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Improvement Performance of Some Tape Insulations for High Voltage Application

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Abstract*—There are variety of types available for electrical tape insulation for high voltage application. This paper will include a comparison and improvement dielectric properties of mica glass tape and glass cloth tape. Polyester and Titanium Dioxide (TiO_2) are used as backing of mica glass and glass cloth tape to improve dielectric properties. The Electrical properties of the cured tapes were thoroughly evaluated. The effects of thermal exposure and immersion in water on dielectric strength are investigated. The tape samples were thermally at 30, 80, 100 and 150 ºC for 24 h, to study the influence of thermal exposure. Moreover, to explore the effect of moisture absorption, other tape samples were immersed in distilled water for up to 24 h at room temperature. The polyester and TiO_2 has an important role in the performance of mica glass and glass cloth tapes. This paper reviews the results of breakdown voltage of the mica glass and glass cloth tapes after treatment by polyester only and polyester with TiO_2; showing breakdown voltage of mica glass tape backing with polyester is equal to 25.2 kV while breakdown voltage of mica glass tape backing with polyester and TiO_2 is equal to 27 kV. Also breakdown voltage of glass cloth tape backing with polyester is equal to 11 kV while breakdown voltage of mica glass tape backing with polyester and TiO_2 is equal to24.3 kV.

***Keywords*— breakdown voltage, mica glass, glass cloth, tape insulation, polyester, TiO_2**

I. INTRODUCTION

The failure of insulating material under electrical stress is called electrical breakdown. In solid dielectrics, the breakdown always gives rise to permanent damage of the material [1]. The probability of its occurrence must therefore be kept to an absolute minimum. The insulating ability of a material is determined by its dielectric strength, the maximum electrical field that can be applied to an insulating medium without causing breakdown. The dielectric strength is defined in equation (1),

$$E = V_{BD} / d \qquad (1)$$

Where V_{BD} is the electrical breakdown voltage and d is the distance between the electrodes, which is equivalent to the sample thickness [1].

The manufacturer of the mica tape with a flat glass backing indicates that using the flat glass mica paper tape can reduce the size of the electrical generator. A number of approaches have been done in the past to reduce generator size. The basic approach has been to reduce the groundwall thickness of the insulation to improve the heat flow through the thinner insulation [2]. It has been demonstrated that improved dielectric characteristics of glass backed mica paper tapes, when used in vacuum pressure impregnation (VPI) process is obtained through modification of the tapes construction and chemistry [3]. There are different thermosetting resins available for the glass banding tapes. Un- saturated polyester, polyester-imid and epoxy resins are most prominent in the field [4]. The key properties of the tapes including dielectric withstand, organic content, tensile strength, thickness, mica content, and flexibility were verified prior to use [5]. The thinner mica tape then allows more mica to be in the groundwall and a thinner overall groundwall can be designed. The thinner groundwall has evolved over the years mainly because of improvements in the glass backed mica tape. Flat glass mica paper tape will lead to further reductions in overall groundwall thickness.[6-8]

II. EXPERIMENAL PROCEDURES

A. SAMPLES PREPARATION

Two types of tapes are used in this investigation mica glass tape and glass cloth tape. According to D 149 ASTM standard on the two types of tape insulation the power frequency breakdown voltage shall be determined by averaging five breakdown voltages on each specimen. The average breakdown voltage shall be corrected to normal standard condition. All the samples under investigation in this paper were cut from role with width 10 mm and thickness 0.15 ± 0.02 mm. The specimens shall be of sufficient size to prevent flashover under the conditions of test. Immerse the specimen in insulating oil as a surrounding medium during the test to prevent flashover occurs. Polyester and TiO_2 added to modify various properties (mechanical, thermal, electrical, etc) of mica glass and glass cloth tape insulations. Firstly, has been used the polyester only to coating the two types of tape. First immersion in polyester has been done to both types of tapes, mica glass and glass cloth to obtain a one coated layer. After extracting samples from polyester for periods of time immersed again in polyester to obtain double coated layer and immersed double coated layer again in polyester to obtain triple coated layer.

Secondly, has been used polyester and TiO_2 to coating the two types of tapes to obtain at other sixe group as follows one coated layer of mica glass tape, one coated layer of glass cloth tape, double coated layer of mica glass tape, double coated layer of glass cloth tape, triple coated layer of mica glass tape and triple coated layer of glass cloth tape. The samples after treatment we will be exposure to temperature and immersion in water.

B. **WEATHER TESTING CONDITIONS**

The electric strength of insulating materials varies with temperature and moisture content. Where a specification is available for the material to be tested. Three identical sets of samples were prepared and tested using AC (50 Hz) voltage. The different testing conditions are classified as follows:

1) The first set of samples has been tested using AC voltage and shall be conditioned for not less than 24 h at (23 ± °C, 50 % ± 5 % relative humidity.
2) The second set of samples has been tested using AC voltage in dry condition by exposing it to default temperatures at 30, 80,100 and 150 °C.
3) The third set of samples has been tested using AC voltage in dry condition after immersion in distilled water.

C. **TESTING APPARATUS**

1) Electrical Test Supply

According to ASTM D 149 dielectric breakdown voltage and dielectric strength of solid electrical insulating materials at commercial power frequencies the breakdown voltage shall be determined. Voltage source the test voltage is obtained from single phase auto-transformer 5 kVA-100 kV-50 Hz. The capacity of the source shall be sufficient to maintain the test voltage until dielectric breakdown occurs. This test method should specify the surrounding medium and the test temperature. Since flashover must be avoided and the effects of partial discharges prior to breakdown minimized. The temperature of the test specimen and its surrounding medium influence the dielectric strength, although for most materials small variations of ambient temperature may have a negligible effect.

2) The Test Electrodes:

In order to study the breakdown voltage of tape insulation a set of electrodes has been used.
The electrodes shall consist of two metal rods, each 6 mm ± 0,1 mm in diameter, mounted vertically one above the other.

III. EXPERIMENTAL RESULTS

A. **Breakdown voltage of tape against the number of layers without treatment.**

The breakdown voltage has been measured as function of thickness by increasing number of layer of tape insulation for two type mica glass and glass cloth tape under without treatment and the results are shown in Fig. (1).

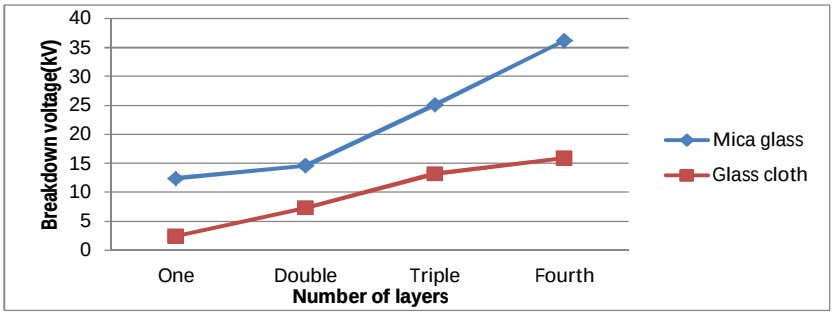

Figure (1) Breakdown voltage as function for number of layer.

It can be observed that the breakdown voltage sharply increased for all samples (mica glass tape and glass cloth tape). The breakdown voltage values are varying from 12.4 kV at one layer of mica glass tape to 35.2 kV at fourth layers and 2.4 kV at one layer of glass cloth to 15.9 kV at fourth layers.

B. **Breakdown voltage of mica glass and glass cloth tapes with treatment of polyester.**

To improvement the breakdown voltage of mica glass tape and glass cloth tape we will use the polyester only by coating the layers of tape insulation until we reach the best value of breakdown voltage as shown in fig (2).

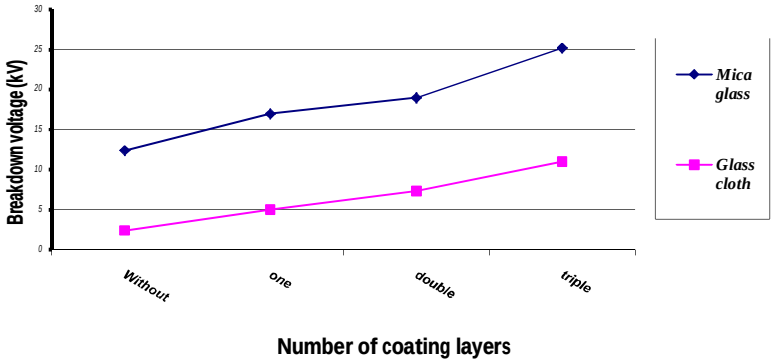

Figure (2) Breakdown voltage as function of coating number by polyester only.

A comparison between mica glass tape and glass cloth tape for without coating ,one coating ,duple coating ,triple coating of polyester only. It can be observed that the breakdown voltage increased for all samples by increasing of number of coating. The breakdown voltage values of mica glass tape are varying from 12.4 kV in case without coating reaches to 17 kV in case one coating, while at double coating reaches to 19 kV, also at triple coating the breakdown voltage increase to reaches 25.2 kV. In other type of tape insulation(glass cloth tape)the breakdown voltage are varying from 2.4 kV in case without coating reaches to 5 kV in case one coating, and 7.3 kV in case of double coating, while reaches to 11 kV at triple coating. It is mean that, by increasing coating of polyester, the breakdown voltage will be increased.

C. **Breakdown voltage of mica glass and glass cloth tape with treatment of polyester&TiO2.**
Polyester and TiO_2 will be used to coating the layers of tape insulation until we reach the best value of breakdown voltage as shown in fig (3).

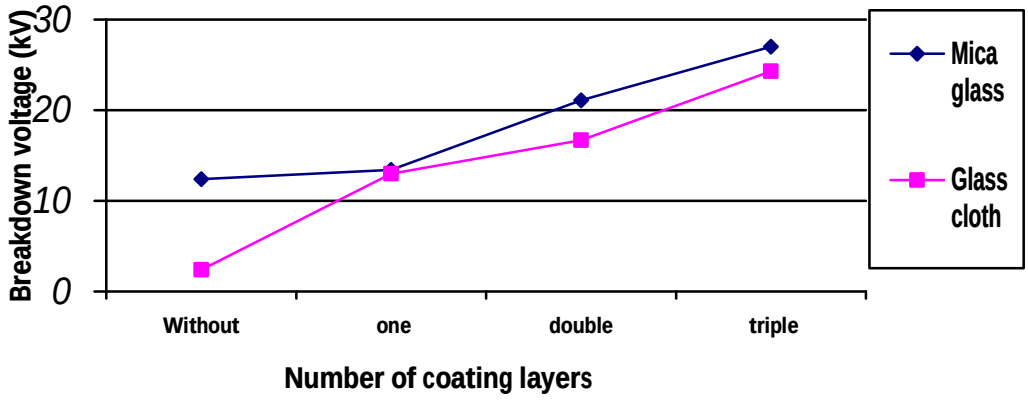

Figure (3) Breakdown voltage as function of coating number by polyester&TiO2.

It can be observed that the breakdown voltage increased for all samples by increasing of number of coating. The breakdown voltage values of mica glass tape are varying from 12.4 kV in case without coating reaches to 13.4 kV in case one coating, while at double coating reaches to 21.1 kV, also at triple coating the breakdown voltage increase to reaches 27 kV. In other type of tape insulation(glass cloth tape)the breakdown voltage are varying from 2.4 kV in case without coating reaches to 13 kV in case one coating, and 16.7 kV in case of double coating, while reaches to 24.3 kV at triple coating. It is mean that, by increasing coating of polyester with TiO_2, the breakdown voltage will be increased.

D. **Comparison between the breakdown voltage of mica glass tape insulation with and without treatment.**
Breakdown voltage of mica glass tape without coating is the minimum as shown figure (4). When mica glass tape was coated the breakdown voltage was increased. Breakdown voltage of mica glass tape at one coating is increased in case coating of polyester only than polyester with TiO_2 as shown in figure (4).Mica glass tape is able to coating again and the breakdown voltage also increased but in this case the polyester with TiO_2 is better than polyester only.

Also Mica glass tape is able to coating again and we get mica glass triple coating and the breakdown voltage also increased to reach best value at coating of polyester with TiO2. The percentage increase for the value of breakdown voltage is highest for coating of polyester & TiO_2.

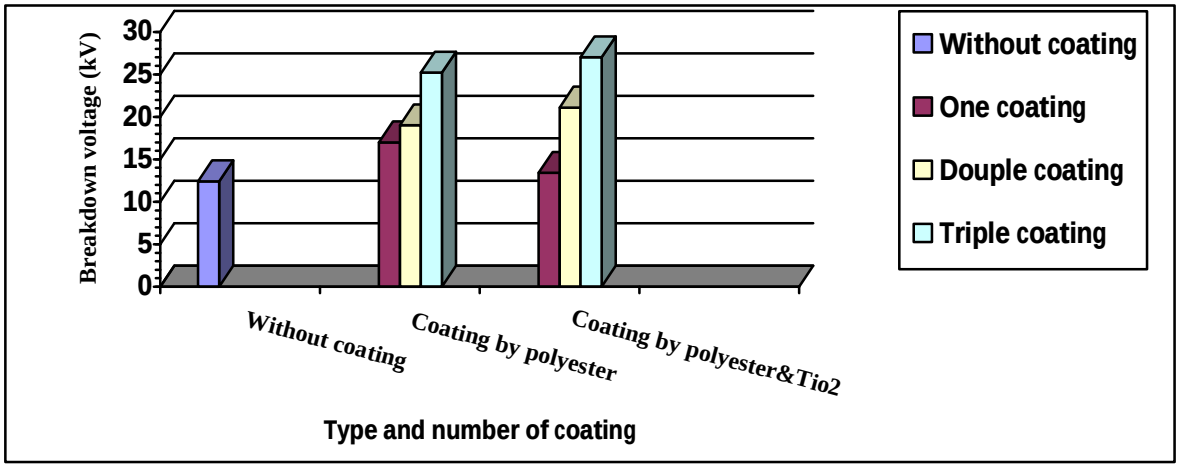

Figure (4) Breakdown voltage of mica glass tape without coating and with coating of polyester only and polyester & TiO_2.

E. **Comparison between the breakdown voltage of glass cloth tape insulation with and without treatment.**
Glass cloth tape without coating was recorded the minimum value of breakdown voltage as shown in figure (5). It is observed that the breakdown voltage after first coating is increased than without coating but rate of raise in case of polyester with TiO2 is highest from polyester only.

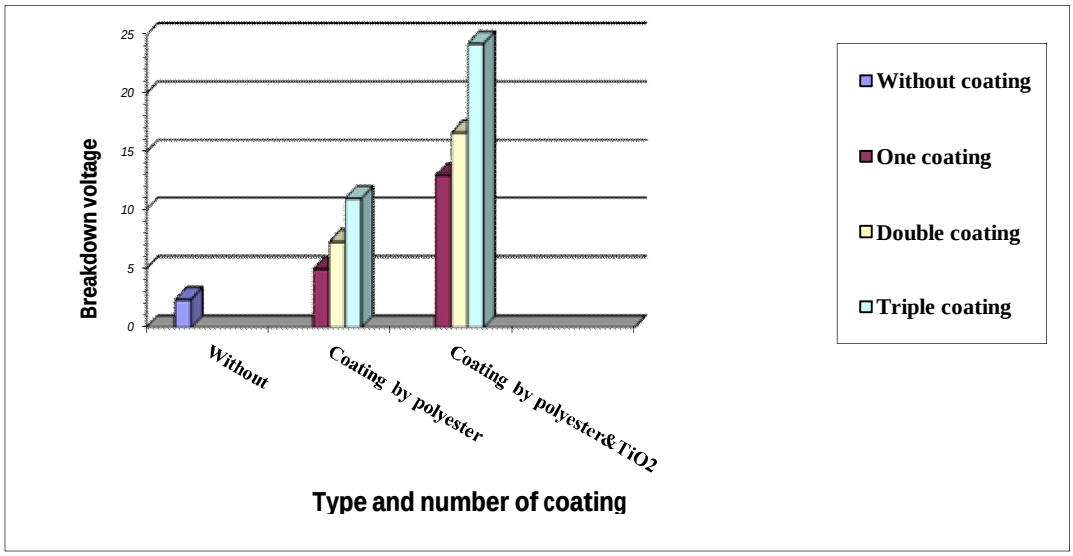

Figure (5) Breakdown voltage of glass cloth tape without coating and with coating of polyester only and polyester & TiO_2.

Glass cloth tape is able to coating again and the breakdown voltage also increased and the polyester with TiO_2 is better than polyester only. Also glass cloth tape is able to coating again and we get glass cloth triple coating and the breakdown voltage also increased to reach best value at coating of polyester only. From this figure it can be noticed that, by increasing the coating of layer tape insulation, the breakdown voltage increases.

F. **Effect of breakdown voltage of mica glass and glass cloth tape insulation at different temperature.**
The breakdown voltage of mica glass and glass cloth tape without and with treatment of polyester and polyester with TiO_2 has been measured as function of number of coating at different temperature.

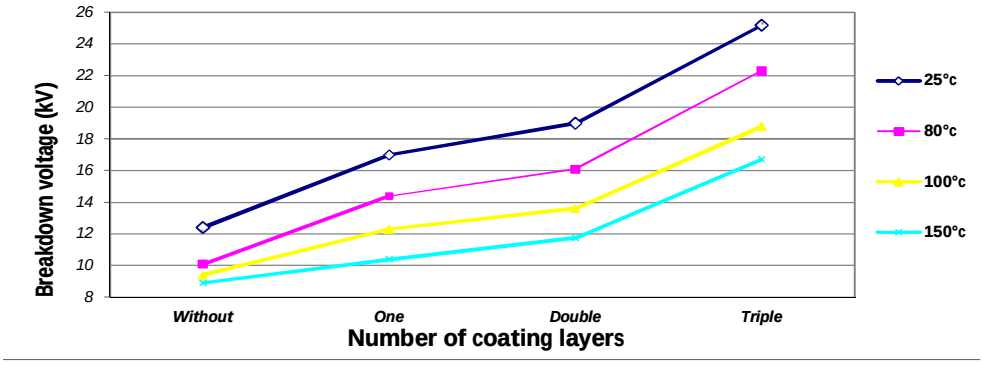

Figure (6) Breakdown voltage (kV) of mica glass tape with and without treatment of polyester only at different temperature.

The effect of increase in temperature reaches to decrees in breakdown voltage of tape insulation. Breakdown voltage for mica glass tape without coating at 25 °C was recorded 12.4 kV, while breakdown voltage at 150 °C was recorded 8.9 kV. If we used polyester coating the breakdown voltage at 80,100 and 150 °C decreased to arrive 16.7 kV at triple coating and temperature 150 °C.

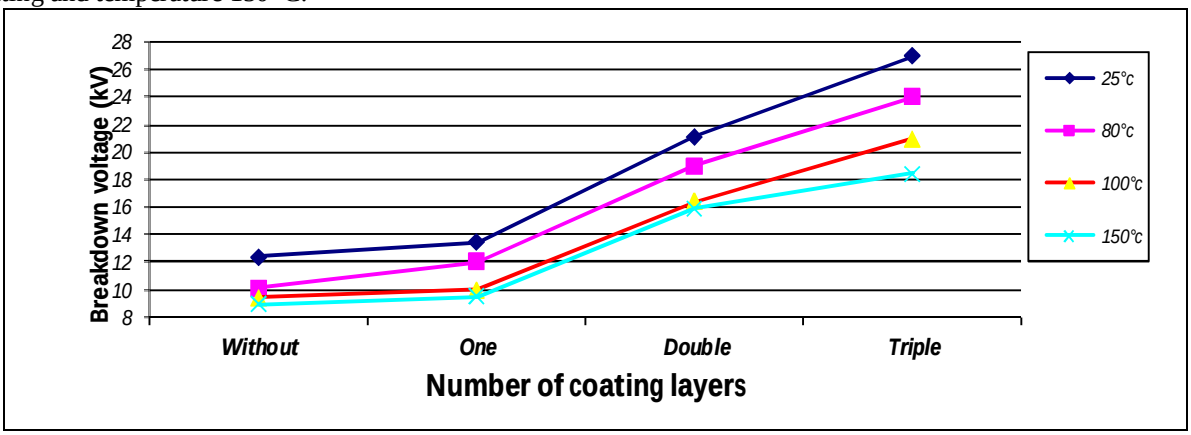

Figure (7) Breakdown voltage (KV)of mica glass tape with and without treatment of polyester with TiO_2 at different temperature.

Figure (7) shows the relationship between breakdown voltage against the with and without coating of polyester with TiO2 after Exposure to different temperatures. It can be observed that the breakdown voltage decreased for all samples with increasing of temperature from to 25 °C to 150 °C by exposure of samples to thermal oven. Breakdown voltage for mica glass tape with one coating at 25 °C was recorded 13.4kV, while breakdown voltage at 150 °C was recorded 9.5 kV. Also at double coating the breakdown voltage was decreased from 21.1 kV at 25°C to 15.9 kV at 150°C. Also at triple coating the breakdown voltage was decreased from 27 kV at 25°C to 18.43 kV at 150°C . From the above if we used polyester with TiO_2 coating the breakdown voltage increased with respect without coating and decreased with increasing of temperature.

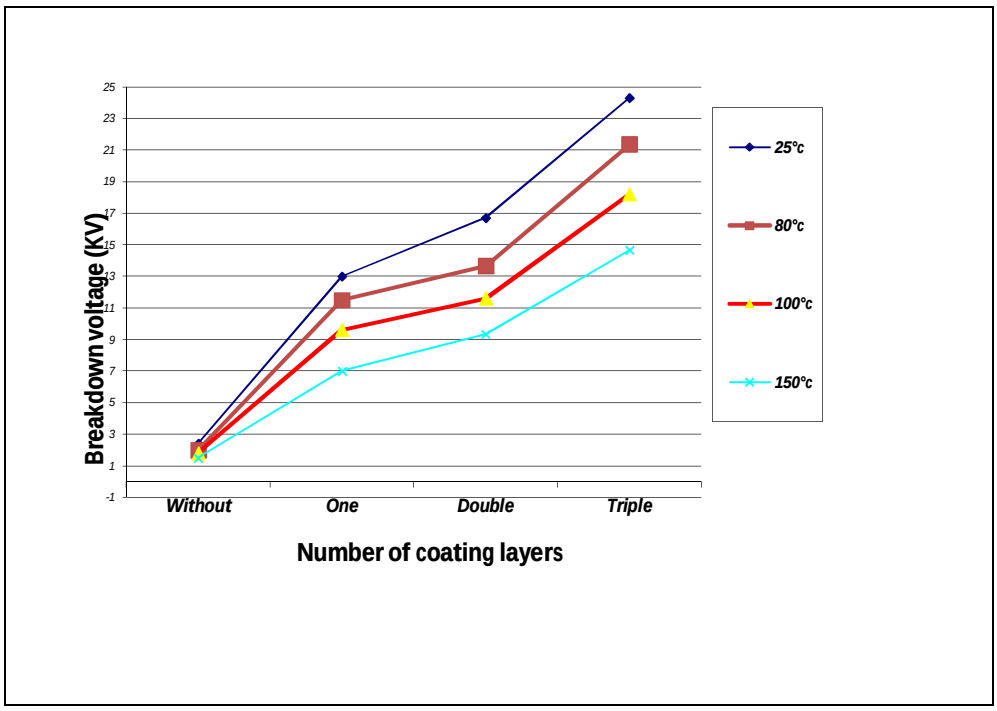

Figure (8) Breakdown voltage (KV)of glass cloth tape with and without coating of polyester &TiO_2 at different temperature.

Breakdown voltage reading of glass cloth without coating at 25°C was recorded 2.4 KV, while breakdown voltage at 150 °C was recorded 1.5 KV. Also at triple coating the breakdown voltage was decreased from 24.3 KV at 25°C to 14.66 KV at 150°C.

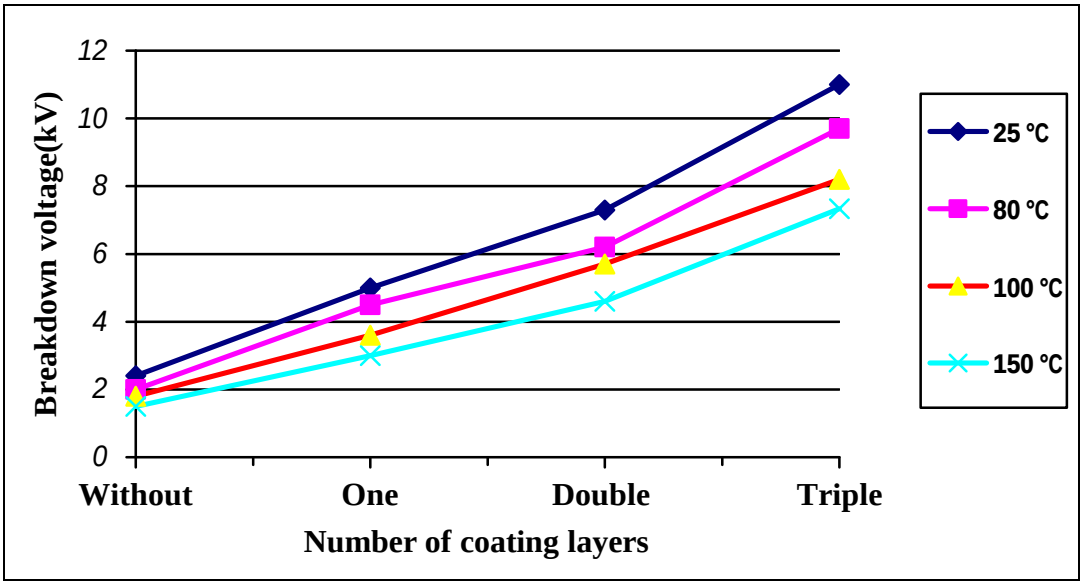

Figure (9) Breakdown voltage (kV)of glass cloth tape with and without coating of polyester only at different temperature.

Figure (9) shows the relationship between breakdown voltage against the with and without coating of polyester only after Exposure to different temperatures. Breakdown voltage for glass cloth tape with one coating at 25 °C was recorded 5 kV, while breakdown voltage at 150 °C was recorded 3 kV. Also at triple coating the breakdown voltage was decreased from 11 kV at 25°C to 7.33 kV at 150°C.

G. **Effect of breakdown voltage of mica glass and glass cloth tape insulation after immersion in water**

A variety of factors influence the performance of tape insulation. Among these factors, humidity is one of the most common causes of degradation and premature ageing. When subjected to humidity, moisture localizes at interfaces between basic components of the material. This results in an increase of permittivity, loss tangent [l0], growth of trees [11], and internal delamination at the interface region [12]. Interfaces constitute the weakest part in composite material. High electrical stress can initiate partial discharge, drive electrical tree propagation along internal interfaces [13], ending up by breakdown.

Fig (10) and fig (11) shows the effect of distilled water on the breakdown voltage of mica glass and glass cloth tape without and with treatment by polyester and polyester & TiO_2

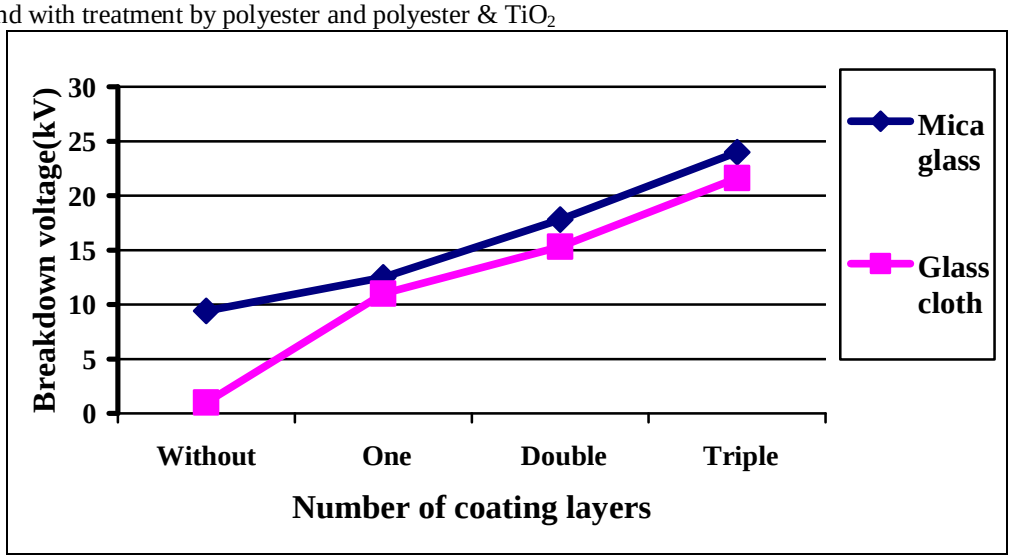

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Figure (10) Breakdown voltage (KV) mica glass tape and glass cloth tape with coating of polyester & TiO_2 against the number of coating after immersed in distilled water.

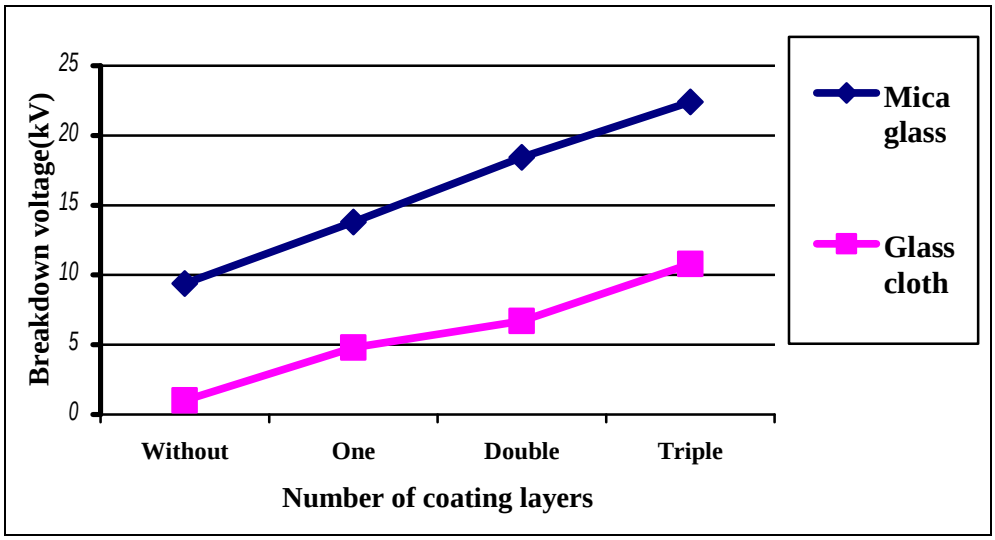

Figure (11) Breakdown voltage (kV) mica glass tape and glass cloth tape with coating of polyester only against the number of coating after immersed in distilled water.

Before coating breakdown voltage for mica glass was recorded 9.4 kV, while breakdown voltage for glass cloth was recorded minimum value 1 kV. It is observed that the adding of polyester and polyester & TiO_2 to increase breakdown voltage of sample with comparison to the breakdown voltage of tape without coating.

IV. CONCLUSIONS

The main conclusions drawn from the present investigations will be summarized as following:

- The breakdown voltage of tape insulation can be improved by using polyester and polyester withTiO_2 as treatment material.
- The mica glass and glass cloth tapes exhibit good dielectric performance when coating layers with polyester and TiO_2.
- The results indicate that breakdown voltage of mica glass and glass cloth tapes have superior performance at increasing the number of coating till triple layers.
- With increasing temperature of thermal exposure and increasing time of immersion in water, the dielectric strength of mica glass and glass cloth tape is decreased.

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