Analysis and Treatment of abnormal Expander Oil Level in a 220kV Current Transformer

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Abstract. A disassembly analysis and treatment of abnormal oil level fault of current transformer expander is introduced in this article. After returning to the factory for a comprehensive electrical test and investigation, it was found that the reason was the wrong wiring of the zero screen lead. Recommendations for quality control and preventive measures and operation and maintenance procedures for this type of electrical equipment are given in this paper, providing a basis for further research.

1. Introduction

Current transformers are important electrical equipment in power grids, which are essential electrical equipment in substations and responsible for functions such as power system metering, measurement, and signals required for relay protection. The primary winding of the capacitive current transformer adopts a U-shaped structure. The externally wrapped capacitor layer (also known as the capacitive screen or the main screen and the insulation layer), and the insulation layer is continuously wound by the cable paper outside the primary winding [1, 2].

The insulation layer is covered by a capacitor layer. The capacitor layer is made of aluminum foil and is wrapped around. The capacitor layer has 4 to 5 secondary screens (also called end screens) at the end to improve the electric field at the end. Overlap and insulate with a total of 20-30 layers. [3,4]. In this paper, the disassembly analysis and treatment of the abnormal oil level fault of the 220kV current transformer expander in a substation is taken as an example to analyze the cause of the defect and the countermeasures.

2. Defects overview

2.1. Failure process

On November 14, 2018, the phase A of the LB7-220W3 current transformer of a 220kV substation was abnormally high during operation. After analysis, it can be seen that there is a high-energy partial
discharge inside the transformer, and a large amount of characteristic gas is generated. Appearance inspection revealed that the expander was deformed and no abnormality was found in other parts.

The following table shows the dissolved gas in the oil from the on-site oil analysis test:

| Dissolved gas in oil | H₂ | CO  | CO₂ | CH₄ | C₂H₄ | C₂H₆ | C₂H₂ | Total hydrocarbons |
|---------------------|----|-----|-----|-----|------|------|------|-------------------|
| Unit: μL / L         | 33281 | 86.77 | 1384.34 | 2442.3 | 227.7 | 3.39 | 4.03 | 2671.8 |

2.2. Basic equipment information
In this 220kV substation, the bus connection method is double bus single segment wiring, while the busbar breaker is in the operating state. Rated current ratio is 2 × 800/5. Grade combination is 5P35 / 5P35 / 0.2S pump / 0.2S pump. Rated secondary load is 50/50/50 (25) / 50 (25). Short-term thermal current is 50kA / 3s. Rated dynamic and stable current is 125kA. Product ex-factory date is August 2018, and commissioning date is September 14, 2018.

3. Diagnostic test and disintegration

3.1. Diagnostic test
On December 30, 2018, the electric transformer was returned to the factory for electrical testing. The specific test data are shown in the following table:

| The measurement of insulation resistance | Room temperature: 8 °C; Relative humidity: 29%; Weather: sunny |
|------------------------------------------|---------------------------------------------------------------|
| Primary to secondary winding and ground  | 2500 MΩ                                                       |
| Between secondary windings and ground    | 2500 MΩ                                                       |
| Last screen to secondary winding and ground | 2500 MΩ                                                   |

| The measurement of Capacitance and dielectric loss factor | Room temperature: 8°C; Relative humidity: 29% |
|----------------------------------------------------------|-----------------------------------------------|
| Voltage (kV)     | C₀  | R₄   | Diagnostic test | Factory test |
| 10              | 775.01 | 0.0041 | tanδ       | Cₓ(pF)   | 0.0027 | 778.27 |
| 73              | 775.01 | 0.0041 | tanδ       | Cₓ(pF)   | 0.0027 | 778.37 |
| 146             | 775.01 | 0.0041 | tanδ       | Cₓ(pF)   | 0.0027 | 778.45 |
| Voltage:3kV     | tanδ | 0.006 | Cₓ(pF)   | 1007.2  |

The conclusion is: Transformer oil chromatographic analysis test failed, and partial discharge measurement failed. Due to the low-energy partial discharge, the transformer oil chromatogram is abnormal, and the transformer oil contains a large amount of gas, which causes the dielectric loss factor and the factory routine test value to increase significantly.
3.2. Equipment disintegration
There is a blackening phenomenon locally on the zero-screen lead, and there is a local overheating trace on the contact part between the zero-screen lead and the aluminum tube, as shown in Fig.1 and Fig.2.

![Figure 1. Localized blackening of the leads](image1)

![Figure 2. Local overheating traces on the contact area between the zero-screen lead and the aluminum tube](image2)

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3.3. The analysis of reasons
This product is a double variable ratio capacitor type insulation structure. The primary conductor is composed of the same two semi-circular aluminum tubes. In order to realize the current ratio conversion correctly, it is necessary to wrap the insulation on semi-circular aluminum tubes to meet the primary turn-to-turn insulation requirements. In order to achieve the equipotential requirements between the zero screen and the primary conductor, two zero screen leads are set at one end of the same semi-circular aluminum tube to ensure the reliability of the connection. During the disassembly on site, it was found that two zero-screen leads were placed at the two ends of the same aluminum pipe. Although this connection method meets the equipotential requirements for reliable contact, the zero-screen leads at both ends reliably contact the zero-screen, and the semicircles connected by them an additional zero screen circuit is formed on the aluminum tube, and the corresponding circuit is as follows:
Figure 3. Zero-screen wiring diagram when connected in series connection

Figure 4. Zero-screen wiring diagram in parallel connection

Figure 5. Zero-screen lead placed incorrectly
3.4. The analysis of Results
This product is a capacitor-type insulation structure. It consists of a zero-screen, a middle-screen and a final screen to form a series capacitor equalizing voltage. The zero screen is connected to the primary conductor through the zero screen lead to achieve equipotential, and the final screen is grounded during operation. In order to ensure the reliable contact between the zero screen and the primary conductor, the design requires that two zero screen leads be provided at one end of the same semi-circular aluminum tube.

According to the disintegration inspection, it can be inferred that individual workers placed two zero-screen lead wires at the two ends of the same aluminum pipe during the zero-screen placement process operation. Although it is also possible to achieve a reliable electrical connection between the zero screen and the aluminum tube, a zero screen additional circuit is formed by the zero screen lead and the zero screen.

According to the analysis of the gas composition of the transformer oil of the faulty product, combined with the three-ratio method, the fault type of this equipment is a low-energy discharge caused by contact with overheating. Combined with the disintegration phenomenon, the device has a zero-screen additional circuit due to the incorrect placement of the zero-screen lead. When the product is filled with oil, there is transformer oil between the zero screen lead and the aluminum tube, which causes the contact resistance at this part to increase. After the equipment is put into operation, the system current flows through the zero-screen circuit, resulting in contact overheating, which causes the transformer oil at this location to decompose, and the decomposed gas to accumulate on the upper part of the product and cause the expander to expand and jack up. Therefore, the cause of this fault is: the zero-screen lead is incorrectly placed, and an additional circuit is formed, resulting in low-energy discharge caused by contact overheating [5, 6].

4. Conclusion
During the period when the inspection plan is not determined, it is recommended to strengthen the inspection and inspection on the spot: pay close attention to and record the oil chromatographic changes, and recommend that the detection interval be 1 month to prevent problems as soon as possible; pay close attention to and record the oil level change trend and expansion Device status, problems can be detected early. It is recommended to strengthen the detection of ultrasonic and ultra-high frequency partial discharge of current transformers in the future. If there is an abnormality, the detection period should be shortened, and diagnostic tests should be performed under conditions to detect equipment defects in time.

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