How to Diagnose and Analyze 500kV Power Transformer Fault

Wang Fengxiang, Ao Ming, Wang Shuo, et al

HIMALAYAL - SHANGHAI - CHINA

Abstract: A short circuit fault of 500kV transformer is detected. An in-depth investigation into transformer transportation, installation and operation status is carried out. Moreover, Field fault diagnosis and simulation test have been conduced to conclude that short circuit fault occurs in the internal transformer. Hanging-cover inspection after returning to the factory confirms that the fault is turn-to-turn short circuit of low-voltage side, which is directly caused by water in transformer oil.

Key words: 500kV voltage grade, power transformer, fault diagnosis, investigation and analysis

1. Introduction

Failure of main transformer in 500kV substation will pose a great threat to safe operation of power grid, causing severe consequences. It is relatively difficult to diagnose the fault and takes longer time to maintain. The model of 500kV main transformer in some substation is ODFPSZ-250MVA/500kV. The test object is single-phase self-coupling transformer with non-directed oil-forced cooling. Rated voltage is 525/230±9×1.33%/63kV. It was produced in August 2005, and was put into use in March 2006. On June 9 2012, there was something wrong with W-phase of this transformer. Main transformer heavy gas action occurred; the breaker of primary side operated with that of secondary side; main transformer stopped operating. When the transformer broke down, light gas protection of main transformer also sent out alarm signal.

2. Operation Condition of Main Transformer and Post-fault Diagnosis

2.1 Operation condition of main transformer

When main transformer develops faults, the weather is good, and the system is in normal operation. Inspection shows that main transformer has ever been subject to following abnormal conditions during the transportation, installation and operation: abnormal external impact, 500kV line to ground short circuit caused by breaker fault and low-voltage side short circuit of transformer.

2.2 Post-fault diagnosis

After the fault, insulation resistance of low-voltage coil to iron core and other

winding reaches only 0.5 MΩ through transformer insulation test, which is far lower than normal value; chromatographic analysis and simplification test have been carried out for transformer oil on that day. Test results are shown in Tab.1, 2 and 3.

Tab.3 Data of simplified transformer oil chromatographic test

seen from three support brackets at the end of coil; water-drop-like is detected at the bottom of transformer.

Based on on-site inspection results, low-voltage side of transformer is thought to have severe short circuit, and broken transformer cannot be maintained on site. Moreover, it needs returning to the factory for further inspection to locate broken part,

Tab.1 Data of transformer oil chromatographic analysis μL/L

Phase	φ(H_2)	φ(CH_4)	φ(C_2H_6)	φ(C_2H_4)	φ(C_2H_2)	φ(CO)	φ(CO_2)	φ(C_1+C_2)
W	1 011	272	230.01	20.10	217.10	768	1 250	739.21

Tab.2 Data of transformer gas chromatographic analysis μL/L

Phase	φ(H_2)	φ(CH_4)	φ(C_2H_6)	φ(C_2H_4)	φ(C_2H_2)	φ(CO)	φ(CO_2)	φ(C_1+C_2)
W	396 352	5 642	2 025	66.4	4 226	48 707	2 694	11 959.4

Phase	MW/(mg · L^{-1})	Breakdown voltage/kV	Loss(90 C)/%
W	7.2	57.5	0.038

The main transformer protection condition, insulation test and oil chromatographic analysis can further prove that partial short circuit discharge fault occurs in the internal transformer.

3. On-site Inspection of Broken Transformer

According to detailed inspection scheme, first of all, the oil is evacuated, and then close inspection of internal transformer is carried out by professional staff. It reveals that thin black particles spread at the bottom of oil tank, which are confirmed as carbon black; the small black material at the bottom of oil tank is pieces of carbonized and insulated paper; a large piece of burned wire insulation paper is at the bottom of oil tank near fault part; obvious black area can be

Based on on-site inspection results, low-voltage side of transformer is thought to have severe short circuit, and broken transformer cannot be maintained on site. Moreover, it needs returning to the factory for further inspection to locate broken part, analyze causes and finally maintain broken transformer. Given that low-voltage side lead and insulation parts are severely polluted, and polluted coils and iron cores, all coils, wires and insulation parts are changed, and iron cores are to be washed.

4. Returning to the Factory, Hanging the Cover and Carrying out the inspection

After broken transformer returns to the factory, it is treated with gas-phase dry deoiling, and is inspected with the cover hanged. It is found that support brackets at the high voltage side displace obviously but high-voltage folding screen and coils are in normal condition. After removing high and medium voltage coil, it is found that other parts does not have abnormalities except slight carbon pollution. The first layer of folding screen cracks due to discharge but not discharge to external

medium-voltage coil; burning loss of copper conductor in the low-voltage internal side is no severer than that of external side, but has obvious internal short circuit and deformation (curve inside); serious turn-to-turn short circuit occurs in the internal low-voltage coil; fault is located at ninth gear at the right side where there is no transposition S curve. Except routine winding, there are no special processes such as papering, welding and shaping etc. The discharge faults of internal coil are short circuit of turn-to-turns and segments.

5. Analysis of Fault Causes

The inspection confirms that turn-to-turn short circuit in the low-voltage side of transformer causes the fault. Because low-voltage side short circuit can cause high voltage side to generate high short circuit current. The power generated by short circuit current distorts support bracket of high-voltage coil. Also, previous short circuit will have an influence on high-voltage support bracket. However, the main influence should be turn-to-turn short circuit of low-voltage side. At the same time, inspection results verify that both high-voltage diagnosis test and chromatographic analysis are correct. Possible fire disaster is avoided, thanks to fast removal of broken transformer via correct heavy gas protection.

Based on features of transformer fault, an investigation into faults of same type of transformer is conducted. The same type of transformer in Yunan State Grid had ever one turn-to-turn short circuit fault of medium-voltage coil. This transformer is subject to above 50 short circuit faults of varying degrees during the process of operation. When disassembling the transformer, it is found that faults most occur at S curve of medium-voltage winding. Analysis indicates that unreasonable design of support bracket causes turn-to-turn short circuit of the coil. However, fault of this broken transformer is not at S position, and the above-mentioned cause can be excluded. The North China Grid had also two transformer faults. The cause for both are that imported NYNAS oil used contains sulphur. The surface of copper conductor is corroded, generating green cuprous sulfide. Conductive attributes of cuprous sulfide, insulation paper permeating and pollution reduce insulation strength. Finally, transformer turns are subject to insulation breakdown, and transformer winding is burned and damaged. The broken transformer uses KRY No.45 oil with low sulphur, which will not corrode copper line. The conclusion is also verified via sampling.

The low-voltage coil of transformer adopts traditional simplified design. There are 176-turn, 92-segment 63kV low-voltage coils in total. Two continuously transposed conductors are wound in parallel. Traditional pie-type coil is used and constantly wound. No welding and insertion shielding are in the internal coil. Except S-curve process and papering, there are no other special processes.

Analysis shows that the position where water-drop-like is located in is just below broken coil. Therefore, it is very likely that turn-to-turn short circuit is caused by the water in the transformer oil. Simulation test conducted in the lab proves that the transformer oil contains the water. The water in the transformer oil directly causes turn-to-turn short circuit of low-voltage coil.

6. Conclusions

(1) Conclusions made by broken transformer inspection verify that on-site inspection procedure, oil chromatographic analysis, preliminary judgment are correct, which provides references for dealing with and analyzing transformer fault in the future.

(2) The type of transformer fault is consistent with that of transformer of same type in Yunan Grid and North State Grid. However, the causes are different.

(3) Both system short circuit and turn-to-turn short circuit of low-voltage coil cause support bracket of high-voltage coil of transformer to displace. Although support brackets displace, they do not lose stability. That illustrates that the main cause for support bracket displacement is turn-to-turn short circuit of low-voltage coil.

(4) KRY No.45 transformer oil with low sulphur does not corrode copper conductor.

(5) The simulation test proves that turn-to-turn short circuit of low-voltage side of transformer is caused by the water in the transformer oil. But how the micro-water is generated in the transformer oil needs to be further investigated.