

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

Kulbeer Singh<sup>1</sup>, Harinder Singh Sandhu<sup>2</sup>

<sup>1</sup>Student, Department of Electrical Engineering, AIET Faridkot, Punjab, India

<sup>2</sup>Assistant Professor, Department of Electrical Engineering, AIET Faridkot, Punjab, India.

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**Abstract** - The utilization of paper as a insulation material in various engineering applications is more due to its mechanical and electrical properties. As paper is flexible therefore it has been designed as insulation material in electrical engineering for various parts and components. The raw electrical insulation material used for conventional transformer is kraft paper and further modification is done by layering of phenol formaldehyde resin through certain procedure. The electrical and mechanical properties of newly modified paper are improved as compared to the existing one.

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

## 1. INTRODUCTION

The transformer is like a heart of the power system. Transformers are vital components of electric power generation, transmission, allocation and widely held of transformers consists of liquid dielectrics such as hydrocarbon oil and solid insulation as paper. Most of the transformers are oil-immersed type 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]. A few insulation materials were known for low temperature power applications in early days. Paper was one of the first insulation material used in high voltage technology. A combination of electrical stress and the degradation of insulation are constantly happening, as one of the major causes of insulation failure is general wear and tear. But nowadays insulation papers with improved electrical and mechanical properties are developed and Kraft paper is one of the widely used insulating materials in transformers.

A lot of the research work has been done by researchers on the modification for improvement of insulation of oil [3-5]. But research to improve the insulation of paper is not approached to desirable levels, which is also a very important concern in regard to improve the efficiency and life of a transformer. As life of transformer totally depends on insulation.

## 2. USE OF PHENOL FORMALDEHYDE RESIN

It is commonly used in products of rubber. The phenol formaldehyde resin ensures good solubility in hydrocarbons and serves as indispensable modifying

agent for chloroprene rubber. The bonding with the cellulose paper is like a lamination. When particles of Phenol Formaldehyde Resin are used in layering, they can be attached to the cellulose surface. 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 will improve insulation properties.

## 3. SAMPLE PREPARATION

Layering is best way to add up new properties in existing one paper. The samples are prepared by layering with the help of brush in small step movements.



Fig -1: Kraft Paper Sheet

The transformer paper(3mil) is collected from the firm named as Kraft paper. Two samples are prepared first by one side layering and second one with double side layering. The results of these two samples are compared with unmodified fresh paper to get desired results.

Identification of sample is:

TP- without Layering

TP1- One side layered

TP2- Both side layer

All the three samples of transformer paper are prepared from a sheet of 100x30 cm<sup>2</sup>. Thickness of whole sheet is 3 mil.

#### 4. EXPERIMENTAL WORK

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

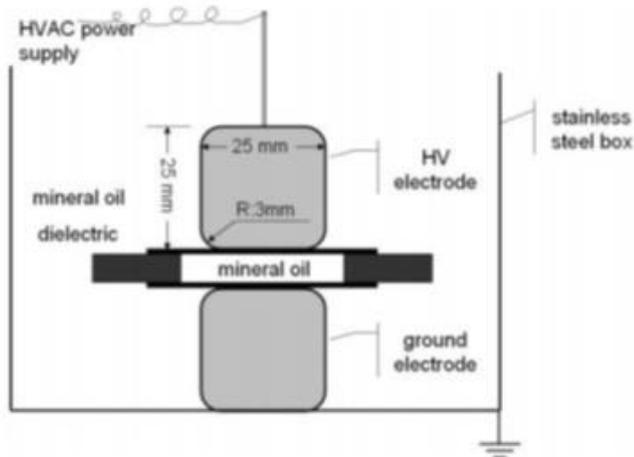


Fig -2: Diagram of electrodes

The experiment was performed for finding the electric strength of paper in oil and air. The oil gap was formed in the 3 cm-diameter hole of the 3 mm-thick paperboard. The thickness of the experimental papers is about 75, 90,104 microns respectively. The external diameter of the paperboard was 6 cm. Circles of 4cm diameter of paper sheet were cut. 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

According to clause 5 of IEC publication 243 the test is carried out in air and oil. 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 faces of the electrodes shall be parallel and free from pits or other imperfections. All test pieces should be sufficiently large to avoid flash-over. The number of tests may be made on one test piece. The application of voltage is 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 which can material bear without causing breakdown or damage, usually expressed in kilovolts per unit of thickness. The test is performed for air and oil separately. The sample size used for the testing is 4 cm-diameter circles. The results are little bit improved in air after the layering of paper and much improved in oil. It is clear from the reading that modified paper is electrically very strong in oil under the load conditions. But its good sign for us the electric strength is gradually increased in oil. The readings noted from the testing procedure to determine Dielectric Strength for fresh and modified papers after layering 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

Property	Units	TP	TP1	TP2
Dielectric Strength in air	kV/mm	11	14.1	16.4
Dielectric Strength in oil	kV/mm	45	58.5	70.3

#### 7. DISCUSSIONS

The graphs are plotted for comparison of original sample TP with modified papers TP1 TP2. After results it is obtained that electric strength of paper in oil has been improved very well. But Electric Strength in air is increased little bit that is not much important.

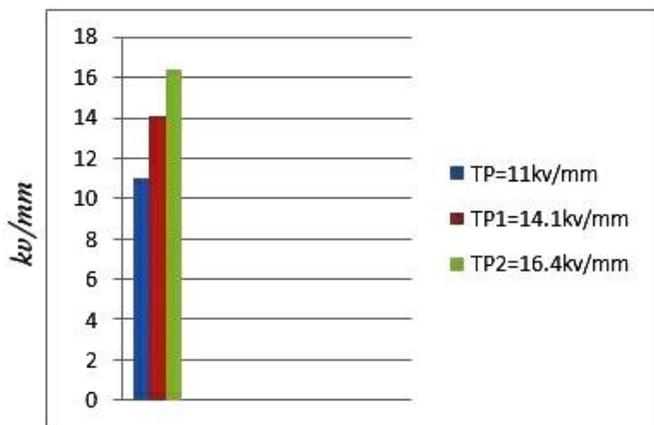


Fig-1: Dielectric strength in Air

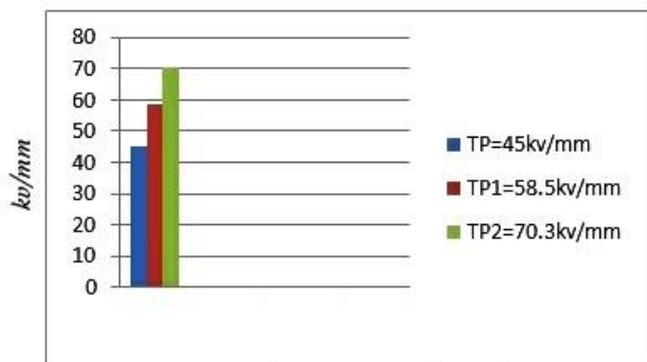


Fig-2: Dielectric strength in oil

The graph shown in Figures are of Dielectric Strength of papers in air and oil respectively. These Figures represents the values obtained for Dielectric Strength. It is 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 layering of Phenol Formaldehyde Resin improves the dielectric strength of paper in both air and oil. The graph shows the ascending trend for the Dielectric Strength as we move from left to right.

## 8. 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 modified Kraft with phenol formaldehyde resin in oil and air have the better results as compared to the original fresh samples of Kraft paper.

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