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Detection of Negative Tan Delta (Dissipation factor) in Condenser Bushing: A Review

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Abstract - This review paper provides different techniques which are used to detect negative Dissipation Factor (tan delta) and mitigation of it in Condenser Bushing of Power Transformer. The Dissipation Factor is a very serious concern for controlling quality of high voltage equipment. The error must be determined otherwise it may decrease dielectric strength, lifespan or failure of transformer; which may cause to external equipment damage and fire.

Keywords — Power Transformer, Condenser Bushing, Dissipation Factor, Dielectric Loss, Power Factor and Insulation Deterioration

I. INTRODUCTION

The negative Dissipation Factor i.e. tan delta mainly appears due to concentrated moisture, winding bushing contamination and carbonization [1-2]. In this paper, the traditional methods used to detect the Dissipation Factor. *i,e* Voltage distribution method, AC Dielectric Loss method and Power Factor method are commonly used to find out the Dissipation Factor are studied. In insulation the negative Dissipation Factor cannot be detected completely so the service is interrupted continuously [3]. In High voltage transformers this problem causes insulation ageing or failure [4]. There is another technique to measure Active Power, Power Factor and Apparent Power on-site but it cannot measure these parameters continuously It is difficult to relate negative Dissipation Factor with insulation performance of Power Transformer.

The negative Dissipation Factor raises a technical challenge which indicates the fault in insulation. If the detection and mitigation process of negative tan delta (Dissipation Factor) fails, it may result into the breakdown of dielectric strength which leads to catastrophic failure of Power Transformers. This problem may become a reason for the fire and external damage; which may lead to financial loss, time loss in repair or replacing the transformer. After that it will become a concern for the quality of product and manufacturing company, so that company may lose their reputation as well as customer. In this paper, the analysts used Doble software to analyse and test Dissipation Factor measurement for Power Transformer. Main purpose of work is solving the urgency of customer and to sustain reliability of Condenser Bushing of the transformer supply.

In this paper, the main causes of negative tan delta after considering the dissipation related parameters, excitation of current, examined environmental conditions are studied. This will increase the lifespan and quality of condenser bushing.

II. THEORY OF DISSIPATION FACTOR

Applying ac voltage to Power Transformer and measure the phase difference between the waveform of voltage & output current gives the Dissipation Factor value. This phase angle is used to resolve the total current (I) into its charging current (Ic) and loss (I_R) component. Tan delta, also called Dissipation Factor (DF), It is the ratio of the loss current to the charging current, as shown in equation 1.

$$DF = \frac{I_R}{I_C} = \frac{\sqrt{I^2 - I_C^2}}{I_C} \quad \text{.............1}$$

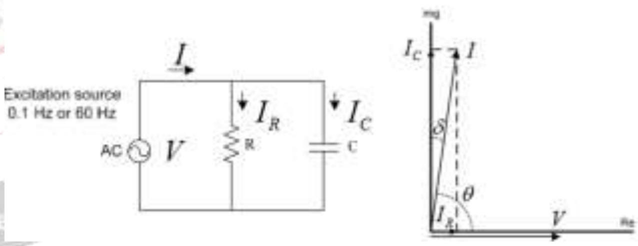

Figure 1a: Tan delta Measurement figure1.b Phasor diagram[8]

Figure 1.a shows an equivalent circuit of Tan delta measurement whereas figure 1.b shows the phasor diagram . The Tan delta measures at a frequency ω and voltage "V", is the ratio of resistive (I_R) and the capacitive (Ic) current according to equation 2.

$$DF = \tan(\delta) = \frac{I_R}{I_C} = \frac{V/R}{V/(1/\omega C)} = \frac{1}{\omega RC} \quad \text{........... 2}$$

The terms Dissipation Factor and tan delta can be used interchangeably.

III. EFFECT OF NEGATIVE DISSIPATION FACTOR ON CONDENSER BUSHING OF POWER TRANSFORMER

A. *Problem of Dissipation Factor*

In Power Transformer, Condenser Bushing failure is

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mainly due to the negative dielectric Dissipation. Due to error, corrosion occurs on solid insulation material so that it causes the breakdown in devices. Hence, identifying the approximate measurement of negative dissipation factor is a true challenge. Negative dissipation factor may show the undesirable resistive current. This is not good for the system

B. Solution Proposed

We are proposing the novel solution in this paper on this problem for the sustainable practice in the industries. Before the complete failure of Power Transformer negative Dissipation Factor(tan delta) appear there, so to avoid the breakdown of Power Transformer negative Dissipation Factor detections serve as caution[9][13]. That is why it helps a lot to maintain the quality of Power Transformer. The main concerns is detecting the negative dissipation and mitigate the same by using technique which determine the power factor, active power and apparent power of power transformer. In this paper, we resolve the concerns to

find out the main reason of negative tan delta and advice to manufacturing company with a proper solution for it and mitigate the error.

IV. TESTING RESULTS

If an engineer found a negative Dissipation Factor on site, then the testing of condenser bushing plays the vital role to determine the quality of dielectric responses. Cellulose insulation, interfacial polarization and oil, these are three components response. Insulation geometry, oil conductivity, conductive aging by-product, moisture and temperature influences on dielectric response [4] [5].

A. Real time measurements in Factory

According IEEE standards 62-1995 [6], power factor should be recorded regularly. The complete test for old apparatus gives the information about inner insulation winding and ground of Power Transformer. Power factor of old transformer should be greater than 0.5 at 20°C

The results of dielectric Dissipation Factor performed in Condenser Bushing in industry are shown in Table1.

Table1: Dielectric Dissipation Factor results performed on Condenser Bushing in industry.[8]

Test	**Measure**	**Inputs**	**Test Results**				
		Test KVA	**mA**	**Watts**	**%PF**	**Capacitance (pF)**
1	CH+ CHL	10	12.173	0.4110	0.35	3228.9
2	CH	10	11.267	0.3970	0.17	2988.8
3	CHL(USI)	10	0.9020	0.0150	0.15	239.33
4	CL + CHL	10	11.521	0.3080	0.28	3056.2
5	CL	10	10.899	0.3010	0.10	2891.1
6	CHL(USI)	10	0.6200	0.0060	0.11	164.45

According to standards of IEC, the dissipation factor must between 0.1 to 0.5, for any other values are considered as deteriorated [7]. Negative Dissipation Factor occurs rarely. So, the test plays vital role to determine the quality of dielectric response.

B. Measurements on Fields

After installation of Power Transformer on site, all routine tests were conducted for validating the factory results. After analyzing the results, we found that the tan delta is negative, as shown in table 2.

TABLE 2:ON SITE TEST RESULTS AFTER OFFLOADING [8]

Test	**Measure**	**Inputs**	**Test Results**			
		Test KVA	**mA**	**Watts**	**%PF**	**Capacitance (pF)**
1	CH+ CHL	10	11.082	0.4110	0.35	3228.9
2	CH	10	10.362	0.3970	0.17	2988.8
3	CHL(USI)	10	0.7170	0.0150	0.15	239.33
4	CL + CHL	10	10.022	0.3080	0.28	3056.2
5	CL	10	9.667	0.3010	0.10	2891.1
6	CHL(USI)	10	0.487	0.0060	0.11	164.45

For testing dielectric strength, tan delta, moisture and resistivity oil sample were taken and results were positive. After that oil regeneration was conducted assuming there was small hidden dirt in Power Transformer. There may be some other interference like overcast sky, high humidity, fog or high wind. If we have less samples of dissipation factor and capacitance, we may face more difficulty in finding out accurate measurement and hence negative tan delta might be produced. As shown in table 3, we can observe that dissipation factor after regeneration decreased and the transformer is in healthy condition and passed the entire test.

TABLE 3: TEST AFTER RE-GEN [8]

Test	**Measure**	**Inputs**	**Test Results**			
		Test KVA	**mA**	**Watts**	**%PF**	**Capacitance (pF)**
1	CH+ CHL	10	11.091	0.776	0.70	3566.0
2	CH	10	10.374	0.929	0.89	3335.5
3	CHL(USI)	10	0.714	-0.199	-2.66	229.3
4	CL + CHL	10	10.030	0.728	0.69	3225.0
5	CL	10	9.542	0.978	0.98	3068.1
6	CHL(USI)	10	0.487	-0.250	-4.90	156.5

After increasing the voltage range from 10 kV to 12kV, dissipation factor increases negatively, readings are shown in table 4. After that it was decided that transformer needed servicing and monitored the same by taking oil sample for every two-four month.

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TABLE 4: RESULTS FOR HIGH VOLTAGE[8]

Test	Measure	Inputs	Test Results			
		Test KVA	mA	Watts	%PF	Capacitance (pF)
1	CH+ CHL	12	11.085	0.731	0.65	3564.2
2	CH	12	10.367	0.930	0.89	3333.2
3	CHL(USI)	12	0.707	-0.198	-2.76	230.5
4	CL + CHL	12	10.026	0.752	0.73	3223.6
5	CL	12	9.536	0.876	0.90	3065.9
6	CHL(USI)	12	0.487	-0.260	-5.23	156.5

Recommendation

a) Dielectric strength and moisture contents of transformer oil should be check for every three to four months regularly[6],[10][12].

b) After doing all tests, error still continued and become worse than before and reason still unknown then transformer should be send for servicing[11][14].

V. CONCLUSION

The technique for Dissipation Factor has been described briefly. Measurement of Dissipation Factor for Condenser bushing of Power Transformer over the various conditions were considered and reported well. Presence of live lines above or near to Power Transformer may cause the disturbance which may influence on result. Some other assumptions are to be taken into consideration so that the Condenser Bushing of the Power Transformer may not fail due to negative Dissipation Factor.

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