CHARACTERIZATION OF PERFORMANCE OF PAPER-OIL INSULATION SYSTEM IN THE PRESENCE OF DBDS

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Abstract

Premature death of power and converter transformers as a result of formation of Corrosive elements on copper conductors due to sulpher in transformer oil is a serious phenomenon that is haunting power industry over the years. Addition of Dibenzyl disulphide (DBDS) by the manufacturers of transformer oil, so as to increase the performance characteristics of transformer oil is one of the reasons for formation of copper sulphide. Copper sulphide being conductive, affects the voltage distribution due to surface discharges. The insulation is damaged due to these discharges and leads to the breakdown of insulation. In the present work experimental analysis has been carried out to investigate the role of DBDS in increasing the discharge activity and thus reduction in breakdown strength of transformer insulation.

Keywords*- DBDS, Transformer oil, Leakage current, Breakdown strength.*

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1. INTRODUCTION

In the previous two decades, the systematic studies carried out throughout the world on transformer oil and oil immersed equipments and their breakdown have had clearly and conclusively proved that sulphur present in transformer oil and its reaction with copper conductors leads to the formation of copper and cupric sulphide [1-6]. The semi conducting copper sulfide which is formed on the copper conductor of windings, starts migrating towards inner papers layers [7,8]. This leads to dielectric loss in the insulation, followed by thermal instability and finally ends up in thermally induced dielectric breakdown of the insulating system. The main source of sulphur in transformers is the mineral transformer oil used as a coolant. This being a by-product of crude petroleum, necessarily contains reactive and corrosive sulphur. Apart from that, the manufacturers add anti-wear and anti-oxidants like DBDS and di-butyl paracresol (DBPC) to achieve certain performance characteristics which are otherwise difficult to. Experimental results have revealed that DBDS enhances the oxidation stability of oils but also makes oil more corrosive to attack copper and form copper sulphide [9-13]. This study was taken up with the sole objective of understanding the effects of DBDS on transformer oil. Further, it was aimed to know its effect on V-I characteristics of pig-tail sample that is simulated to represent an actual transformer.

2. EXPERIMENTAL METHODOLOGY

The methodology adopted to carry out the investigations is:

2.1 Preparation of Pig-Tail Sample for Test

The pig tail sample [14] consists of two rectangular copper conductors of 10 (W) X 100 (L) mm with five layers of paper over it. The thickness of paper was 80± 5 µm. The paper at the end portions of the conductor are cut open for electrical connections. One copper conductor of the pig tail specimen is the HV and the other, the LV terminal. The structure of pigtail configuration is shown in Figure 1.

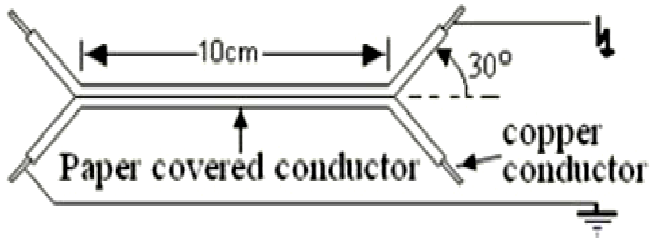

Fig 1 Pig-tail configuration of specimen representing portion of transformer winding

Fig 2 Pig-tail configuration of specimen representing portion of transformer winding placed in oil cell

i. Leakage current was measured for pure transformer oil for different voltages applied between the electrodes.
ii. Different amount of DBDS was added in fresh and virgin oil and suitable conditions for formation of Cu_2S and hence its migration into different paper layers were simulated in the lab. Further, leakage current was measured and breakdown voltage was determined along with corresponding voltage-leakage current characteristics. [15-22]

3. RESULTS AND DISCUSSIONS

In this section, the results obtained for clean oil and oil mixed with different concentrations of DBDS have been presented and discussed.

There seems to be linear rise in leakage current with applied voltages for the case where oil is free from dibenzyl disulphide. As the concentration of DBDS is increased in transformer oil, the leakage current for the same applied voltage rises. These results are depicted in Table I and Figure 3.

Table 1. LEAKAGE CURRENT MEASURED AT DIFFERENT APPLIED VOLTAGES WHEN PIGTAIL SAMPLE IS IMMERSED IN PURE OIL & OIL WITH DIFFERENT DBDS (10-30PPM) CONCENTRATION WITH AGEING OF OIL AT 120^{0}C

Applied voltage (kV)	Leakage current (mA) for different DBDS concentrations in ppm			
	Pure oil	10	20	30
1	0.04	0.04	0.04	0.04
2	0.045	0.045	0.045	0.05
3	0.05	0.05	0.05	0.06
4	0.055	0.055	0.055	0.07
5	0.06	0.06	0.065	0.085
6	0.07	0.07	0.075	0.1
7	0.08	0.08	0.085	0.11
8	0.09	0.095	0.1	0.12
9	0.1	0.105	0.105	0.16
10	0.105	0.12	0.13	BD
11	BD*	BD	BD	

*Breakdown

This rise in leakage current is in sync with the reported results.

These variations or the rise in leakage current is mainly due to the formation of Cu_2S and its possible migration, both lateral and surface migration. [21] Mainly, the field distribution near the electrodes is affected as the Cu_2S is conductive in nature and the characteristics follow both Ohm's (I α V) and power law (I α V^n). From the results as shown in Figure 1, it is seen that the leakage current rises following only the Ohm's law for the clean oil case. For, further rise in concentration of DBDS upto 20 ppm in steps of 10 ppm, rise in leakage current upto applied voltage of 8kV it is linear but follows power law further.

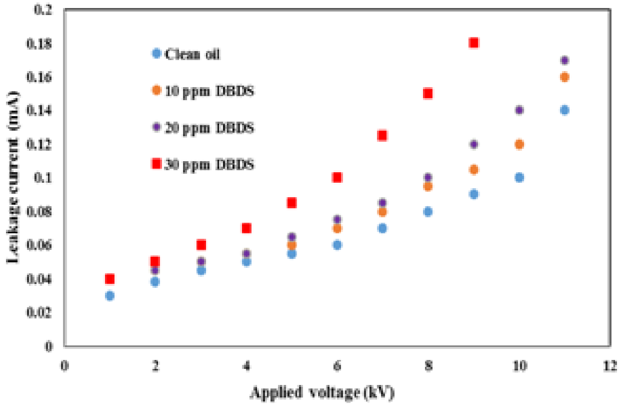

Fig 3: Leakage current as a function of applied voltage for clean oil and oil with different concentrations of DBDS (10-30 ppm) aged at 1200C

For 30 ppm of DBDS, the rise in leakage current with respect to the applied voltage exponential above 4 kV itself. Experiments were continued for 40-60 ppm of DBDS added with transformer oil. The leakage currents measured at different concentration of DBDS added were noted which are tabulated in Table II.

Table 2. LEAKAGE CURRENT MEASURED AT DIFFERENT APPLIED VOLTAGES WHEN PIGTAIL SAMPLE IS IMMERSED IN PURE OIL & OIL WITH DIFFERENT DBDS (40-60PPM) CONCENTRATION WITH AGEING OF OIL AT 120^{0}C

Applied voltage (kV)	Leakage current (mA) for different DBDS concentrations in ppm			
	Pure oil	10	20	30
1	0.04	0.0432	0.0436	0.055
2	0.045	0.0594	0.0654	0.077
3	0.05	0.0756	0.0872	0.099
4	0.055	0.0972	0.109	0.132

5	0.06	0.1188	0.1308	0.16
6	0.07	0.1417	0.154	BD
7	0.08	BD	BD	
8	0.09			
9	0.1			
10	0.105			
11	BD*			

Results for extended concentrations of DBDS are graphically represented in Figure 4. There is much sharp increase in leakage current for these concentrations. This confirms the hypothesis that increased concentrations of DBDS has bearing on formation of Cu_2S and in turn on distribution of field lines which get affected and finally results in non-linear rise on leakage current.

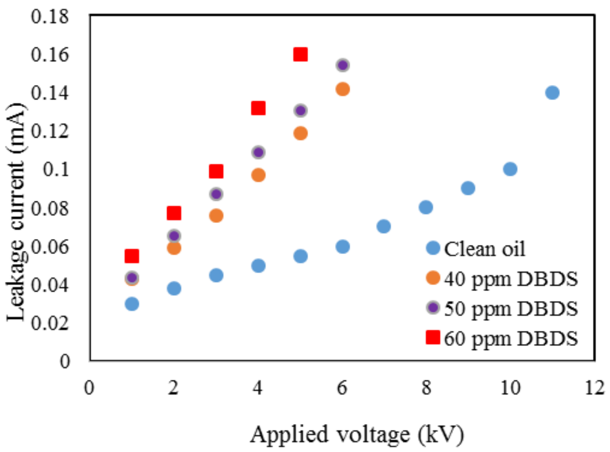

Fig 4: Leakage current as a function of applied voltage for clean oil and oil with different concentrations of DBDS (40-60 ppm) aged at 120^0C

To analyse the effect of DBDS on leakage current as a function of applied voltage, % rise in leakage current was calculated from the obtained results and it is depicted in Figure 5. It was seen that for a concentration of 10 and 20 ppm the % rise in current was found to be between 4% and 7% for different applied voltages.

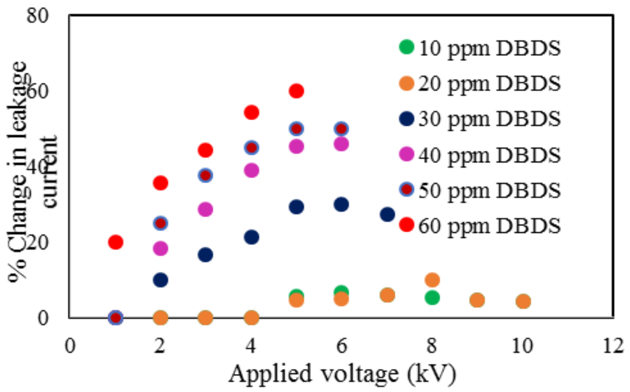

Fig 5: % Change in Leakage current as a function of applied voltage for clean oil and oil with different concentrations of DBDS (10-60 ppm) aged at 120^0C

A quantum jump of 60% in leakage current was found at 60 ppm of DBDS addition in pure oil. The rise was recorded at an applied voltage of 5kV.

4. CONCLUSION

(1) From the experimental investigations on pure oil and DBDS mixed oil, it was observed that the electric strength of oil in the presence of DBDS drastically reduces depending upon the concentration of DBDS in oil.

(2) Though DBDS addition in transformer oil enhances the performance characteristics, rise in leakage current is enormous at large concentration and sharply reduces the dielectric withstand capacity of oil.

(3) Presence of around 60 ppm of DBDS, increases the leakage current significantly by nearly 60% at just 5 kV of applied voltage.

ACKNOWLEDGMENT

The authors would like to thank the authorities of Ghousia College of Engineering, Ramanagaram for all the cooperation and encouragement extended in carrying out this work.

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