Test Method and Precautions for Grounding Current of Transformer Core

Jiang Ling[1], Zhou Bin[1], Yu Xiaochen[1], Xin Tian[1], Zhao Yinghe[1], Sun Lu[1], Fang Yulong[1], Xing Yuqing[1], Lin Yuan[2], Liu Bo[2], Shi Diancai[2]

[1]Dandong Power Supply Company, Liaoning Electric Power Company Limited, State Grid, China

[2]Fushun Power Supply Company, Liaoning Electric Power Company Limited, State Grid, China

Keywords: transformer, core, grounding current, test method

Abstract: Core was an important component of transformer. The magnetic circuit for normal operation of the transformer was provided by the iron core. The smoothness of the main magnetic circuit of the transformer could also be guaranteed by it. The most simple and effective way to prevented the multi-point grounding fault of transformer core was to measure the grounding current of transformer core. However, in the actual measurement, due to the different measurement position and the different connection mode of transformer core grounding, the wrong judgment was caused by abnormal value of grounded current. Therefore, the case of nonstandard test method in actual measurement was analyzed to provide reference for correct measurement of transformer core grounding current.

1. Introduction

Clamp ammeter was used to measure the grounding current of transformer core in operation, which was a routine test work of electrical tester. Since this test was carried out, state grid Dandong electric power supply company had measured the core grounding current of each transformer in its substation once a year. In recent years, there had been several cases of abnormal current measurement. However, the data of live detection and power failure test were normal. Good current value could be obtained after rectifying the core grounding mode or changing the measuring position. In order to avoided misjudgment in the actual measurement process, several cases of wrong measurement method of transformer core grounding current were analyzed.

2. The significance and principle of measuring the grounding current of transformer core

2.1. Measurement significance.

The core of transformer must be grounded in normal operation, and only one point could be grounded. When the core lost ground, through the coupling effect of parasitic capacitance between high voltage winding and low voltage winding, low voltage winding to core and core to shell, the core generate suspended potential on the ground was made by the live winding, thus the discharge to ground was caused by it. However, when the core had two or more points of grounding, a circuit would be formed between the core and the earth. This would lead to the appearance of inadmissible circulating current and surged of current value, which would cause local overheating and even burnt out the iron core. Therefore, measuring the grounding current of transformer core was an important means to detected whether core multi-point grounding occurs. This was of great forward-looking significance.

2.2. Measuring principle.

The one point grounding principle of single-phase three winding transformer core was shown in Figure 1. It could be seen from the figure that there was distributed capacitance between each winding and iron core. The current flowing through the core was the sum of the current of each winding.

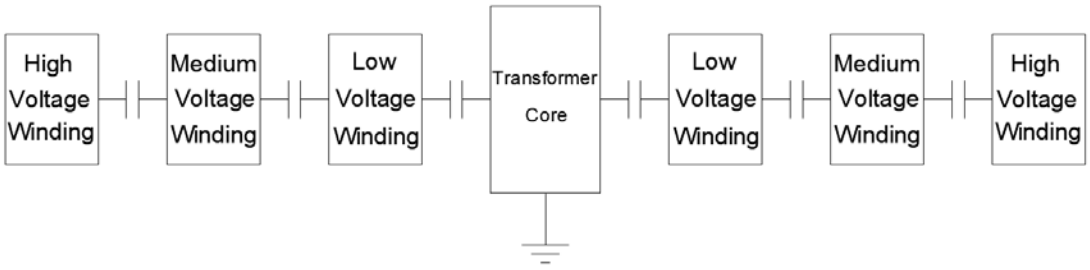

Fig.1 One point grounding schematic diagram of iron core

The equivalent circuit diagram of core one point grounding was shown in Figure 2. Among them, C1, C2 and C3 were respectively the distributed capacitance of low voltage winding to iron core, medium voltage winding to low voltage winding and high voltage winding to medium voltage winding. UH, UM and UL were respectively the voltage of high, medium and low voltage winding. RM was the equivalent resistance of the insulating film on the surface of the silicon steel sheet of the iron core. CM was the equivalent capacitance of the insulating film on the surface of the silicon steel sheet of the iron core. RP was the equivalent resistance of iron core silicon steel sheet. As could be seen from Figure 2, the impedance of the whole circuit was the total impedance after capacitive reactance of capacitance between windings of transformer and resistance of insulating paint film were connected in series.

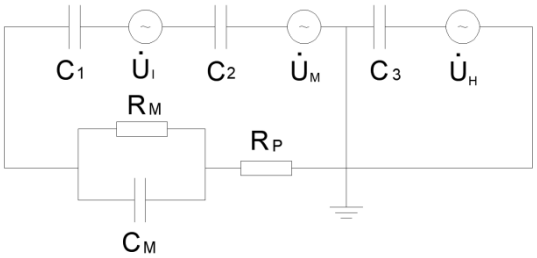

Fig.2 One point grounding equivalent circuit diagram of iron core

However, the capacitive reactance of the capacitor was much greater than the resistance of the insulating film. Therefore, the impedance of the whole circuit could be regarded as capacitive reactance between windings. According to the calculation, the current flowing through the core of single-phase transformer in normal operation was generally within 10 mA. Similarly, for three-phase transformers, if the three-phase voltage was completely symmetrical and the capacitance between the windings was completely equal, the grounding current after three-phase superposition shall be zero. However, this ideal situation was impossible in reality, so the actual measurement results always had a certain value, and the value was generally smaller than the grounding current of single-phase transformer (The measurement results of core grounding current of main transformer in state grid Dandong electric power supply company are generally about several hundred microamps). When the core was grounded at two or more points, the current value would surge and even reach hundreds of amperes.

3. Case analysis and rectification plan of improper test method

3.1. Core grounded flat iron clings to leakage current sensor.

When measured the core current in Kongjiagou 220kV substation, the tester found that the core grounding current measured under the leakage current sensor was far greater than the value measured above it, as shown in Table 1.

After eliminating the possibility of problems with the clamp ammeter and leakage current sensor, it was found through careful inspection by the tester that the grounding flat iron of the transformer core was closely connected with the leakage current sensor. The insulating paint on the surface has worn and exposed the metal part. According to the analysis of the experimenter. Because of the contacted between the grounding flat iron and the metal part of the sensor, when measuring the core

grounding current under the sensor, the value obtained includes the induced current in the sensor coil as well as the current in the grounding flat iron, which led to the measurement value exceeding the standard. After that, the ground flat iron and the sensor were separated by the tested and measured again, and the data returns to normal, as shown in Table 1.

Table 1 Grounding current value under different measuring positions and conditions

Location and conditions	Below sensor	Above sensor	After insulation	After rectification
Grounding current value(mA)	191	0.9	1.9	0.8

The contact between the grounding flat iron and the exposed metal of the sensor was caused by the abrasion of the insulating paint on the surface of the leakage current sensor. This caused the induced current generated in the coil to be incorporated into the core ground current. The wear of the insulating paint on the sensor surface was mainly caused by the too wide grounding flat iron, which was easy to rub with the sensor. In order to solve this problem, the shape of the grounding flat iron was rectified by the tester, and the part of the grounding flat iron passing through the sensor was transformed into an arc shape. The above friction problems were solved. After rectification, the measurement data above and below the sensor were consistent, as shown in Table 1.

3.2. The core ground point is set on the top of the transformer.

A part of the core current measuring points of the transformer were set on the top of the transformer. The iron core was led to the top shell of the transformer through a small insulating bushing. When the core grounding current of the transformer was measured, it was found that when the clamp ammeter was placed in different position, different measurement results would be obtained. This was because the core ground point was near the high voltage side of the transformer, and the clamp ammeter was easily affected by the alternating magnetic field at the top of the transformer during the measurement. In this way, the magnetic field inside the clamp ammeter changed, which led to the measurement error. According to Biot Savart law, the magnetic field intensity of a point was inversely proportional to the square of its distance when other factors were constant. The most powerful radiation source of substation was transformer. The iron core ground wire was connected to the top shell of the transformer. Therefore, when measuring the core grounding current, the tong-type ammeter was strongly interfered by the transformer magnetic field. This was the case for the transformer of the Chengbei 66kV substation in. The measured core current value was shown in Table 2.

Table 2 Grounding current value under different measuring positions and conditions

Location and conditions	The measuring point is on the top of the transformer	After rectification
Grounding current value(mA)	121	1.1

In view of this problem, the transformer core grounding point was rectified by the tester. The original iron core grounding method was removed, and the special grounding wire was used to lead the iron core guide rod at the top of the transformer directly to the grounding grid at the bottom of the main transformer for grounding. The tong-type ammeter was wrapped with metal fiber fabric to shield electromagnetic interference.

3.3. There are metal fixing points in the middle of transformer oil tank.

When checking the core current of the transformer according to the specified period, it was found that some of the measured values exceeded the standard. Combined with oil chromatography analysis, there was no obvious change in characteristic gas and historical data. It could be inferred that there were external interference or other environmental reasons in the measurement. After

careful inspection by the test personnel on site, it was found that there were two fixing points of the grounding flat iron in the middle of the transformer oil tank, which were made of metal, one for the iron core and one for the down lead of the clamp. The results of measurement above and below the metal fixed point were significantly different, as shown in Table 3.

Table 3 Grounding current value under different measuring positions and conditions

Location and conditions	Below metal point	Above metal point	After rectification
Grounding current value(mA)	3100	0.1	0.2

After analysis, because there were many connection points between the core grounding down lead and the transformer shell, the induced current was generated due to the closed circuit in the alternating magnetic field. This was the reason for the abnormal value of core grounding current. This was similar to the typical non-standard grounding installation mode of the transformer core with the core grounding down lead first connected to the transformer bottom shell and then grounded, as shown in Figure 3.

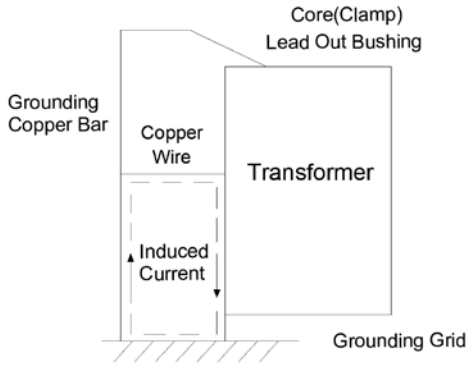

Fig.3 Typical non-standard iron core grounding installation method

In view of the problem that the grounding current measurement value was abnormal due to the improper installation of iron core and clamp grounding down lead, two schemes were adopted by the tester. One was to isolate the metal connection point between the grounding flat iron and the transformer shell with insulator, so as to eliminated the loop formed by the grounding flat iron and the transformer body. The others was to cancel the original grounding mode and directed the iron core guide rod to the grounding grid at the bottom of the transformer. For transformers that cannot be rectified, the current value above the metal connection point shall be measured as the accurate measurement value. After rectification, the measured value of core grounding current was normal, as shown in Table 3.

4. Precautions for field measurement

In order to be able to measure the accurate value, combined with the analysis of the listed cases, it is concluded that the following two aspects should be paid attention to when measuring the grounding current of transformer core on site.

1) Considering that it was easy to be interfered by magnetic field in the measurement process, tong-type ammeter or other tester with strong anti-interference performance shall be selected for measurement.

2) Proper measurement position shall be selected during field measurement. Generally, it was the middle part of the transformer oil tank, which should not be close to the large cover ring as far as possible, so as to prevented the internal leakage flux of the transformer from passing through the tong-type ammeter and causing error. In addition, the jaw of the tong-type ammeter shall be fully toothed and perpendicular to the grounding down lead during measurement. In order to ensure the consistency and continuity of the measurement data and eliminate the magnetic field interference,

the same transformer shall be measured at the same position every time.

5. Introduction

If the grounding current of iron core exceeded the standard, first check whether the measurement value was abnormal due to the incorrect test method. After excluding this possibility, the test value shall be compared with the data of previous years and similar equipment. According to the trend and rate of change, we could make a comprehensive judgment to avoid misjudgment. For the intermittent grounding fault of iron core in some special weather conditions, waveform analysis could be carried out, or online monitoring device could be used for continuous monitoring to find out the cause of the fault. For transformers with clamps leading out to earth separately, if the grounding current of core and clamp increased sharply and the value was close, the insulation deterioration or short circuit between core and clamp was suspected. The insulation resistance of the clamp shall be further determined by measuring the core. When determining the multi-point grounding of iron core, the method of large current impact was generally adopted on site to burn through the fault point. Removed the unstable grounding fault caused by iron core burr, rust, sludge or solid suspension deposit at the bottom. If it was not possible to use large current, it should be checked by hanging cover, and the parts where the transformer core may be grounded should be checked. If the transformer could't or didn't need to be out of operation for maintenance, the series resistance current limiting method could be used to limit the circulating current of the core grounding circuit.

6. Conclusions

It is very important to measure the grounding current of transformer core to prevent multi-point grounding fault. It could know the working condition of iron core and early failure symptoms in time to avoid malignant accidents. However, in the real measurement, there may be inaccurate measurement data due to the lack of understanding of the grounding connection mode of transformer core and the incorrect measurement method. For abnormal measurement values, in order to eliminate the hidden trouble, a series of unnecessary auxiliary detection and test items would be carried out by the tester, or even the fault treatment would be carried out in a hurry. This was undoubtedly an unnecessary waste. Therefore, when the grounding current value of transformer core was abnormal, whether the test method was appropriate should be checked first. Then checked whether the measurement was interfered by the magnetic field, whether there was a parasitic circuit and affected by the induced current, and whether the measurement position was reasonable. Only by adopting the correct test method could the grounding current of transformer core be measured accurately, avoiding the occurrence of misjudgment. Accurate core grounding current value was one of the important basis for timely detection of core multi-point grounding fault.

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