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Research on Judging Methods for Oil-Paper Capacitive Bushing Oil Lacking

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Abstract. The function of components and the theory of oil-paper capacitive bushing are introduced by analyzing its contracture, and the electric properties of insulation materials are instructed. The reasons and damages of lack of oil are proper illustrated, and the judging methods are offered. The distinguishing process of lack oil of bushing is illustrated by examples, and the accuracy and rationality of lack of oil finding by capacitive volume, dielectric loss angle, oil chromatogram analyzing and infrared ray test are demonstrated.

Introduction

The bushing is a kind of widespread used electrical equipment in power system. With a bushing the high voltage lead wire can pass through the earth body (wall, metal partition board and so on) or the oil box cover of electrical equipment to connect to other equipments. The transformer bushing and the wall bushing are used frequently for insulation and wire supporting in power system.

The oil-paper capacitive bushing has been widely used in 66kV and upper voltage system because of its high utilizing factor of insulation, large specific capacitance, reasonable structure and small volume. In the long-term operation, the bushing have to bear the highest working voltage of long-term but also withstand all kinds of possible over-voltage, while the bushing itself due to dielectric (cable paper, transformer oil) gradual deterioration, moisture and partial discharges and other reasons, susceptible to various accidents. Ingress of moisture which will make the bushing oil lacking, resulting in insulation damp, will lead to partial discharge occurred within the bushing, causing the explosion [1].

Structure of oil-paper capacitive bushing

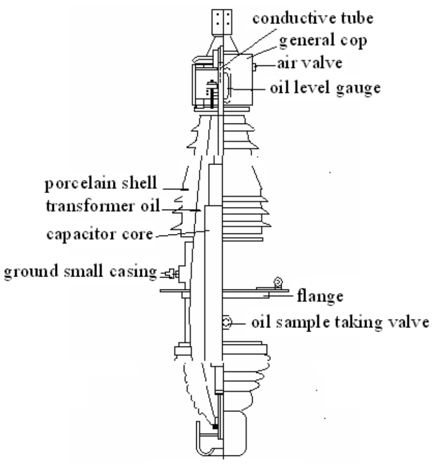

Fig. 1 Structure of oil-paper capacitive bushing

Oil-paper capacitive bushing consists of the copper conductive tube (pole), oil impregnated paper condenser cores, ceramic or compound hollow insulator and accessories [2]. The structure of the oil-paper capacitive bushing indicated in Figure 1.

The reasons and damages of oil-paper capacitive bushing

(1) The reasons of bushing oil lacking

The main reasons of bushing oil lacking are quality defects, improper operation and maintenance.

1) Bad manufacturing quality. End of the bushing and other parts with a gasket seal are not perfect before their installation, there is within the seepage or leakage.

2) Improper operation and maintenance. There are sealing gasket aging, cracking, oil leaking during the long time operation.

3) Oil recharging has not been done after taking samples repeatedly.

(2) The damages of bushing oil lacking

There are many adverse consequences of bushing oil lacking, presented as the following three forms.

1) Moistening

If failure to take the vacuum oiling in time when the oil is lacking and oil samples are taken from the release valve when the oil valve has not been open sometimes and the bushing cap is not tight contact with deformation and gasket is aging, air will be caused into the bushing cavity. The transformer oil and capacitor cores will be moistened. So the insulation level will be reduced and the dielectric aging is accelerating. In this situation, the leakage current increases, the polarization of interlayer dielectric interface and the polarizing loss increase [4]. $tg\delta$ increasing will cause heating of internal insulation, and the temperature increased further. If this cycle continues, thermal collapse of the internal thermal insulation and even explosion will happen.

2) Surface discharging

When serious short of oil, the inner ceramic wall in the high part and the capacitor core will be exposed to the air, thus surface discharging may occur between them because the electrical properties of the air is worse than transformer oil. The discharging current will increase with surface discharge, cause heat to slip into flash discharge, when through poles, the surface flashover is generated to form a spark discharge or arc discharge, then will have a lot of gas, may lead pipe explosion.

3) Partial Discharge

Dielectric moisture will result in partial discharge occurring. Partial discharge will result in pyrolysis of insulating oil or insulating paper, and generate a lot of X wax between shields. Thus the dielectric loss will increase.

① Partial discharge of oil bubbles

If short of petroleum and oil spills caused due casing will allow the oil moisture, will produce bubbles in the run, in the role of AC voltage field, the bubbles formed in series with the oil medium, the equivalent circuit is shown in Figure 2 [5].

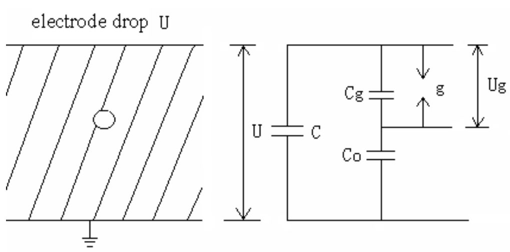

Fig. 2 The theory diagram of partial discharge of oil bubbles

In AC circuits, the electric field intensity distribution is in inverse proportion to the relative dielectric constant of the medium. The relative dielectric constant of oil ε_o is 2.2, while the relative dielectric constant of air ε_g is 1.

The voltage distribution by capacitance, the voltage of the bubble is $U_g = U[C_o/(C_g + C_o)]$,
As the equivalent capacitance C_g is smaller, so the voltage on the gap is larger, but the field intensity is 2.2 times the oil, that is $E_g = 2.2E_o$.
The field strength of gas breakdown is much lower than oil, so partial discharge will be first produced at the bubble, which makes the bubble temperature increase, gas volume expand, therefore partial discharge further aggravates. In addition, some minor impurities in oil or water under the action of the electric field can easily be polarized along the electric field orientation by the liquid medium of bridge discharge theory, and forms bridge type of discharge channel easily with bubbles, lead to partial discharge [6, 7].
② Partial discharge between air gaps of capacitor cores
When short of oil, there are air gaps between the oil-paper layers. Under AC voltage, the voltage exposed on gaps is larger than on paper layers, but the breakdown voltage of the air gap is much lower than that of paper layers, so the partial discharge happens between air gaps.

The judging methods for oil-paper capacitive bushing oil lacking

(1) Preventive tests
1) Bushing oil lacking can be judged by its capacitance reducing in the case of bushing non-wet.
The insulating part of bushing will not be moistened if oil lacking caused by oil samples taking, so $tg\delta$ does not change significantly. If the volume of lacking oil is large enough (more than 20% of total oil), the capacity will be significantly reduced.
The capacitance of normal bushing is made up of the transformer oil and a capacitor core in shunt connection. i.e. $C = C_o + C_p$. But the capacitance of oil lacking bushing consists of the air, transformer oil and a capacitor core in parallel connection. i.e. $C' = C'_g + C'_o + C'_p$, which relative dielectric constant separately is $\varepsilon_g = 1$, $\varepsilon_o = 2.2$, $\varepsilon_p = 6$. As the capacitance of transformer oil in normal condition is larger than the sum of the air and the oil in oil lacking condition. i.e. $C_o > C'_o + C'_g$, so the $C' < C$.
The relationship between the capacitance variation and the degree of oil lacking
A simulation test value of transformer bushing (modeled BRDLW-126/1250) is for reference shown in Table 1.

Table 1 the relationship between the capacitance variation and the degree of oil lacking

volume of oil	measuring capacitance (pF)	rated capacitance (pF)	variation of capacitance (%)
full of oil	345.7	345	0.2
cavity	293.9	345	-14.8
20% oil lacking	311.5	345	- 9.7

2) Chromatographic analysis
The oil lacking bushing will have capacitance and $tg\delta$ increments in the case of bushing moistening. So it is difficult to judge weather a bushing is lack of oil only by the variation of capacitance in both oil lacking and moistening situation. Chromatographic analysis has been used as an auxiliary way for bushing oil lacking in this situation. The oil lacking can be judged if the chromatographic analysis data are larger than the normal value.

(2) Infrared detection
Infrared detection can judge whether oil is lacking sensitively and accurately, also identify the phenomenon of false oil level.

(3) Touring inspection
Bushing touring is for checking whether oil leakages in junction components.

Case study

(1) Example 1

October 15, 2008, a preventive test on the bushing modeled BRDLW-126/1250-3 of a main transformer was carried out at a 220kV substation. The results are shown in Table 2.

Table 2 the preventive test data of the transformer bushing

phase	tgδ	measuring capacitance (pF)	rated capacitance (pF)	variation of capacitance (%)
N	0.368	341.0	345	-1.16
A	0.315	347.1	349	-0.54
B	0.286	314.9	348	- 9.51
C	0.251	345.6	347	-0.40

According to the test data of preventive test, phase B bushing is lack of oil is judged.

(2) Example 2

April 27, 2007, a preventive test on the bushing modeled BRDW-72.5/630-3 of a main transformer was carried out at a 66kV substation. The results show measuring capacitance and $tg\delta$ increasing significantly. So chromatographic analysis was carried out, the results are shown in Table 3.

Table 3 the chromatography analysis data of the transformer bushing

phase	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	CO	CO_2
N	22	25.87	14.97	29.80	0	636	4700
A	20	8.63	10.15	19.96	0	322	4264
B	884	79.17	40.84	35.60	2.05	5411	8812
C	57	12.63	24.45	3.87	0	844	4454

The phase B bushing is lack of oil is judged because the value of H_2, CH_4, CO and CO_2 are larger than the normal.

(3) Example 3

March 11, 2008, the oil level of a bushing modeled BRDW-72.5/630-3 of the main transformer has been checked by infrared at a 66kV substation, the result is the C-phase oil level is half, showing in Figure 3.

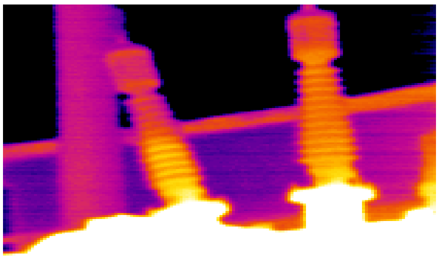

Fig.3 The 66KV transformer infrared image

Conclusion

The right comprehensive analysis and judgments of bushing oil lacking depend on preventive tests, chromatographic analysis and infrared methods, considering with empirical art of tester. Thus the hidden perils of oil lacking will be eliminated in time to ensure the safe operation of power system.

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