Computer Simulation Analysis of Power Transformer Test Design Technology

Yongsheng Duan1,2, Kaiping Li1
1Wenshan Power Supply Bureau of Yunnan Power Grid Co., Ltd., China, 663099
*Corresponding author e-mail: 1210503010@qq.com

Abstract. Transformer is an extremely important electrical equipment in power system. The quality of transformer test directly affects the safety and reliability of industry, agriculture and household power supply. Therefore, power transformer plays a very important role in the power system. Before putting into operation, we should carry out handover test, which will check the correctness of manufacturing. Through the simulation analysis, we can better verify the rationality of the function and performance design of the power transformer, which will ensure the safe, reliable and stable operation of the transformer during the test. Through the simulation experiment, we can determine whether the function of power transformer can meet the demand in advance, which will avoid the cost of direct test verification. TRT is an important test item in transformer test, which needs computer simulation at the same time. Therefore, this paper takes the temperature rise test (hereinafter referred to as TRT) as an example. Firstly, this paper lists the experimental items of transformer. Then, the TRT is selected as the verification item. Based on the analysis of the design of automatic control system for TRT, the computer simulation analysis is carried out in this paper.

Keywords: Power Transformer, Test Design Technology, Simulation Analysis

1. Introduction

Transformer is an extremely important electrical equipment in power system. The quality of transformer test directly affects the safety and reliability of industry, agriculture and household power supply. If the transformer installed in the key position is damaged and the power transmission problem occurs, it will affect the normal power supply of industry, agriculture and people's life. At the same time, the power supply range of large capacity high voltage transformer is very large, once damaged, it will cause a large area of power failure, which will bring great losses to the national economy [1]. For example, a large-scale blackout occurred in the northern part of the United States in 2003 [2].

With the rapid development, the continuous improvement of generator capacity and transmission and transformation voltage makes the reliability requirements of power transmission and transformation equipment more and more high. In case of damage, the repair and return costs of the
transformer are very high. Therefore, we should improve the accuracy and reliability of the transformer factory test, which will ensure the safe and reliable operation of the transformer [3]. At present, the TRT and lightning impulse test are the most special among the type test and routine test items of transformer test. Therefore, this paper puts forward new requirements for the temperature rise of transformer oil flow. Through accurate simulation and calculation of transformer temperature rise and comparison of various results of test analysis, we can judge the operation temperature of transformer, which will ensure the reliable operation of transformer and provide technical reference. By predicting the temperature rise of hot spot and oil flow, we can timely reflect the actual operation of the transformer. Then, by improving the design, we can improve the cooling effect of the power transformer, which will extend the operation life [4].

It is a kind of real system simulation technology which can replace the real power system simulation. The basic requirements of digital simulation are authenticity, applicability and flexibility. Authenticity means that the simulation can establish various models according to the actual system and correctly simulate the action behavior of the device after failure. Applicability means that the simulation can objectively reflect the dynamic and static characteristics of the device in different environments. Flexibility means that the simulation can easily query and change the parameter settings of the device, and can also be based on the action logic of different protection devices.

2. Basic theory

2.1. Test items of transformer

The national standard GB 1094.1-1996 "power transformers Part 1 general principles" stipulates the variant test and routine test of special test items [5]. As shown in Figure 1.

![Figure 1. Transformer experiment project](image)

2.2. Test process
According to JB/ T501-91, there are several methods for transformer TRT: short circuit method, direct load method, mutual load method, zero sequence current method, and so on. The short circuit TRT needs to determine the test power supply capacity and test current. By connecting the test circuit, we can start the test. During the test, the loss and current added to the tested transformer are monitored and compared with the set value. If it exceeds the allowable error range, the test power supply is adjusted. After a predetermined time interval, we need to test and record the temperature of the test site, and then judge the measurement results. Until the change rate of top oil temperature rise is less than 1K / h and continues to maintain for 3 h, the top oil temperature has been stable. And ten, we take the average value in the last hour. After that, we can start the second stage of the test: winding TRT [6].

3. Simulation analysis of oil temperature rise of power transformer

3.1. Main technical parameters of DFP-240000 / 400th transformer

The main technical parameters are as follows the table 1.

| NO. | Test items                                      | NO. | Test items                             |
|-----|------------------------------------------------|-----|----------------------------------------|
| 1   | Rated voltage: (400 / V3 ± 2x2.5%) / 20kV     | 6   | Short circuit impedance: 15%           |
| 2   | Connection group label: II0                    | 7   | Cooling mode: ODAF                     |
| 3   | Rated capacity: 240 / 240 MVA                  | 8   | No load loss: 105kW                    |
| 4   | Load loss: 450KW                               | 9   | Temperature rise limit: top oil number 50K |
| 5   | Average temperature rise of winding: 55k       | 10  | Temperature rise of winding hot spot: 68K |

3.2. Simulation and calculation method of oil flow temperature rise of power transformer

The analytic method of transformer temperature rise is the average temperature rise and hot spot temperature calculated according to the known transformer thermal model, experience and design parameters. The numerical calculation value is used for the design and test of transformer; the test results are used to verify the numerical calculation results. Through the simulation calculation of the transformer temperature field, we can establish a mathematical model.

3.3. The result of analytical method

According to the analytical method, this paper calculates the results of DFP-240000 / 400th transformer, as shown in Table 2. Among them, the calculation value of no-load loss is 100 kW. Load loss calculation value: 447kw, using YF3-140 cooler, a total of 6 groups.

| High pressure | Low pressure |
|---------------|--------------|
| Inner diameter of coil (mm) | 2217 | 1614 |
|---------------------------|------|------|
| Coil outer diameter (mm)  | 2552 | 2035 |
| Number of struts          | 48   | 48   |
| Cushion block width (mm)  | 60   | 50   |
| Insulation line width (mm)| 19.9 | 1900/2/20 4:48 |
| Insulation wire height (mm)| 19.53 | 20.25 |
| Through current (a)       | 989.7(1041.8) | 12000 |
| Current density (A / mm²) | 2.64(2.779)  | 1.795 |
| Number of pie segments    | 104  | 82   |
| Number of turns of cake   | 8    | 0.5  |
| Average oil temperature rise (k) | 20.1 |
| Top oil temperature rise (k)  | 30.4 |
| Average temperature rise of winding (k) | 46.2 | 40.7 (41.7) |
| Winding hot spot temperature rise (k) | 52.55 | 56.7 |

### 3.4. Numerical calculation results

This paper takes oil immersed power transformer model as an example. According to the theory of transformer temperature rise, this paper calculates the temperature rise and thermal load of layer winding and pie winding. By establishing the physical model of transformer oil flow temperature field, the temperature rise of oil flow under three kinds of boundary conditions is simulated and calculated. The calculation results are shown in Table 3. The simulation results are shown in Figure 2 and Figure 3.

| Table 3. The calculation results |
|---------------------------------|
|                                 | High pressure | Low pressure |
| Copper oil temperature rise (k) | 23.5          | 19           |
| Hot spot temperature (°C)      | 93            | 95           |
| Hot spot temperature (°C)      | 92.55         | 96.7         |
| Hot spot location              | The 14th cake | The 7th cake |
Among them: ambient temperature: 400°C; average oil temperature rise: 19K; top oil temperature: 25K.

**Figure 2.** Cloud chart of temperature distribution (℃)  **Figure 3.** Velocity distribution at exit (M / s)

4. Conclusion

In the calculation of ODAF forced guide oil circulation, the hot spot position of winding still appears in the upper middle position. But the temperature distribution of each cake is not different. The calculation method of transformer oil flow temperature rise is studied, and the transformer hot spot temperature simulation is carried out on the computer. Through the simulation and test of transformer product model, the calculation results are verified in this paper.

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