Overheating Fault Analysis of Electromagnetic Unit in 220kv Capacitive Voltage Transformer

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Abstract. This paper introduces the structure and principle of capacitive voltage transformer, the overheating caused by the failure of the electromagnetic unit on 220kV capacitive voltage transformer in operation is analyzed, it is based on infrared detection technology, combined with the method of power outage diagnostic test for joint fault diagnosis, the diagnostic results are accurate and reliable, some suggestions on field detection and fault diagnosis of capacitive voltage transformer are put forward.

1. Introduction.
Because capacitive voltage transformer has the advantages of high impact insulation strength, small volume and simple manufacture, and can effectively avoid ferroresonance and other advantages [1].It widely used in power networks with voltage levels of 220 kV and above. This leads to the relatively small insulation distance between the internal space and the components of the electromagnetic unit of the capacitive voltage transformer because of its design, structure and other reasons, and it often bears the overvoltage of the power grid, the influence of poor operating condition. It is often subject to the influence of over-voltage and poor operating conditions of the power grid during operation. In addition, there are many manufacturers of capacitive voltage transformers, the assembly process is uneven, and some manufacturers are not strict about the quality of raw materials. Therefore, the probability of failure of the electromagnetic unit of the capacitive voltage transformer is significantly higher with respect to the capacitance unit at present.

2. Working principle of Capacitance Voltage Transformer
Capacitance voltage transformer can be divided into capacitor voltage divider and electromagnetic unit. Capacitive divide comprises a high-voltage capacitor C1 and a voltage-dividing capacitor C2, the electromagnetic unit is composed of an intermediate transformer, compensation reactor, voltage limiting device and damper composition, etc. The voltage schematic diagram of the 220 kV capacitive voltage transformer is shown in Figure1. In figure 1, C1 is a high voltage capacitance, C2 is a partial voltage capacitor, T is an intermediate transformer, L is compensation reactor, Z is a damping device, S is the protection gap, a-x is the primary secondary winding, af-xf is an auxiliary secondary winding.
Compensation reactor L is used to compensate the influence of capacity-resistant pressure drop with secondary load variation on the accurate stage of capacitive voltage transformer. The dampers Z are used to dampen the ferroresonance that may occur in the capacitive voltage transformer. This is because capacitive voltage transformer capacitor divider, core compensation reactor and intermediate transformer constitute series circuit of capacitance and nonlinear inductance. Ferroresonance will occur under certain conditions.

At present, there are two main types of dampers: fast saturation reactor type and harmonious mode. Fast saturation reactor damping device is based on the fast saturation of the iron core to quickly connect the resistance to the capacitive voltage transformer circuit, under the condition of power frequency, the reactor has a large impedance, the current through the damper is small, its usually only a few dozen milliamperes, its power consumption and energy storage are very small, and when ferromagnetic resonance occurs, the inductance of the reactor decreases sharply, quickly connect the resistor to the resonant circuit to absorb resonance energy, it has a good transient response [3]. The resonance type damping device is composed of a resistor, an inductor and a capacitor in series and parallel. In power frequency, the inductance and the capacitance form a parallel resonant circuit, the equivalent impedance of the whole damping device is infinite, its equivalent to no access; when the frequency division resonance occurs, the resonant circuit of inductor and capacitance is destroyed, dampers as a valid impedance access used to suppress resonance, but its transient response is not good enough [4].

3. Fault case

3.1. Fault profile
19:30, 17 November 2018, The electromagnetic unit in Phase A of the first generatrix Voltage Transformer on 220kV ShengLi station has abnormal heating phenomenon, then the infrared accurate temperature measurement of the voltage transformer is carried out. The weather is clear on the day, the temperature is 8°C, the humidity is 55%, and the wind speed is grade 1, infrared detection atlas is shown in figure 2.

Infrared accurate temperature measurement display that the electromagnetic unit of the voltage transformer does have heating phenomenon, and it is a voltage-induced type defect. The maximum temperature of phase A measured is 16.7 °C, the temperature in the same part of phase B is 12 °C, the temperature in the same part of phase C is 12 °C.
3.2. Diagnostic test and disintegration examination

The phase of capacitive voltage transformer was replaced by power outage and its defect diagnosis test and disintegration examination were carried out. The appearance and oil level of capacitance voltage transformer are checked. There is no obvious discharge trace and the oil level of fuel tank is normal.

3.2.1. Status of diagnostic tests. 1) Capacitor unit dielectric loss and capacitance measurement (the instruments: PH2801), dielectric loss and capacitance data are shown in Table 1, Compared with the initial value (November 2016 test), the initial difference of capacitance is within the qualified range which is less than the standard required value (±2%). Compared with test procedure for condition maintenance of transmission and transformation equipment, the dielectric loss data is less than the standard value (0.25%), dielectric loss and capacitance test results are up to standard.

| Test site | Tanδ(%) this time | Tanδ(%) initial value | Electric capacity(pF) this time | Electric capacity(pF) initial value | Initial value difference |
|-----------|------------------|----------------------|-------------------------------|------------------------------------|-------------------------|
| C1        | 0.176            | 0.167                | 12970                         | 12900                              | 0.54                    |
| C2        | 0.193            | 0.179                | 50170                         | 49890                              | 0.56                    |
| C         | -                | -                    | 10305                         | 10249                              | 0.54                    |

remarks: temperature: 18°C; humidity: 70%

2) Measurement of Insulation Resistance of electromagnetic Unit, the test data of insulation resistance of electromagnetic unit are shown in Table 2, The test data of the insulation resistance is qualified, it is shown that the main insulation of the first and second windings of the electromagnetic unit is good.
Table 2 The test data of electromagnetic unit insulation resistance

| Test site | Primary side to secondary side and ground | a/x to primary side and ground | af/xf to primary side and ground |
|-----------|------------------------------------------|-------------------------------|----------------------------------|
| Insulation resistance(MΩ) | 10000 | 10000 | 10000 |

Remark: temperature: 18°C; Humidity: 70%

3) Winding DC resistance test, test winding before and after the damping device was removed. The test data is shown in table 3, the test data of the winding dc resistance test is qualified, and the winding is not broken and short circuit.

Table 3 The number of DC resistance test

| Test site | Primary winding | a/x winding | af/xf winding |
|-----------|-----------------|-------------|--------------|
| DC resistance(Ω) | 3080 | 0.06354 | 0.1178 |

Remark: temperature: 18°C; Humidity: 70%

4) The test variation ratio before and after the damping device is removed, the test data was shown in table 4. The test results showed that the damping device has a greater influence on the test results than the test results. The test results of the undamped device were close to the actual value. The test results of the damping device were different from the actual values. Therefore, the initial doubt damping device was defective.

Table 4 The winding variation ratio test data

| Variation ratio | (A/X)/(a/x) | (A/X)/(af/xf) |
|-----------------|------------|--------------|
| pre-demolition  | After demolition | actual demolition | pre-demolition  | After demolition | actual demolition |
| 242.6 | 224.21 | 225.16 | 141.84 | 129.8 | 130 |

5) The airborne test of the electromagnetic unit, Test select secondary winding terminal af, xf to apply voltage. In the two cases, the empty load test was carried out in both cases. The test data was shown in table 5-6.

Table 5 Null load date (With damping device)

| Article I. | voltage (V) | 10.6 | 20.3 | 31.4 | 40.8 | 50 |
|------------|-------------|------|------|------|------|----|
| electric current(A) | 0.95 | 1.8 | 2.75 | 3.55 | 4.31 |
| loss(W) | 9.98 | 36.72 | 86.96 | 145.18 | 215 |

Table 6 Null load date (With damping device)

| Article II. | voltage (V) | 10.39 | 20.133 | 30.297 | 41.39 | 50.489 |
|-------------|-------------|-------|--------|--------|-------|--------|
| electric current(A) | 0.0146 | 0.034 | 0.054 | 0.076 | 0.093 |
| loss(W) | 0.249 | 0.498 | 0.995 | 1.991 | 2.987 |

The test results showed that the damping device had a significant effect on the test results. When the damping is loaded, the current load current increases rapidly, and the load loss increases sharply. If the load voltage was 50V, the empty current is 4.31A and the loss was 215W. When voltage applied without damping, the current rises gently. When the same voltage is 50V, the empty load current is 0.093A, and the loss is only 2.987W. Therefore, it can further suspect that the damping device is defective, which causes the data anomaly of the damping empty load test.
6) Test of core excitation characteristic. Test select secondary winding terminal a, x to apply voltage. After the damping device was removed, the test core excitation characteristic curve was shown in figure 3. The inflection point voltage is 71.07V, and the current is 0.2984A.

![Figure 3](image)

**Figure 3** Excitation characteristic curve of capacitor voltage transformer

The inflection point voltage was low, about 1.25 times the rated working voltage. The quality of iron core cannot cause the heat deficiency under normal working voltage. Through the above test results, it was possible to determine the overheating failure of the electromagnetic unit of the capacitor voltage transformer due to the damage of the damping device. In order to further determine the cause, find the heat point and decide to check the electromagnetic unit.

3.2.2. Breakdown Inspection. After the oil was finished, the external inspection of the components of the electromagnetic unit was first examined. The results found that the damping resistance had a severe charred trace and the other components were similar. The elements were tested for electrical parameters, as shown in table 7.

| test value | The manufacturer provides the value |
|------------|-----------------------------------|
| resistance(Ω) | 9.934 | 10 |
| inductance(mL) | 36.46 | 37 |
| capacitance(μf) | Broken down, cannot be tested. | 288 |

The results show that the damping resistance and the inductance value were normal, and the capacitance of the capacitor was not measurable. The capacitor has been fully perforated and developed. It is found that the outer insulation cloth of the fast saturation coil has obvious signs of overheating ablation. when the electromagnetic unit of the capacitive voltage transformer is disassembled, further dissection found that there is a significant inter-turn insulation ablation inside the coil. There are several suspected friction sections on the coil surface at the ablation position as shown in Fig. 4 and Fig. 5.

![Figure 4](image)

**Figure 4** The insulating tape is ablated

![Figure 5](image)

**Figure 5** The inter-turn insulation of the coil is burned
4. Fault Analysis

The damper belongs to the resonant damper. A resistance is made in tandem with a resistance by an inductance and capacitance. The principle diagram is shown in figure 6. In normal working state (industrial frequency) the inductance and capacitance are in parallel resonant states, the parallel branch is the same as the open circuit state, and the damping resistance r is not connected. And when the system happens to operate the overvoltage, in the current, the frequency or high frequency component increases, and the parallel resonance condition of the damping device circuit is destroyed, Resistor R is connected to suppress resonance.

![Figure 6 Damping device z principle structure](image)

Through the examination and examination of the diagnostic test of the fault capacitor voltage transformer, the comprehensive judgment is verified, and the comprehensive judgment is determined. The root cause of the abnormal heat of the capacitor voltage transformer is because the capacitor in the damping device is fully broken under the long working voltage or internal overvoltage. Lead to the damage of the frequency resonant condition of the workers, the damping resistance causes the fever in the long term.

5. Peroration

1) The abnormal heat of the capacitor voltage transformer is caused by the complete breakdown of the capacitance unit in the damping device, which is damaged by the long working voltage or internal overvoltage. The damping resistance is in the long term of the working voltage, which flows through the large current to cause the damping resistance, and the heat diffusion leads to the overheating of the entire electromagnetic until.

2) The characteristics of the temperature rise of the fuel tank are characterized by the defect of the resistance flow, and the infrared heat image can be detected accurately and timely. Meanwhile, for old CTV should coordinate the seasonal professional inspection and conduct accurate temperature measurement. Especially the electromagnetic unit with the resonant damper, should be detailed records, the inspection time focuses on timely discovery equipment defects.

3) Infrared thermal image detection technology can effectively detect the heat deficiency of the electromagnetic unit of capacitor voltage transformer. In the case of infrared detection, the temperature of the heating area is compared, avoiding the error sentence and error sentence.

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