PERFORMANCE OF PCCC IN PRESENCE OF MERCAPTANS IN TRANSFORMER OIL USING Ø-t-N TECHNIQUE

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Abstract— **Paper–oil insulation is widely used in transformers. The reactive sulphur forms copper sulfide and dispersing in oil causes the reduction in insulation of the transformer. It is reported that during life cycle of transformer, paper and pressboard insulation undergoes deterioration mainly because of increase in sulphur content in transformer oil. The Ø-t-N distribution is a popular choice for PD representation as the discharge magnitude is associated with the state of insulation. Representations based on the charge magnitude are susceptible to influence of the measuring system, discharge and equivalent characteristics. On the other hand, the Ø-t-N representation offers much flexibility.**

Index Terms: PD, Sulphur corrosion, paper-oil insulation, Mercaptan sulphur.

1. INTRODUCTION

The reliability of power transformers is normally quite high and the expected life time of transformers typically exceeds 30 years. Power transformers are crucial elements in all power networks and are considered particularly important due to the relatively long repair time of transformers. The Transformer often fails in the system causing undesirable instability of the power system. Transformer oil is a mineral oil containing organic and sulfur compounds [1, 2]. Sulfur is commonly found in crude oil source. Elemental sulfur and the sulfur-containing Mercaptans are very reactive followed by sulfides. It is observed that non corrosive sulfur can become corrosive after being exposed to elevate temperatures on hot metal surfaces and thus produce metal sulfides. The effects of corrosive / reactive sulfur not only adversely affect the conductor material and other metal surfaces but also can have drastic effects on insulating materials such as paper [3, 4]. The serious contamination due to sulfur-containing surfaces can drastically reduce the dielectric strength of the paper insulation. Though the transformer oil passes the standard corrosive sulphur test, the sulphur compounds which are nonreactive at normal operating conditions become reactive at extreme conditions in the transformer and form copper sulphide. In 2005 CIGREE had setup WG A2-32 to deal with the problem of the formation of copper sulfide in transformer insulation. The full extents of problem due to copper sulfide formation in the insulation are still not mapped in great detail. The paper insulation is damaged due to these discharges and leads to breakdown of insulation. In this study, samples of paper insulated conductors are subjected electric stress. Mercaptan sulphur is also added to oil for investigation. The discharge characteristics of the insulation were also studied for establishing correlation between copper corrosion and partial discharge [PD] characteristics using Ø-t-N technique.

Once began, PD causes progressive deterioration of insulating materials, ultimately leading to electrical breakdown. The effects of PD within high voltage equipment can be very serious, ultimately leading to complete failure. The chemical transformation of the dielectric also tends to increase the electrical conductivity of the dielectric material surrounding the voids. This increases the electrical stress in the unaffected gap region, accelerating the breakdown process. The Ø-t-N representation offers much flexibility. The Ø-t-N distribution is constituted by time related parameters which can be precisely measured. Ø-t-N distribution has time interval parameter represented in sequence that can be used for pulse correlation and study pulse behavior along the phase angle therefore it has pulse to pulse correlation values present in the natural sequence of occurrence along the phase angle in the pattern.

II. DETAILS OF EXPERIMENTS

The main objective of this study was to replicate the environment of power transformer with paper oil insulation. Straight detection method was used for the

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measurement of PD. The schematic diagram of the PD measuring setup is shown in fig.1. A high voltage transformer (10kVA, 230/100kV, WS test systems make Bangalore) used for applying high voltage across the specimen. Supply to the high voltage testing transformer taken through a voltage regulating air cooled dimmerstart. Test setup has discharge free voltage up to 70kV (rms). Coupling capacitor C_k (1000pF ± 20%, 120kV ac 50Hz) used for coupling the PD pulses. An R-L-C measuring impedance (Z_m) connected in series with the coupling capacitor. The measuring impedance shunted by a paper gap for protection of electric circuitry. The whole setup is connected in a shielded room having background noise less than 2pC. PD pulses appearing across the measuring impedance is amplified using a narrow band detector (centre frequency 500 kHz, bandwidth 50 kHz, resolution of 100µs, 2volts maximum). The amplified output is given to the data acquisition and analyzing system [DAA] build using NI PCI-5154 high speed digitizer/PC-based oscilloscope (The NI PCI-5154 is a 2 channel, having sampling rate of 2G samples/sec and 1GHz bandwidth, with onboard memory of 8MB/channel, 50Ω input impedance. It has 390µV to 19.6mV sensitivity and voltage range of ±50mV to ±2.5V).

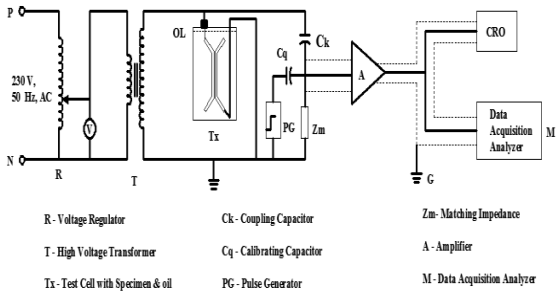


Fig.1: Block Diagram of PD Measuring System

The PD data Acquisition system receives the PD signals from an Amplifier, which is sensed by coupling capacitance Cc, due to the discharges in the test sample. The discharge parameters measured and stored in computer system for further analysis.

SAMPLE PREPARATION: In order to simulate the field condition of power transformer insulations in the laboratory the paper covered copper conductor insulation (PCCC) also known as paper-oil insulation is configured in pigtail arrangement. Two copper conductors each of 9mm width, 3.5mm thickness and length 130mm are used. The pig-tail model is developed as shown in fig.2 comprising of three portions namely, straight portion of length 100mm at the centre with two bend portions of 15mm on either side making an angle of 30^O with the horizontal are joined together and held firmly by wrapping of PTFE tape at the two ends of the straight portion. The conductors are wrapped with either 3 or 5 layers of 0.055mm thickness Kraft paper insulation. The paper insulation used confirm to IEC-554-3-5 (1984) (Rev.3) standards for the transformers. The pig-tail specimen is dried at a temperature of 100^0C for 12 Hours.

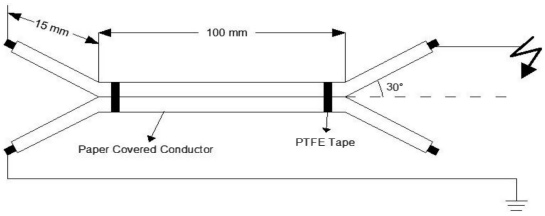


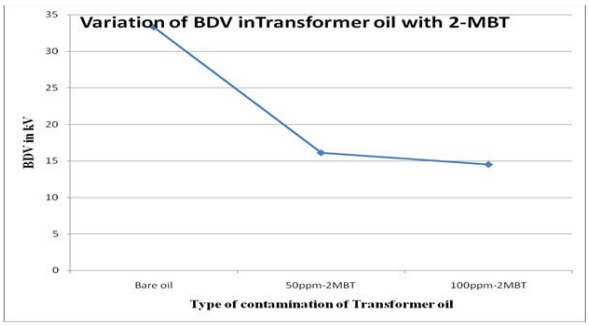
Figure.2. Pig-tail configuration of sample.

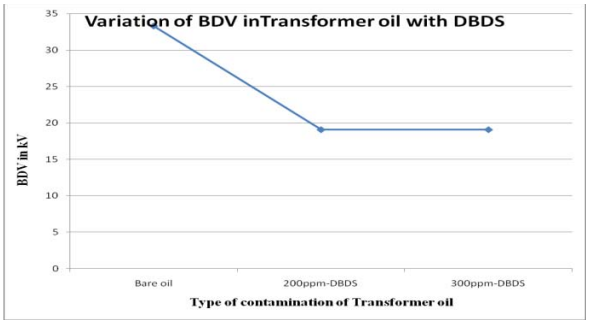
III. MEASUREMENTS

The paper oil insulation was subjected to voltage stress in test cell. The measurements on sample included measurement of partial discharge included PD inception, PD extinction, discharge magnitudes and number of pulses for each cycle. Measurements were made with treated transformer oil and sulphur contaminated (50ppm and 100ppm of Mercaptan sulphur and 200ppm DBDS and 300ppm DBDS) Transformer oil. The PD parameters are recorded over duration of 1 sec contentiously for 14400 sec with a pause of 10 sec between the record, for 1.4times PD inception voltage and allowing a stabilization period of 60 seconds.

IV. RESULTS AND DISCUSSIONS

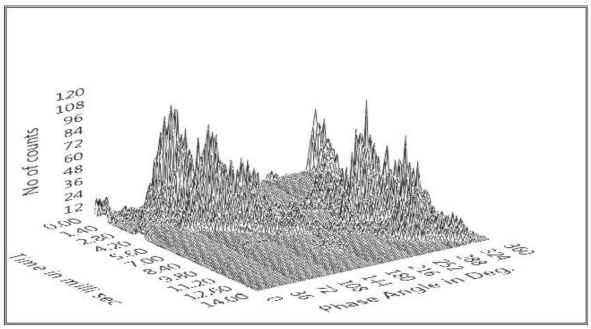
The inception and extinction voltage of treated and contaminate oil are shown in fig.3. It is observed the change in the inception, Extinction voltage are lower in sulphur contaminated oil compared to treated transformer oil.

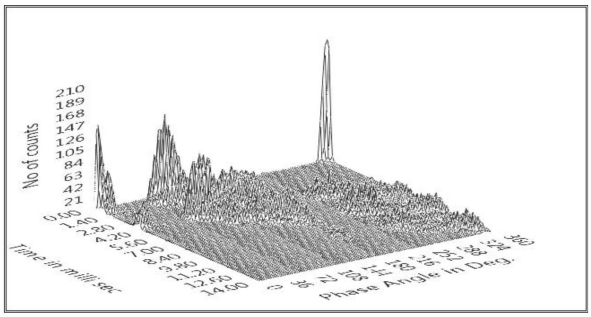


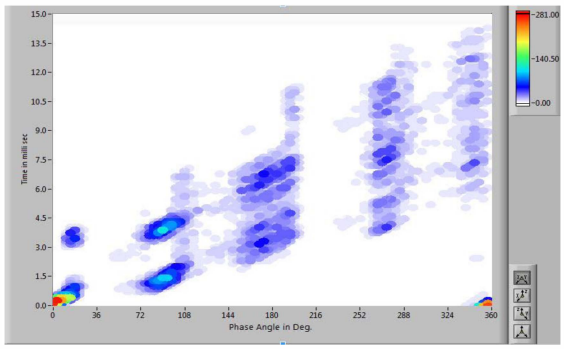


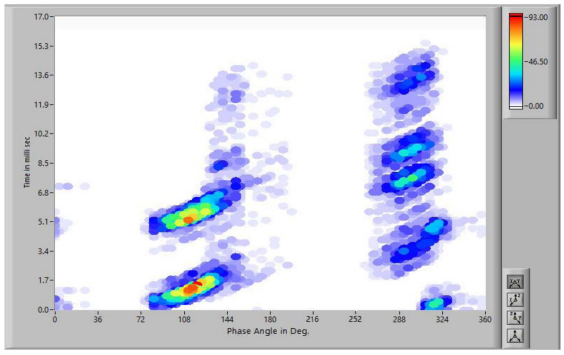
The Φ-t-N method to analyze the behavior of the insulation under

(a) Treated oil

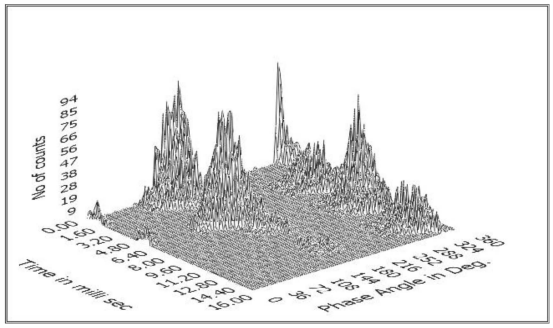


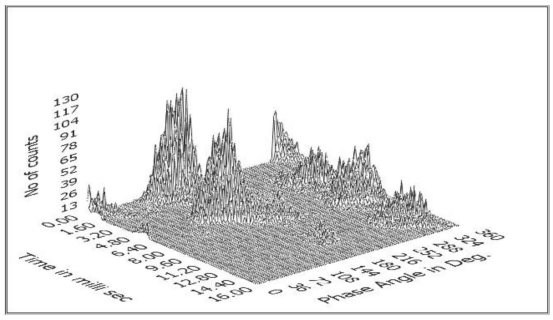


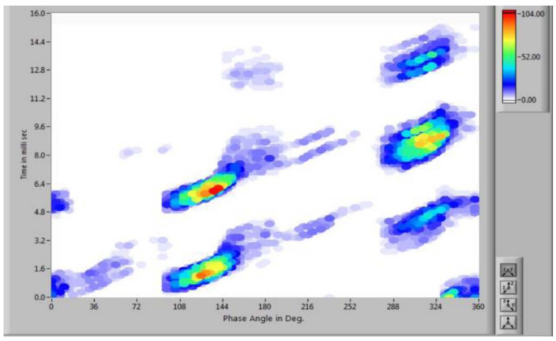


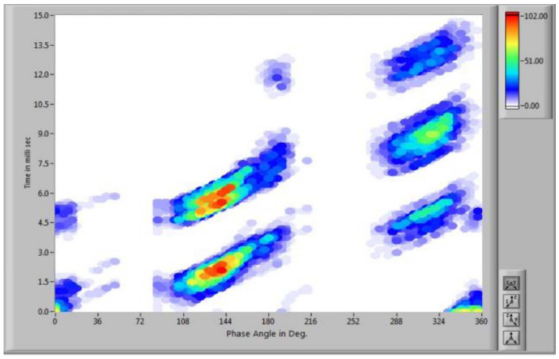


(b) 50ppm-2-MBT-contamionated oil

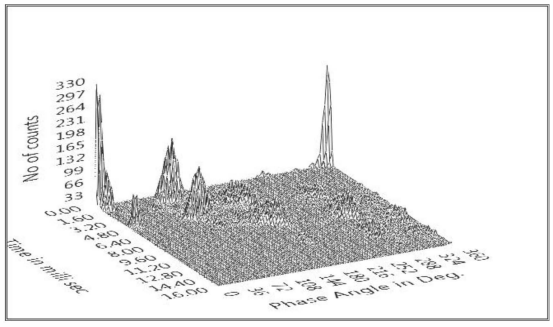


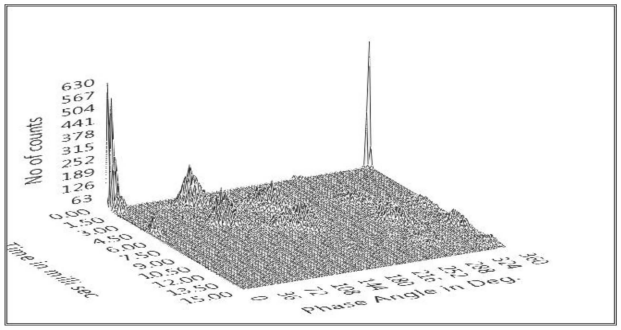


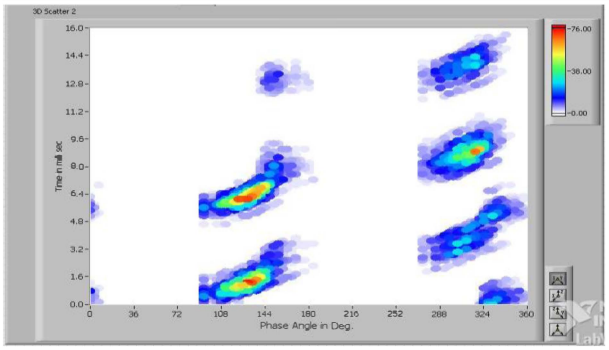


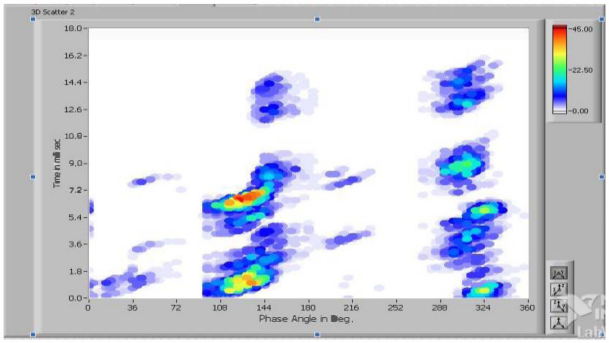


(c) **100ppm-2-MBT-contamionated oil**

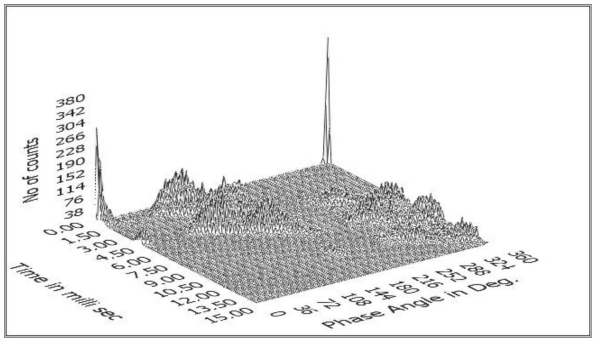


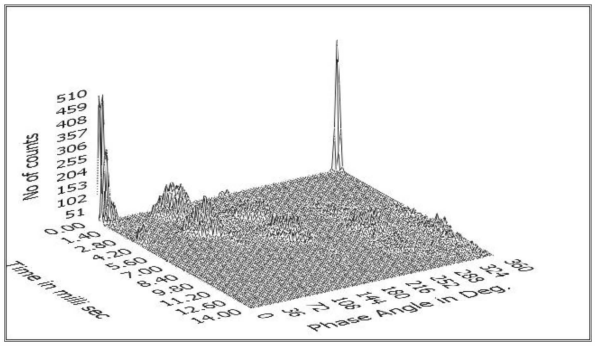


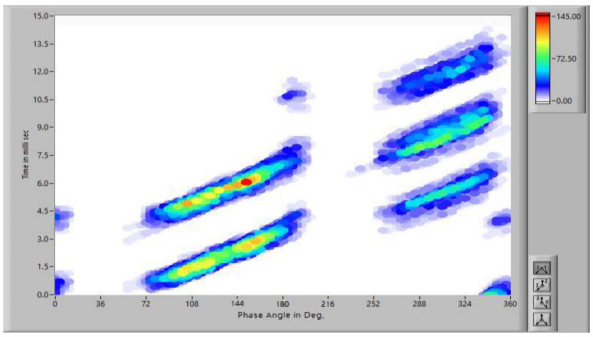


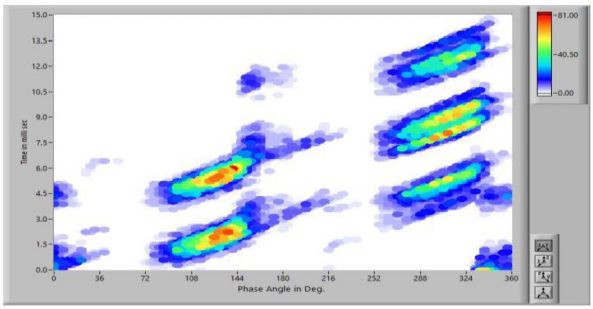


(d) 200ppm-DBDS-contaminated oil

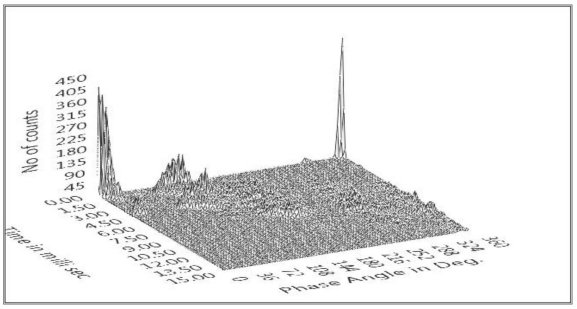


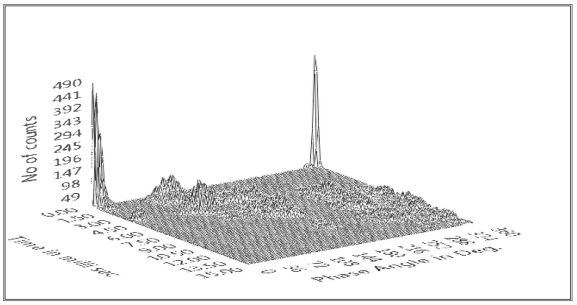


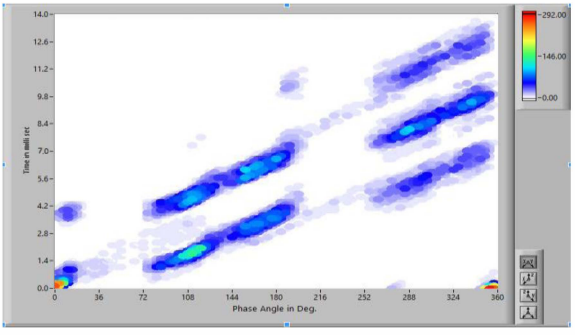


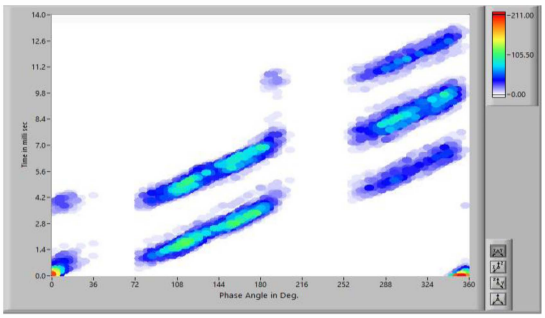


(e) 300ppm-DBDS-contaminated oil









The Φ–t–N representation offers much flexibility. The Φ–t–N distribution is constituted by time related parameters which can be precisely measured. Φ–t–N distribution has time interval parameter represented in sequence that can be used for pulse correlation and study pulse behavior along the phase angle therefore it has pulse to pulse correlation values present in the natural sequence of occurrence along the phase angle in the pattern. Phase-time-count variation is plotted separately for treated and contaminated transformer oil. It is observed that the time between the clusters of pulses in treated oil is 3mS to that of 2-MBT and DBDS contaminated oils is 3.5mS and phase angle of treated oil is 130^0 while 2-MBT has 180^0 and DBDS has 140^0. The phase distribution is wider in contaminated oil and changes with type of contamination. The time of inter pulses (inter pulses time of occurrence) will increases with type of contamination. The number of pulses occur in positive cycle is more and increases as the time of experiment increases. The wider phase and increase of time of occurrence (inter pulses time of occurrence) will increase the stress on the insulation which in-turn reduces the life of the insulation. The above factor indicates the deterioration in insulation of the Paper Covered Copper Conductor subjected to the type and level of contamination of oils.

V. CONCLUSIONS

Some of the important conclusions of the study are:

1. The Discharge events number/second "N" increases sharply due to formation and migration of conductive copper sulphide.
2. It will be difficult to depend on discharge inception and extinction measurements to detect copper corrosion, especially at early stages.
3. The type of contamination and level of contamination plays important role in performance of insulation.
4. It is concluded that as the contamination increases the phase wider increases which results in more PD of the insulation.
5. The time of inter cluster of pulses changes with type of contamination and level of contamination.
6. The change in time and wider the Pd increases the stress on insulation which in turn reduces the performance of the insulation.
7. Discharge signatures can be established for conditions of copper corrosion and consequent migration of copper sulphide into different layers of Paper insulation.

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