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Development of a New Solid Insulation with the use of Phenol Formaldehyde Resin Material for a Liquid-Immersed Transformer

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Abstract - *The use of paper as a solid insulation material in various engineering applications is so extensive due to its physical and electrical properties and ease of manufacture. As a result of flexibility of paper, it has been selected or designed as an electrical insulation material for various parts and components in high voltage technology. In the current study, a kraft paper employed in conventional transformers is selected as a raw electrical insulation material and further modified with layering of phenol formaldehyde resin through laboratory procedures, improved the electrical and mechanical properties of newly developed paper as compared to the existing one.*

Key Words*: *Kraft paper; Phenol Formaldehyde Resin; Electric Strength in air; Electric strength in oil.

1. INTRODUCTION

The transformer, a very important member of power network, is like a backbone of the power system. Most of the transformers are oil-immersed one and their insulation is provided by mainly dielectric mineral oil and solid insulation paper. Insulation paper, which is widely used in oil-immersed transformers, is made of natural cellulose [1, 2]. In the early days, a few insulation materials were known for low temperature superconducting power applications. But nowadays insulation materials have made significant changes and progress and Kraft paper is one of the widely used insulating materials in transformers.

Transformer insulation should be developed continuously with an increase in voltage and power in transformer. A plenty of the research work has been done by researchers on the modification and improvement of oil insulation [3–5]. However, research to improve the insulation paper is not approached to high levels, which is also a very important concern in regard to enhance the efficiency of a transformer and in other electrical equipments for which it is used.

2. USE OF PHENOL FORMALDEHYDE RESIN

The Alkyl Phenolic Resins is the result of condensation reaction between aldehyde & alkyl phenols and is commonly used in rubber products. The phenol alkyl resin ensures good solubility in hydrocarbons and serves as indispensable modifying agent for chloroprene rubber.
When particles of Phenol Formaldehyde Resin are used in layering, they can be attached to the cellulose surface. The bonding with the cellulose paper is like a lamination. This effect may greatly change the dielectric properties of oil-impregnated insulation paper. Therefore, high density Formaldehyde resin is used for the layering process. The results show that this newly prepared paper by layering improves the electric strength of solid in oil. An experimental procedure was performed for the modification of the insulation paper because raw paper got torn out if it directly applied for insulation in a transformer.

3. SAMPLE PREPARATION

The layering process of raw paper is done with the help of a tool called brush in small step movements.

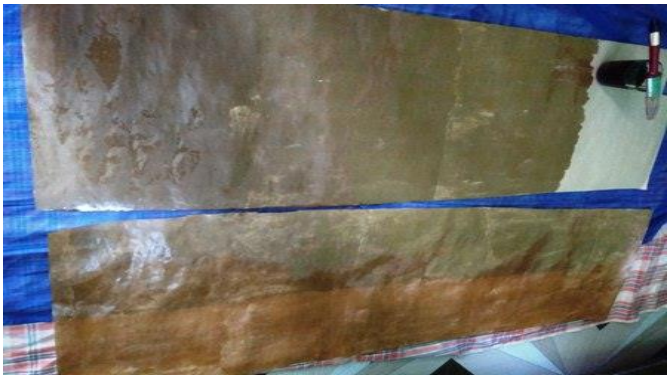

Fig -1: Kraft Paper Sheet

Two types of 4 mil paper is collected from the different firms named as Kraft paper and Electra paper and further processed with layering so that samples of both without

layering and with layering are compared to get desired results.
Total six samples are taken in which first two samples are of original Kraft paper and Electra paper and out of other four samples; two are prepared by the one side layering and another two with double side layering.

Identification of sample is:

KP- without Layering
KP1- One side layered
KP2- Both side layer

EP- without Layering
EP1-One side layered
EP2- Both side layer

All the three samples of Kraft paper are prepared from a sheet of 100x30 cm^2. Thickness of whole sheet is 0.89 mm nearest to 4 mil. Similarly, three samples of Electra paper are prepared from the size of 75x75 cm^2, thickness 0.114 mm slightly more than 4 mil.

4. EXPERIMENTAL

The diagram of the electrodes for measuring the breakdown voltage of the hand sheets is shown in Figure 2. The diameter and height of the high-voltage (HV) and ground electrodes were both 25 mm. A copper bar was used to connect the HV electrode with the HV AC current power. In this experiment test, mineral oil was used for the dielectric in the stainless steel box.

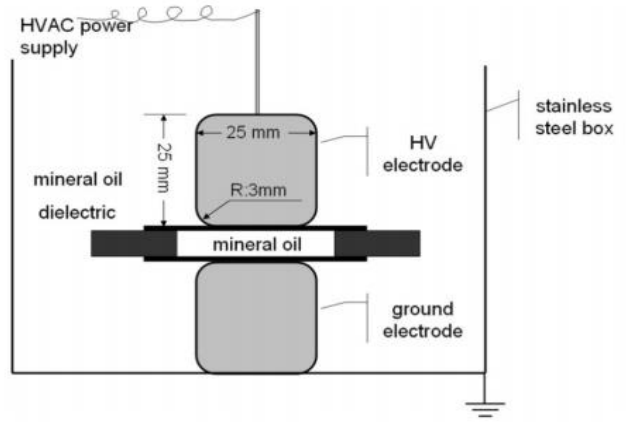

Fig -2: Diagram of electrodes

The focus of the experiment was the electric strength of paper in oil and air. Therefore, the thickness of the oil gap was only 3 mm. The oil gap was formed in the 3 cm-diameter whole of the 3 mm-thick paperboard. The external diameter of the paperboard was 6 cm. The thickness of the four kinds of experimental hand sheet papers 85,104,150 microns Kraft paper samples KP KP1 KP2 and 67,94,114 microns for Electra paper samples EP EP1 EP2. The hand sheet papers were cut into 4 cm-diameter circles. All samples were put into the vacuum chamber and were dried at 90 °C for 48 h, and then the mineral oil at 40 °C was infused into the glass bottles in the vacuum chamber to immerse samples for 24 h.

5. TEST APPARATUS

The test is carried out in air and oil accordance with clause 5 of IEC publication 243. The electrodes shall be in accordance with Sub-clauses 6.1.1 or 6.1.3 of the publication. The preferred electrodes are the 25/75 mm electrodes. The smaller electrodes shall be used only if the width of the material prevents the use of the large electrodes. The faces of the electrodes shall be parallel and free from pits or other imperfections.

All test pieces shall be sufficiently large to avoid flash-over. The requirements number of test may be made on one test piece. Where more than one thickness is required to form the test piece, the number of superimposed layers shall be given in Part 3.The application of voltage in accordance with the Sub-clause of IEC publication 243. Criterion of breakdown, see clause of that publication. Nine tests made according to standard

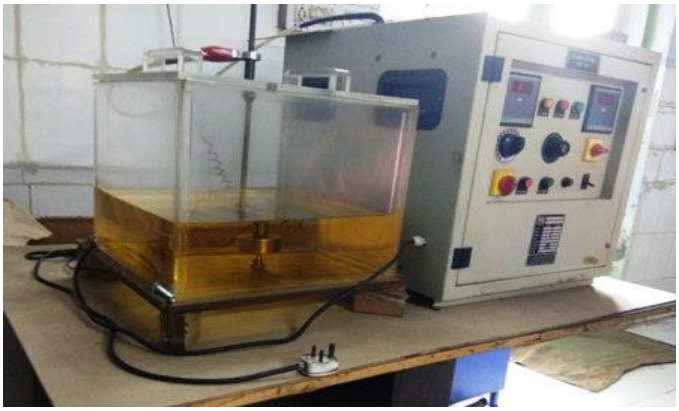

Fig -3: BDV Tester

6. RESULTS

The maximum voltage that can be applied to the material without causing it to breakdown, usually expressed in kilovolts per unit of thickness. The sample size used for the testing is 4 cm-diameter circles. The test is performed both for air and oil. The electric strength in air little bit increased after the layering of paper. But its good sign for us the electric strength in oil is gradually increased in oil. It clear from the reading modified paper is electrically very strong in oil under the load conditions. The readings noted from the testing procedure to determine Dielectric Strength for fresh and modified papers with the specified methodology prescribed in [7] are tabulated below. The actual results are obtained by calculating the mean value of three breakdowns reading for same sample.

Table -1: Readings of samples collected

Readings of Samples							
Property	Units	KP	KP1	KP2	EP	EP1	EP2"
Electrical Strength in air	kV/mm	11.33	12.72	14.15	12	13.57	15.11
Electrical Strength in oil		45.75	55.5	64.8	47	57.75	66

6. DISCUSSIONS

The graphs are plotted to comparison of original sample KP and EP with KP1 KP2 EP1 EP2. After results it obtained electric strength of paper in oil improved very well. But Electric Strength in air increased little bit that is not much important because we have to need to strong the electrical strength of paper in oil for use in transformer.

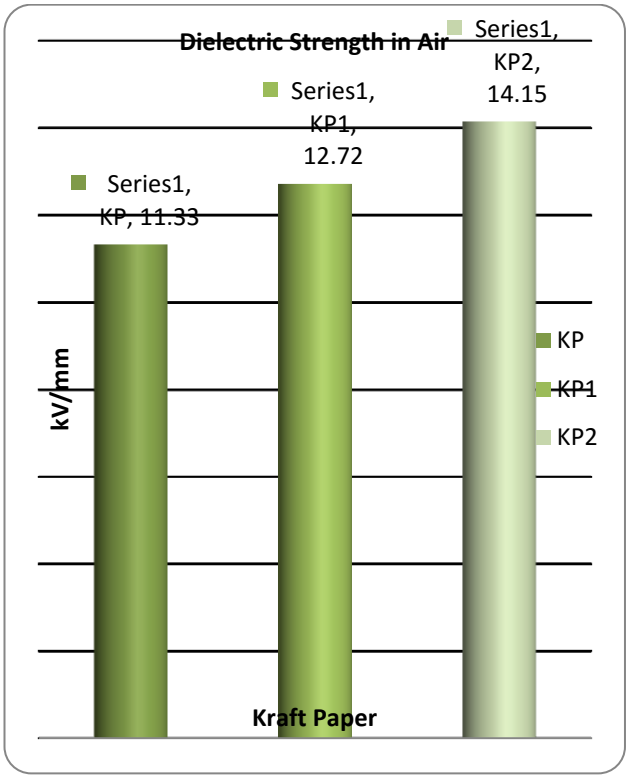

Fig - 4: Dielectric Strength in Air Kraft Paper

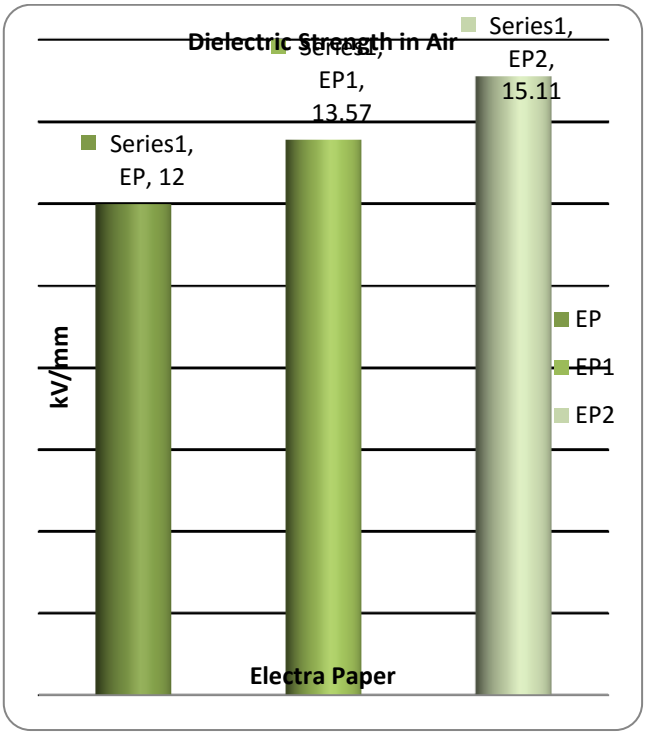

Fig-5: Dielectric Strength in Air Electra Paper

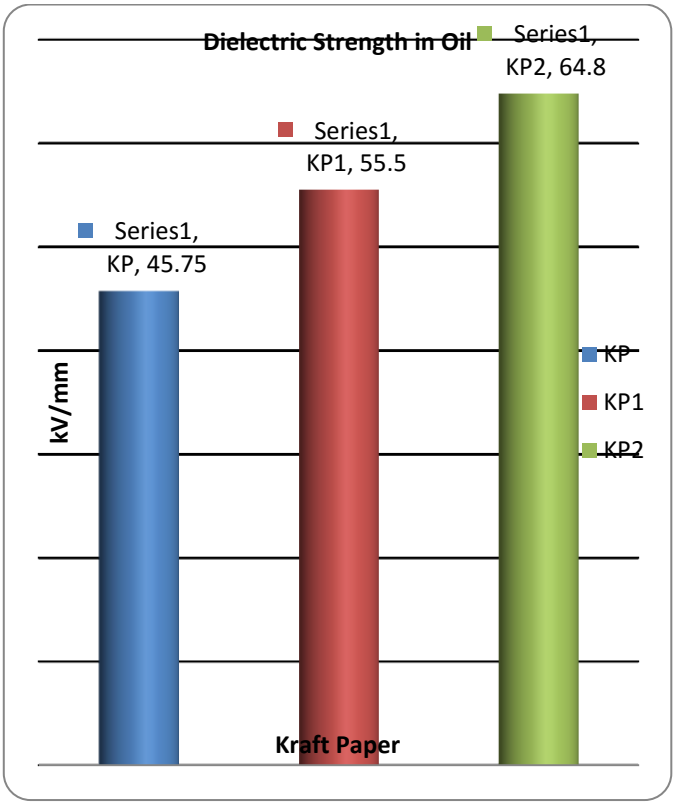

Fig-6: Dielectric Strength in Oil Kraft Paper

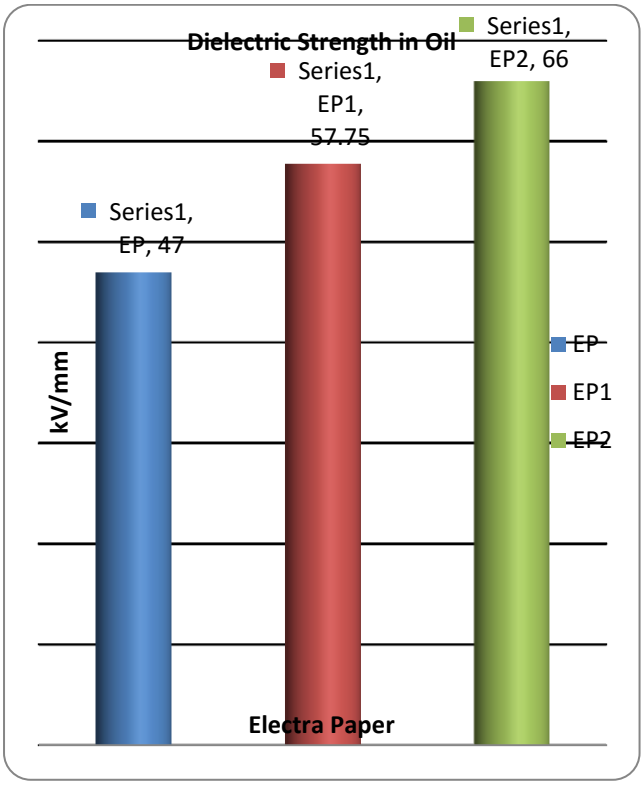

Fig-7: Dielectric Strength in Oil Electra Paper

The graph shown in last four Figures are Dielectric Strength of papers in air and oil. These Figures represents the values obtained for Dielectric Strength recorded by the procedure followed in laboratory at room temperature on the sample of fresh and modified insulating papers w.r.t. kV/mm of Dielectric Strength. The Dielectric Strength is improved after the modification of paper in both air and oil for Phenol Formaldehyde Resin. The graph shows the descending trend for the Dielectric Strength as we move from right to left along the different sample axis. The resultant value of all the readings obtained from procedure was the arithmetical mean as shown by dot on Dielectric Strength line.

7. CONCLUSIONS

In summary, it is easy to implement method as implemented to improve the Dielectric properties of the Kraft paper. Additional test of physical & dielectric properties were also performed on fresh and modified paper to examine the full potential of the Kraft paper, and it was found that Dielectric breakdown characteristics of both modified Kraft and Electra papers with phenol formaldehyde resin in oil and air have the better results as compared to the original samples of Kraft paper and Electra paper.

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