Diagnosis and Research on Local Overheat Fault of Main Transformer

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Abstract. The main transformer is a transformer used to deliver power to a power system or user in power plants and substations. This paper introduces the use of infrared imaging detection technology and gas chromatography analysis technology as the main means to accurately diagnose a local transformer overheating fault. The article elaborates the diagnosis method, diagnosis process and treatment suggestions, and deeply analyse the causes of the local transformer overheat fault, and provides reference for the diagnosis and analysis of the same type of transformer fault.

1. Introduction
The main transformer, referred to as the main transformer, is the main transformer mainly used for power transmission and transformation in power plants or substations, and is also the core part of the substation. The transformer is the core equipment of the electric locomotive traction power supply system, and also the key equipment to ensure the safe and stable operation of the traction power supply system. The capacity of the main transformer is generally large and requires high reliability of operation. Although the main transformer failure rate is not high, in the event of a failure, it will cause significant losses. If it is light, it may cause equipment failure; if it is heavy, it will cause fire and endanger normal transportation safety. Therefore, it is very important to analyze the cause of the transformer fault and take corresponding preventive measures. In the fault diagnosis of transformers, commonly used methods include infrared diagnostic technology, gas chromatography analysis, partial discharge method, recovery voltage method, frequency response analysis method and vibration analysis method. At present, the most widely used is infrared imaging detection technology. This paper introduces a fault diagnosis and fault analysis and processing method for local overheating of the main transformer.

The main transformer of a power plant is a three-phase integrated main transformer produced by Baoding Tianwei Transformer Factory. The transformer adopts forced oil circulation air cooling, the capacity is 800MVA, the wiring group is Yn/d11, and the short-circuit impedance Ud=18%. The main transformer adopts the no-load voltage regulation mode, and the voltage variation ratio is 525±2×2.5%/22kV, and there is no excitation voltage regulation. Power transformers are important electrical equipment in power systems and play an important role in transmitting and distributing electrical energy. Therefore, power transformers are listed as key detection targets in power plants.
2. Troubleshooting methods and procedures

2.1. Fault Diagnosis Analysis Based on Infrared Imaging Detection Technology

Infrared thermal imaging uses photoelectric technology to detect infrared specific band signals of object heat radiation, convert the signals into images and graphics that can be visually resolved by humans and further calculate temperature values. All types of power equipment in the power system generate a certain amount of heat during normal operation. However, as the running time of the equipment increases, some parts appear rust and corrosion, contact failure, ash accumulation or other reasons cause the contact resistance to increase, resulting in overheating of the equipment. These overheated parts radiate more intense infrared rays than normal. Infrared thermal imaging technology has enabled humans to transcend visual impairments, so that one can see the temperature distribution of the surface of the object. The infrared thermal imager can realize the non-contact temperature measurement by measuring the temperature distribution and the change of the surface of the device, and find the temperature abnormality and potential fault defect points of the power equipment through the thermal imaging technology, thereby realizing the fault diagnosis of the device.

On June 19, 2019, during the near-full load of the unit, infrared imaging temperature measurement was performed on the main transformer #1 main transformer and #2 main transformer, and it was found that there were local overheating conditions on both main transformer tanks (high pressure side), #1 The main transformer box reached 109.7 °C along the hot spot temperature (reference temperature 23.8 °C). By continuously observing the change of the hot spot temperature with the load change, the smaller the load, the lower the temperature, the higher the load, the higher the temperature, and the highest hot spot temperature reaches 119.2 °C. Although there is no obvious temperature rise limit for the structural components on the fuel tank body, GB 1094.2-2013 power transformer part 2: temperature rise of liquid immersed transformer suggests that the temperature rise should not be too high, so as not to be heated by its adjacent components. Damage or excessive aging of the insulating liquid (top layer oil temperature allows temperature 85 °C). Diagnostic parameters: background temperature: 31 °C; emissivity setting value: 0.90; transmittance setting value: 100%.

![Infrared imaging picture of a power plant #1 main transformer failure](image)

2.2. Fault Diagnosis Analysis Based on Gas Chromatography Analysis Technology

Insulating oil and other organic insulating materials in the transformer will gradually age and decompose under the long-term action of heat and electricity with the increase of running time, and generate a small amount of gas dissolved in oil such as hydrogen, methane, ethylene, ethane, acetylene, carbon monoxide and carbon dioxide. When there are latent overheating and discharge faults inside the transformer, the rate of generation of these gases is accelerated. As the fault progresses, a part of the decomposed gas is
released in a free form. Most transformer faults have early characteristics. Therefore, the internal gas breakdown of the transformer can be predicted by gas chromatographic analysis of the gas content dissolved in the insulating oil. The purpose of the dissolved gas analysis in insulating oil is to detect whether there is a potential failure inside the transformer, to supervise the insulation of the transformer, and to predict its future operating state. However, the reasons for the increase in dissolved gases in oil are various. When it is considered that there may be an internal fault according to the analysis of the gas, the comprehensive judgment should be made based on the electrical and chemical test results and the maintenance records of the equipment.

For the analysis of the #1 main transformer oil chromatographic test in 2016-2019, the trend chart is shown in Figure 2 below. The #1 main transformer oil chromatographic analysis data is normal, and the calculation of the three ratios is normal. Although the content of co and co2 has a significant change with the change of ambient temperature, according to the DLT 722-2014 Guideline for Analysis and Judgment of Dissolved Gases in Transformer Oil, Section 10.2, the increase of co and co2 content needs to be combined. The comprehensive analysis of other characteristic gas changes is carried out. Because there is no obvious change trend of other characteristic gases, the content of co2 has changed, and it is impossible to judge the transformer.

![Figure 2. Variation diagram of the content of each component in the gas chromatographic analysis of dissolved gas and water in the insulating oil of the #1 main transformer in the past three years.](image)

3. Troubleshooting plan and process
Since the oil chromatographic analysis is normal and the transformer is in an abnormal state, in order to eliminate safety hazards and avoid faults, it is recommended that the electrical maintenance department first install a short-circuit copper bus bar to increase the short-circuit copper bus bar near the bolt with more heat. In the material selection of the short-circuit piece, copper with better conductivity should be selected, and sufficient current-carrying cross section should be added to increase the heat dissipation surface of the bolt and achieve better shunting effect.

After the paint is fully polished near the main heating point, two short copper bars are installed, and the connecting bolts between the upper and lower edges are replaced to facilitate the formation of a circulation, as shown in Figure 3 below.
After repair, the temperature at the full load is significantly reduced to 76.5 °C (where background temperature: 31.6 °C; emissivity setting: 0.90; transmittance setting: 100%), as shown in Figure 4 below, the highest temperature compared to historical detection The value of 119.2 °C has been significantly improved, and equipment failures have been eliminated.

4. Cause analysis
(1) The core of the main transformer is generally made of silicon steel sheet with high magnetic permeability material. Considering the magnetic saturation phenomenon of the iron core, when the three-phase load is asymmetrical, DC bias, etc., if the load increases, the iron core will be supersaturated and cause magnetic flux to overflow, causing an increase in leakage flux. The eddy current loss generated by the leakage flux at the connecting screw, the tank wall, etc. will also increase, and the screw temperature will also increase.

(2) The material of the partial overheating bolt is made of magnetically permeable material, which has strong magnetic permeability. Under the action of the leakage magnetic field and the low-voltage lead magnetic field which change with the load current, the permeability of the air is low. A large amount of leakage flux passes through the better magnetically connected connecting bolts, so that the magnetic flux density inside the bolt is increased, and the high-density alternating magnetic flux will generate a large eddy current in the screw, causing the bolt to generate heat.

If the fault is not handled in time, it can cause the following safety hazards:
(1) When the transformer is connected to the upper and lower bells, the screw is partially overheated, which may cause the sealing pad to accelerate aging or even be burned out, causing the transformer to leak oil, which reduces the insulation and cooling effect of the transformer;

(2) The local overheating of the upper and lower bells of the transformer is often accompanied by the increase of the local oil temperature, which may cause the transformer insulating oil to age and decompose due to local overheating. The gas is generated by the evolved gas, and even the gas output will cause the tank pressure to increase. Cause local deformation; the thermal decomposition of the transformer oil will produce suspended matter in the oil, the acid substance generated by the decomposition will corrode the insulation of the winding, and the generated sludge will accumulate on the surface of the winding, hindering heat dissipation and blocking the oil passage, making the winding insulation strength is lowered, which may cause the winding insulation to be broken down and the transformer to be damaged.

5. Conclusion
Transformers play an important role in the power grid. In daily power production work, equipment maintenance personnel should pay special attention to the operating state of the transformers, do a good job of inspection and maintenance of the transformers, and actively use infrared thermal image detection and gas phase. Chromatographic analysis and other technologies, do a good job in monitoring the operation status of the transformer and early warning of the fault, in order to find the latent faults and eliminate the defects in time to ensure the power generation of the power generation enterprise and the safe and stable operation of the power grid.

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