Engineering and Technology Journal e-ISSN: 2456-3358
Volume 07 Issue 09 September-2022, Page No.-1444-1448
DOI: 10.47191/etj/v7i9.02, I.F. – 6.484

Investigation of Model Transformer Insulation Behavior during PD Activity in Di-Benzo-Di-Sulfide Sulphur Contaminated Transformer Oil Using Online Tanδ Measurement

L. Sanjeev Kumar[1], B. Ramachandra[2], S. Senthil Kumar[3]
[1]Professor, Electrical and Electronics Engg. Sri Siddhartha Institute of Technology Tumakuru, SSAHE, Karnataka, India
[2]Professor, Electrical and Electronics Engg. PES College of Engg. Mandya, Karnataka, India
[3]ABB Global Industries and Services Private Limited Bangalore, Karnataka, India

ABSTRACT: Sulphur can be present in mineral insulating oil and can manifest in stable, highly reactive and corrosive form. The corrosive sulphur reacts with the copper conductor in transformer and forms semi conductive copper sulphide at the surface of the copper conductor. The paper insulation used on the copper conductor may get damaged due to copper sulfide deposits which also affect the partial discharge activities prevalent in the transformer paper-oil insulation. The affect of Sulphur on model transformer paper-oil insulation is studied with online measurement of Dissipation factor (tanδ) and partial discharges (PD). The paper presents results of the investigatory work carried out with on-line tanδ and PD measurements made during experiments with Paper covered copper conductor (PCCC) in presence of Di-Benzo-Di-Sulfide contamination in transformer oil.

KEY WORDS: PCCC, Sulphur corrosion, tanδ, paper-oil insulation, DBDS sulphur.

INTRODUCTION

The reliability of power transformers is normally high and their expected life time typically exceeds 30 years. A recent observation of premature transformer failures in the field caused by copper sulfide deposition has raised a large interest in the power industry [1]. The importance of sulfur and its compounds, which concerns the quality of mineral insulating oil, is well recognized and the amount of sulfur contained in typical insulating oil may range from 0.001 to 0.5%. Also it has been recently reported that number of HVDC transformer failures are attributed to the presence of high content of DBDS sulfur in oil. The DBDS sulfur reacts with the copper conductor and forms copper sulfide on the surface. These become the sites for initiation of partial discharges causing damages to the layers of paper in contact with the conductor. The copper sulfide thus formed also migrates to other layers of paper in contact with the conductor and causes reduction in insulation resistivity [2,3]. Since copper sulfide is conductive, it affects the voltage distribution leading to surface discharges which results in degradation of paper insulation leading to breakdown of insulation [4]. As per the literature, DBDS sulfur can attain concentration upto 350ppm in transformer oil [3]. Tanδ can be a measure of imperfection in dielectric material and its higher value can indicate presence of contaminants [6]. Normal ageing of an insulating material will cause the dielectric loss to increase and contamination of insulation by moisture or chemical substance may cause losses to be higher than normal [7]. The dielectric diagnostic methods most commonly used in industry are the dissipation factor (tanδ) and capacitance measurements at power frequency. The variation of tanδ provides useful information about the insulation quality [8]. The paper presents a technique for on-line tanδ measurements along with PD studies for the following reason:-

1. It may be possible to determine the instants of time at which significant copper sulfide migration takes place.
2. It can also reveal information for understanding the change in capacitance and resistance which occurs due to copper sulfide migration.
3. Computed tanδ values can reveal deterioration of insulation including due to copper sulfide migration.

It is well known that PD activity produces a permanent or quasi-permanent trapping of charge on the surface because of the presence of PD-generated surface charges. The electric field in the gap [example between the paper layers] and around the solid dielectrics will be modified. This phenomenon will affect subsequent PD pulses, along with the deterioration effect in insulation including that occurring due to release of the copper sulfide in the transformer oil with DBDS. Therefore, simultaneous studies of PD and tanδ are interesting to observe change in PD and tanδ behavior and to attempt correlation with change in the PCCC samples placed in transformer oil.

SAMPLE PREPARATION

A conductor-insulation, PCCC sample in a pigtail arrangement was prepared to simulate an equivalent electric field condition of a transformer winding in the laboratory, the PCCC also known as paper-oil insulation is configured in pigtail arrangement [9]. Two copper conductors each of 9mm width, 3.5mm thickness and 130mm length are used to prepare the samples. A representation of the developed pigtail model is shown in Figure1, which has three portions namely, straight portion of length 100mm at the center along with two bend portions of 15mm on either side making an angle of 30 ^{O} with the horizontal. These conductors are wrapped with 3 layers of kraft paper insulation of 0.055mm thickness.

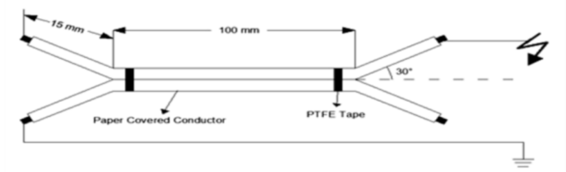

Figure 1: Pig-Tail Configuration of Sample.

EHV grade transformer oil procured in a single batch was used for experiments in batches, a quantity of DBDS sulphur was added to achieve 200ppm and 300ppm contamination level in transformer oil to create sulphur contaminated oil for experiments. This oil and the dry PCCC samples were treated suitably for removing moisture. The dry PCCC samples with due precaution were later immersed in oil for obtaining oil impregnation PCCC samples for experiments.

PD Experimental setup with on-line tanδ measurement

A straight detection PD experimental setup is shown in Figure2. The test voltage from 100kV, 10kVA testing transformer was discharge free upto 70kV. The experiments are performed in a Faraday cage where the background noise is less than 2pC. Voltage of 1.4 times the inception voltage is applied to the test specimen. The PD pulses appearing across the measuring impedance are amplified with a wide band detector and is fed to a data acquisition system developed using NI PCI-5154 card having sampling rate of 2G samples/sec and bandwidth of 1GHz. For on-line tanδ measurement, the scaled down applied voltage and current through the sample were acquired with 16 bit NI-ADC together with PD pulse data acquisition. The acquired applied voltage signal was also used as reference for phase resolved PD measurement.

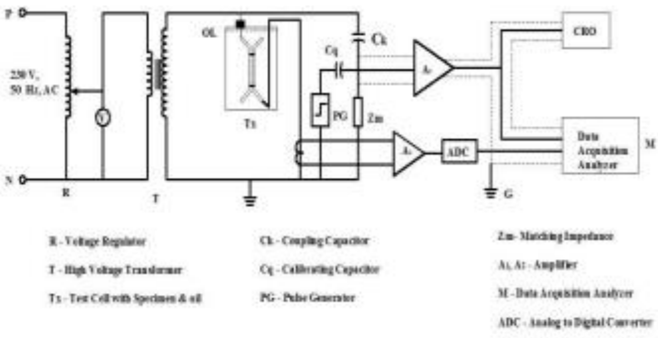

Figure. 2: Block Diagram Of Pd Measuring System

Experiments were performed with oil impregnated PCCC samples placed in uncontaminated oil and in 200ppm and 300ppm DBDS sulphur contaminated oil. Tanδ values were computed from phase difference measurement between applied voltage and current signals. Also values of capacitance and resistance were computed from tanδ values.

RESULTS AND DISCUSSIONS

a. Online tanδ Measurement

The variations of tanδ value for samples in treated (uncontaminated) transformer oil, 200ppm and 300ppm DBDS contaminated transformer oil is shown in Figures 3 to Figure 5. It is observed from figure 6, that the time taken for change in tanδ values in contaminated transformer oil is less compared to that for the pure transformer oil. The change in tanδ between initial and final values during experiments and the %change of tanδ calculated between treated and contaminated oil are shown in Table I.

The change in tanδ occurs due to the release of copper sulfide and deleterious effect of PD. It is observed from Figure 4 that the change in tanδ in a PCCC samples placed in treated oil occurs at 1847 sec onwards and its value changes from 0.001745331 to 0.094527831. However for a PCCC samples placed in 200ppm and 300ppm DBDS contamination levels, the change in tanδ values are observed from 10sec and 21sec onwards respectively as shown in Table I.

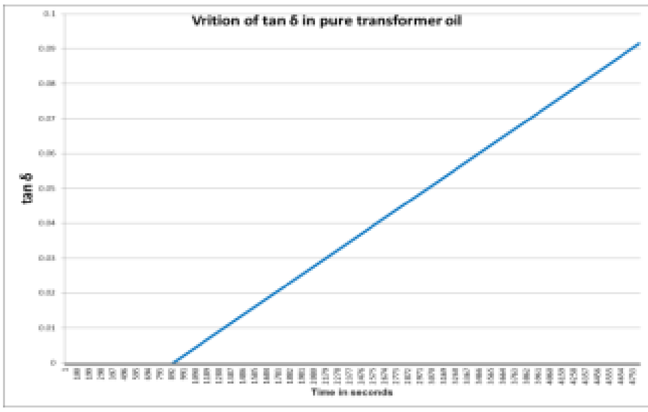

Figure.3: Variation of tanδ with time for pure transformer oil

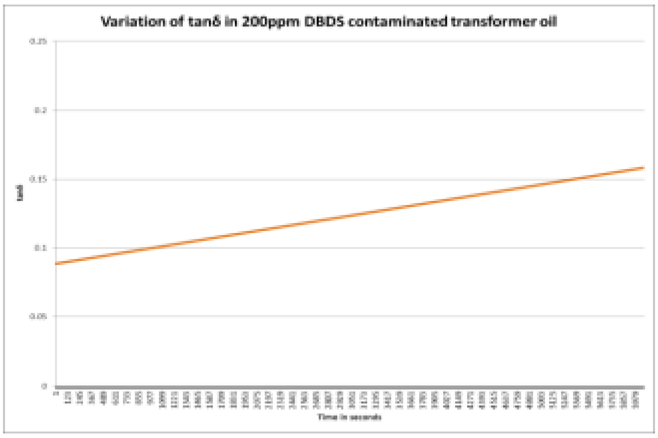

Figure.4: Variation of tanδ with time for 200ppm DBDS contaminated oil

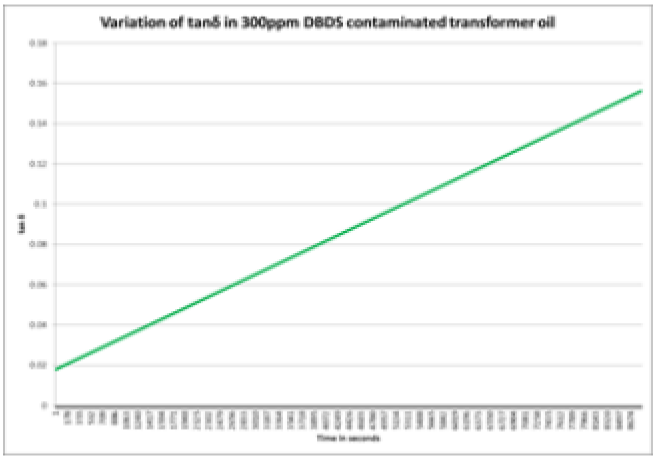

Figure.5: Variation of tanδ with time for 300ppm DBDS contaminated oil

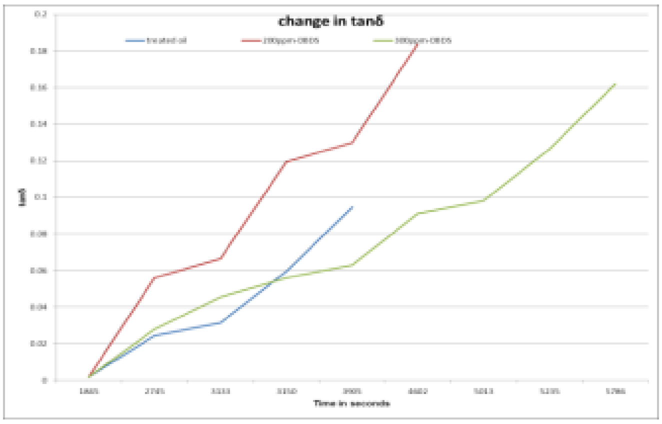

Figure.6: combined variation of tanδ with time for pure and DBDS contaminated oil

Table I: change in tan-δ of pig-tail specimen with DBDS oil

Type of oil		Time of occurrence (seconds)	Change in tanδ values: Initial	Change in tanδ values: Final	% change of tanδ
Treated oil		1847	0.0017	0.0945	---
DBDS contaminated oil	200 ppm	10	0.0017	0.1943	105.63
DBDS contaminated oil	300 ppm	21	0.0017	0.1619	71.34

b. Change in capacitance of the PCCC

The variations of capacitance value are calculated in treated transformer oil, 200ppm and 300ppm DBDS contaminated transformer oil are shown in Figures 5. The change in capacitance between initial and final values during experiments and the %change of capacitance are calculated for treated and contaminated oil and shown in Table II.

Table II: change in capacitance of pig-tail specimen with pure and DBDS contaminated oil

Type of oil		Time of occurrence	Change in capacitance in pF: Initial	Change in capacitance in pF: Final	%change of capacitance
Treated oil		1847 sec	250.43	46.44	---
DBDS Contaminated oil	200 ppm	10 sec	203.54	18.61	59.91
DBDS Contaminated oil	300 ppm	21 sec	162.83	17.77	61.72

In all the experiments performed, the change in capacitance is in accordance with tanδ behavior. It is observed from Figure 7 that the change in capacitance for samples in treated oil occurs at 1847 sec onwards and its value changes from 250.43pF to 46.44487. However in 200ppm and 300ppm DBDS contamination levels, the change in capacitance values are observed from 10 sec and 21 sec onwards respectively and its value reduces to 203 and 162 pF at starting respectively. The capacitance reduction accounted to 59.91% in 200ppm and 61.72% in 300ppm contaminated transformer oil compared to treated transformer oil.

c. Change in resistance of the PCCC

The variations of resistance value is calculated for a PCCC samples placed in treated transformer oil, 200ppm and 300ppm DBDS contaminated transformer oil are shown in Figures 6. The change in resistance between initial and final values during experiments and the %change of resistance are calculated for treated and contaminated oil and shown in Table III. The change in resistance is in lieu with tanδ behavior. It is observed from Figure 6 that the change in resistance in treated oil occurs at 1847 sec onwards and its value changes from 7.28GΩ to 7.248GΩ.

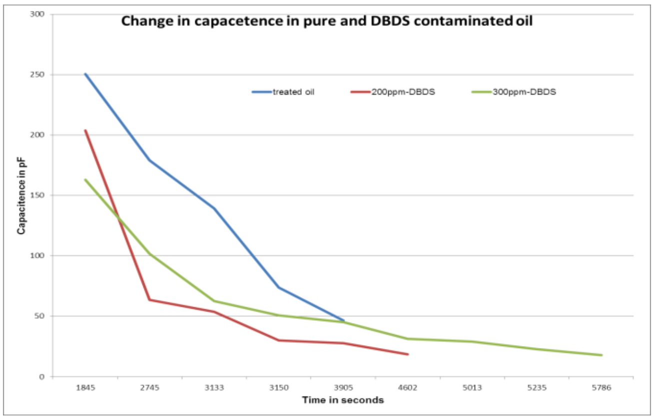

Figure 7. Combined change in capacitance in pure and DBDS contaminated oil

Table III: change in resistance of pig-tail specimen with oil

Type of oil		Time of occurrence	Change of Resistance in GΩ		%change of Resistance
			Initial	Final	
Treated oil		1847 sec	7.279	7.247	---
DBDS Contaminated oil	200 ppm	10 sec	6.959	6.832	5.73
	300 ppm	21 sec	5.499	5.429	24.22

However in 200ppm and 300ppm DBDS contamination levels, the change in resistance values are observed from 10sec and 21sec onwards respectively and its value reduces to

6.959 and 5.49GΩ at starting respectively. The resistance reduction accounted to 5.73% in 200ppm and 24.22% in 300ppm contaminated transformer oil compared to pure transformer oil. It is observed that the resistance change in a PCCC samples placed in contaminated oil is % change wise small compared to that placed in treated transformer oil.

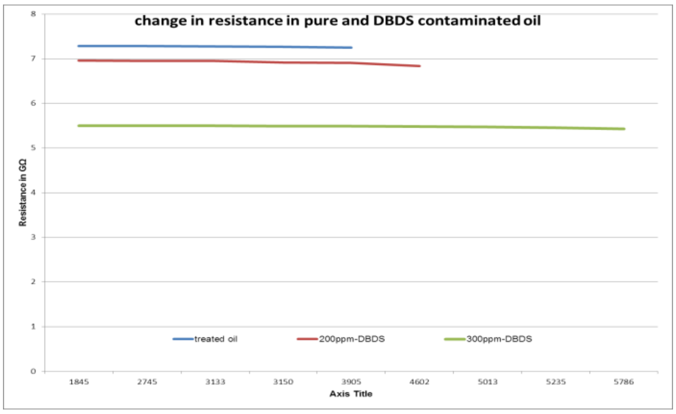

Figure 8. change in Resistance in pure and DBDS contaminated oil

CONCLUSIONS

In order to understand the effect of DBDS sulfur on behavior of insulating samples. Insulation properties is studied with PD. tanδ, capacitance and resistance obtained with experiments. Some of the important observations of the study are:

1. The change in tanδ occurs at early, and rapidly in higher level of contamination of DBDS in transformer oil
2. The contamination levels have increasing negative effectson the performance of the PCCC samples in transformer oil.
3. The early insulation deterioration occurs due to the presence of DBDS and space charges created due to this. 4. The change in the insulation behaviour is due to the change in tanδ because of the presence of DBDS contamination in transformer oil.

ACKNOWLEDGEMENT

Author likes to thank **Dr. B. V. Sumangala**, Professor and Head, Department of Electrical and Electronics Engineering **Dr.A.I.T**. Bengaluru, for providing the opportunity to conduct the Experiments in their laboratory. Author also extends gratitude to **Dr.J.Sundara Rajan** JD, CCARCentral Power Research Institute, Bangalore for his valuable suggestions and help to complete this work. Author owe his existence and development as faculty of Sri Siddhartha Institute of Technology and would like to record heartfelt gratitude to **Dr.G.Parameshwara**, Joint Secretary, SSES who has encouraged and provided the opportunity for carrying out research work.

REFERENCES

1. C.Bengtsson et.al, "Oil Corrosion and Cu Cu2S Deposition in Power Transformers", CIGRE Moscow Symposium 2005.
2. F.Scatiggio, V.Tumiati "Corrosive sulfur induced failures in oil-filled electrical power transformers and shunt reactors"
3. IEEE transactions on power delivery, vol, 24, No.3, July 2009 [3.] B.P.Singh, T.S.R.Murthy, G.Jayaraman "Effect of Mercaptans Sulphur on Insulation

Performerence of HVDC Converter Transformer" Cigree 2006

4. J.Sundara rajan, K.Dwarakanath, Srilatha, C.Jairam naidu and A.K.Tripathy " Monitoring of Total and Mercaptans sulfur under combined thermal electrical ageing of paper-oil insulation system"
5. Shuagzan Ren "A Research Summary of Corrosive Sulfur in Mineral Oil" proceedings of 9th international conference on properties and application of Dielectric Materials, July 1923,2009, Harbin, China
6. Jashandeep Singh, Yog Raj Sood &Piush Verma "The Influence of Service Aging on Transformer Insulating Oil Parameters" IEEE Transactions on Dielectrics and Electrical Insulation Vol. 19, No. 2; April 2012
7. Donald Chu, Andre Lux, "On-Line Monitoring of Power Transformers and Components: A Review of Key Parameters" IEEE Transformer On-Line Monitoring Task Force
8. C.F.Ten, M.A.R.M.Fernando and Z.D.Wang "Dielectric Properties Measurements of Transformer oil, Paper and Pressboard with the effect of Moisture and Ageing.
9. J.Sundara Rajan "partial discharge phenomena in paper oil insulation under conditions of copper corrosion due to sulphur in oil" proceedings of the 9th international conference on properties of dielectric materials July 19-23, 2009, Harbin, china
10. R. J. Vam Brunt"Stochastic Properties of Partialdischarge Phenomena" IEEE Transactions on Electrical Insulation Vol. 28 No. 5, October 1991
11. S.Sentil Kumar, Y.P.Narayanachar and R.S.Neema, Response of Narrow Band Detector and Analyzer to Ageing Experiment‟, IEEE Conference on Electrical Insulation and Dielectric Phenomena (2002 CEIDP), Cancun, Quintana Roo, Mexico,(October 20-24, 2002)
12. L.Sanjeev Kumar, Ramachandra.B., S.Senthil Kumar, "Performance of PCCC in presence of DBDS in transformer oil using Ø-t-N technique" International Conference on Power and Advanced Control Engineering (ICPACE), 2015 IEEE Xplore 12-14 Aug. 2015, Bangalore, pages 393 - 398