Oil Impregnated Paper Condenser Transformer Bushing Damage Accident Analysis

Tong Wu, Lixia Shang, Huijie Cao, Jiaying Wang, Xiaolei Yang, Xinming Chuai, Haoming Zhao, Zhao Zhang, Shuyi Tao, Huiyan Cao

Marketing Dept. Metrology Division Liaoning Province Electric Power Co., Ltd, China

Keywords: Main transformer, Oil chromatographic analysis, the porcelain sleeve, bushing

Abstract: Through the search for penetration cracks in the lower bushing of the main bushing, the effectiveness of the combination of oil chromatography and electrical testing is demonstrated. The structure and composition of the main transformer bushing and the common discharge forms and locations are introduced in detail. The main fault location where the low energy discharge occurs may be the bushing, winding, main transformer core or tap changer. Scientific means to conduct a one-by-one investigation. Finally, the low-energy discharge failure caused by the penetrating crack of the lower bushing of the bushing is concluded, and the repair time of the main transformer is shortened. Because of the bushing failure type of paper is very little, analysis methods and steps of the search bushing fault has left valuable experience. This has a certain reference value.

1. Introduction

Main transformer (hereinafter referred to as transformer): is the core power supply equipment of substation. It is composed of five parts: transformer body, fuel tank, protection device, cooling system and outlet bushing.

Transformer body: the body is composed of iron core, winding, lead wire and insulating medium. It is used for direct electromagnetic energy conversion.

Fuel tank: the fuel tank is composed of mainly box body, box cover, bottom of box, attachment (oil valve, oil type valve, drain plug, ground bolt, etc.).

Protection device: the protection device is composed of oil storage tank, oil level gauge, oil purifier, flow relay, moisture absorber, signal thermometer, etc.

Cooling system: the cooling system is composed of coolers, submersible pumps of oil and ventilators.

Bushing: The lead out wire of the transformer winding must pass through the insulation bushing, which should be insulated between the lead out wires and between the lead out wire and the transformer shell, and it plays the role of fixing the lead wire.

The bushing is one of the most important components of the transformer, it includes oil filled bushing (for 35kV transformer), dry bushing (for 10kV transformer) and oil-immersed capacitor bushing (for 66kV and above). The bushing is also one of the current-carrying element, load current and short-time overcurrent will be used for long term operation of transformers, so it must have good thermal stability to withstand the instantaneous overheating of the short circuit. The main form of bushing accident is dampness of capacitor core and main insulation breakdown, flashover of external insulation in rain, joint overheating and poor sealing, discharge, shedding and end shield bad grounding of uniform pressure ball, upper and lower porcelain sleeve rupture, oil leakage, etc. If the transformer bushing has defects or faults, the transformer's safe operation and its power supply reliability will be directly endangered..

2. The Transformer Bushing Structure

Short lower part oil paper capacitor bushing is composed of terminal block, oil conservator, upper porcelain sleeve, lower porcelain sleeve, capacitor core, conductive tube, insulating oil, flange, grounding small bushing, voltage tap and equalizing ball[4].

  DOI: 10.25236/isrme.2019.100

The outer insulation of the bushing is usually divided into an upper porcelain sleeve and a lower porcelain sleeve. It is required to have a high creepage ratio, good sealing property, high insulation performance, and must have prescribed electrical strength and sufficient mechanical strength.

The inner insulation is a cylindrical capacitor core, and the copper conductive tube at the center of the cylinder is both a skeleton of the capacitor core and a lead hole for the sleeve to pass through the lead cable, and the copper conductive tube is the starting screen of the entire capacitive screen.

The capacitor core is the main insulation of the bushing, which is responsible for the system voltage. It is composed of an aluminum foil with a semiconductor layer on the edge and an insulating material between the screens wound around the conductive tube to form a multi-layer concentric cylindrical capacitor. These series capacitors are fixed to form an integral capacitor core.

The inter-screen insulation medium in the capacitor core is a cable paper with a thickness of 0.08mm and a breakdown strength of 7kV/mm. The silicon paper or high-quality transformer oil is used to impregnate the cable paper with water, and the electrical strength of the treated cable paper is obtained. Improved, short-term electrical strength is about 100kV / mm, while also greatly reducing hydrophilicity and water absorption. Measuring terminals and voltage taps are mounted on the intermediate flange of the bushing. The measuring terminal is wound from a capacitor screen of the outermost layer of the capacitor core into a copper strip of about 0.3 mm thick and 50 mm wide. After the capacitor core is machined, a small window is dug, the copper strip is exposed, and then soldered. The soft copper stranded wire is connected to the inner guiding rod of the grounding small sleeve and is led out through the insulating sleeve. The capacitive screen is mainly used to measure the dielectric loss angle and capacitance of the capacitor sleeve.

The formation of bushing failure is mainly caused by poor structure or manufacturing process, poor installation process, etc., causing overheating of the bushing joint; external insulation of the porcelain bushing is flashing in the rain under harsh environment; poor grounding of the oil screen causes the oil chromatogram to exceed the standard; The gasket is aged and cracked, oil leakage and water seepage occur; the maintenance is not in place, the through-cracks of the upper or lower porcelain sleeve of the bushing are broken, the insulation performance is lost, and even the bushing explosion occurs in serious cases. Therefore, the monitoring of the bushing in operation should be strengthened, timely inspection, maintenance and testing, and preventive measures should be taken in advance to ensure the safe operation of the equipment.

In the long-term operation of the bushing, it must withstand the long-term maximum working voltage and withstand various over-voltages that may occur, and the bushing itself is gradually deteriorated due to the capacitor core and transformer oil, moisture and partial discharge. The upper and lower porcelain sleeve parts of the bushing may be damaged due to the material problem of the porcelain sleeve, the shatter damage during transportation, the external force damage during installation, the strong mechanical force caused by the short circuit of the transformer outlet, etc. So defects in the bushing are inevitable.

3. Accident Situation

The main transformer of a substation becomes SZ11-31500/66, the junction group YN, d11, and the products manufactured in July 2015. On December 15, 2017, the main light gas alarm, chromatographic analysis found that all types of gas increased, in which H_2, CH_4, C_2H_2, total hydrocarbons and other gases increased by a large margin, total hydrocarbons exceeded the specified value of 150 μL / L, The chromatographic tracking test data is shown in Table I.

Table I .The Chromatographic tracking test data content (μL / L)

CH_4	C_2H_4	C_2H_6	C_2H_2	C_1+C_2	H_2	CO	CO_2	Time	Note
1.34	0.65	0.23	0.35	2.57	1	24	160	2015.11.25	Before operation
12.51	0.93	0.87	0.08	14.39	38	325	483	2017.03.03	Routine test
16.21	1.68	1.52	0.79	20.20	53	432	627	2017.12.14	Light gas
31.45	25.15	2.66	70.38	129.64	127	507	726	2017.12.15	Routine test
33.22	26.79	2.82	73.23	136.07	147	539	771	2017.12.18	Low energy discharge

At present, many years of experience at home and abroad have shown that the method of judging the relative content of characteristic gases is a more effective method for judging the internal fault properties of transformers.

Using three ratio method, C_2H_2/C_2H_4=73.23/26.79=2.73, because the ratio of 2.73 between 1 and 3, so the code is 1. CH_4/H_2=33.22/147=0.23, because the ratio of 0.23 between 0.1 and 1, so the code is 0. C_2H_4/C_2H_6=26.79/2.28=9.5, because the ratio of 9.5 is greater than 3, so the code is 2. Therefore, the three-ratio method is coded as "1, 0, 2", which is a low-energy discharge fault.

4. Determine the Defect Location

There are four types of defects that may occur in the main transformer's low energy discharge fault: low energy discharge fault caused by bushing; low energy discharge fault caused by winding short circuit in winding; low energy discharge fault caused by multi-point grounding of main transformer core The arcing discharge fault caused by the operation of the tap changer. The nature of the fault can be determined by the exclusion method.

4.1. Using Conventional Test Methods

The conventional test methods include DC resistance test, ratio test, and no-load test. The routine test was carried out on the main transformer. The test data and the original test data did not change. It proves that the low-energy discharge fault has nothing to do with the main transformer winding, thus discharging the low-energy discharge fault caused by the turn-to-turn short circuit of the winding. The arcing discharge fault caused by the operation of the tap changer is also discharged.

4.2. Using Roger Method

Using Roger method, CH_4/H_2=33.22/147=0.23, C_2H_6/CH_4=2.88/33.22=0.087, C_2H_4/C_2H_6=26.79/2.28=9.5, C_2H_4/C_2H_4=73.23/26.79=2.73.The Rogers method is coded as “0, 0, 2, 2”, which belongs to low-energy discharge, and the initial judgment does not belong to the discharge caused by the iron core. Next, the core insulation resistance test is performed, and the insulation resistance of the core to the ground is 1200 MΩ. The test results show that there is no defect in the insulation resistance of the core, and therefore, the low-energy discharge fault caused by the multi-point grounding of the main transformer core is discharged.

5. Core Inspection

On December 21st, 2017, the main transformer was checked at the site for hanging cores. After the core was removed, cracks were found in the lower porcelain sleeve of the bushing. Up and down through cracks occurred along the circumference of 1/3 of the area. The damaged part of the porcelain sleeve falls off, and the exposed surface of the corresponding insulating core had a large area of significant carbon black discharge traces. There was a large amount of ice in the upper cavity of the sleeve uniform pressure ball. As shown in Figure 1.

Fig.1. Damage of the lower porcelain sleeve of the bushing

According to the observation, there was icing phenomenon on the upper part of the uniform pressure ball in the bushing oil, which was caused by the water flowing out of the bushing after the damage of the lower porcelain sleeve. The direct cause of bushing discharge and cracking of lower porcelain sleeve was water inflow inside the bushing. Therefore, it was the key point to analyze whether there was a sealing problem in the bushing. In addition, no apparent leakage of oil was found in the above part of the flange in the bushing appearance observation. It was determined that there was no leakage of water in the parts below the oil surface in normal condition (the oil level window range of the oil gathering box) of the bushing.

According to the analysis conclusions in the appearance inspection, there was no leakage of water in the parts below the oil surface in normal condition of the bushing. Therefore, all sealing points in the oil surface above were further examined and analyzed. There are 3 sealing positions involved in the parts above the oil surface. (1) Between the bushing connection seat and the oil collecting box cover. (2) Between the oil collecting box cover and oil collecting box. (3) The drain plug of the head of the bushing. The inspection had shown that the fasteners between the bushing connection seat and the oil collecting box cover, the oil collecting box cover and the oil collecting box were not loose, and the sealing gaskets were intact. However, it had been found that the drain plug of the head of the bushing was not effective in fastening (the plug should be loosened by hand), the sealing performance was not enough, and there were traces of water seepage in the interior of the bushing, so as to judge it should be the leakage point of the bushing. As shown in Figure 2.

Fig. 2.The bushing failure location

Through the analysis of bushing operation and core inspection, it is believed that the root cause of the failure here is that the bleeder plug is not tightened during the operation of the bushing bleed plug, and its sealing performance is destroyed. When the ambient temperature of the site is low, the transformer oil in the bushing is in a state of micro-negative pressure due to the thermal expansion and contraction. The water vapor and rain and snow, which are present near the venting plug of the bushing head, are sucked into the bushing. The tube flows along the inner wall of the porcelain sleeve to the tail of the sleeve.

Due to the short insulation part in the bushing with short lower part oil, in the case of water accumulation in the tail of the bushing, the water content in the oil is increased, the insulation performance is lowered, and the bushing is discharged along the surface of the capacitor core under the operating voltage to generate acetylene, resulting in acetylene. The porcelain sleeve is broken.

6. Conclusion

The bushing is the main insulation device outside the main transformer box. The lead wire of the transformer winding must pass through the insulation bushing to insulate between the lead wire and the lead wire and the transformer shell, and also functions as a fixed lead wire. At the same time, bushing is one of the most important components of transformers. The bushing is also a current carrying element. The transformer will run through load current and short-time overcurrent for a long time. Therefore, the bushing must have good thermal stability to withstand transient overheating during short circuit. Due to the very small percentage of bushing accidents in the main transformer accidents, especially the porcelain bushing damage accidents of the bushings, the faults of the lower bushings of the bushing bushings will leave valuable experience and methods for the future.

References

[1] Cao Jianzhong, Electrical Test. Beijing: China Power Press, 2005.

[2] Chen Huagang, Power Equipment Preventive Test Methods and Diagnostic Techniques. Beijing: Science and Technology Press, 2001.

[3] Yin Kening, Transformer Design Principle. Beijing: China Power Press, 2003.

[4] Zhang Jiaxiang, Transformer Coil Wave Process. Beijing: Water and Power Press, 1983.