Simulation and Analysis of DC Current Distribution in AC Power Grid around the UHVDC Transmission Ground Electrode

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Abstract

Due to the DC bias of the neutral earthed transformers caused by UHVDC earth-return current, it's very important to study the DC current distribution in AC power grid. Based on the ±800kV Xiangjiaba-Shanghai UHVDC power transmission project, this paper simulates the DC current distribution in Northern Zhejiang AC grid by establishing a complete model based on the actual power grid and soil data in CDEGS. By the comparison of the simulation values and measured values, the validity of the model is verified. At last, a proposal is put forward to restrain DC current distribution in Northern Zhejiang AC grid.

Keywords: UHVDC; current distribution; DC bias; DC ground electrode; soil resistivity; surface potential

1. Introduction

Nowadays, our country is making great efforts to the development of UHVDC transmission. In the future, UHVDC transmission will play a key role in long distance power transmission and interconnection [1-2]. However, with the development of UHVDC transmission technology, it also brings some problems to be solved in this field.

When DC transmission runs in the monopole ground circuit operation mode, the earth passes through huge direct current as one of a wire. A part of the current of DC ground electrode flows to the AC power grid through the grounding transformers' neutral, then flows back to the earth through other grounding transformers' neutral. The direct current makes an adverse impact on the AC power grid around the ground electrode, wherein, DC bias is an obvious and key problem [3-5]. In order to ensure the safe and stable operation of power grid, research on DC current distribution caused by UHVDC transmission is urgently needed. Then, effective measures to restrain DC current can be adopted.

As great efforts made to develop DC transmission projects, research on computer simulation of DC current distribution has made great progress. The papers [6-7] analyze soil parameters and marine's influence on DC current distribution. The papers [8-9] use moment method and circuit theory to analyze DC current distribution of local power system and analyze the relevant law. The paper [10] gets the complete DC power system information with the data of power flow calculation.

The measures to restrain DC bias current were also obtained a series of achievement. The papers [11-14] put forward some restraining measures to reduce the DC bias current's effect to AC grid. The papers [8, 12, 14] demonstrate the feasibility and effectiveness of the restraining measures.

At present, obtaining the AC power grid topology and DC parameters accurately is still difficult. General literature use simplified model to analyze surface potential distribution and DC current distribution. The reliability of the results should be improved. This paper will model and simulate according to the actual power grid and soil data, and can make the results more close to the real situation.

This paper analyzes the influence of various factors in the model of DC current distribution in AC power grid. Based on this, this paper combines soil model and grid model by CDEGS, then, establishes a concrete and complete model to compute. By using real topological relation and real DC parameters, this paper introduces the application of CDEGS in computing and simulating DC current distribution in Northern Zhejiang AC grid when ±800kV Xiangjiaba-Shanghai UHVDC transmission system runs. Moreover, this paper puts forward some proposals to restrain DC current distribution in Northern Zhejiang AC grid according to the simulation result.

2. Modeling and simulation

After the direct current flows from the ground electrode to earth, soil and AC power grid consists of a DC power system. The DC current distribution around the DC ground electrode is influenced by direct current flowing into earth, soil resistivity, ground resistances of the substations, equivalent DC resistance of the transformers, topology of the power grid, DC parameters and many other factors. Each kind of factors should be considered carefully. The steps of modeling and simulation are as follows:

1) Determine the coordinates of the DC ground electrode, power plants and substations according to the actual terrain and the grid model.

2) According to the actual topography and soil resistivity, select the appropriate soil model, determine the soil resistivity and thickness of soil layer, and finish the soil model.

3) Complete the DC ground electrode model according to the actual DC ground electrode.

4) Determine coordinates of the power plants and substations, calculate the surface potential distribution around ground electrode and potential of the power plants and substations by CDEGS.

5) Complete the grid topology of the whole region according to the actual situation of power grid, including model of the circuits, the power plants and substations, ground resistance of the substations, equivalent DC resistance of the transformers, DC resistance of the power lines.

6) Simulate and calculate by CDEGS, and get DC current distribution of the region.

7) Compare the results of simulation with the measured data, and put forward some proposals to restrain DC current distribution.

3. Modeling of project instance

This paper will simulate the surface potential distribution of Northern Zhejiang and the DC current distribution of the 500 kV power plants and substations which are grounded when ±800kV Xiangjiaba-Shanghai UHVDC transmission system runs. Modeling of the project is as follows.

3.1. Soil model

According to the test results of soil resistivity around the DC ground electrodes in Shanghai and the ground resistance's measured values of the power plants and substations, this paper determine the soil model of Northern Zhejiang by calculating and comparing repeatedly. Model data is as shown in Table 1.

Table 1: Soil model in simulation

Layer	Resistivity(Ω·m)	Thickness(m)
1	10^{18}	∞
2	10	350
3	300	10000
4	10000	10000
5	100	∞

3.2. Ground electrode model

According to the information provided by the design unit, Fengxian DC Ground Electrode of the ±800kV UHVDC transmission project which is from Xiangjiaba to Shanghai adopts the ring electrode. Grounded conductor adopts the round steel whose diameter is 70mm, the ring's radius is 250m. Thereinto, the conductivity is $\sigma=1\times10^6$S/m and the permeability is μ_r=200H/m. The model is as shown in Fig. 1.

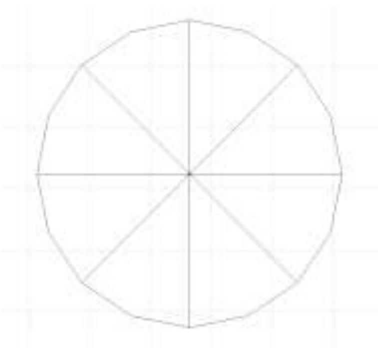

Fig. 1: Fengxian HVDC Ground Electrode model

3.3. Power grid model

According to the "geographical wiring diagram of 2010 Zhejiang power grid", 220kV and above power system of Northern Zhejiang totally has 21 500kV power plants and substations, 65 220kV power plants and substations and 276 transmission lines (29 of them are 500kV lines, and the remainders are 220kV lines). The equivalent model is based on the 500kV power system of Northern Zhejiang. The grounding grid model of power plants and substations adopts a model of Chinese word "田". The ground resistance and the DC resistance of each power plants and substations are dealt with equivalently based on the measured values. As for the power plants and substations without measured values, this paper adopts the general ground resistance of 500kV substations. The DC resistance of transmission lines is defined by the design unit's data.

The completed power grid topology model of Northern Zhejiang is as shown in Fig. 2.

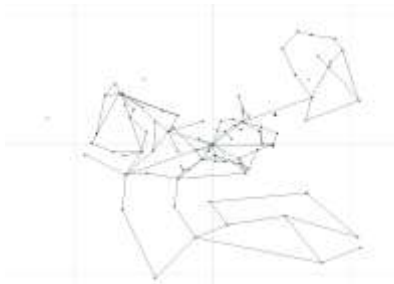

Fig. 2: Power grid topology model of Northern Zhejiang

4. Simulation and analysis of project instance

4.1. Simulation results

This paper mainly researches the surface potential and DC current distribution of Northern Zhejiang under DC bias, and identifies all 21 500kV power plants and substations as observation points according to the actual investigation. The simulation results are as shown in Table 2.

Table 2: Surface potential distribution and DC current distribution of 500kV observation points

Observation point	Surface potential (V)	DC current (A)	The number of main transformers	DC of main transformer (A)
Wangdian	7.758	13.1	3	4.366667
Fenhu	13.8625	5.33	2	2.665
Jiaxing	13.4205	26.7	4	6.675
Qinshan	7.81	1.8	5	0.36
Youquan	6.1965	5.25	2	2.625
Hanshan	5	10	2	5
Qiaosi	4.144	3.68	3	1.226667
Renhe	3.186	3.77	2	1.885
Pinyao	2.376	5.87	3	1.956667
Tianhuangping	1.656	5.72	3	1.906667
Fuyang	2.07842	4.11	3	1.37
Yongchao	3.444	12.8	3	4.266667
Guyue	4.5148	0.426	2	0.213
Juzhang	6.013	13	2	6.5
Lantin	2.898	2.31	3	0.77
Shunjiang	3.91598	0.87	2	0.435
Hemu	5.152	4.11	3	1.37
Beilun	2.362	6.94	5	1.388
Chunxiao	2.539296	0.672	2	0.336
Tianyi	2.639	6.62	3	2.206667
Fengyi	1.2496	2.74	2	1.37

According to the results, we can find that 500kV Fenhu Substation and 500kV Jiaxing Power Plant have the highest surface potential, respectively 13.8625V and 13.4205V. Rest observation points' surface potential is much lower than theirs, the values are from 1.2496V to 7.81V. The DC current of observation points is from 0.426A to 26.7A, thereinto, 500kV Jiaxing Power Plant has the largest value and 500kV Guyue Substation has the least value. The DC current of every point's transformer whose neutral point earthed is from 0.213A to 6.675A, thereinto, 500kV Jiaxing Power Plant's is largest and 500kV Guyue Substation's is least.

4.2. Comparison and analysis

According to the measured current of some observation points, the simulation values and measured values are compared and analyzed, the data is as shown in Table 3.

Table 3: Comparison of simulation values and measured values

Point	Simulation value (A)	Measured value (A)	AE (A)	RE (%)
Fenhu	5.33	4.2~9.2	0	0
Jiaxing	26.7	30.78~31.53	4.08	13.2
Hanshan	10	10.29~12.82	0.29	2.8

Fenhu Substation's simulation value falls within the measured range and is consistent with the actual situation by the comparison of simulation and measured values. There is some extent between Jiaxing Power Plant's simulation value and measured value, the relative error is 13.2%. Hanshan Substation's simulation value is agreeable with the measured one, the relative error is 2.8%. Then we can find that the gap between simulation and measured values is not large. But a certain error is acceptable due to some unavoidable factors like soil, operational mode and ground resistance. Therefore, we can think of the simulation results are consistent with the actual situation. The simulation model and calculation method in this paper are feasible and effective.

4.3. Proposal to restrain DC current distribution

Nowadays, one important measure is to install DC inhibition devices on neutral point. Considering the realization of devices, the cost, the influence on power grid and relay protection system, resistance type is recommended. From Table 2 we can find, the main transformers' neutral DC current of Wangdian Substation, Jiaxing Power Plant, Hanshan Substation, Yongchao Substation and Juzhang Substation is larger. But in consideration of the entire power grid, Yongchao Substation and Juzhang Substation are far away from Fengxian Ground Electrode and the rest are nearby. The latter are more suitable for the installation of devices.

Suggestions are as follows according to the simulation results. Resistance type DC inhibition devices can be installed on all or some of all the stations' neutral point mentioned in last paragraph. But indepth research is needed to study the resistors' values and the effect after installation.

5. Conclusion

The DC current distribution around the DC ground electrode is influenced by direct current flowing into earth, soil resistivity, ground resistances of the substations, equivalent DC resistance of the transformers, topology of the power grid, DC parameters and many other factors. In this paper, each factor has been considered and simulated by the actual situation, instead of the general simplified model. Through the establishment of specific and complete AC power grid model, this paper has introduced its application in forecasting and restraining the DC current distribution of Northern Zhejiang.

According to the simulation of project instance, this paper has got the DC current distribution of Northern Zhejiang under the influence of ±800kV UHVDC transmission system and proposed some suggestion to restrain. Then this paper illustrated the feasibility and validity of this model by comparison of the simulation values and measured values.

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