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Study on Earth Surface Potential and DC Current Distribution around DC Grounding Electrode

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ABSTRACT

DC magnetic biasing problem, caused by the DC grounding electrode, threatened the safe operation of AC power grid. In this paper, the characteristics of the soil stratification near DC grounding electrode was researched. The AC-DC interconnected large-scale system model under the monopole operation mode was established. The earth surface potential and DC current distribution in various stations under the different surface thickness was calculated. Some useful conclusions are drawn from the analyzed results.

Keywords: DC Grounding Electrode; Magnetic Biasing; Soil Stratification; Earth Surface Potential; DC Current Distribution

1. Introduction

From an economic point of view, at the first stage of construction, domestic HVDC transmission project often put into an electrode firstly, as shown in **Figure 2**. At this point, DC flowed through the grounding electrode into the earth, and its breadth and depth of the diffuser was still an open. However, the negative effects of this operation mode had been a consensus[1-18], mainly the following three points: electromagnetic effect, thermal effect and eletrochemical effect. In this paper, the surface potential distribution was a kind of electromagnetic effects. In this commissioning and operation of DC transmission system, these problems really existed. Therefore, the study of surface potential and DC current distribution was of great significance.

2. Calculation Model

Take the Shanxi-Jiangsu ± 500 kV DC transmission line project for example, which was from ± 500 kV HVDC converter station (in Yangcheng county, shanxi province)to another one(in Liyang, Jiangsu province).

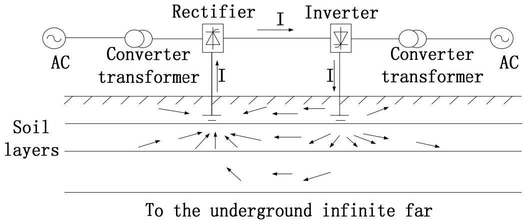

Figure 1. The monopolar ground circuit operation mode

2.1. Location Coordinate

The relative position of each station in AC-DC interconnected power system was demarcated in the form of rectangular coordinate, as shown in **Figure 3**. Gaoping DC grounding electrode was located in Jincheng city, Shanxi province. The position of this electrode was considered as the origin of coordinate, with the radius of 100km as the research scope.

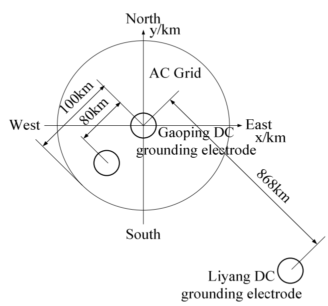

Figure 2. AC-DC interconnected system location coordinate diagram.

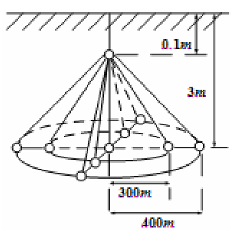

Figure 3. The view of DC electrode.

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2.2. Soil Stratification Structure

Soil surface with low resistivity was usually very shallow. Below the surface was the salt soil layer, which the resistivity was up to thousands of Ω•m. Then it reached to the rock, with the resistance rate was up to 100000 Ω•m above and the thickness was about hundred km. The resistivity of the lower crust began to decrease, which was only 200 Ω•m or less; Corresponding to 100-200 km depth, the resistivity of low-velocity layer was 10 Ω•m. In the depth of 400-650 km, the resistivity in turn drastically reduced to 1 Ω•m. The resistivity of the lower mantle was only 0.1 Ω•m in the depth of 1500 km[19-21] .

The loess layer in southeast of Shanxi was thinner, mostly about 50 meters[22], and the thickness of various regions was uneven , therefore, it should select different thickness values when calculated, which were as follows:100 meters, 50 meters, 10 meters. Based on the typical reference value, the loess resistivity was defined as 200 Ω•m. The soil in Jindongnan area was divided into five layers, as can be seen in **Table 1**.

2.3. DC Power System

The full-length of HVDC transmission lines was 865.45 km, of which the Shanxi segment was 45 km, and Jincheng grounding electrode line was 80 km. The overlook and view of DC double-ring grounding electrode were shown in **Figure 4**.The large ring with a radius of 400m, the small ring with a radius of 300 m. Grounding conductor was made of round steel materials, whose radius was 35 mm. With 8 cables, the current, from the current injection points, was introduced into the grounding ring. The cable was made of copper, and its cross- sectional area was 240 mm^2, which was 0.1 m high from the ground. The grounding electrode was 3 m below the ground. The center of which was located in the Gaoping area of Jincheng. Current injection segment was made of copper wire, and the cross-sectional area: 240 $mm^2 \times 8 = 1920$ mm^2.

2.4. AC Power Grid

AC system mainly includes substations, AC grounding nets and HVAC transmission lines. According to the

Table 1. The soil stratification.

layers	Resistivity(Ω•m)	thickness(m)
surface	200	10~100
layer 2	1500	2000
layer 3	6000	10000
layer 4	100000	100000
layer 5	200	∞

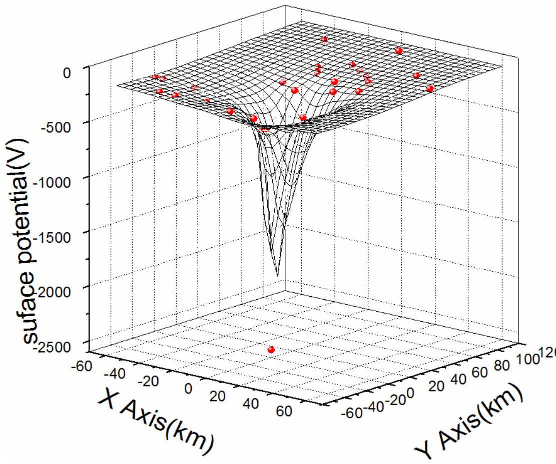

Figure 4. The view of earth surface potential.

importance of substations,1000 kV, 500 kV and 220 kV substations, which are located in the scope of 100 km radius from Gaoping DC grounding electrode, were studied. The equivalent DC resistance of transmission line was decided by wire type, length, division number and loop number.

3. Results Analysis

In this paper, the station with symbol "■" was ±500kV converter station. The station with symbol "▲" was 1000kV substation. The stations with symbol "●" were 500kV substations. Others without symbol were 220kV substations.

3.1. Earth Surface Potential

As shown in **Table 2**, **Table 3** and **Figure 5**, with the different thickness of loess, the surface potential was difference. the value of Dc grounding electrode was -1489.2 V, -1894.3 V and -2529.6 V. The value of converter station was -173.73 V;-181.94 V and -189.18 V. The value of 1000 kV UHV AC station was -226.15 V; -237.88 V and-248.29 V.

The value of 500 kV and 220 kV was about from -550 V to -100 V.

Take the surface soil thickness 10m for example, the closer to the distance from DC grounding electrode, the larger of the step voltage. It ranges from 0 to 1 km. The potential decreased to 1.251 V of the average per parameter, and the largest step voltage was about 1.6 V, which was lower than the largest safety limit value 2.5 V prescribed by the Chinese government.

3.2. DC Current Distribution

DC current distribution at station in the city Jincheng and Changzhi were as shown in **Table 4** and **Table 5**. The "+" represented inflow, and "-" represented outflow.

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Table 2. Earth surface potential AT STATION in Jincheng city.

Station name	Earth suface potential/V		
	100m	*50m*	*10m*
DC electrode	-1489.2	-1894.3	-2529.6
SN	-485.23	-517.93	-547.50
JC●	-468.51	-499.47	-527.26
DH	-443.30	-471.79	-497.12
BYC	-336.39	-356.01	-373.49
LC	-312.57	-330.47	-346.43
DG	-236.05	-248.46	-259.48
JS	-232.79	-245.00	-255.83
QD	-216.35	-227.39	-237.13
FC	-188.64	-197.85	-205.98
YCB●	-176.68	-185.07	-192.50
YC■	-173.73	-181.94	-189.18
QC	-169.62	-177.54	-184.50

Table 3. Earth surface potential AT STATION in Changzhi city.

Station name	Earth suface potential/V		
	100 m	*50 m*	*10 m*
DPT	-251.16	-264.62	-276.60
JDN▲	-226.15	-237.88	-248.29
SD	-221.19	-232.58	-242.65
XZ	-195.48	-205.14	-213.68
CZ	-193.65	-203.18	-211.59
DM	-180.07	-188.68	-196.27
KZ	-171.13	-179.17	-186.25
JA●	-167.21	-174.66	-181.46
RH	-160.76	-168.12	-174.60
HJG	-153.53	-160.44	-166.54
HB	-146.57	-153.03	-158.70
PC	-133.32	-139.05	-144.19
ZC	-129.81	-135.25	-140.01
QZ	-111.07	-115.32	-118.99
WJY	-105.74	-109.70	-113.14

When the surface soil thickness was considered as 100 m，50 m，10 m respectively, the inflow DC current could respectively reach 1.2 A、1.4 A、1.4 A at the Yangcheng converter transformer side, and the outflow DC current of the Jindongnan 1000 kV substation could respectively reach 2.2 A、2.3 A、2.8 A.The largest influence subtations of DC grounding current were Shengnong, Jincheng, Danhe and Beiyicheng.

Table 4. DC current distribution AT STATION in Jincheng city.

Station name	DC current amount/A		
	100m	*50m*	*10m*
SN	-19.7	-21.1	-22.0
JC●	-18.3	-19.6	-20.4
DH	-17.0	-18.3	-19.0
BYC	-10.0	-10.6	-11.0
LC	-8.2	-8.7	-9.0
DG	-2.9	-3.1	-3.2
JS	-2.8	-2.9	-3.0
QD	-1.7	-1.8	-1.8
FC	+0.2	+0.27	+0.31
YCB●	+1.0	+1.1	+1.2
YC■	+1.2	+1.4	+1.4
QC	+1.6	+1.7	+1.8

Table 5. DC current distribution AT STATION in Changzhi city

Station name	DC current amount/A		
	100 m	*50 m*	*10 m*
DPT	-4.1	-4.3	-4.4
JDN▲	-2.2	-2.3	-2.8
SD	-2.0	-2.1	-2.2
XZ	-0.17	-0.15	-0.13
CZ	-0.23	-0.16	-0.18
DM	+0.72	+0.85	+0.86
KZ	+1.4	+1.6	+1.6
JA●	+1.7	+1.9	+2.0
RH	+2.0	+2.2	+2.2
HJG	+2.5	+2.7	+2.8
HB	+3.1	+3.3	+3.4
PC	+4.0	+4.2	+4.4
ZC	+4.1	+4.4	+4.6
QZ	+5.4	+5.8	+6.0
WJY	+5.8	+6.2	+6.4

The DC grounding current could propagete to adjacent other substations along the AC transmisson lines, when it inflowed one substation. The **Figure 6** and **Figure 7** described the DC current distribution in AC transmisssion lines of Jincheng and Changzhi. When the soil thickness was considered as 10 m, the maximum DC current was on the 500 KV AC transmission lines from the substation of Jindongnan to Jincheng.

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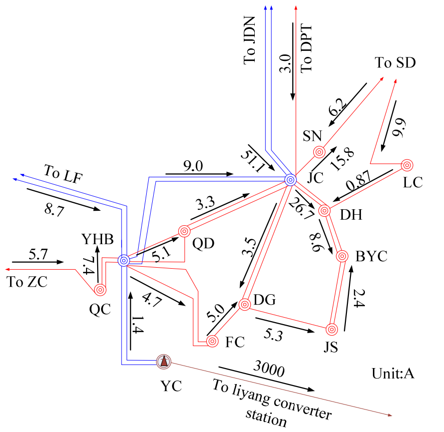

Figure 6. DC current distribution in AC transmission lines of Jincheng city.

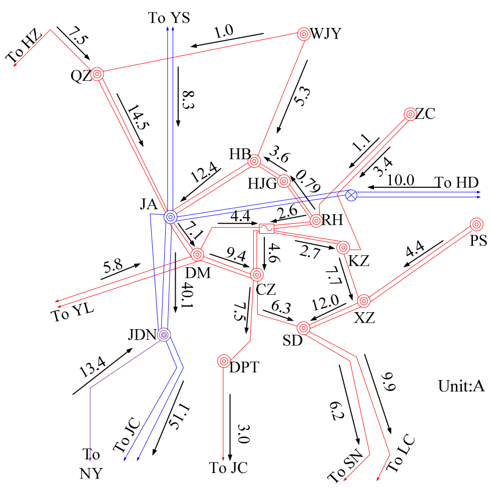

Figure 7. DC current distribution in AC transmission lines of Changzhi city.

4. Conclusions

The smaller the thickness of the surface soil is, the greater the absolute value of earth surface potential. The farther away from the grounding electrode, the smaller the absolute value of the surface potential, which formed the exponential decay function and tended to zero gradually.

The DC current amount of the distal substation was not always less than the recent substaion. The DC current would select the pathway of which the DC resistance was the minimum. The DC current, flowing through the substation, of which the topological structure was more complicated, was relatively large. The soil sructure had some influence on the DC current distribution: the smaller of the surface soil thickness, the larger of DC grounding current influence on the AC system.

5. Acknowledgements

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