" I hereby declare that I have read through this report entitle "Correlation Between Resistivity And Dielectric Performance Of Polymeric Material Insulation Under Standard Test Procedure" and found that it has comply the partial fulfilment forwarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature :

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Correlation Between Resistivity And Dielectric Performance Of Polymeric Material Insulation Under Standard Test Procedure

NUR NABILA BINTI NOOR AZMAN

A report submitted in partial fulfilment of the requirement for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2016

I declare that this report entitle “Correlation between resistivity and dielectric performance of polymeric material insulation under standard test procedure” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : …………………………………………

Name : NUR NABILA BINTI NOOR AZMAN

Date :

Dedicated to my beloved family, friends and lecturers for their never ending support, encouragement, and understanding towards the completion of my work.

ACKNOWLEDGEMENT

Firstly, my biggest thanks to Allah S.W.T who gave me opportunity in doing this project and always giving me hope and ways in completing the tasks.

My great appreciation goes to my supervisors, Dr. Aminudin Bin Aman for his guidance, skill, knowledge, and patience in helping his final year students for the two semesters.

I also want to give my appreciation to other lecturers, technicians, and friends who are wiling to help me whether directly or indirectly in completing this final year project. Their good deed will always been remembered.

CORRELATION BETWEEN RESISTIVITY AND DIELECTRIC STRENGTH PERFORMANCE OF POLYMERIC MATERIAL INSULATION UNDER STANDARD TEST PROCEDURE

NUR NABILA BINTI NOOR AZMAN

This report is submitted in Partial Fulfillment of Requirements for the Degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

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ABSTRACT

High voltage insulation technology has gone through a continuous developments and improvements, starting from ceramics to polymer composite insulating synthetic material. Some researches has been done, but there are still available spaces of improvements in terms of the performance of insulating polymer. Synthetic polymer is widely used in high voltage insulation. It is divided into two types which are thermoplastic and thermoset materials. This project focuses on the performance of a thermoplastic material, Polypropylene (PP) as insulators. Among the essential needs to evaluate and examine the performance of selected materials as extra high voltage applications is its resistivity and dielectric strength level. In determining the dielectric strength of the selected material, breakdown test on the specimen was conducted using a flat shaped electrode. The test parameters, dimensioning and condition of the specimen are prepared based on the international standard, BS EN 60243-1:1998. The resistivity test is divided into two terms which are the surface, and the volume of the material based on international standard BS 6233-1982. The experiment was carried out by determining the strength of long term solid electrical insulating materials at power frequencies of 50 Hz. Based on this project, Polypropylene (PP) satisfies the requirements of the breakdown field strength under flat shapes of electrodes which exceeds the minimum requirement of 10 KV/mm with reference to the international standard BS EN 62039:2007. Pin electrode does give the most impact on Polypropylene (PP) dielectric performance that results on the highest breakdown value of polymer. Hence, the breakdown results can be used to determine the characteristic of the resistivity test, processing variables, against condition and other manufacturing or environmental situation in high voltage polymeric insulation application.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Insulation plays a big part on the performance and life expectancy of high voltage equipment. The dielectric strength and electrical field are the main elements that lead to failure of insulation [1]. The dielectric breakdown behaviors of an insulation material depend on the electrical stress conditions, chemical structures and their implementation environment [2]. Polymer traditional porcelain and glass are used in this project [3, 4]. An assemble of studies has been carried out to review on polymer material for electrical application [5, 6]. Polypropylene (PP) is chosen because this material is widely used in the high insulating system as it has high performance electrical properties [7]. Our foregoing breakdown review shows that the breakdown voltage drops approximately as the square root of the gap for metal surfaces with gap 2 and 8 mm [8]. To be specific, this project determines the resistivity insulation and dielectric strength of insulation applied [9, 12].

This project is conducted by following the British Standard Institution, the selection guide for polymeric materials for outdoor use under high voltage stress, PD IEC/TR 62039.2007. This guideline states the electrical property to test material and for parameter listed breakdown field strength test was compiled using IEC 60243-1 or BS EN 60243-1 and test for volume and surface resistivity of solid electrical insulating using IEC93:1980 or BS 6233:1982 with the minimum requirement need to fulfill in order test material.

1.2 Project Background

Nowadays, a lot of high voltage test has achieve to investigate withstands voltage or other review courses. However, these tests demand following standard to get reliable results, by using the standard test procedure behavior of insulating material in actual implementation can be determined. The result of the testing for observe changes can be used to determine the characteristic of processing variables, aging condition and other manufacturing or environmental situation in high voltage polymeric insulation application. A part from that, by using this standard test procedure, the testing laboratory identify for safety, the outcome of the testing polymeric material is valid, and used for benchmarking of performance. Therefore, the standard test according to international standard is vital to be compiled for use by polymeric insulation, material research and a safety need for high voltage implementation.

1.3 Problem Statement

A mass research has been right on the electrical properties of high voltage insulation materials. Generally, there are two types of test can be conducted, the standard test used for product test and non-standard test for research work. On previous reviews, the test has been impart to determine volume resistivity and surface resistivity of solid electrical insulating and the dielectric strength of flat polymer material where the breakdown test are conducted to investigate the dielectric strength. Both tests are to analysed performance of polymeric insulation properties. In this modern era, this high voltage testing is going to be used to determine the voltage breakdown and method resistivity of material using flat shape of electrode and analyse the characteristic of electrical breakdown beside volume and surface resistivity. Since the experiment generates high voltages, compulsory handling steps and safety precaution need to be taken when handling the equipment.

The safety precautions cover the laboratory safety and user safety. Therefore, the standard test procedure accordingly to international standard is vital to be complied and must follow to get reliable results. And by referring to the British Standard Institution. Selection guide for polymeric materials for outdoor use under HV stress PD IEC/TR 62039.2007 [10]. The minimum dielectric strength to be fulfilled for outdoor high voltage polymeric insulation shall not be less than 10 kV/mm while minimum volume resistivity isΩm. In order to do testing on the dielectric strength of the polymer insulation, the international standard BS EN 60243-1:1998 and for surface and volume resistivity test used BS 6233:1982.

1.4 Objectives

The objectives for this project are stated as below**:**

i. To determine volume resistivity and surface resistivity of polymeric and non-polymeric material.

ii. To investigate relationship between resistivity and dielectric strength of material under standard test procedure

iii. To compare the dielectric strength of material under test based on their resistivity.

1.5 Scope of research

The research scope is limited to:

i. Used Polypropylene (PP) and glass as insulation specimen

ii. The parameter to be studied are volume, surface and dielectric strength

iii. The standard to be complied for surface and volume resistivity are BS 6233:1982

iv. The standard to be complied for dielectric strength is BS EN 60234-1:1998

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Insulation plays a vitally important in determining the performance and lifetime of high voltage equipment. This chapter covers all correlated study the characteristic of polymer insulator and electrodes used. It also characterized the development of polymeric insulation, Reviews of Electrical Properties Test, appropriate tests, detection of surface features, standard correlated to methods.

2.2 Degradation and breakdown

2.2.1 Electrical field stress

The dielectric strength of insulating materials and the electrical field stresses evolved in them are the important elements in high voltage applications. Conductors and insulators are the basic material used in high voltage apparatus, while the conductors bring the current and insulators prevent the flow of currents in undesired paths. The dielectric strength of an insulating material can be defined as the maximum dielectric stress which the material can resisted. Electrical breakdown strength of insulating material depends on various parameters, such as pressure, temperature, humidity, type of applied voltage, defects in the dielectric materials, material electrode and electrode surface conditions. The main reason for existence of insulation failure in the release of either void in the insulation failure in the release of either void in the insulation or on the surface of insulation [1].

2.2.2 Solid breakdown

If the solid insulating material is truly homogenous and is free from imperfections, its breakdown stress will be high as 10kV/mm. Nonetheless, in practice, the breakdown fields achieved are very much lower than this value where the breakdown results over the surface than in the solid itself [1]. The breakdown of insulation can result due to mechanical failure caused by mechanical stress produced by the electrical fields. The termed is "electromechanical breakdown". Breakdown can also results due to chemical degradation caused by heat generated due to dielectric losses in the insulating material [2]. When the conducting path is developed, it is called "tracking", and results in degradation of the material. Surface flush over normally results when the solid insulation is absorbed in a liquid dielectric. Surface flash over, as already mentioned, is the most frequent cause of trouble in practice. Porcelain insulations for use on transmission line must accordingly be design to have a long path over the surface. The failure of solid insulation by discharges which may the internal voids and cavities of the dielectric, called "partial discharges" is receiving much attention today, mostly because it determine the life versus stress characteristics of the material [7].

2.2.3 Electrical breakdown

Strict loss of the insulating properties of test specimen while exposed to dielectric stress, which causes the current in the test circuit to operate an appropriate circuit breaker [6].

2.2.4 Short term breakdown

Electrical field due to the very high stress may not result in the second or quickly without damaging the insulation surface before failure [6].

2.2.5 Long term breakdown

Breakdown of long term aging is also known as insulation. The main effects eventually responsible for the aging of insulation, lead to the damage arising from the heat and partial discharge [6].

i. Aging and breakdown due to partial discharge

ii. Aging and breakdown due to changes in surface insulation

2.2.6 Accelerated aging test

Aging of polymer insulators depending on the chemical and physical properties of materials and stress exposure. In these cases, the aging factor can be determined by careful test whether directly or indirectly. Other than that, several international organizations and national standards provided for accelerated life tests such as IEEE, IEC, CIGRE, ANSI, BS, and NEMA. There are no specific standard that apply to all implementation and conditions. That's mean the lack of standard means all materials. As a continuation of material technology, manufacturing often adjust the current test to suits different product [5]. These tests are designed to reveal the performance of the materials and the pressure is divided into four components, test the electrical properties, mechanical properties testing, physical and chemical testing environmental testing. Typically the surface condition of polymeric materials under test is used as diagnostic tool to represent the level of performance and aging. Continuity of technology, manufacturing often adjust the current test to suit different products [5].

Due to fact that the effect of aging process of long term, the accelerated aging test is usually done either in materials or complete product samples insulating polymer. This test will be conducted on either polymer insulation under electrical stress or the environment. Usually the test is performed for insulation materials such as UV test experience, tracking and erosion tests, reducing test corona, and oxidation stability test. In the meantime, a special test for complete insulation products like insulation, surge arrester and other detection and corrosion testing, salt fog test and test various environmental stresses. These tests are designed to reveal performance of the materials and the pressure is divided into four components, test the electrical properties, mechanical properties testing, physical and chemical testing environmental test. Typically the surface condition of polymeric materials under test is used as a diagnostic tool to represent their level performance and aging. A diagnostic test to measure aging is shown as in a figure 2.1 [5, 12].

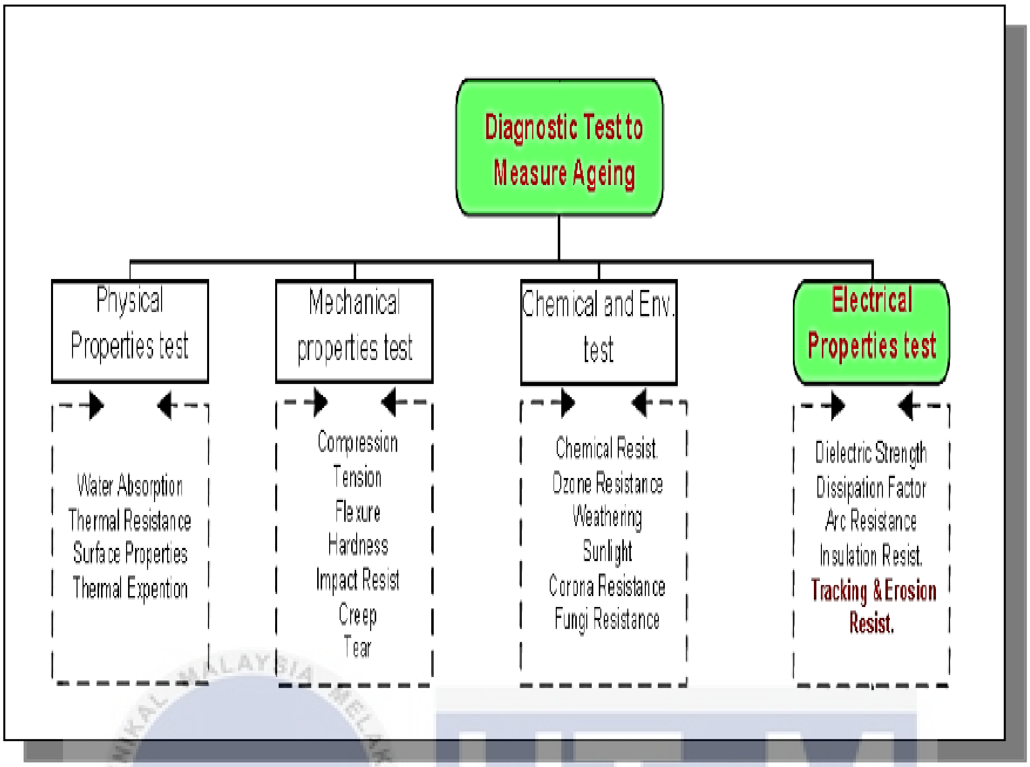

Figure 2.1: diagnostic test to determine the ageing

2.3 Selection material

For this study polymeric material to be studied are Polyvinyl Chloride (PVC), Polypropylene (PP), and high density Polyethylene (HDPE). For this project the thermoplastic polymeric material has been selected in Polypropylene (PP) and stainless steel electrode with flat end shaped.

1. Polypropylene (PP)

Polypropylene or PP can be used to make medical syringes, beakers, and insulating materials. It has high lubricated, high resistance to bending (excellent material to rely on), excellent dielectric strength and chemical resistance, good impact strength, and high solvent resistance. Polypropylene (PP) has the best balance of electrical and mechanical properties. PP is a highly versatile resin suitable for processing in molding or extruded parts and it is one of the lowest in cost [1].

2. Glass

Glass is an organic compound that consists of a complex system oxide (SiO2). Glass dielectric strength varies from 3000-5000kV/ cm and decrease with increasing temperature, reaching half its value at 100^{o}C. glass is typically created as a tool of protection and internal support in electrical bulb, X-ray equipment, capacitors and insulation on the phone. The glass insulations have strong chemical stability to resist ageing, which means it has a high surface energy. With high surface energy, glass is easily wetted as well as surface adhesion of contaminants and can lead to flashover at contaminated area. It does not perform well under polluted conditions [1].

2.4 Type and shape of electrode

Since the standard test assured the stainless steel is the most reliable electrode to be used in the experiment, flat-end shaped electrode is prepared.

a. Flat-end

i. Unequal diameter electrode

The electrode shall consist of two metal cylinders with the edges rounded to give a radius of 3mm ± 0.2mm. One of the electrode shall be 25mm ± 1mm in diameter and approximately 25mm high. The other electrode shall be 75mm ± 1mm in diameter and approximately 15mm high. These electrodes shall be arranged coaxially within 2mm as shown in figure 2.2 and figure 2.3 shows the actual arrangement of this electrode.

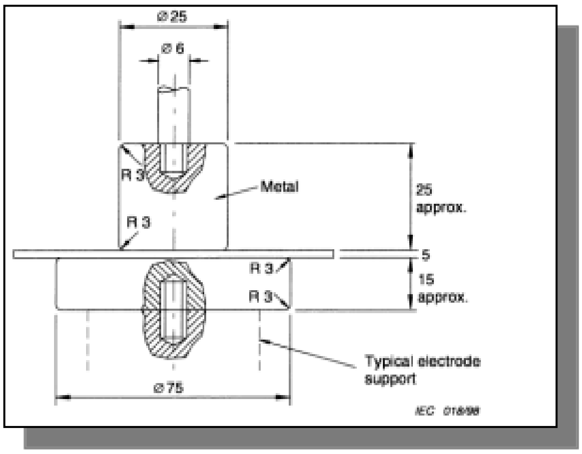

Figure2.2: electrode arrangement of unequal electrodes [11]

Figure 2.3: actual arrangement of unequal electrode

ii. Equal diameter electrode

If a fixture is employed, which accurately aligns upper and lower electrodes within 1.0 mm, the diameter of the lowest electrode may be reduced to 25mm ± 1mm, the diameters of the electrodes differing by no more than 0.2 mm. the results obtained will not necessarily be the same as those obtained with the unequal electrodes. Figure 2.4 and figure 2.5 shows the electrode arrangement for equal diameter test.

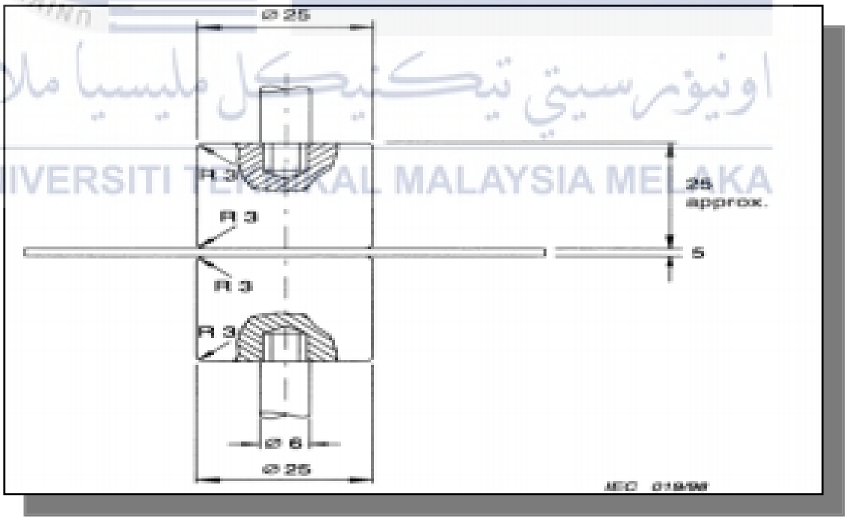

Figure 2.4 electrode arrangement of equal diameter [11]

Figure 2.5: Actual electrode arrangement of the diameter

1.5 Classification of Resistivity

2.5.1 Volume resistance

The quotient of a direct voltage applied between two electrodes placed on opposite of a specimen and the steady state current between the electrode, excluding current along the surface and neglecting possible polarization phenomena at the electrode [13].

2.5.2 Volume resistivity

The remainder of an immediate current electric field quality and the enduring state current thickness inside of a protecting material. In a practice, it is taken as the volume resistance decreased to a cubical unit volume.

2.5.3 Surface resistivity

The quotient of a direct voltage applied between two electrodes on a surface of a specimen, and the current between the electrodes at a given time of electrification, neglecting possible polarization phenomena at the electrodes.

2.6 Reviews of electrical properties test

In Previous research paper, IEEE Application Guide Evaluating Non-Ceramic materials for High Voltage - External Applications (IEEE 1133-1998) [9] was used as a reference for the development of polymer materials. However, it only defines the physical parameters of the test in the broadest sense; utilities and industry with specific tasks were defined physical parameters important for polymeric materials used for insulation outdoor and guidelines, including minimum requirements of their organizing. For example, existing guidelines such as BS EN 62039-2007User-Polymer Materials Selection for Outside use under HV stress [10] used to determine and evaluate the performance of the polymer material is selected as the external application of high voltage.

These guidelines have listed the physical parameters related to the characteristics of electrical and mechanical to be met. In this work, polymer Material Selection Guide outdoor use under HV stress BS EN 62039-2007 mentioned. Important features, minimum requirements and standard testing option for outdoor use under HV stress in accordance with BS EN 62039:2007 presented in table 2.3.

Table 2.1: important properties and minimum requirement of polymeric insulation [10].

No. of material	Property to test	Minimum requirement	Test standard
1	Resistance to tracking and erosion	1A3, 5b	IEC 60587*
2	Tear strength	>6 N/mm	ISO 34-1*
3	Volume resistivity	>10M Ω	IEC 60093
4	Breakdown field strength	10kV/mm	IEC 60243-1*
5	Water diffusion test	"voltage test"-12kV-1min or $\tan \partial < 0.2$	IEC 62217* IEC60250*
6	Arc resistance	>180 s	IEC 61621*

CHAPTER 3

METHODOLOGY

3.1 Introduction

The experiment will be supported by using BS EN 60243 as standard offers test methods for determining the strength of the long term solid electrical insulating materials at power frequencies of 48 Hz to 62 Hz. It not sort out into account of test liquids and gases, although this is set and used as a medium of solid insulating material around to testing. This method to determine the breakdown voltage along surface of the insulation material included.

3.2 Flow chart of methodology

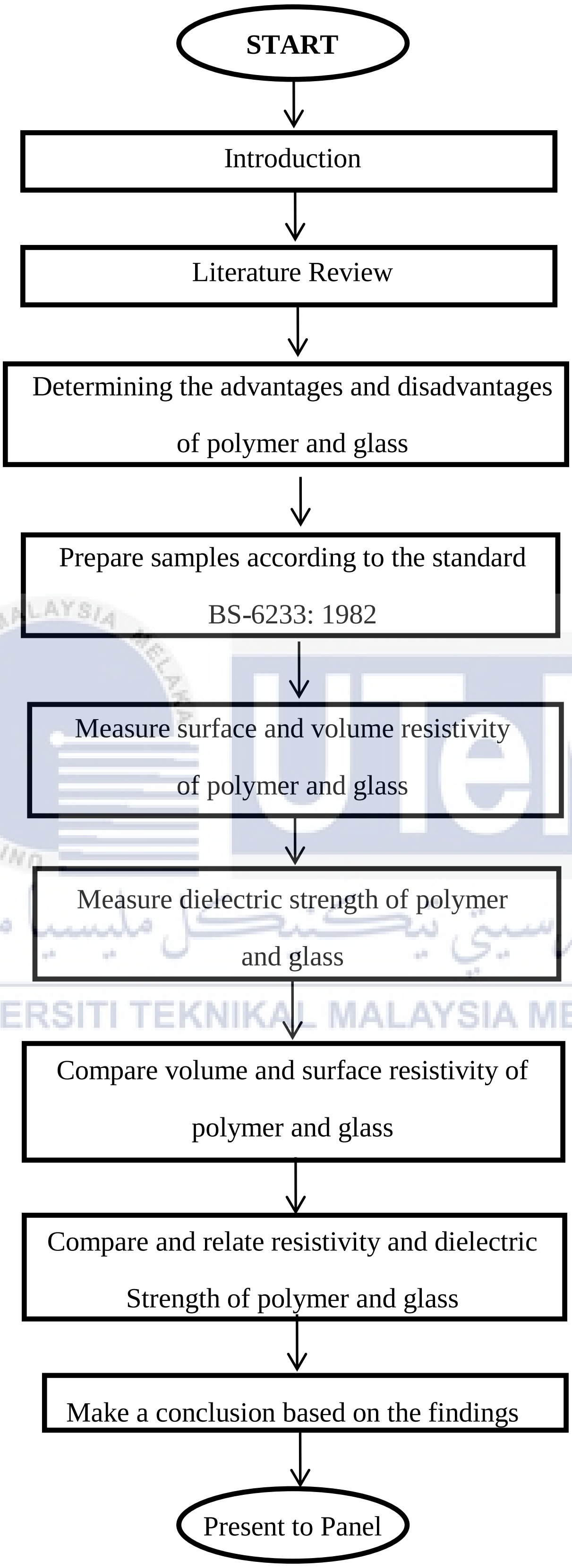

Figure 3.1 (a): Flow Chart FYP 1

3.3 Standard test procedure

3.3.1 Electrodes and specimen

The metal electrodes shall be maintained smooth, clean and free from defects at all times. This maintenance becomes more important when the specimens are being tested. Stainless steel electrodes are preferred to minimize electrode damage at the breakdown. The lead to the electrodes shall not tilt or otherwise move the electrodes or affect the pressure on the specimen, nor appreciably affect the electric field configuration in the neighborhood of the specimen.

3.3.2 Tests perpendicularly to the surface of specimen materials

When specified, boards and sheets over 3mm thick shall be reduced by machining on one side to 3mm ± 0.2mm and then tested with the high potential electrode on the non-machine surface.

3.3.3 Number of tests

Unless otherwise specified, a few tests shall be conducted which is resistivity surface and resistivity volume test to compare the value of both of them. Then the value will related to the dielectric strength test.

3.3.4 Volume resistivity test specimen

For the determination of volume resistivity the test specimen may have any practicable from that allows the use of third electrode to guard error from surface effect. For specimens that have negligible surface leakage, the guard may be omitted when measuring volume resistance, provided that it has been shown that its omission has negligible effect on the result. The gap on the surface on the specimen between the guarded and guard electrodes should be of uniform width and as narrow as possible provided that the surface leakage does not cause error in the measurement. A gap of 1mm is usually the smallest practicable.

3.3.5 Surface resistivity test specimen

For the determination of surface resistivity the test specimen may have any practicable from that allows the use of electrode to guard against error from volume effects. With suitable dimensioning of the electrodes, however, the effect of the volume resistance can be made negligible for wide ranges of ambient conditions and material properties. This condition may be achieved for the arrangement when the electrodes are dimensioned so the surface width is at least twice the specimen thickness; 1mm is normally the smallest practicable. The diameter of the guarded electrode should be at least ten times the specimen thickness, and for practical reason usually at least 25mm. alternatively, straight electrodes or other arrangement with suitable dimensions may be used.

3.3.6 Conditioning before test

The dielectric strength of the insulation material varies with temperature and moisture content. If the specifications are available for the material to be tested, it should be observed. If not, the specimen shall be conditioned for not less than 24 hours at (23 ± 2)°C, 50% ± 5%relative humidity.

3.3.7 Mode of increase of voltage short-times (rapid-rise) test

The voltage shall be raised from zero to a uniform rate until breakdown most commonly to occur between 10s and 20s. For materials which differ considerably in their breakdown voltage, some samples may fall outside these limits. It is acceptable if the majority of breakdowns occur between 10s and 20s. Rate increase must be selected from the following: 100v/s, 200v/s, 500v/s, 1000v/s, 2000v/s and 5000v/s. For a broad spectrum of materials, commonly used rate hike is 500v/s. For materials formed, the rate of increase 2000v/s is recommended to get comparable data.

3.3.7 Voltage source

The test voltage shall be obtained from a step-up transformer supplied from a variety sinusoidal low-voltage source. The transformer, its voltage source and the associated controls shall have the following properties. The ratio of the crest of root-mean-square (R.M.S.) test voltage shall be equal to 2 ± 5% (1, 34...1, 48), with the test specimen in the circuit, at all voltages up to and including the breakdown voltage. The power rating of the source shall be sufficient to meet the requirements of 3.2.6.1 until electric breakdown occurs. For most materials, using electrodes as recommended, an output current capacity of 40 mA is usually adequate. The power rating for most tests will vary from

0.5 KVA, for testing low-capacitance specimens at voltages up to 10 KV, to 5 KVA for Voltages up to 100 KV. To protect the voltage source from damage, it shall be equipped with a device which disconnects the power supply within a few cycles on the breakdown of the specimen. It may consist of a current-sensitive element in the HV supply to the electrodes

3.3.9 Criterion of breakdown

When a short statement required result, the first thing and the six lowest and highest must be accompanied by an increase included. Electric fraction of current flowing in the circuit and the voltage drop [7].The increased current circuit breaker can trip or blow a fuse. However, tripping a circuit breaker can sometimes be affected by lightning more, specimen charges, leakage or partial discharge current, magnetizing current equipment or work. Therefore, it is important that the improved circuit breakers coordinated with the characteristics of the test equipment and materials under test, if not, the circuit breaker can be operated without breakdown of the specimen, or fail to operate when the damage has occurred and therefore do not provide positive criteria damage [7]. Even under the best conditions, a premature breakdown in the ambient medium may occur, and observations can be made to track them during the test. If damage is observed in the ambient medium, they should be reported for any material error-detecting circuit sensitivity is of particular interest, standards for materials that should determine which tests are made perpendicular to the surface of the material, there is usually no doubt when the damage was happening next and simple visual inspection shows the actual breakdown channel, whether it is filled with carbon or not [7].

3.3.10 Electrodes and sample of specimens

Figure 3.1 and figure 3.2 shows the unequal electrode and equal electrode.

Figure 3.1 unequal electrode

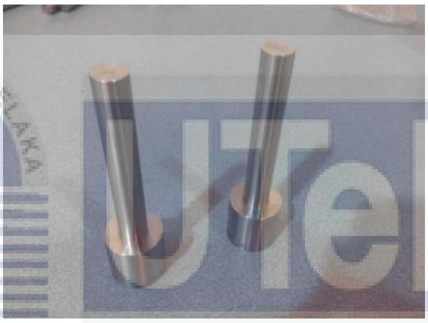

Figure 3.2 equal electrode

3.1.11 Experiment Set up for AC Test

Figure 3.3 shows a schematic diagram of AC test setup. These diagrams show the value of each capacitor that has been used in AC test setup with the right ratio.

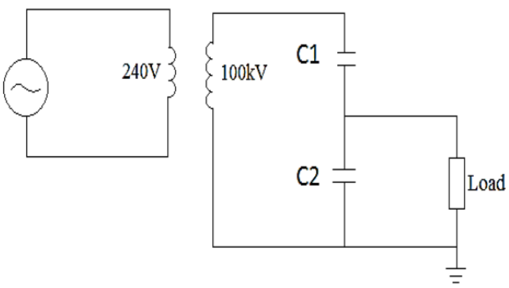

Figure 3.3: Schematic diagram of AC test setup

C1: Charging/ Measuring Capacitor (100pF/ 100kV AC)

C2: Secondary Capacitor (6nF/ 100kV AC)

3.3.12 Apparatus of high voltage test:

a) OT-operating Terminal

b) Discharge Rod

c) DT-Digital Measuring Instrument

d) Faraday Cage with interlock System

e) Oscilloscope

f) Single Phase Step up Transformer

There are two types of test electrodes, the perpendicular and parallel to the sample under test is available to test the dielectric strength. It likewise calls for a number of specimen types such as wood and sheet material, elastic tubes and sleeving tape, moving picture and narrow band. Here, the dielectric strength test was carried out accordingly with the means to test boards and sheets of materials to the electrode for testing. Figure 3.4 shown electrode set up BS EN 60243-1[11].

Figure 3.4: Electrode set-up to comply with BS EN 60243-1 [11]

In summation to the test electrode, some important equipment that was practiced. They are Operation Terminal (OT) 276, Digital Measuring Instruments (DMI) 551, oscilloscope, and single phase Haefely transformer that is able to generate voltages up to 100 KV high voltages. Figure 3.5 shows the oscilloscope, OT 276 and 551 DMI for high voltage control and measurement.

Figure 3.5: High voltage control and measurement equipment

3.3.13 Procedure of dielectric strength

1. The apparatus was set up as shown in the figure 3.6 and the actual setup is shown in figure

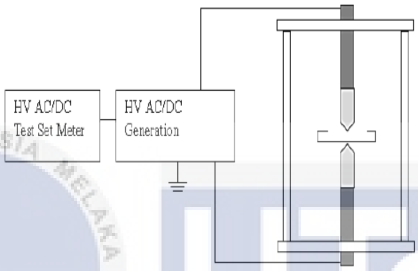

Figure 3.6: dielectric strength test set up

Figure 3.7: actual set up for AC test

2. The Operating terminal and Digital measuring were turned on

3. The specimen placed at Testing Electrode set-up.

4. Increase voltage 10 V at operating terminal and rest for 5 second, repeat this increasing voltage until breakdown occurs as shown in Figure 3.8.

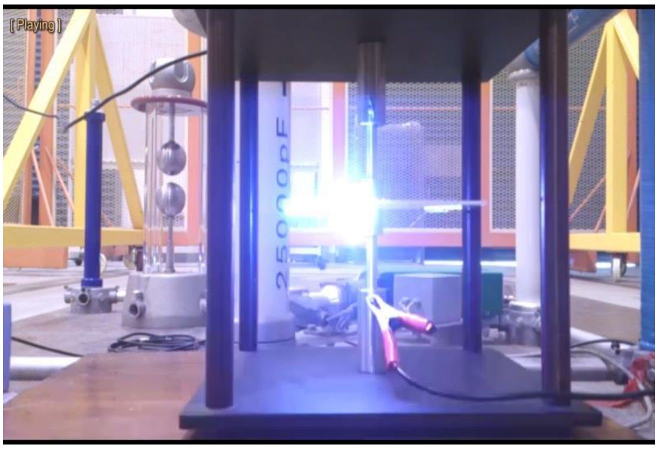

Figure 3.8: Breakdown occurs at test set up

5. The indicator reset at Digital measuring was ON when breakdown.

6. The voltage was then decreased to 0V and HV AC/DC Test Set Meter was turned off.

7. The Breakdown voltage was read and record from digital measuring.

8. The reset button was pushed.

9. The apparatus was then discharged

10. The steps were repeated for the next material

3.3.14 Safety

Safety takes the most important part during conducting tests in the high voltage laboratory. All aspects should need to be taken in order no harm or injuries happen during experimental work. Operation and safety precaution must be observed to insure safety for people that conduct testing and also prevents damage to equipment.

3.3.14.1 User safety

a) When utilizing the high voltage lab, rule listed below must be follows.

b) No student is permitted to work in Laboratory in the absence of either lecturers or technician.

c) No student should be allowed to charge the connection of the generator without supervision of the lecturer or technician.

d) Don’t work alone; in case of an emergency another person‟s presence may be essential.

e) Wear rubber shoes or sneakers as a protection to the user.

f) Have a fire extinguisher rated for electrical fires readily accessible in a location.

g) Connect or disconnect any test leads with the equipment unpowered.

h) The experimental work cannot be done when the user is tired to avoid careless happen during testing.

i) All the supplies must switch off before leaving the laboratory

3.3.14.2 Faraday cage with interlock cage

The installation of high voltage generator itself in the lab should also be enclosed by the safety system. The reason of system is to protect human or livestock or the equipment itself from harm and damage. Testing area for generator is covered by cage to prevent unwanted movement by human. The area should be isolated with metal cage height at least 1.8 meters and a maximum grid spacing of 50 millimeters. The area surrounds the generator should all be grounded to the earth and equipped with additional safety system such as interlocking, which mean the system cannot operate as long as cage are considered open and unsafe by the system. The system was equipped with the contact at the door and the discharge rod. Both door and the discharge rod need to be placed in a proper place if it were not opened during the testing period, the contact will open and interlocking system will shut the generator automatically and terminate the voltages.

3.3.15 Resistivity Test

This test is to measure the total resistance of a solid insulation. There have two part of test which is surface resistivity and volume resistivity.

3.3.15.1 Procedure Resistivity Test for Volume

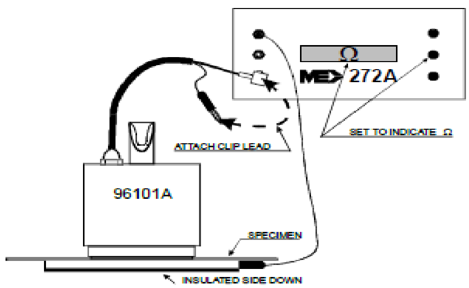

Figure 3.9: Resistivity Test for Volume

1. Connect the probe to the Model 272A by attaching the coaxial plug to the mating connector in the front panel and inserting the miniature banana plug into the jack directly above.
2. Surface-a metal plate with an insulative surface-and a cable with banana plugs on each end.
3. Connect this cable between the hole on the side of the plate and the metallic jack on the side of the Model 272A.
4. Place a specimen on the insulative surface of the plate and set the probe on top of the paper.
5. Press the ON-OFF switch.
6. The value will be displayed within a few seconds.
7. . The apparatus was then discharged
8. The steps were repeated for the next material

3.3.15.2 Procedure Resistivity Test for Surface

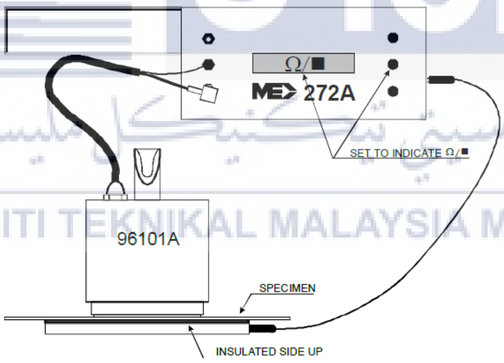

Figure 3.10: Resistivity Test for Surface

1. Connect the probe to the Model 272A by attaching the coaxial plug to the mating connector in the front panel and inserting the miniature banana plug into the jack directly above.

2. Surface-a metal plate with an insulative surface-and a cable with banana plugs on each end.

3. Connect this cable between the hole on the side of the plate and the metallic jack on the side of the Model 272A.

4. Place a specimen on the insulative surface of the plate and set the probe on top of the paper.

5. Press the ON-OFF switch.

6. The value will be displayed within a few seconds.

7. The apparatus was then discharged

8. The steps were repeated for the next materia

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

This project focuses on the correlation between resistivity and dielectric performance of polymeric material insulation under standard test procedures. Basically, polymeric insulating materials have a lot of advantages compared to ceramic materials. This is because; the size of polymer is larger than the size of ceramic. Other than that, the weight and breakage of polymer is significantly higher than ceramic. These are the reasons why polymeric materials are chosen rather than ceramic materials.

Table 4.1: Comparisons between Ceramic and Polymeric Insulation

Property	**Ceramic**	**Polymer**
Compressive Strength	+	-
Size	- -	+ +
Weight	- -	+ +
Breakage	- -	+ +
Material Cost	+	-
Ageing	+ + +	+ +

+good – weak

4.2 Test conditions of dielectric strength test and resistivity test

As referred to the previous chapter, the flat sheet specimen sample of propylene (PP), glass and tiles was 3mm thick. First, resistivity test done for volume and surface test of specimen sample. After that, continued with dielectric strength test. During pre-test for dielectric strength , the surface of the electrode were cleaned by using ethanol in between two successive voltage applications in order to make sure that the electrode is clean from dusts and other impurities. Table 4.2 describes the condition of specimen during test.

Table 4.2: condition of specimen under test

Test conditions	Notice
Specimens: Type: Thickness: Number of specimens:	Propylene (PP), glass and tile Flat sheet surface 3 ± 0.2 millimeter, by digital caliper 5 samples used
Frequencies used	50 Hz
Treatment and conditioning before testing	N.A
Temperature	$25 \pm 3^{o}C$
Humidity	70%RH
Electrode	Stainless steel:304 Unequal diameter electrodes- 25mm/75mmØ Equal diameter electrodes- 25mm/25mmØ
Method of measurement :	Electrical strength V/mm Surface resistivity Volume resistivity
Mode of the voltage rises	Short time-rapid rise test 2000V/s

4.3 Result of the project

The recorded result for each experiment will be shown in details for each sample of high density Propylene (PP), glass and tiles under an equal and equal shape of electrodes. Then, it will be analyzed for better understandings.

4.3.1 Breakdown of specimen

Dielectric strength test is done to know the maximum voltage that certain insulators can withstand and the voltage is call breakdown voltage. Table 4.3 shows the value of breakdown voltage of specimen.

Table 4.3: Breakdown voltage of specimens

Number of Specimen	Breakdown Voltage of Different Materials (V)					
	Glass		Tile		PP	
	kV	kV/mm	kV	kV/mm	kV	kV/mm
1	79.29	55.45	20.49	14.33	95.33	66.67
2	79.29	55.45	21.38	14.95	95.33	66.67
3	79.29	55.45	20.49	14.33	95.33	66.67
4	79.29	55.45	22.27	15.58	95.33	66.67
5	79.29	55.45	29.40	20.56	95.33	66.67
Average	79.29	55.45	22.81	15.95	95.33	66.67

4.3.2 Resistivity of specimens

Resistivity test is done to know the values of surface and resistivity that certain insulators can withstand. Table 4.4 shows the value of surface and volume resistivity of specimen.

Table 4.4: Resistivity of specimens

	Glass	**Tile**	**Propylene**
Surface (Ω/m^2)	3.71x10^8	1.83x10^{11}	Value to high
Volume (Ω/m)	1.95x10^{11}	1.18x10^{12}	Value to high

4.4 Discussion

In this section the results from previous section were discussed. The results from tables are converted to bar chart to ease viewing and analyzing. The difference in breakdown voltage and resistivity of surface and volume are to be discussed later.

4.4.1 Breakdown voltage of polymer using equal and unequal electrodes

The mode voltage raises that used are short time-rapid test 10kV/s. In equal shape of electrode, after voltage increased in valued of 13.36kVpeak or 18.7kV in rms.

4.4.2 Breakdown voltage of glass

For glass, Figure 4.1 shows the AC waveform during a breakdown voltage of specimen is 55.45kV.

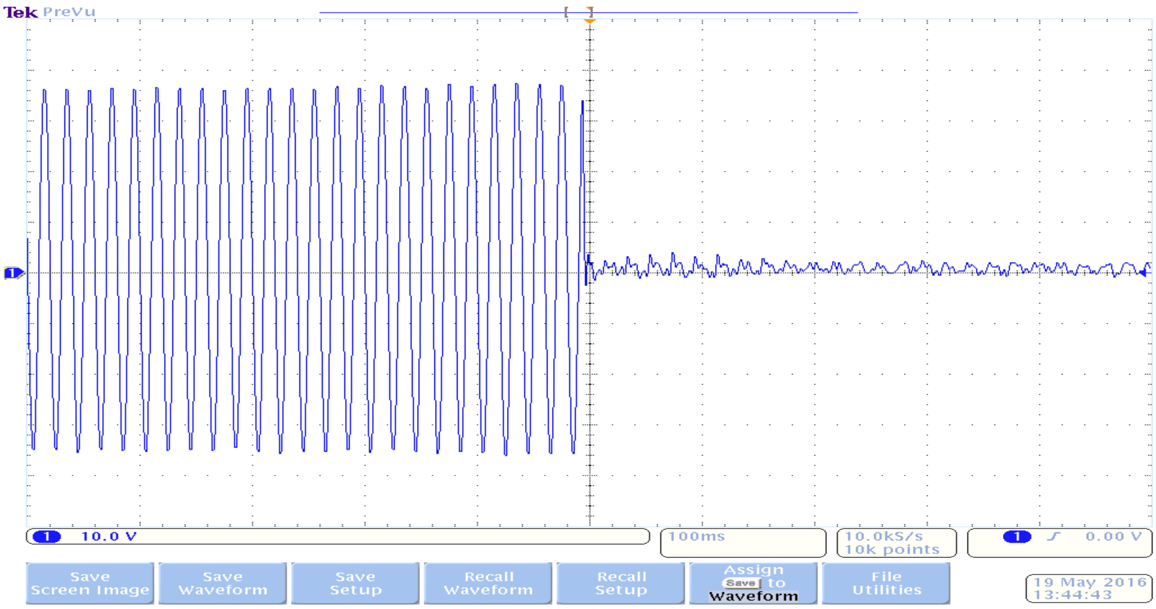

Figure 4.1: captured AC wave during breakdown voltage of glass

4.4.3 Breakdown voltage of polymer propylene

For propylene, Figure 4.2 shows the AC waveform during a breakdown voltage of specimen is 66.66kV.

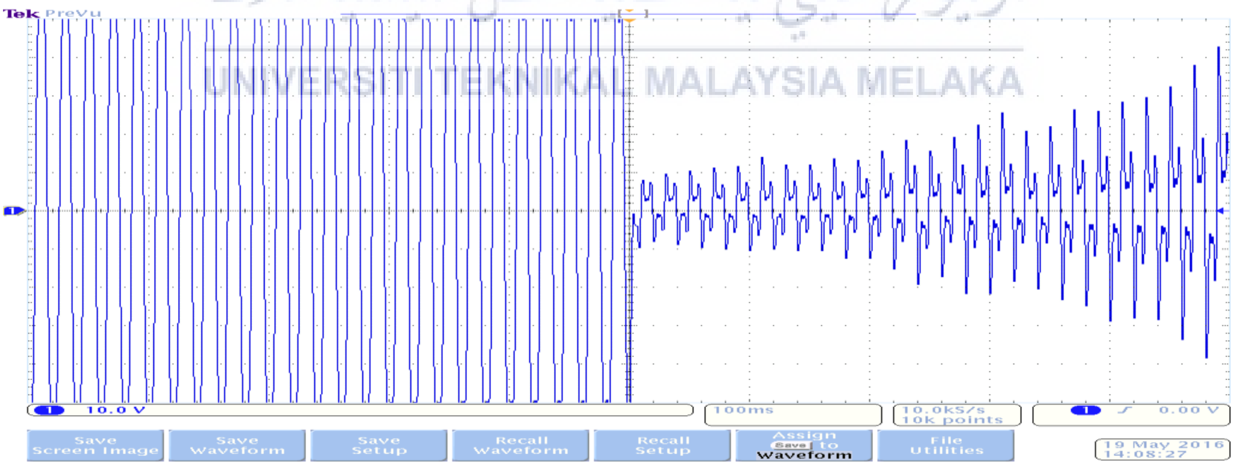

Figure 4.2: captured AC wave during breakdown voltage of polymer propylene

4.4.4 Breakdown voltage of tile

For tile, Figure 4.3 shows the AC waveform during a breakdown voltage of specimen is 14.95kV.

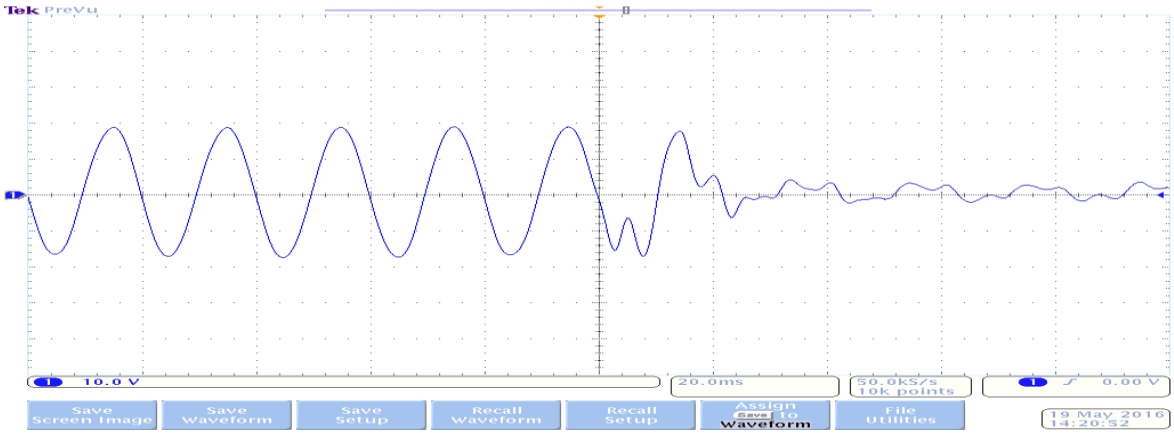

Figure 4.3: captured AC wave during breakdown voltage of tile

From all result of different type of materials, breakdown voltage of result was plotted as Figure 4.4; five specimen of each material are tested to find breakdown voltage and by calculating the average voltage for each specimen. The performance of dielectric strength for different type of material can be evaluated while Figure 4.5 shows the average breakdown voltage under different materials.

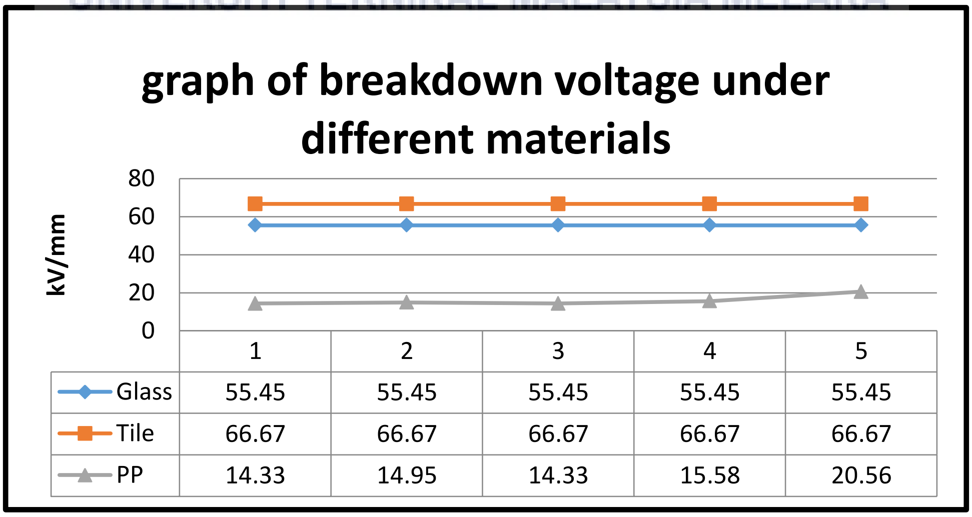

Figure 4.4: breakdown voltage of different materials in kV/mm

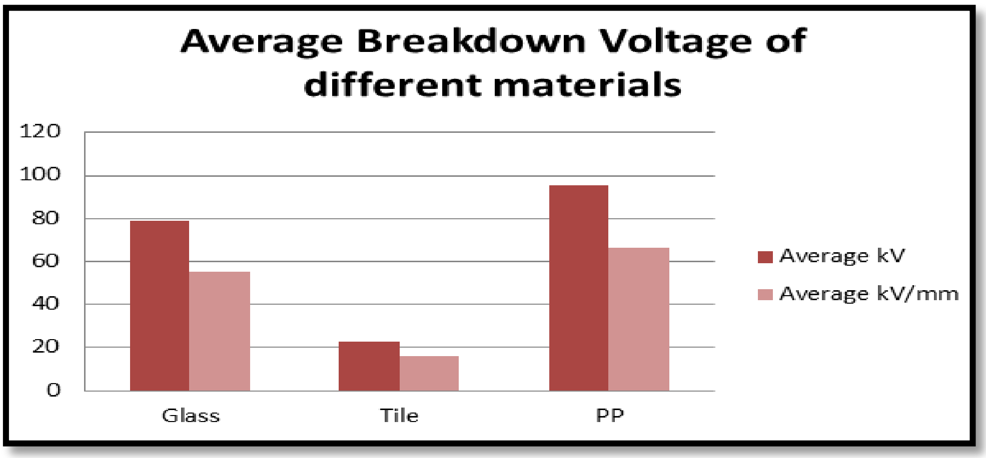

Figure 4.5: Average breakdown voltage of different materials

From the test was held out as BS EN 60243-1-1998 [11],the minimum field strength requirements of the material glass, tile and propylene breakdown should be greater than 10kV/mm. The specimen of those materials was tested and average of breakdown voltage was calculated in kV and kV/mm. For glass, tile, and propylene, the average value of breakdown is 79.29, 22.95, and 95.33 in kV and 55.45, 15.95, and 66.67 in kV/mm. The performance of dielectric strength of those materials can be judged by the values same goes to resistivity value. Other than that, the minimum volume resistivity requirements of the material glass, tile and propylene breakdown should be greater than 10^{10} Ωm. For glass and tile, the value of surface resistivity is 3.7x10^{8}, 1.8x10^{11}, and value too high for propylene. All the value in Ω/m^2. The value of surface resistivity shows that the propylene is too high beside the volume value. The specimen of those materials for volume resistivity is in Ω/m. The value of volume resistivity for glass and tile is 1.95x10^{11} and 1.183x10^{12}, propylene also has value too high. This is because the value of propylene is greater than limit which is 2.0x10^{14}Ω. However, propylene has the highest value in breakdown voltage, surface resistivity and volume resistivity. This value does past the demand of breakdown, surface and volume resistivity to replace glass and tile due to lowest values of them. So this type can be employed as a good design in high voltage insulation design; it is recommended for this type of polymer to improve the performance in each test of dielectric and resistivity, by serving lots of research since this polymer can be used as high voltage insulation in the future.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

For the conclusion, this study focuses on the performance thermoplastic materials as high voltage insulation material with two others material which is glass and tile. In this study the thermoplastic polymeric materials has been selected is propylene (PP). Among the basic needs to examine and evaluate the performance of selected materials as external high voltage applications is its dielectric strength and resistivity level. In finding out the dielectric strength of the selected material, breakdown test on the specimen is taken and resistivity test is done. The test parameters, dimensioning and condition is conducted based on three different material which is glass, tile, and propylene accordingly to the British Standard of volume resistivity and surface resistivity of solid electrical insulating materials, BS 6233:1982 and also the British Standard for electrical strength of insulating materials, BS EN 60243-1:1998. With the standard, all the criteria of the standard must comply in society to get proof of the result measurement and all measures already discussed in the former chapter. The aim of this project to study correlation of dielectric strength and resistivity of polymeric material in insulation and determine up the experiment based on dielectric strength and resistivity standard are achieved. The analysis of dielectric strength and resistivity, performance of different type of materials need to bear in order to evaluate which materials can be used as high voltage insulation.

From the finding of project, Propylene (PP) meet the requirements of different material under all the breakdown field strength and resistivity test. However Propylene has the value too high in resistivity test and highest in breakdown voltage but still the breakdown of this polymer does comply with the request, which is must greater than the minimum requirement of 10^{10} Ωm with the reference to the international standard to the British Standard of volume resistivity and surface resistivity of solid electrical insulating materials, BS 6233:1982 and also must exceed the minimum requirement of 10kV/mm with the reference to the British Standard for electrical strength of insulating materials, BS EN 60243-1:1998 that has the most influence on performance of polymeric material. From this analysis, is it hoped that the result will help industries and better understanding of the insulations cases. There was always have a better way to improve the insulation material in order to help or preventing damaged and injured to worker during unexpected condition.

5.2 Recommendation

For future study of this project, there are some recommendations to be suggested. First is in order to increase the performance of the dielectric strength of propylene (PP), a smaller diameter of electrode which will later give a higher breakdown voltage.

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