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Research on temperature rise method of low voltage switch equipment

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Abstract: *Aiming at the problems of many output circuits and complex current regulation in the temperature rise test of low-voltage complete sets of switches, a three-branch outgoing circuit is designed by the current inverted input method to meet the stable output of three-phase 800 A, 630 A and 400 A currents, which solves the problems of difficult adjustment and poor stability of the test current, and realizes the uniform and stable output of the temperature rise test current.*

Keywords: *Low voltage complete switch; temperature rise test; inverted current input*

1. Introduction

In the type test, the temperature rise test of low voltage switchgear is the key index to measure the product quality and ensure the safe and stable operation of the power grid. The temperature rise test method is to input the rated current. When passing through the switching equipment, the influence of conductor resistance, contact resistance and other factors produces heat loss. When the equipment heats up, the temperature rise does not exceed 1K within 1h, and the test ends [1].

The low-voltage switchgear is composed of a single inlet end and a multi-branch outlet end, which is characterized by multiple output loops and unequal test currents. By adjusting the impedance shunt, the problem that the current drift caused by the temperature rise of the copper resistance needs to be adjusted in real time cannot be solved, and the test complexity is improved. When the shunt is uneven, the accuracy of the temperature rise test is affected by this, which affects the test results.

Therefore, a three-branch outlet circuit is designed, which is short-circuited at the inlet side of the low-voltage switchgear, and the current is inverted at the outlet side of the multi-branch outlet, and the current at the confluence row is superimposed on the rated current for temperature rise test. It ensures that the current of the multi-branch outlet circuit is adjustable and stable, improves the accuracy and efficiency of the test, accurately predicts the product quality, and ensures the safe operation of the power grid.

2. Heat transfer mechanism analysis

The temperature rise test satisfies that the temperature rise is stable between 1K within 1h, and the test ends, that is, the heating and heat transfer of the dominant electric circuit are flat. Heat generation mainly includes resistive loss, hysteresis loss and eddy current loss[1] [2]. Heat transfer is the transfer of heat energy, which is affected by heat conduction, heat convection and heat radiation.

2.1 Heat conduction heat transfer mechanism[3]

The heat transfer process that occurs when an object at different temperatures is in direct contact or has a temperature difference inside the object is called heat conduction. The mechanism is to rely on the thermal motion of microscopic particles such as molecules, atoms and free electrons to generate thermal energy. There are two ways of heat conduction in solids. One way is to rely on the direct lattice vibration of atoms to transfer energy. The other is that the conductor represented by metal relies on the movement of free electrons to transfer energy.

The French mathematician Fourier refined the heat conduction data and practical experience, and

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summarized the heat conduction law as Fourier 's law. The basic expression of Fourier 's law is that the heat conduction rate of the isothermal surface is formed by the temperature gradient and the heat transfer area :

$$q = -\lambda \frac{d\theta}{dx} \tag{1}$$

In the formula, q is the heat flux density, which represents the heat flow transmitted per unit area and per unit time, and the unit is W/m2.

It is the temperature gradient and it is the vector, both the size and direction, the normal direction indicates the direction of temperature increase;

λ is the proportional coefficient, which is called the thermal conductivity, and the unit is W / (m·K).

Thermal conductivity is one of the physical properties of the material, which characterizes the thermal conductivity of the material. It is generally related to the type and temperature of the material. The thermal conductivity of various materials used in engineering calculations is determined by experiments. In general, the thermal conductivity of solids is the largest. Among all solids, the thermal conductivity of metals is the largest.

2.2 Thermal convection heat transfer mechanism[3]

The heat exchange between the fluid and the solid when the fluid flows through the solid surface is called convective heat transfer. The heat transfer mode of convection consists of two mechanisms. In addition to the capacity transfer caused by random molecular motion, the overall or macroscopic motion of the fluid can also transmit energy, that is, the total heat transfer is the superposition of energy transfer caused by the random motion of the molecule and the overall motion of the fluid.

The relationship between convective heat transfer and temperature difference is calculated by Newton cooling formula, namely

$$Q = \alpha A(\theta_1 - \theta_2)\ [\mathrm{W}] \tag{2}$$

Where A is the area of the wall in contact with the fluid;

θ_1 is the temperature of solid wall [K] ;

θ_2 is the average temperature of the fluid [K] ;

α is the convective heat transfer coefficient [W / m^2 · K].

The thermal resistance of convective heat transfer is:

$$R = \frac{1}{\alpha A} \quad [\mathrm{K / W}] \tag{3}$$

From Eq. (3), it can be seen that the heat transfer is proportional to the convective heat transfer coefficient, and is also proportional to the heat transfer area and temperature difference. The study of convection ultimately comes down to the study of the method of determining the heat transfer coefficient α.

2.3 Thermal radiation heat transfer mechanism[3]

All objects are composed of molecules or atoms, which move violently based on the absolute temperature of the object. With this moving object emits electromagnetic waves of various wavelengths, the so-called radiation is the general term for these electromagnetic waves, in which the wavelength range that can be detected in the form of heat or light is called thermal radiation. Thermal radiation refers to the radiation in the wavelength range from visible light to 100 μm (infrared). Radiation transmission energy does not require a material medium. In fact, radiation transmission is most effective in vacuum.

For the radiative heat transfer between a small surface with a temperature of Ts and an isothermal surface Tsur which is much larger than it and completely surrounded by it, the calculation formula of net radiative heat transfer is:

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$$Q = \varepsilon\sigma A(T_s^4 - T_{sur}^4) \tag{4}$$

In the formula: *e* for the emissivity.

3. Methods and principles

3.1 Thermal convection heat transfer mechanism

Due to the composition of multi-branch outlet end of low-voltage switchgear, it is necessary to carry out temperature rise test for each branch, so it is assessed twice. Fig.1 is the schematic diagram of temperature rise test:

The first test: for the disconnector fuse group and 630 A residual circuit breaker (C1 branch), the three-phase rated current is applied to the inlet end, and the C1 outlet end is shorted by three-phase cable. The measurement point is 1 ~ 5, the operating handle and the shell.

The second test: for the disconnector fuse group and the 400 A residual circuit breaker (C2, C3 branch), through the current inverted input method, the input current of the C2 branch is 400 A, the current of the C3 branch is 230 A, and the in-phase input current is merged into the busbar and superimposed to 630 A, which satisfies the rated current of the disconnector fuse as the output end, and it is shorted. The measuring points are 1 ~ 3, 6 ~ 9 operating handles and casings.

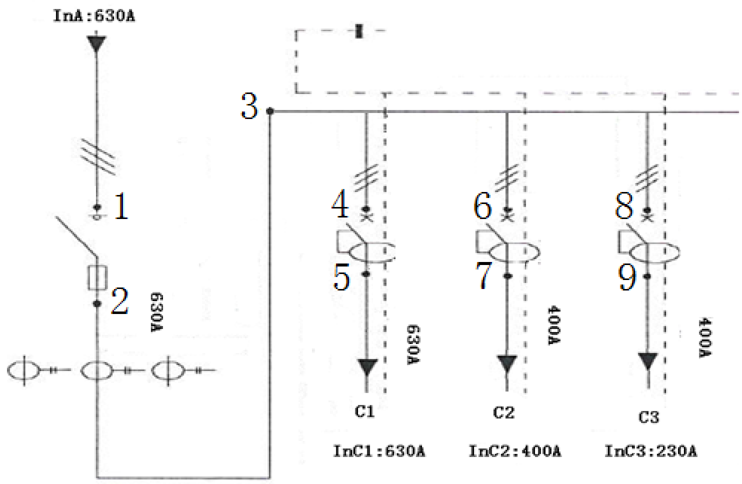

Figure 1: Schematic diagram of temperature rise test

3.2 Principle of test platform

In the second test of low-voltage switchgear, the conventional method is to input the rated current into the fuse group of the disconnector, and the C2 and C3 outlet ends are short-circuited through the three-phase cable respectively. In order to ensure the current size and stability of each branch test, it is realized by adjusting the impedance of each branch, but it cannot solve the current drift caused by the temperature rise of the copper resistance. It needs to be adjusted in real time, and the test complexity is improved and the efficiency is reduced.

Fig.2 is the structure diagram of the test platform, which is composed of current source, transformer, transformer, impedance and so on. The temperature rise is collected remotely through WIFI module [1]. The current source automatically adjusts the current size through the control element; transformer feedback current changes, through the control unit to automatically adjust to prevent grid fluctuations and temperature changes caused by the impact; the magnitude of the impedance is adjusted by the numerical feedback of each branch current to realize the stable input of the test current.

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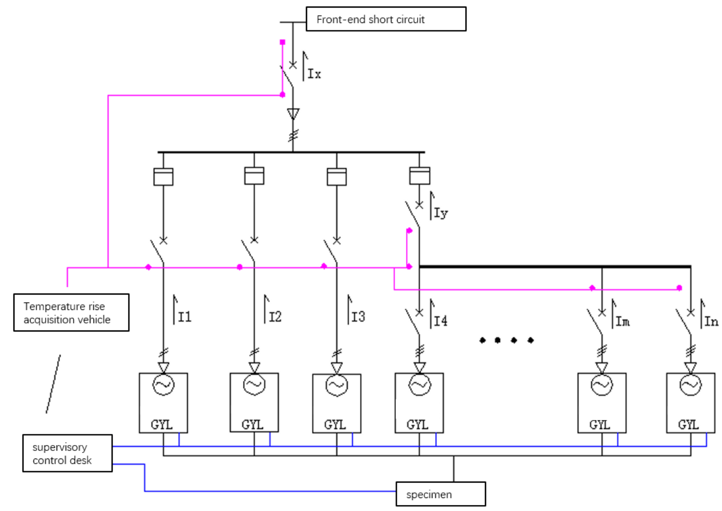

Figure 2: Test platform structure diagram

Figure 3 is the flow chart of the test platform, which is composed of touch screen, PLC, AD acquisition module, communication module, voltage regulation and so on.

The touch screen can realize human-computer interaction, adjust and set the output current size; the main function of PLC is to scan and calculate the I / O and AD data in real time, and carry out negative feedback control. AD acquisition module is to collect voltage and current, combined with PLC to meet the control requirements; the communication module can realize remote monitoring and data acquisition; the electric voltage regulator is used for voltage regulation, and the step-up / step-down regulation is automatically performed through PLC feedback.

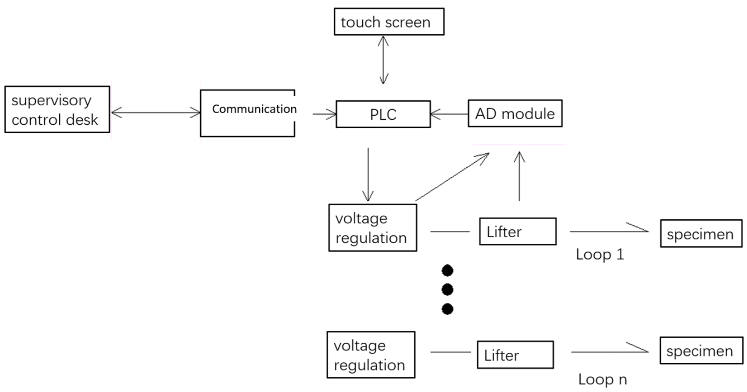

Figure 3: Flow chart of test platform

4. Test analysis

4.1 Test readiness

Fig. 4 is the temperature rise test diagram. The current of C1, C2 and C3 branches of the prototype is 630A, 400A and 400A respectively, and the rated current is 630A. According to GB / T 7251.1,630A test circuit uses two 185mm2 copper wires per phase, and 400A test circuit uses one 185mm2 copper wire per phase. The test is divided into two steps. The first step is for the disconnector fuse group and the C1 branch, and the second step is for the C2 and C3 branches. The specific test method and measurement point position are shown in 3.1.

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Figure 4: Temperature rise test

4.2 Test result analysis

Fig.5 is the schematic diagram of the first step temperature rise curve. The horizontal axis represents the test time, and the vertical axis represents the temperature rise value. It can be seen from the figure that the temperature rise rises sharply at the beginning of the temperature rise test, and the temperature rise increases slowly until it stabilizes after 2 hours. Therefore, in the temperature rise test of low-voltage switchgear, the temperature rise value of 2 hours before the test is used to evaluate whether the test passes. The temperature rise curve in the figure is a horizontal line representing the ambient temperature. During the test, the ambient temperature tends to be constant.

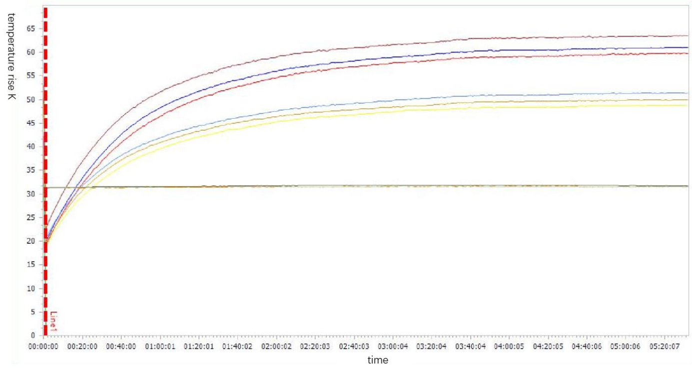

Figure 5: Temperature rise curve diagram

Figure 6 is the temperature rise curve of the first 2 hours of the second step. This test uses the current inverted input method to test. It can be seen from the diagram that the temperature rise curve of the last 2 hours changes slowly and tends to be stable. In this test, the impedance is automatically adjusted by current feedback, which reduces the complexity of the test and saves the test time.

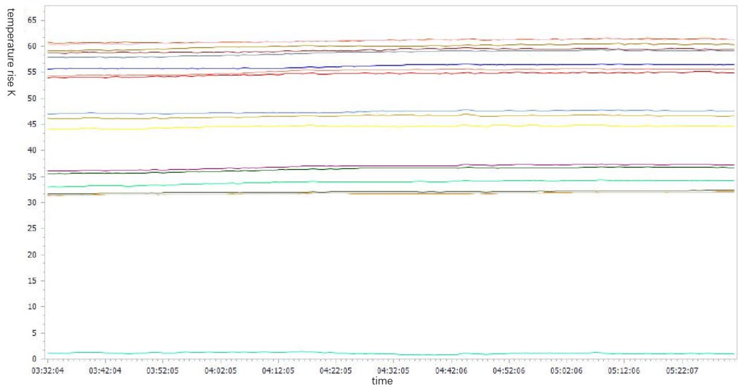

Figure 6: Temperature rise curve 2 h before stabilization

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5. Summary

In this paper, a temperature rise test platform is built for the temperature rise test of low voltage switchgear. The temperature rise test of the rated current 630 A prototype is carried out by the current reverse input method. The impedance is automatically adjusted by negative feedback to meet the test current output, reduce the complexity of the test and improve the test efficiency.

References

[1] Hongwei Z, Zhuxun Z, Hongju M, et al. A New Composite Switch for Low Voltage Equipment Control[C]//Computer Distributed Control and Intelligent Environmental Monitoring (CDCIEM), 2011 International Conference on. IEEE, 2011. DOI: 10.1109/CDCIEM. 2011.336.

[2] Aziz A, Arifin M K .Current transformer performance in high voltage and low voltage systems [J]. 2008.

[3] Sivakumar K. Low Voltage Switch Disconnector Fuse Units Specifications [J]. Electrical India, 2011, 51(7):p. 50-52.