Analysis on the Influence of Remote 110kV Substation on Transformer DC Bias

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Abstract. High voltage direct current (HVDC) transmission system has the advantages of large capacity, long distance and low loss. Relying on the advantages of HVDC transmission, China has established a large-scale energy transmission channel in the west, effectively solving the problem of uneven local energy distribution. However, HVDC transmission will generate ground current when it is operating in a single pole, which will cause the DC bias effect of the transformer. At this time, the core magnetic circuit of the transformer is saturated. Transformers will experience increased vibration, increased noise, local overheating, and surge in harmonics. This paper, based on the Jinhua HVDC transmission project as a background, established a power grid topology model in Zhejiang area based on the field-circuit coupling method. The focus is on calculating the DC bias of Shenze transformers in Jinhua area, and proposing treatment measures based on the calculation results. According to the actual measurement of the project, the accuracy of the calculation result is verified, which reflects the effectiveness of the governance measures.

1. Introduction

Since the DC transmission system adopts single-maximum return line mode and bipolar unbalanced mode operation, the current into the ground enters the AC system, causing the grounding transformer to produce a DC bias effect [1-3]. The DC bias of the transformer will make the core magnetization curve asymmetrical, which will result in increased transformer loss, increased temperature rise, local overheating, increased vibration and other adverse reactions, which will seriously endanger the safety of the power system. Scholars from various countries have carried out many studies on DC bias suppression measures. Commonly used methods include reverse injection current method, neutral point series resistance method, and neutral point series capacitance method. The current suppression measures generally limit the magnitude of the DC current by changing the impedance or by connecting a capacitor in series to achieve the purpose of blocking DC to suppress the DC bias [4].

The Shenze Substation is located in Jinhua and contains two main transformers. The two transformers were changed from the original single grounding to two simultaneous grounding. Before the adjustment, the No. 1 transformer is equipped with a capacitor DC blocking device, and the neutral point of the No. 2 transformer is not grounded. After adjustment, the high-voltage side and medium-
voltage side of the No. 2 transformer are directly grounded. Because the distance between the 220kV Shenze Substation and the Jinsi grounding electrode is only 52km, there is a risk of DC bias. Therefore, it is necessary to conduct a DC bias risk assessment for the 220kV Shenze Substation and provide supplementary treatment plans. The Shenze No. 1 transformer has been subjected to capacitance blocking treatment, no DC current will flow through the transformer. Therefore, the Shenze transformer in the following text refers to the Shenze No. 2 transformer [5-6].

2. Electrical wiring of Shenze transformer

The 220kV high-voltage side of the two main transformers of 220kV Shenze Substation has been equipped with a shared capacitor-type DC blocking device. However, the 110kV neutral point of the No. 1 transformer has a DC current of 15.8A, which causes the sound of the main transformer to be abnormal. Shenze Substation is located in Pan’an District. The electrical wiring of the surrounding 110kV substation is shown in Figure 1.

![Fig 1. Schematic diagram of 110 kV neutral point grounding in Pan'an area](image)

Assuming that the source of the transformer's DC is 220kV to 110kV through current, only the 220kV Dongyang Substation has the possibility of entering the 110kV system current from the 220kV system through the transformer coil. Dongyang Substation has two autotransformers, both of which are equipped with resistive current suppression devices. So the current amplitude of Dongyang Transformer is limited to less than 5A, which cannot constitute the high amplitude of 15.8A of Shenze Transformer. Therefore, the DC source does not cross from 220kV to 110kV.

From the above analysis, the DC source of the medium voltage side of Shenze Transformer is the bias current of the local earth circuit in Pan'an area. There is no neutral-grounded substation in the Jinhua substation system network, so it is impossible to pass the bias current from the grid. According to the grid topology data, the neutral point of the transformer in Sanquli Power Plant and Dingfeng Power Plant is grounded. Between the two plants and the Shenze Substation, there are any two paths through the 110kV grid for bias current transmission. In the initial stage, more capacitive blocking devices were installed. So the area of magnetic bias pollution is gradually expanding, which may have
severely affected the Pan’an area. Therefore, it is necessary to consider the local circulation between
the two 110kV power plants and Shenze Substation when establishing the simulation model.

3. DC bias calculation model
In order to consider the impact of the nearby AC power grid, the Zhejiang Power Grid is used as the
object to model the DC bias calculation. When calculating, the current of the gold wire grounding
electrode into the ground is 5000A. The Jinhua power grid part refers to the grid structure of the 14th
Five-Year Plan, and both the 220kV Qiaonan transformer and the 220kV Xianqiao transformer have
adopted the resistance current limiting method for governance. In addition, the model has
supplemented the information of Dingfeng Wind Farm, Weixin Wind Farm, Sanquli Power Plant and
related lines connected to the medium voltage side of the 220kV Shenze Substation, as shown in Table
1.

The model includes 1264 substations and power plants, including 5 substations of 1000kV, 54
substations of 500kV, 244 substations of 220kV, 958 substations of 110kV, and 3 power plants. The
model contains 1,348 lines, including 9 lines of 1000kV, 53 lines of 500kV, 368 lines of 220kV, and
918 lines of 110kV.

Among them, the Jinhua Power Grid includes 119 substations and power plants, including 25
substations of 220kV, 91 substations of 110kV, and 3 power plants. There are 178 related lines,
including 3 lines of 1000kV, 5 lines of 500kV, 43 lines of 220kV, and 127 lines of 110kV. The
calculation model topology of Jinhua Power Grid is shown in Figure 2, which only shows 220kV and
above. The partial model of 220kV Shenze Substation is shown in Figure 3.

| Power plant                  | latitude      | transformer number | line                      | Voltage level | Length/km    |
|-----------------------------|---------------|--------------------|---------------------------|---------------|--------------|
| Dingfeng Wind Power Plant   | 28.855607     | 1                  | Shenze-Dingfeng           | 110           | 13.98        |
| Weixin Wind Power Plant     | 28.930402     | 1                  | Shenze-Pan’an-Jianshan-Sanquli | 110           | 11.17+36.2+3 |
| Sanquli Power Plant         | 29.227909     | 2                  | Shenze-Xuetian-Reform     | 110           | 24.5+12      |
| Xuetian Substation          | 28.998679     | 1                  | Shenze-Xuetian-Jianshan-Sanquli | 110           | 24.5+53.9+3  |

Table 1. Information of supplement power plant and line
4. calculation results and treatment plan of DC bias

4.1. Calculation results
The bias current in 220kV Shenze Substation and power plants exceeds 10A, as shown in Table 2. Among them, the 220kV Dongyang Substation main transformer series winding and 220kV Shenze Substation main transformer high voltage winding bias current exceeds 10A, respectively -17.00A and
15.50A. The bias currents of Dingfeng Wind Farm, Weixin Wind Farm and Sanquli Power Plant are relatively small.

| Substation/Power Plant     | Main transformer type | High voltage winding/A | Medium voltage winding/A | Distance to DC pole/km |
|----------------------------|-----------------------|-------------------------|--------------------------|------------------------|
| Dongyang Substation        | Autotransformer       | -17.00                  | 3.53                     | 58                     |
| Shenze Substation          | Non-autotransformer   | 15.50                   | 4.65                     | 52                     |
| Dingfeng Wind Power Plant  | Non-autotransformer   | 2.63                    | 0.00                     | 55                     |
| Weixin Wind Power Plant    | Non-autotransformer   | -1.74                   | 0.00                     | 75                     |
| Sanquli Power Plant        | Non-autotransformer   | -5.56                   | 0.00                     | 92                     |

4.2. Only treat the high voltage side of Shenze transformer
First of all, the high-voltage winding of the main transformer of 220kV Shenze Substation is treated by capacitor DC blocking device. After treatment, the bias current of 220kV Shenze Substation and power plants exceeded 10A, as shown in Table 3. According to the calculation results: 1) The bias current of the series winding of the 220kV Dongyang Substation's main transformer decreases slightly, but still exceeds the limit; 2) The bias current of the 220kV Shenze transformer medium voltage winding increases sharply due to the transfer of the bias current. The bias current of the 220kV Shenze transformer medium voltage winding reaches 13.40A, which is close to the limit. The medium voltage side of Shenze transformer should be supplemented.; 3) The bias current of Weixin Wind Power Plant and Sanquli Power Plant has increased but did not exceed the limit; 4) The bias current of the 220kV Dongyang transformer series winding slightly exceeds the limit, but the bias current of the autotransformer is relatively strong, so it is treated as an observation station.

4.3. Both the high-voltage winding and medium-voltage winding of Shenze transformer are treated
Both the high-voltage windings and medium-voltage windings of the main transformer of 220kV Shenze transformer are treated by capacitor DC blocking device. In order to fully consider the randomness of the soil structure of the earth, 220kV Dongyang Substation and power plants should be observed. After treatment, except for the series winding of the main transformer in the 220kV Dongyang transformer, the bias currents of the other main transformers are all less than 10A.

5. Conclusions
Based on the topology model of Jinhua Power Grid, this paper mainly analyzes the influence of DC bias in Shenze Substation. Finally, this article puts forward suggestions on DC bias control of Shenze Substation Station.

1) It can be obtained from the analysis that the DC bias of Shenze transformer exceeds the standard because the 110kV system forms a local earth loop.

2) When establishing the calculation model, the influence of the surrounding power grid was fully considered. This paper established the topology model of Zhejiang Power Grid and the model of power plants around Shenze Substation.

3) According to the calculation results, the treatment plan of Shenze Substation is proposed.

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