between substations i and m, we can get,

$$U_{im} = U_i - U_m = E_i L_i - E_m L_m \quad (1)$$

where, L_i and L_m are respectively the straight line distances between substations i and m, and the ground, E_i and E_m are respectively the ground electric field intensities between substations i and m.

Assuming that the ground current is I_g and injected into the ground electrode. There is the following relationship with the subsurface current field consisting of n substation grounding grids and one grounding pole [10]:

$$U_n = I_n R_{nn} + I_g R_{ng} \quad (2)$$

where, R_{nn} is the impedance matrix of the ground network of n substations, R_{ng} is the mutual impedance vector between the grounding pole and the substation. In general, when the substation DC bias voltage U_n is greater, the greater the substation bias current I_n .

2.3. Bias current extreme value model

When the DC grounding electrode is fixed, Resistivity model, for an exchange system to establish bias current model extreme steps are as follows.

Step 1 is to enter the information of the Earth resistivity and power grid.

The second step is to calculate the transmission line and neutral bias current level.

Step 3, adjust the operating mode, for all possible modes of bias bias current level of the estimate, select one of the bias level generally higher than the operating mode stand-by.

3. DC bias risk assessment model

3.1. bias current time product

We define the bias current time product as follows:

$$IT = \int_{t \in T} I_{DCi} \cdot dt \quad (3)$$

Equation (3) shows the consequences of the bias current, which can characterize the heating effect of the DC bias of the transformer.

3.2. Transformer DC bias distribution coefficient

Given n consecutive intervals $[0, u_3), [u_3, 2u_3), \dots, [(n-1)u_3, nu_3)$, the bias current bias can be defined as

$$H_{I_{DC}} = -C_{\text{onst}} \sum_{k=1}^n \frac{I_{DC}(k)}{T} \lg \frac{I_{DC}(k)}{T} \quad (4)$$

where, $I_{DC}(k)$ is the number of transformers in the k th continuous range where the neutral point bias DC of the substation falls. T is the total number of transformers. C_{const} is a constant. The minimum value of H_{IDC} is 0 and the maximum value is $C_{const} \lg n$. The larger the value is, the more inhomogeneous distribution of the DC over-limit state of the neutral point in the substation is.

3.3. DC bias risk assessment process

The specific methods for assessing the risk of DC bias in the power grid are as follows:

Step 1: According to the geodetic sounding data, establish the earth resistivity model, input the information of the grounding pole position and parameters, the location of the substation of the AC system and the parameters of the power grid.

Step 2: Adjust the power system operation mode in turn and calculate the DC bias risk assessment indexes of equations (3) and (4) on the basis of the first step data.

Step 3, comparing and analyzing the risk assessment indexes under different operation modes, selecting the worst case of grid fault caused by DC bias and outputting the grid parameters.

4. Case analysis

Figure 1 shows the location of Harbin Hazheng ± 800 kV DC transmission grounding pole and its surrounding substations. Table 1 shows the high resistivity model of the Hami power network.

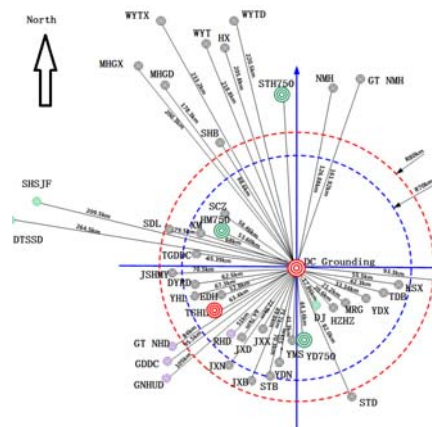


Figure 1. grounding pole and Xinjiang.

Table 1. Layered Earth resistivity parameters of Hami.

Thickness km	Resistivity (ohm-m)
0-15	18000
15-25	200
25-150	1000
150-350	100

Power Grid substation location diagram

Take DC injection $I_0 = -5000\text{A}$. Hami grid DC bias risk assessment process is as follows:

Firstly, we estimate the distribution of electric field in the Hami grid coverage area, the results shown in figure 2:

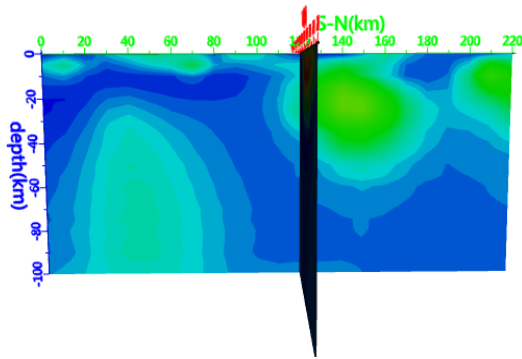


Figure 2. S-N earth resistivity.

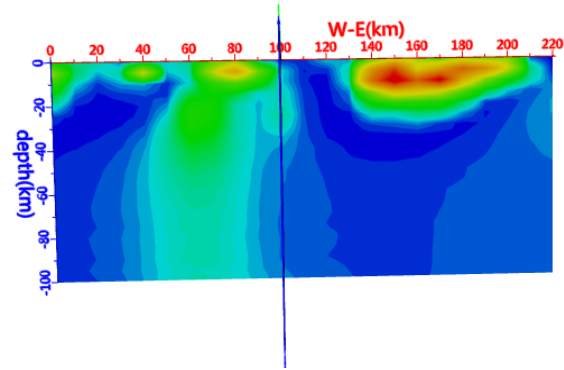


Figure 3. W-E earth resistivity.

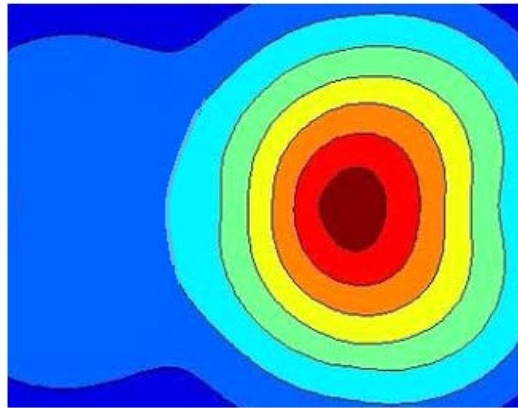


Figure 4. Hami power grid (V) contour distribution.

Secondly, based on the calculation results of geoelectric field distribution, the bias current levels are calculated according to equations. (1) and (2).

Finally, adjust the operation mode of power system, calculate the risk assessment index, and evaluate the DC bias risk of HAMC under different operation modes (the IT index takes unit time).

Table 2. Hami grid DC bias risk assessment results

Index	IT	$H_{I_{DC}}$
Method 1	0.5687	0.1345
Method 2	0.6143	0.4355
Method 3	0.6532	0.7345
Method 4	0.1998	0.6231
Method 5	0.2176	0.0345

IT and $H_{I_{DC}}$ are scalar indicators in table 2, the value interval is [0,1]; Method 4, Method 5 is based on risk assessment after the installation of risk management device risk indicators. It can be seen from table 2 that the IT indexes of Method 3 are the highest in Modes 1, 2, and 3, indicating that the level of bias current is high and the index $H_{I_{DC}}$ of Mode 3 is high, which indicates that the distribution of bias current in substations is extremely uneven. The high level of magnetic current and the risk of burning down. After installation of management methods, the indicators 4 and 5 can be seen that the

bias current level is significantly reduced, but the indicator

$H_{I_{DC}}$ in mode 4 is still high, indicating that after the installation of the control device, the whole network of substation bias Current distribution is uneven, there may be individual substation there is still a substantial DC risk.

5. Conclusion

A DC bias risk assessment method for AC system caused by HVDC transmission project was proposed. Based on the Earth data, the high resistivity model of HAMC was established. According to the transformer DC bias effect, the DC bias Risk assessment index are proposed. Finally, the risk assessment method is carried out. The results of the evaluation can provide a reference for avoiding the risk of grid disaster triggered by DC bias in extreme conditions.

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