ROLE OF SULPHUR IN TRANSFORMER OIL AND ITS INFLUENCE ON THE PERFORMANCE OF PAPER

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Abstract— Paper–oil insulation is widely used in transformers. In recent years, the utilities in India have shown a lot of concern over the allowable limits of sulphur in transformer oil. 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. Further, the effect of increase in sulphur content in transformer on the performance of paper and pressboard insulation is also not clearly understood. There is a need for generating data on the limits of sulphur in transformer oil and to define its end point, behind which the oil becomes unserviceable.

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. The failure of the Transformer in the system is because of the many reasons, however one of the reasons found is the corrosion of the copper conductor due to the presence of sulphur in Transformer oil [1]. Transformer oil is a mineral oil containing organic and sulphur compounds [2]. The byproducts of ageing of cellulose insulation in Transformer oil are sulphur compounds, water, acids and oxygen. These byproducts pose polygonal problems to the working of the Transformer. The presence of the semi-conductive copper sulphide which is produced due to the reaction of sulphur presence in oil with copper of the winding is found to pose a serious threat to the life of the Transformer [3,4]. The reactive and corrosive sulphur components are of very low order in fresh transformer oils but during service, some sulphur components are converted to reactive and corrosive forms which react with copper forming copper sulphide [5]. Copper sulphide migrates from conductor surface to outer layers of paper and from there it is carried to other parts of the transformer. Since copper sulphide is conductive, it affects the voltage distribution leading to surface discharges. 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. The reference number should be shown in

II. DETAILS OF EXPERIMENTS

The main objective of this study was to replicate the environment of power transformer with paper oil insulation. The samples used are paper covered copper conductors from transformer manufacturers who had reported failures. Transformer oil was procured from a reputed manufacturer in these investigations. The Partial Discharge (PD) experiments were carried out in Faraday cage where the back ground PD level inside the shielded room was less than 2pc. The PD measurements were carried out using the precision PD measuring system. The System set-up is as shown in fig.1.where the discharge free high voltage transformer used was 100kV, 10kVA rating

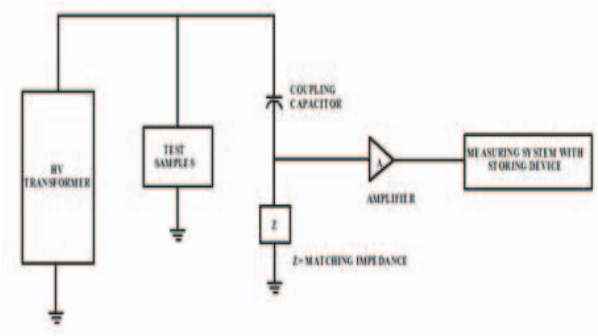

Fig.1: BLOCK DIAGRAM OF PD MEASURING SYSTEM

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: Two copper conductors of 150 mm length were brought together with an overlapping straight portion of 100 mm. The two conductors were bent at the ends as shown in figure2. This configuration has been conventionally referred to as "pig-tail" model. The two conductors are held firmly by wrapping of PTFE tape at two places. For each set of experiments, 25 such samples were prepared, vacuum dried and impregnated with transformer oil.

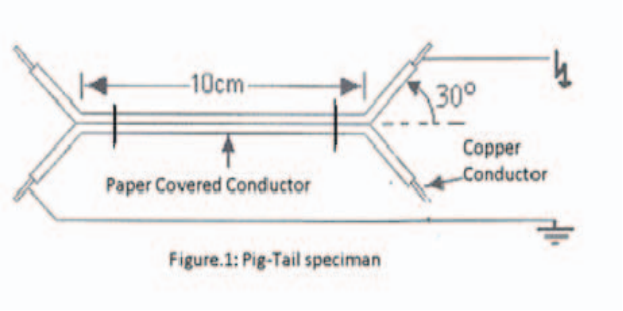

Figure. 2 Pig-tail configuration of sample

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 (100ppm of Mercaptan sulphur) Transformer oil. The PD parameters are recorded over duration of 1 sec contentiously for 50 sec with a pause of 10 sec between the record, for 1.23times 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 table 1.It is observed the change in the inception, Extinction voltage are lower in sulphur contaminated oil compared to treated transformer oil.

Type of Experiment	Inception Voltage	Extinction Voltage	Applied Voltage
Treated oil	2.8KV	2.6Kv	3.44KV
2MBT-contaminated (sulphur)oil	2.4KV	2.0KV	2.95KV

Table.1. Comparison of Inception and Extinction voltage

1. Phase-No of counts (Φ-N) results:

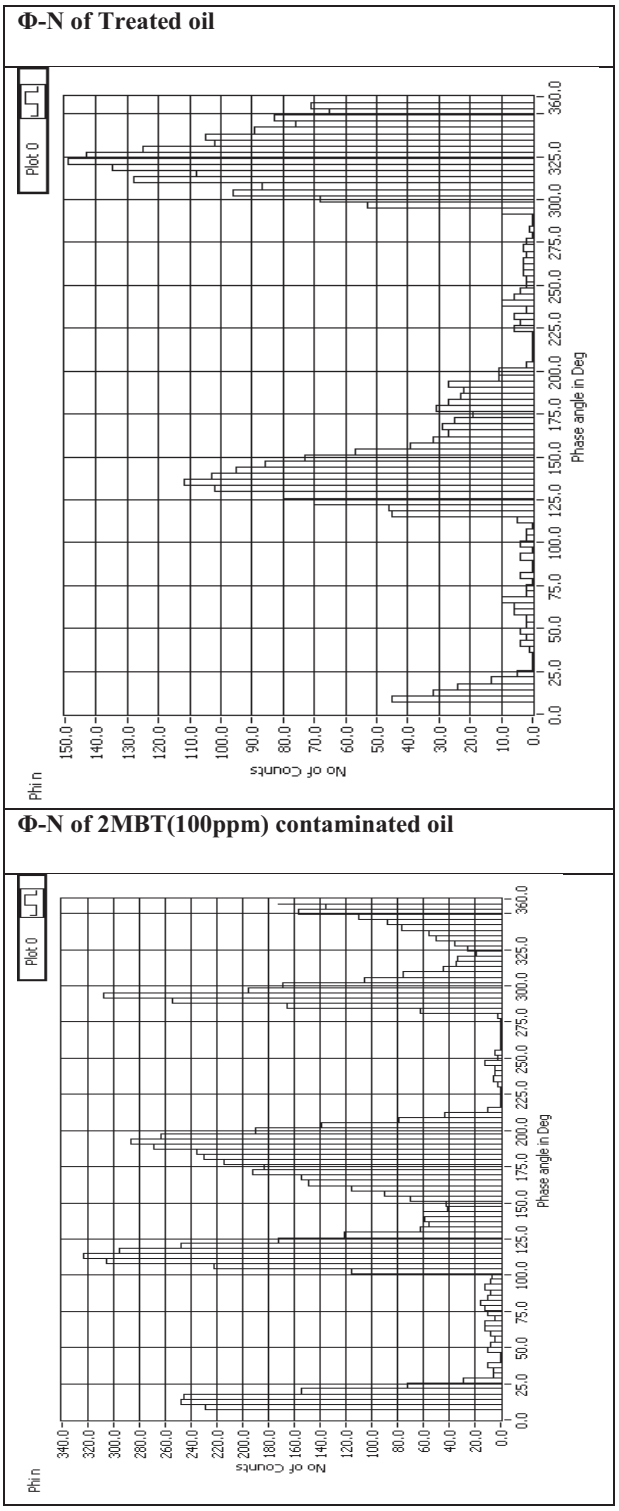

Figure.3: Φ-N Distribution of one cycle

The phase angle v/s no of PD pulses (N) distribution over one cycle for the sample with treated and sulphur contaminated

transformer oil are shown in fig. 3. It is observed that the no of counts are more in contaminated oil

2. Phase-charge (Φ-Q) results:

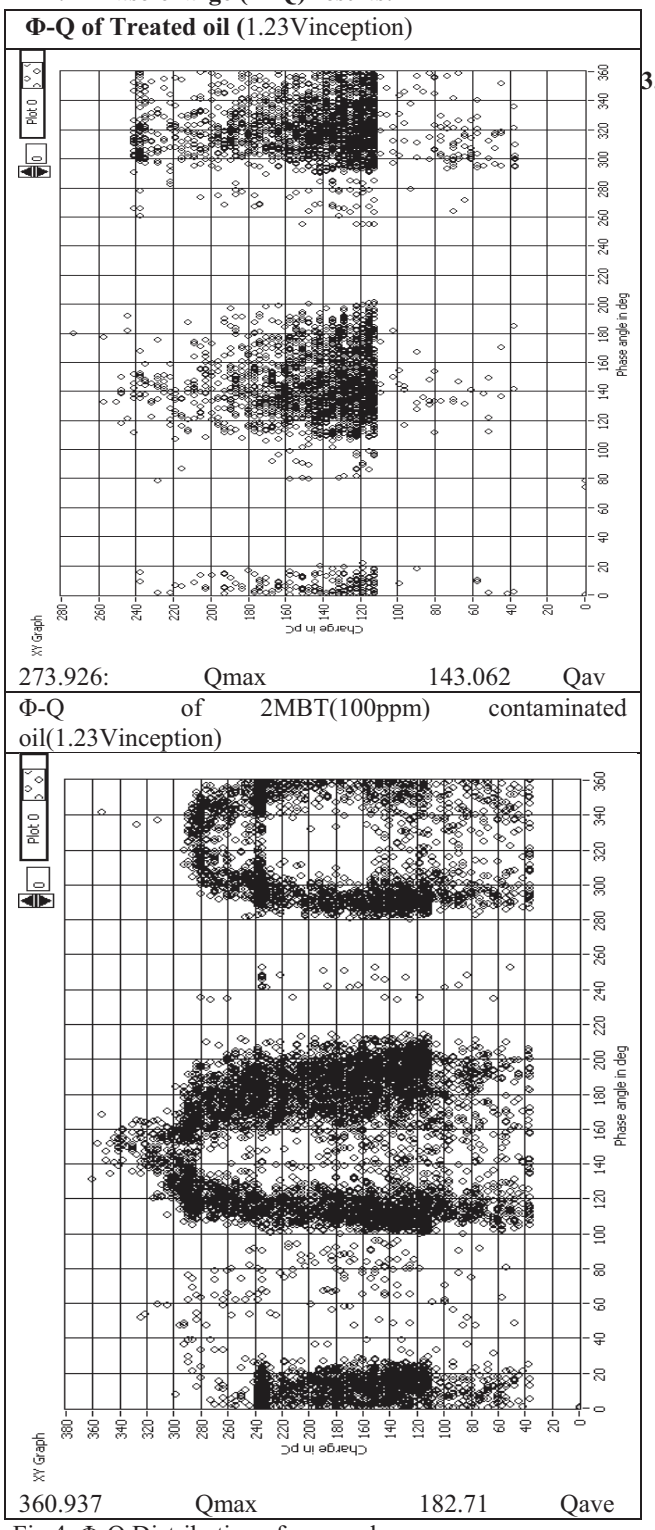

Fig.4: Φ-Q Distribution of one cycle

The phase angle v/s charge distribution over one cycle for the sample with treated and sulphur contaminated transformer oil are shown in fig. 4. It is observed that the no of charge distribution is more in contaminated oil, and max charge is more in contaminated oil

3. 3. Charge-No of counts(Q-N) results:

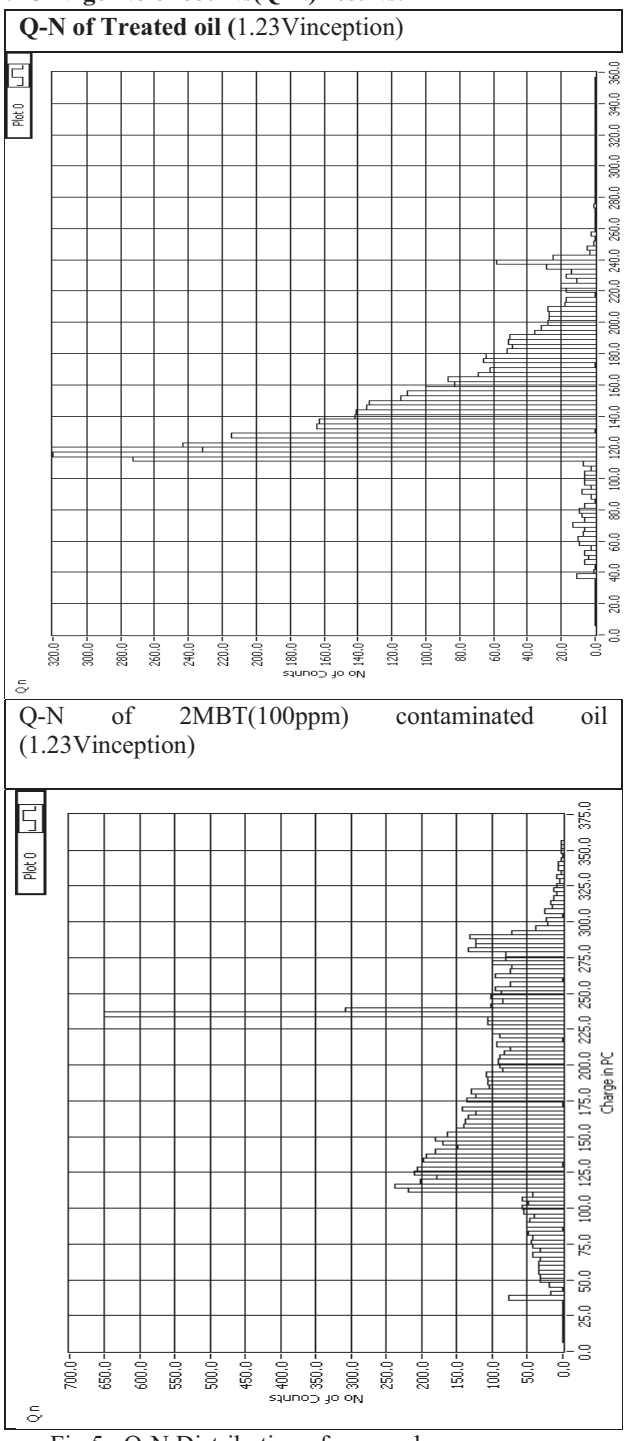

Fig.5: Q-N Distribution of one cycle

The charge v/s Number of counts distribution over one cycle for the sample with treated and sulphur contaminated transformer oil are shown in fig. 5. It is observed that the no of charge distribution is more in contaminated oil, and max charge is more in contaminated oil

4. **Phase-Charge-No. of Counts (Φ-Q-N) results:** A 3-dimensional histogram can also bring out the relationships between phase, discharge magnitude and number of PD in 1 cycle. It is shown in fig.6.

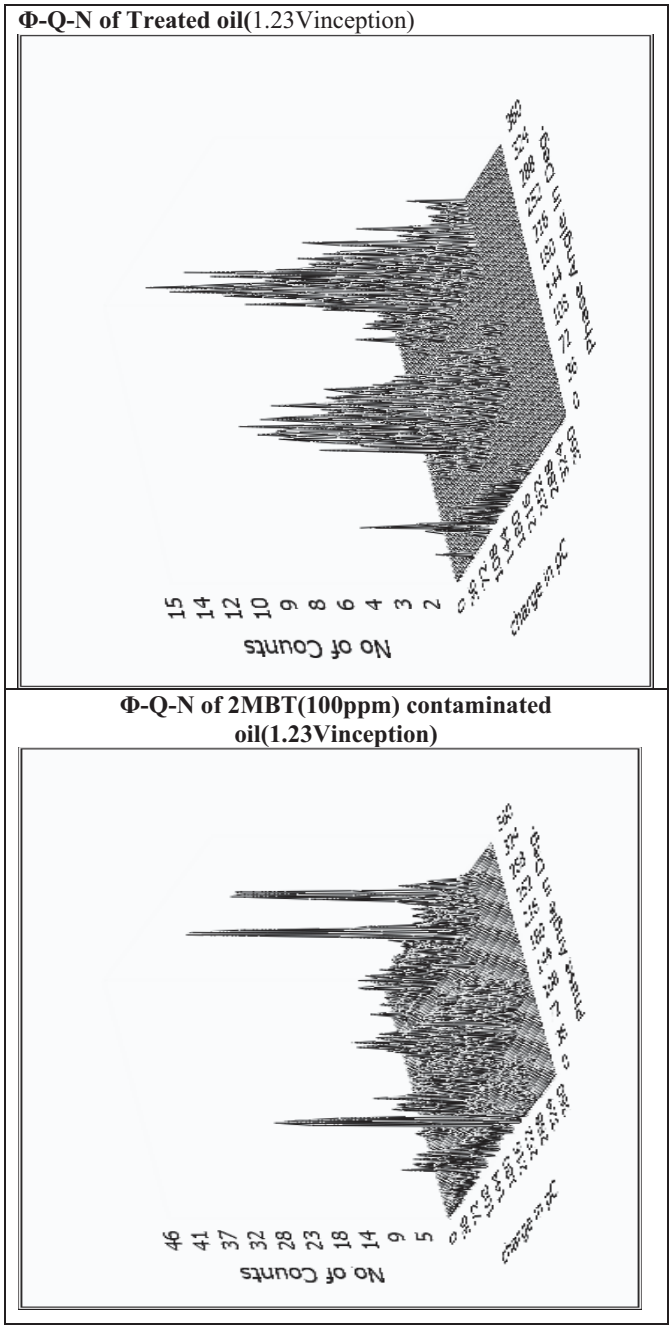

Fig6: Φ- Q-N Distribution of one cycle

The Ø–q–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 equipment characteristics. With this as background the results were compared and it is found that the charge of 108pC to 120pC is more predominating in both the cases. This indicates that the contaminated oil behavior is irregular. The number of count will also increases in contaminated oil compared to treated oil.

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 copper sulphide.

(2) It will be difficult to depend on discharge inception and extinction measurements to detect copper corrosion, especially at early stages.

(3) Detection and recording of discharges, over a Voltage range much below the operating stresses and analysis of trends in variation in Q, n and phase of applied ac is useful.

(4) Trends in variation of Q, n and phase bear a good correlation to insulation and contamination in oil.

(5) 2-D histograms help in identifying the underlying causes of ageing of paper-oil insulation.

(6) Discharge activity has good correlation to phase and it is significant when copper corrosion spreads to more paper layers

(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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