

## Research Article

# Investigation on Dielectric Properties of Press Board Coated with Epoxy Resin, Quartz, and Rice Husk Ash

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Epoxy resin mixed with rice husk ash and quartz powder increases its dielectric strength. This paper presents the dielectric properties of the press board coated with this epoxy mixture. In this work, the press board, which is used in the transformer, is coated with three components: epoxy resin, rice husk ash, and quartz powder. The nanometer-sized quartz powder and rice husk ash are mixed in the particular ratio with the epoxy resin. The mixture of epoxy resin, quartz powder, and rice husk ash is coated on both sides of the press board. The dielectric constant, volume resistivity, and Tan Delta (dissipation factor) of the coated press board are compared with the noncoated press board. The results reveal that the coated board is having high dielectric constant and volume resistivity when compared to the noncoated board.

## 1. Introduction

Insulators play a major role in electrical power transmission and distribution system. As the demand for electricity is increasing day by day, transmitting extrahigh voltage or ultrahigh voltage has become indispensable. So researchers are interested in doing many research studies with insulators. In the power system, three types of insulators commonly used are solids, liquids, and gases. Dielectric property and reliability are most important characteristics of any insulator. Introducing ecofriendly insulators or using naturally available materials along with the conventional insulator with increased dielectric strength has turned into a trend. In addition to the insulating property, the excellent mechanical and thermal properties are also required for an insulator for the consistent operation of electric power apparatus [1–6].

Insulators are the one which are essential parts of high-voltage engineering and are used to separate live conductors from the earthed objects such as transmission towers in transmission system and transformer tanks in transformers. Along with the understanding of the design, consistency, and protection, the researcher must know about its physical and chemical properties because only these properties decide the dielectric property of the particular insulating material.

In high-voltage power apparatuses, epoxy resin is used extensively because of its exceptional insulating behavior towards electricity, extraordinary resistance to heat, and good mechanical properties. Nanoparticles-filled epoxy exhibits good properties when compared to the epoxy filled with micrometer filler. The epoxy material with SiO<sub>2</sub> shows good dielectric properties when compared to the other fillers [7–10]. Silica obtained from the materials shows good

dielectric property [11]. In this work, rice husk ash is used as a filler since it consists of  $\text{SiO}_2$ .

Rice husk has been considered as the horticulture squander material in rice creating nations all throughout the planet. Every year tons and tons of rice husks are burned considering it as a waste, and it creates air pollution also. But these rice husks delivered silica when they are singed, and it comprises around 20 to 25 wt. % silica ( $\text{SiO}_2$ ). The consuming temperature is around  $500^\circ\text{C}$  to  $800^\circ\text{C}$  [12]. The ash obtained from rice husk is rich in silica, and it has been already proved that silica has good dielectric property [8]. It is being accounted for that the change of  $\alpha$ -quartz can be framed beneath  $573^\circ\text{C}$  and  $\beta$ -quartz from  $573^\circ\text{C}$  to  $820^\circ\text{C}$ . At lower temperature, the indistinct condition of rice husk debris silica will be shaped [10, 13].

Quartz is the most ordinary form of crystalline silica that is found in nature [14]. The insulation property of quartz ceramics is high, and it is possessing heat insulation property also. They are not expensive and available in nature. The breakdown voltage of quartz ceramics is high at atmospheric temperature and at high temperature. Dielectric permittivity is low, and its other properties such as dissipation factor and lowest thermal conductivity made it is suitable for electrical insulation [15].

Many research studies have been carried out with epoxy and silica composites as the insulating material [16, 17]. Press boards are broadly used in power transformers and instrument transformers. In addition to this, press boards are used in high-voltage switches also. Here, the transformer press board is coated with three different materials: epoxy resin, rice husk ash, and quartz powder. When the board is coated with epoxy resin, the moisture absorption can be reduced [18]. This paper reports on testing of the dielectric property and resistance of the insulating material. The difference in our insulating material is that we used the combination of rice husk ash, quartz powder, and epoxy resin coated on the press board.

## 2. Specimen Preparation

Materials required for preparing the specimen are press board, epoxy resin, rice husk ash, and quartz powder. The chemical structure of the materials and their properties are discussed first in this section.

### 2.1. Chemical Structure and Properties

**2.1.1. Epoxy Resin.** Epoxy resin is a fluid that has a low viscosity so it is easy to blend it. Epoxy resins have properties of low consistency, simple to frame, low shrinkage, high bond, high mechanical properties, high electrical protection, and great compound opposition. Most epoxy pitches that are broadly created are from bisphenol and epichlorohydrin [19]. The chemical structure of the epoxy resin is shown in Figure 1.

**2.1.2. Quartz Powder.** Quartz is a hard, translucent mineral made out of silicon and oxygen (silica dioxide), as shown in Figures 2 and 3. It is essentially perhaps the most well-

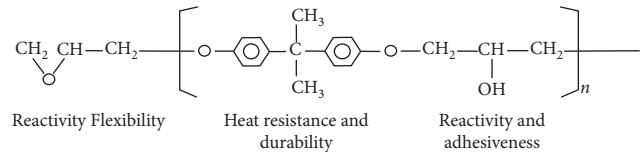


FIGURE 1: Structure of epoxy resin.



FIGURE 2: Quartz powder.



FIGURE 3: Structure of the quartz powder.

known and the second most bountiful mineral with numerous utilizations found on Earth. It is a significant part of rocks (molten, transformative, and sedimentary shakes) and structures in all temperatures. Quartz in its most flawless structure is clear or white in shading yet various contaminations inside the nuclear cross-section can make the shading change to purple, pink, earthy colored, dark, dim, green, orange, yellow, blue, or red, and sometimes, multi-color. Quartz is one of the hardest normally happening minerals and subsequently cannot be eroded without any problem. It has an exceptionally high softening point and can withstand basically high temperatures. It is synthetically steady and does not respond with different synthetics and substances. It is chemically stable and does not react with other chemicals and substances.

**2.1.3. Rice Husk Ash.** Removal of rice husk is one of the significant difficulties looked by mill operators all over world. Rice husk when consumed in the kettle as fuel produces debris known as rice husk debris. RHA is rice husk debris ecological waste; it contains 60% to 80% undefined silica [19]. When burnt at  $500^\circ\text{C}$  to  $700^\circ\text{C}$ , it turns into amorphous silica. It reduces the leakage current during high voltage [20–23], when used as a filler in epoxy. It is useful in various industries. Figure 4 shows the picture of rice husk ash, and the structure of rice husk is shown in Figure 5.

**2.2. Specimen Preparation.** Press board (IS-1576) used in the transformer (Figure 6) has thickness of about 3 mm. The press board used in the specimen is collected from the



FIGURE 4: Rice husk ash.

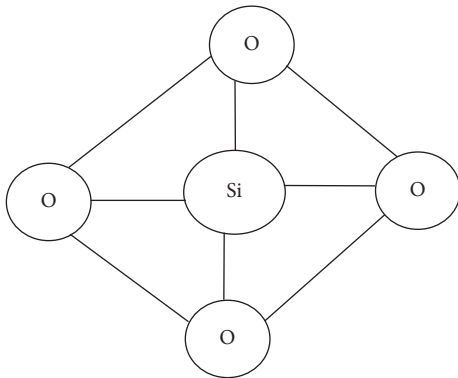


FIGURE 5: Structure of rice husk ash.

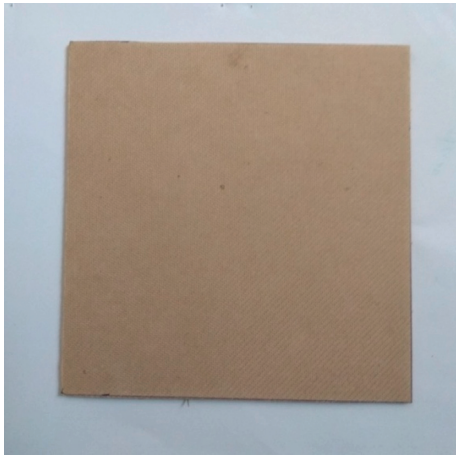


FIGURE 6: Press board used in the transformer.

distribution transformer manufacturers. The board used for this work is from Associated Transformer Private Limited, Dindugul, Tamilnadu. Epoxy resin used here is belonging to Araldite Company. This pack comes with the resin and the hardener. The mixing proportion of resin and hardener is discussed in below preparation. Quartz powder of 74 microns is actually a powdered form of quartz crystal. Rice husk ash, which is the agriculture waste, is burnt and processed to get silica content ash. The consuming temperature is around  $500^{\circ}\text{C}$  to  $800^{\circ}\text{C}$  [12]. It is being accounted for that the change of  $\alpha$ -quartz can be framed beneath  $573^{\circ}\text{C}$  and  $\beta$ -quartz at  $573^{\circ}\text{C}$  to  $820^{\circ}\text{C}$ . At lower temperature, the

indistinct condition of rice husk debris silica will be shaped [20].

The press board (IS-1576) refers IS standards (Figure 1), which is to be coated with the resin mixture, is dried in sunlight for 4-5 hours to remove humidity from the board. Then, the mixture is mixed with 1 : 1 ratio of standard epoxy resin (AW 106 IN) and standard hardener (HV 953 IN) and then added the 2 : 1 ratio of quartz powder and rice husk ash, as shown in Figure 7. Then, these components are blended evenly without any bulges. The surface of the press board is cleaned to remove dust. Next, the epoxy resin mix is coated on the press board on one side evenly, as shown in Figure 8, and allowed to dry for 8-12 hours. Again, the same step is repeated on another side of the press board.

### 3. Experimental Setup

The basic predominant tests (dielectric constant test, Tan Delta test, and volume resistivity test) which are necessary to ensure the insulating property of any new solid insulator are performed [19, 24]. These tests were performed as per IS & IEC standards.

- (1) Dielectric constant test (IEC60250)
- (2) Tan Delta test (IEC60247)
- (3) Volume resistivity test (IEC62631-3-1)

The main importance of the test is to test the dielectric, loss dissipation, and resistance properties of the specimen.

**3.1. Dielectric Constant Test.** The dielectric constant of an insulating material can be defined as the ratio of the charge stored in an insulating material placed between two metallic plates to the charge that can be stored when the insulating material is replaced by vacuum or air. It is also called as electric permittivity or simply permittivity. A dielectric test is an electrical test performed on an insulator to decide the dielectric strength. The test is carried out by placing the test sample between the two electrodes, and the standard voltage is applied between the two electrodes, and the value is noted. Normally, the dielectric value of the insulator should be greater than 2. First, the noncoated press is tested, and then, the coated press board is tested, and the ratio of these values gives the dielectric constant of the material.

**3.2. Tan Delta Test.** The test sample on which the Tan Delta test or dissipation factor test to be conducted is first isolated from the system. A test voltage is applied across the equipment whose insulation is to be tested. The Tan Delta test is carried out by placing the test sample between two electrodes, and the ac voltage is applied. When a dielectric material is placed across the AC voltage, no power is utilized. The current will lead the voltage applied by  $90^{\circ}$ . This proves that no power loss occurred in the insulator. In most of the situation, the energy is dissipated in the insulator when the voltage is applied. This is called dielectric loss. The leakage current which is the phase angle will be less than  $90$ . This is





FIGURE 7: Mixture of epoxy resin, quartz powder, and rice husk ash.



FIGURE 8: Material coated using the epoxy mixture.

known as the loss angle ( $\delta$ ). Therefore,  $\tan \delta$  is called the power factor of dielectrics.

**3.3. Volume Resistivity Test.** Volume resistivity is the protection from leakage current through the body of an insulating material. The higher the surface/volume resistivity, the lower the leakage current and the less conductive the material is. A standard size test is set between two anodes' plate, as demonstrated in Figure 9 and 10. For sixty seconds, a voltage is applied and the check is assessed. Surface or volume resistivity is resolved, and clear worth is given (60 seconds time).

## 4. Experimental Results

All the three tests, dielectric constant test, Tan Delta test, and volume resistivity test, are done with noncoated press board (NPB) and coated press board (CPB). The results obtained are discussed.

**4.1. Dielectric Constant Test.** The dielectric constant values of specimens are obtained for the supply voltage of 1 kV ac supply. The test results obtained for the dielectric constant

test of the specimen shows that the dielectric constant value for the coated press board is high when compared to the value of the noncoated press board. The dielectric constant of the coated press board is 3.273 (Table 1) which is higher than the dielectric constant of NPB (2.650). The dielectric constant of the epoxy-coated press board and noncoated board is plotted against supply voltage 1 kV and is shown in Figure 11.

**4.2. Tan Delta Test.** In the Tan Delta test, the Tan Delta value of the noncoated press board is slightly more in the value when compared to the epoxy-coated press board. The value is 0.21 for CPB, and the Tan Delta value of NCB is 0.2. If the insulation is evenly done, the loss will be almost unchanged during increase in voltage. In our case, the Tan Delta value is slightly increased for the coated press board so that the loss angle will be reduced. The values are given in Table 2, and graphical representation is given in Figure 12.

**4.3. Volume Resistivity Test.** The volume resistivity of the material is obtained by the test. The volume resistivity values of the specimens are obtained for the DC supply voltage of value 500 V. The output of the test shows that the volume

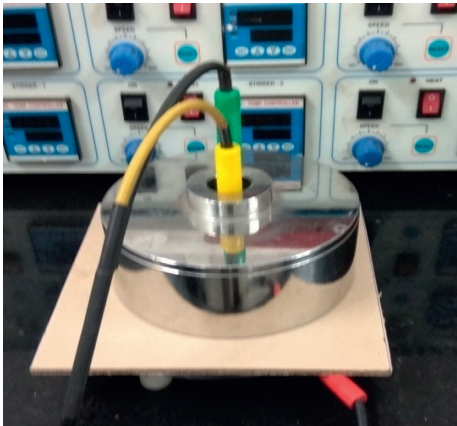


FIGURE 9: Testing of the normal press board.



FIGURE 10: Testing of the press board coated with epoxy coating.

TABLE 1: Dielectric constant of specimens (NPB and CPB).

S. No.	Specimen	Supply voltage (AC)	Dielectric constant
1	NPB	1 kV	2.650
2	CPB	1 kV	3.273

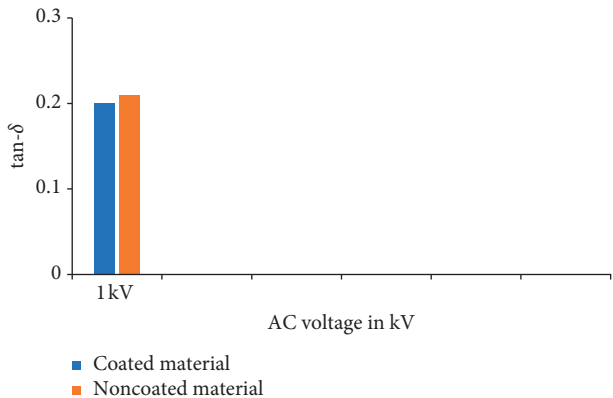


FIGURE 11: Dielectric constant of specimens (NPB and CPB) vs supply voltage.

TABLE 2: Tan delta of specimens (NPB and CPB).

S. No.	Specimen	Supply voltage (AC)	Tan Delta value
1	NPB	1 kV	0.2
2	CPB	1 kV	0.21

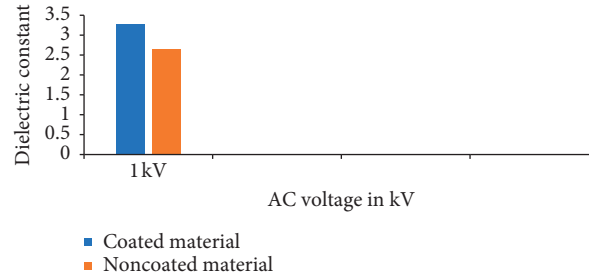


FIGURE 12: Tan Delta of specimens (NPB and CPB) vs supply voltage.

TABLE 3: Volume resistivity of specimens (NPB and CPB).

S. No.	Specimen	Supply voltage (DC)	Volume resistivity in $\Omega$ cm
1	NPB	500 V	$4.96 \times 10^{11}$
2	CPB	500 V	$3.18 \times 10^{13}$

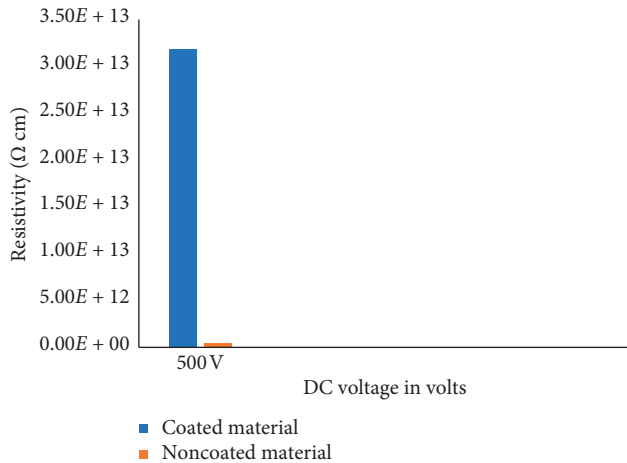


FIGURE 13: Volume resistivity of specimens (NPB and CPB) vs supply voltage.

resistivity of the epoxy-coated material is increased to  $3.18 \times 10^{13} \Omega$ -cm when compared to the noncoated material  $4.96 \times 10^{11} \Omega$ -cm (Table 3). The values show that the resistivity of the material is greatly increased, as shown in Figure 13.

## 5. Conclusion

The epoxy composite mixture coated for the transformer press board is fabricated successfully, and it is tested. The test result shows that the press board coated with epoxy resin along with quartz and rice husk ash has established a better insulation property when compared to the normal press

board. The dielectric constant of the coated press board is 3.273 at 1 kV which is higher than the noncoated press board (2.650 at 1 kV). The volume resistivity is also high  $3.18 \times 10^{13} \Omega$ -cm at 500 V DC supply for the coated press board. Only the dissipation factor, i.e., Tan Delta, value of the proposed specimen is slightly higher than the NCB. Even this can be improved by proper treatment of the specimen before testing. This could be done in the future work. The coated press board has the good insulation under high voltage, and the dielectric property is also increased. These insulators can be effectively applied for high voltage application in the transformers after conducting these tests under various conditions.

## Data Availability

The data used to support the findings of this study are included within the article.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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