Analysis and Countermeasure Study on DC Bias of Main Transformer in a City

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Abstract. According to the December 2015 Guohua Beijing thermal power transformer DC magnetic bias phenomenon, the monitoring data of 24 hours of direct current is analyzed. We find that the maximum DC current is up to 25 and is about 30s for the trend cycle, on this basis, then, of the geomagnetic storm HVDC and subway operation causes comparison of the mechanism, and make a comprehensive analysis of the thermal power plant's geographical location, surrounding environment and electrical contact etc.. The results show that the main reason for the DC bias of Guohua thermal power transformer is the operation of the subway, and the change of the DC bias current is periodic. Finally, of Guohua thermal power transformer DC magnetic bias control method is studied, the simulation results show that the method of using neutral point with small resistance or capacitance can effectively inhibit the main transformer neutral point current.

1. Introduction

In December 2015, Guohua Beijing thermal power plant (referred to as Guohua thermoelectric) 1# main transformer noise increased significantly, after the measurement, the main transformer neutral Direct Current(DC) current reached 16A. Changes in the main substation grounding mode, that is, 2# main transformer neutral grounding, 1, 3# main transformer neutral grounding mode of operation, found that 2# main transformer neutral point DC current reached 25A. The real reason for revealing the cause of DC transformer neutral point, the main transformer neutral point were monitored for 24 hours, found that the neutral point DC current is about 60s cycle changes, in a certain period of time gap interrupt situation.

Previous research suggested that the cause of the DC bias of transformer has two main reasons [1-4], one is the geomagnetic storm, two is the reason of DC transmission at home and abroad; DC transmission completion time is not long, people first discovered the transformer DC magnetic bias is caused by geomagnetic storms. The storm event broke out in 1940, high latitude countries first discovered the transformer DC magnetic biasing [1] reference [2] is proposed for the first time will make the transformer neutral point DC half wave saturation voltage offset will cause power system point of view, initially pointed out the impact of transformer DC bias of power system. With the development of power system, the intensity of storms in 1940 1989 storm the Quebec blackout of [3] Kappaemen, this system was analyzed by [4], and the measured data show that transformer DC bias is the cause of the accident in power grid. Since 2000, with the development of power industry in China, the transformer DC magnetic
biassing appeared in the actual operation of the power system of our country: Guangdong power grid, Jiangsu River, Guohua Yuedian Taishan and Xinjiang Hami power grid and other regions have reported a lot due to the DC transmission DC bias of [5-11] events; in addition, although China is located in the low latitude, but still in the transformer substation in Guangdong Lingao, Jiangsu Shuanglong River, Zhejiang and Fujian East China grid system occurs and transformer noise and strong vibration due to abnormal geomagnetic storm events [12]. Based on the above analysis, it is found that the characteristics of magnetic bias current caused by geomagnetic storm and DC transmission are not consistent with the DC current of the event.

The neutral point DC current monitoring and its characteristics as the basis, the location of the main transformer, the surrounding environment and electrical contact and other factors are analyzed, and finally determine the operation of the subway is the main cause of transformer DC bias, and put forward the corresponding control methods, the effectiveness of the method is validated by the simulation of governance.

2. Analysis of DC bias and monitoring data of main transformer neutral point

2.1 Analysis of DC bias of main transformer in thermal power plant

The typical phenomena of DC magnetic bias include the increase of transformer noise, the increase of temperature, the increase of reactive power loss and harmonic wave. At the beginning of December 2015, China 1# main transformer noise power increases obviously, preliminary determination of transformer DC current exceed the standard, the main transformer neutral DC current reaches 16A. Change in the main substation grounding mode, 2# main transformer neutral DC current up to 25A. 2# thermal power plant main transformer is a three-phase five column structure, rated current is 1002A, according to the standard DL/T 437-2012 "HVDC technology guide" the ends of 6.3, allowing the winding DC limit of the rated current is 5 per thousand 2# main transformer, 7.55 per thousand and the actual flow through the DC transformer capacity, beyond 50%, with an increase in noise the obvious phenomenon, can determine the thermal power plant transformer DC magnetic bias has occurred.

In order to find out the main causes of the main transformer DC bias, the continuous DC current monitoring should be carried out.

2.2 main transformer neutral point DC monitoring data

The monitoring of the neutral point of Guohua thermal power main transformer was carried out for 24 hours, as shown in figure 1.

![Figure 1. Distribution of neutral point DC current distribution of Guohua 2# main transformer](image)

As can be seen from figure 1:

① The DC current is positive and negative, the variation period is about 60s, far less than the AC frequency 50HZ;

② If the inflow of the main transformer neutral point in the direction is positive, the outflow of main transformer neutral point in the direction is negative, then the maximum DC current value is 22.7A,
appeared in 25 8:32:53; the negative maximum value of -21.4A, appeared in 24 19:32:49;
(3) DC current concentration occurs at 24 9:15 - 25 0:00 and 25 5:00 - 25 10:19. In 25 0:00 - 25 5:00 this time period, the absolute value of the DC current is less than 1A, belonging to the device zero drift, can be considered in this period of time the main transformer neutral DC current;
(4) In 24 hours, the 2# main transformer appeared serious DC magnetic bias, the DC magnetic bias time in 5:00 - 24:00.

3. Analysis on the causes of DC bias of Guohua thermal power transformer

3.1. DC magnetic bias analysis
Geomagnetic storms and High Voltage Direct Current (HVDC) project is regarded as the main cause of the DC bias: the complex interaction with the earth's magnetic field solar wind to the earth, change the earth's magnetic field intensity, the formation of a geomagnetic storm. The variation of the geomagnetic field induced electric field on the earth surface, the formation of potential gradient, when the low frequency and has a certain induction duration of the electric field in the grounding of power transformer, the equivalent of an external voltage source. HVDC monopole operation, the electromagnetic field distribution near the surface potential is changed, the earth surface will also present different potential distribution, when the grounding is located at different potentials, the grounding potential difference exists between the location, the equivalent of an external voltage source function. It can be seen that the DC bias phenomenon is caused by the existence of DC potential difference between the neutral point of transformer grounding in the power system under the two causes. However, the DC bias caused by the two different characteristics of the problem.

Figure 2 is the monitoring of the neutral point current curve of the main transformer in Guangdong Ao Ao nuclear power plant in September 16, 2005, when the three - DC - DC operation.

Figure 2. Results of the DC current in transformer neutral point in Ling Ao Nuclear Power Station, September 16, 2005

Figure 3 is at 2:30 on November 10, 2004 at 6:30 on November 11th, during the geomagnetic storm, Guangdong Ling Ao Nuclear Power Plant No. 1 transformer neutral point of the GIC current monitoring results.

Figure 3. GIC monitoring curve of neutral point of transformer in Ling Ao Nuclear Power Station, November 10-11, 2004

As compared with figure 2 and figure 3, the rate of change of GIC is greater than that of HVDC. This is mainly due to geomagnetic storms, the variation of the geomagnetic field is violent, the change of GIC but also more intense; High Voltage Direct Current(HVDC) transmission power change is very small, so the changes in the size of DC current in transformer neutral HVDC monopole operation point is very small, basically stable.

3.2. Cause analysis of transformer DC bias in thermal power plant
Comparison of 1, 2 and 3 showed that the basic characteristics of thermal power plant DC current neutral DC current trends and geomagnetic storms and HVDC causes under the changing trend, period and frequency difference: solar geomagnetic storms produce geomagnetic current (GIC) AC frequency 1Hz, which can be approximated by DC. The inflow of the AC line can also trigger the main transformer DC magnetic bias. The geomagnetic storm caused by solar activities to make the grid in high latitude regions appear bias this phenomenon in middle and low latitudes, will result in high resistivity area, long distance EHV transmission system of DC bias, but DC bias caused by the geomagnetic storm in time should be a few ten years of time. For a few minutes to a few days in the region should be great geographical scope; grounding position, grounding current of HVDC is certain, but in exchange for a considerable period of time the grid architecture, the soil resistivity will not change. Therefore, the main transformer bias current should be a fixed value.

The main cause of transformer DC bias is judged as follows:

Firstly, according to the release of Key Laboratory of space weather information shows that geomagnetic storms during December 2015 24-25, the level of geomagnetic activity is low, Guohua thermal power DC magnetic bias duration more than 7 days, and 3 transformer voltage level is not high, it is not connected to the long-distance transmission line, so it can be initially ruled out causes of geomagnetic storms.

Secondly, thermal power plant position analysis. There is no HVDC transmission project in Beijing, Hebei, there is no DC transmission project. The monitoring data is different from the DC current caused by the DC transmission, so the origin of HVDC transmission can be excluded.

The third step, thermal power plant surrounding environment analysis. Guohua Beijing gas power plant is located in Beijing City, Chaoyang District Jin Yu Lu, belonging to the Beijing northeast gas power center. Distance from the subway line 6, the airport line straight distance of 3 km, 10 km, schematic see figure 4.

![Figure 4. Schematic diagram of Guohua thermal power and Metro Line](image)

In addition, figure 1 shows that the 0:00 - 5:00 time, 2# main transformer neutral point DC component, in the meantime, Beijing subway stop running, monitoring the current positive and negative frequency change basically accord with the characteristics of power supply system of Metro DC bias, can determine the initial cause of thermal power plant, the DC magnetic bias is around the subway.

3.3. Analysis of transformer DC bias mechanism caused by metro operation

Beijing metro power supply system using DC power supply mode, mostly DC750V, due to the short distance of 750V power supply voltage, stray current, now use 1500V. Divided into unilateral power supply system and bilateral power supply system. Power supply principle see figure 5:
Figure 5. single / double power supply system

Due to the locomotive running track and ground is not completely insulated, part of the DC component will flow into the earth. This part of the current is called stray current. As shown in Figure 6 (single side power supply has such problems, as shown in the unilateral power supply system):

![Figure 6. sketch of stray current in subway power supply system](image)

Figure 6. sketch of stray current in subway power supply system

Due to the effect of stray current in the ground, the distribution of ground potential. Similar to the HVDC Ground electrode. If at this time, the two connecting terminals with AC connection are located at different potential, which will produce a certain bias current. As shown in figure 7:

![Figure 7. DC magnetic bias of main transformer caused by stray current in subway power supply system](image)

Figure 7. DC magnetic bias of main transformer caused by stray current in subway power supply system

In the actual operation of the subway, the same line on a number of locomotives two-way traffic. In fact, the running position of the locomotive is the location of the stray current. Therefore, the influence of the DC component of the neutral point of the main transformer is the combined action of the stray current generated by multiple locomotives. At different times, the location of the locomotive is different, the location of the stray current is different, the specific impact of the way and the direction of the DC current generated see Figure 8 and figure 9.
All locomotives are equivalent to one, when the locomotive is located at position 1, the neutral current of the main transformer A is negative, and when the locomotive is located at position 2, the neutral current of the main transformer A is positive. The actual situation, subway locomotive number itself, speed, will cause a change in positive and negative DC current transformer ten seconds, and flights a day subway locomotive is generally fixed, so the main variable changes the frequency of positive and negative DC current is relatively stable, which also explains the trend of monitoring data in the period ca. 60s in the visible, the subway is the main reason for the DC bias of transformer thermal power plant.

4. Main transformer DC bias control measures
According to the above analysis, the main transformer substation will be affected by the operation of the subway and the phenomenon of DC bias. Considering the importance of the main transformer in main transformer neutral point series capacitor blocking device, this method is more practical in the actual project, with its simple principle, obvious effect, after the installation does not need to modify the protection and automatic safety device settings to get the industry recognized technical characteristics.

5. Conclusion
Previous studies suggest that geomagnetic storms and HVDC power system is the main reason causing the DC bias [1-4]. However, Guohua thermal power transformer DC magnetic bias events show that the subway can also cause the surrounding transformer DC bias. Firstly the paper introduces the process of determining the city power plant DC bias causes, and then analyzes the cause mechanism and characteristics of the DC bias of the subway operation methods are given in urban heat and power plant transformer DC magnetic bias control.

The subway operation caused by the DC bias of transformer is a new phenomenon, as China's power plant modernization and modern city construction and development of electric rail transportation, is established in the vicinity of the main transformer in power plant and substation will be more and more
influence power supply system for urban rail transit and the DC bias phenomenon. This paper through the analysis of the incident, the system was put forward, the method to determine the causes of DC bias and countermeasures and some problems that need further study, in order to similar DC bias events and provide theoretical reference for governance.

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