

Comprehensive Detection Technology In The Application Of Transformer Insulation Diagnosis

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Abstract

The internal defects of transformer can be detected by dissolved gas in transformer oil. In this paper, we firstly have the routine test such as DC resistance of transformer, dielectric loss, and so on. Then we do the transformer induction withstand voltage experiment, partial discharge test and make ultrasonic positioning on the discharge single. Finally, we do strip inspection on the transformer and found aging serious problems of outlet device. Through the comprehensive utilization of chemical, materials, electrical test, the accuracy of fault diagnosis of transformer insulation materials and speediness is largely improved.

1 Introduction

Power transformer is an important equipment in power system, of which healthy and safety plays a very important role on power grid stability. At present, our country has achieved gratifying successes in power transformer manufacturing, but transformer faults are happened frequently in recent years, leading heavy losses to power industry and society. When internal overheating and discharge are happened, in addition to insulating material decomposed to gas, there will be other phenomenon accompanied by electrical, physical and chemical properties. Transformer oil dissolved gas analysis is known as one of the most effective means for transformer internal fault diagnosis. When dissolved gas of transformer oil detected the uncertain failure, it need to combine other test methods including high voltage test, chemical test, material analysis and so on carries on the comprehensive analysis^[1,2].

2 The transformer operating condition throughout the years

The power generation company has the 500 kV main transformer that is single-phase and rated capacity is 210 MVA, with which two high-voltage and low-voltage windings, high rated voltage is 530 kV and low voltage is 20 kV. The transformer was put into operation successfully in November 1991 .

Phase A of the transformer was analyzed through oil dissolved gas in July 2001, which shown the rapid growth trend of some characteristic gas, such as C₂H₂ content is up to 1.7 ppm, however, C₂H₄ content without growth. Take opportunity of power equipment maintenance, when the routine tests are carried on which mainly includes the DC resistance test, dielectric loss test, etc., however, no abnormalities were found. Then tracking the growth situation of dissolved gas in transformer oil. In 2001 to July 2012, the characteristic gas that C₂H₂ content in the oil has remained steady at between 2-5 ppm and other gas has no growth trend. In August 2012 , it found that C₂H₂ content was in the fast growth, which is up to 15.8 ppm, over the years oil dissolved gas content data of transformer were shown in table 1.

3 Transformer fault diagnosis

3.1 Transformer oil dissolved gas analysis

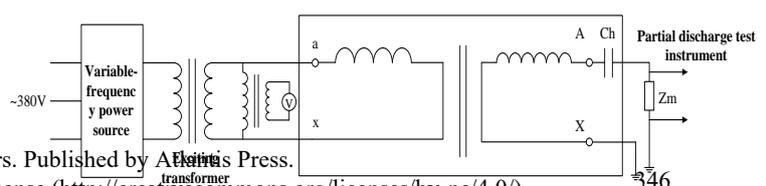
(1)Relative growth rate of total hydrocarbon in the transformer oil every month. Due to the characteristic gas in the oil change apparently before and after the August 2012, analysis characteristic gas in the oil of growth during June and August.

According to National Criteria^[3] that transformer may be abnormal, then abnormal parts should be analyzed by other test means.

(2)Dissolved gas analysis in oil. According to the guidelines which recommend three ratio method [4], the calculation code is "2 0 0", and then combined with the characteristic gas, which indicates low energy discharge had happened in transformer. According to the historical characteristic gas data, due to the growth of characteristic gas is not continuous, that was belongs to low energy of intermittent discharge. Before August 2012, the characteristic gas such as C₂H₂, H₂, C₂H₄ content is relatively stable, so the transformer was in normal operation conditions. After that, total hydrocarbon, C₂H₂, H₂, etc. had obvious growth, so intermittent discharge might have happened in transformer.

3.2 High Voltage Test Diagnosis

Through the high voltage test including transformer winding insulation resistance and DC resistance and dielectric loss, winding deformation and partial discharge diagnostic test^[5,6], in addition to partial discharge test,



which couldn't find abnormalities. Transformer partial discharge test connection^[7] was shown in Figure 1 .

Figure1: Transformer partial discharge test connection

Conduct induction withstanding voltage test and partial discharge test, when high-winding side test voltage up to 412 kV ($1.3U_m/\sqrt{3}$), of which discharge magnitude is about 450pC. When high side voltage continued to rise to 444 kV ($1.4U_m/\sqrt{3}$), significant partial discharge signals have been detected, of which discharge magnitude is about 2000pC. 5 min after, when continue to rise to 476 kV voltage ($1.5U_m/\sqrt{3}$), of which discharge magnitude is about 5600 PC. Through partial discharge pattern analysis shows that the transformer was internal discharge, when using ultrasonic location, after a lot of moving ultrasonic sensor position^[8-11], that found near the bottom of the high voltage wire end obvious discharge signals are detected, as shown in Figure 2.

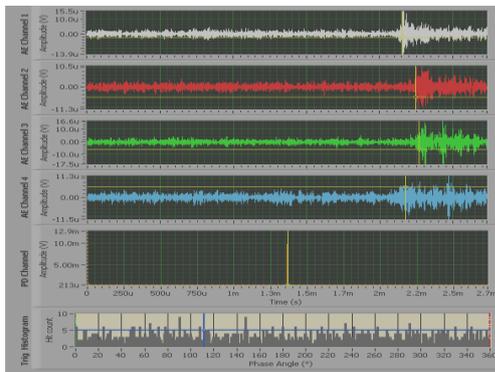


Figure 2: Transformer ultrasound partial discharge test pattern

In transformer oil, it doesn't regularly produce the characteristic gas such as C_2H_2 , which there might more serious problem, combined with the disintegration of station site environmental conditions, then decided to return to disintegration of factory inspection. According to the situation of high voltage test focusing on the high voltage wire connection of the transformer, equalizing sphere around a high voltage conductor .

3.3 Transformer strip inspection

Through the strip inspection in the transformer factory, in addition to the high voltage outlet device, other parts were not found abnormalities. The High voltage outlet device inspection found that the two support blocks of equalizing tube were shift that led to insulation cylinder deformation, as shown in Figure3. Corresponding corrugated plate to the black marks that is about 12 cm long and 5 cm wide. In addition, the corrugated plate surface had many black

stripes, however, support blocks had not been found discharge traces .



Figure 3: High voltage outlet device

In order to further determine the composition of the black mark on the corrugated plate, of which sample was test composition. Test data were shown in table 2 below.

Degree of Polymerization (DP)	Ash Content (%)	Conductivity of Water Extract (mS/m)	PH of Water Extract (mS/m)
295	0.65	15.0	4.61

Table 2: Test data sample of corrugated plate

Test data analysis:

- (1) Degree of polymerization is known as one of the most objective response to the characteristics of the insulation aging condition^[12], the average degree of polymerization is 1000 when new insulating paper. Simulation experiment show that, when degree of polymerization is down to 300, mechanical strength and electrical properties of insulating paper had been lost.
 - (2) Samples of ash content was high indicated that insulating material exist some impurities.
 - (3) From the PH value of water extract, insulating oil had been in partial discharge which produced serious acidification. Conductivity of the water extract reflects the insulation material surface underwent discharge.
- Through the above analysis, the black mark of corrugated plate due to discharge of high voltage outlet device that insulation performance had seriously decline. Combined with the previous test, doubt that characteristics gas produced from high voltage outlet device. In order to further confirm whether the growth of characteristics gas caused by high voltage outlet device or not, replace high voltage outlet device and carry on comparative analysis of induction withstanding voltage test and partial discharge test.

3.4 After processing of transformer test analysis

Transformer replaced the high voltage outlet device (other parts not replaced) and the factory test are all qualified. Focus on the induction withstanding voltage test and partial discharge test. The data of partial discharge test before and after the replacement of high voltage outlet device were shown in table 3:

Through comparative test analysis, identified the cause of high voltage outlet device was partial discharge, explained the characteristics gas such as C_2H_2 is caused by the high pressure outlet device. More than three years after treatment of transformer put into operation, transformer operates safely, of which characteristics gas in the oil aren't grow.

High voltage outlet device to produce C_2H_2 , that is caused by the region insulated electric field distortion for a long time because of support blocks of high voltage outlet device were shift. It is understood that the company had switched the brake operation in August 2012, operating overvoltage caused by induced the equalizing tube discharge to corrugated plate, which burned the surface material of corrugated plate, and produced C_2H_2 in oil. When operating overvoltage was stopped, discharge also immediately stopped, and C_2H_2 content wasn't grow, however, due to the area of outlet had undertaken higher electric field for a long time, which further accelerated insulation aging.

4 Conclusions

(1) Fault diagnosis for insulation materials of transformer, need comprehensively utilized of chemical, material, such as electrical test diagnosis, the methods validation of complementary to each other. Through gas dissolved in transformer oil, finding there may be fault preliminarily, further, locating fault are verified through electrical test, disintegration of transformer is analyzed for insulation material, these test means are the foundation of transformer fault diagnosis and location.

(2) The partial discharge test of ultrasonic location at home and abroad have carried out extensive research, however, when the partial discharge in transformer internal, ultrasonic location are certainly difficult, that mainly due to path ultrasonic discharge signal in the oil, winding, are complicated and degree of signal attenuation is different, which is difficult to locate fault accurately. Fortunately, the transformer discharge was in high voltage outlet device, ultrasonic signal propagation path is relatively simple and location is relatively easy.

(3) Transformer partial discharge will accelerate insulation aging, at home and abroad have done some research on partial discharge on-line monitoring insulation aging for transformer, including the on-line monitoring of partial discharge signal noise suppression, multiple parts at the time

of discharge signal separation and identification, etc. However, there are still a lot of key problems need to research, So the partial discharge monitoring insulation aging diagnosis should also in-depth research on denoising of partial discharge technology, signal hybrid separation technology as well as the method of feature extraction and diagnosis, etc.

References

- [1] Feng Yun. Power transformer insulation aging characteristics and mechanism research [D]. Chongqing: *Chongqing university*, pp. 13-20, (2007).
- [2] Liao Rui-jin, Liu Gang, Yang Li-jun etc. Vegetable oil and ordinary insulating paper composite insulation aging characteristics study [J]. *High voltage technology*, **34**, pp.1889-1892, (2008).
- [3] GB7252-2001, Analysis and judgment guide for transformer oil dissolved gas[S]. Beijing: China planning press, pp.2-20, (2002).
- [4] Chao Dun-kui. Diagnosis and fault in the transformer oil gas analysis. Beijing: China electric power press, pp. 3-20, (2005).
- [5] Dong Qi-guo. Power transformer fault diagnosis and. Beijing: China electric power press, pp.1-7,(2001).
- [6] DL/T 596-1996 power equipment preventive test procedures [S]. Beijing: China electric power press, pp.12-20, (1997).
- [7] Zhang Yong-yue. Wire connections in on-site PD tests of transformers [J]. *Transformer*, **38**, pp. 26-28, (2001).
- [8] LV Fang-cheng, CHENG Shu-yi, LI Yan-qing. Application and Prospect of Ultrasonic Method in Partial Discharge Detection in Power Transformer [J]. *Transformer*, **49**, pp. 45-49, (2012).
- [9] Lu Y, Tan X, Hu X. PD detection and localizations by acoustic measurements in an oil-filled transformer [J]. *IEEE Proceedings-Science, Measurement and Technology*, **147**, pp. 81-85, (2000).
- [10] Zhou Yuan-xiang, Sun Chang-fu, Li Guang-fan. Analysis and Detection of Defects of PD in Field Transformers [J]. *Transformer*, **38**, pp. 42-43, (2001).
- [11] Tang Zhi-guo, LI Cheng-rong, Chang Wen-zhi. The Partial Discharge Location Technology of Power Transformer and the Key Issues of Newly Developed UHF Method [J]. *Southern power system technology*, **2**, pp. 36-40, (2008).
- [12] Chao Dun-kui, XU Wei-zong. Transformer operation maintenance and fault analysis. Beijing: china electric power press, pp. 67-72, (2008).

ppm

Test date	H ₂	CO	CH ₄	CO ₂	C ₂ H ₄	C ₂ H ₆	C ₂ H ₂	Total hydrocarbon
2011.3.7	7.31	865.34	11.50	5288.47	1.34	3.27	1.95	18.06
2011.4.7	7.67	821.47	11.76	5301.92	0.93	2.54	2.12	17.95
2011.5.16	7.49	752.34	12.47	5046.48	0.78	2.33	2.00	17.58
2011.6.13	9.69	843.68	11.81	6200.80	0.93	2.72	2.80	18.26
2011.7.20	12.00	891.13	11.91	6296.31	1.28	3.39	4.32	20.9
2011.8.29	11.03	997.11	13.75	6480.04	1.38	3.12	5.44	23.68
2011.8.30	13.55	987.65	13.75	6570.36	1.34	2.84	5.17	23.11
2011.9.15	13.94	987.22	14.09	6282.79	1.63	3.34	4.38	23.44
2011.10.21	13.69	980.07	15.36	5915.10	2.19	3.27	4.71	25.53
2011.11.21	13.46	983.89	14.37	5510.71	1.94	3.09	4.78	24.18
2011.12.21	12.53	983.42	10.80	5300.08	1.28	3.20	4.43	19.71
2012.1.17	12.23	975.18	12.33	5207.11	1.15	2.83	4.03	20.31
2012.2.20	12.15	942.86	16.18	4920.73	2.22	2.60	4.13	25.13
2012.3.14	11.49	1017.80	15.48	5214.78	2.45	2.34	4.55	24.83
2012.4.12	11.03	982.05	14.61	5036.83	1.94	2.85	4.19	20.74
2012.6.20	10.12	940.52	14.07	5587.19	1.57	3.37	4.90	23.91
2012.7.24	11.69	996.08	12.93	6401.93	2.28	3.59	4.88	23.68
2012.8.22	26.68	964.43	13.16	6109.18	3.47	5.03	15.80	37.44

Table 1: Oil dissolved gas contents

Test voltage/kV	Magnitude of partial discharge/pC		Ultrasonic positioning	
	before	after	before	after
412	450	60	Find obvious discharge signals on above 35 cm at the bottom of the device.	none
476	5600	60	Find obvious discharge signals on above 35 cm at the bottom of the device.	none

Table 3: The data that partial discharge test before and after the replacement of high voltage outlet device