I hereby declare that I have read through this report entitle "Surface Tracking and Erosion Performance Insulation Material Under Different Frequency Behaviour" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)

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Date :

SURFACE TRACKING AND EROSION PERFORMANCE INSULATION MATERIAL UNDER DIFFERENT FREQUENCY BEHAVIOUR

MUHD FAIRUS NIZAM BIN MUHAMAD

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

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

I declare that this report entitle “Surface Tracking and Erosion Performance Insulation Material under Different Frequency Behaviour” is the result of my own search except as cited in the references. This report has not been accepted for any degree and is not concurrently submitted in candidate of any other degree.

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Signature	:
Name	: MUHD FAIRUS NIZAM BIN MUHAMAD
Date	:

To my beloved family especially my father and mother Mr Muhamad Bin Yaacob and Norhawati Binti Haji Harun. Also to my siblings for their supports and also goes to everyone that directly or indirectly in this project.

May Allah bless all of us.

Wassalam.

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First of all I would like to express my gratitude and thanks to our God, Allah S.W.T for HIS guidance to make me finish the report.

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ABSTRACT

This project is conducted to investigate the effect of surface tracking and erosion performance of polymeric insulation material under different frequency behaviour in term of their ageing factor by using an inclined plane test. Although this polymeric insulation has been used for many years, the limitation of this type of insulation material is ageing where their lifetime performance is the main problems. The aim of this study is to investigate the effect of different frequency behaviour on the polymeric insulation material by complying BS EN60587 which the international standard for tracking and erosion. Polymeric material is hydrophobic type where it is water repellent compare than glass ceramic which is a type of hydrophilic. This project has been conducted by constructing the inclined plane test (IPT) to evaluate the resistance of surface tracking and erosion performance under different frequency. Some of IPT advantages is IPT is fast, good educational tool, require close attention and the cheapest among the other test procedure. The method including of development the LabVIEW software circuit, inject the fixed power supply which is 3.5 kV and the varying the frequency where the frequency is changed from 50 Hz to 1 kHz. Data were recorded and analyse between all the specimens to study the effect of surface tracking and erosion performance of polymeric insulation under different frequency.

ABSTRAK

Projek ini dijalankan untuk mengkaji kesan ke atas pengesanan di permukaan dan prestasi penghakisan terhadap bahan penebat pada julat frekuensi yang berbeza dalam terma faktor usia dengan menggunakan IPT dengan mematuhi piawaian kebangsaan BS EN60587. Walaupun bahan penebat polimerik telah digunakan sejak 50 tahun yang lalu, tetapi masalah pada bahan penebat polimerik ini adalah penuaan bahan tersebut dimana prestasi untuk kegunaan jangka masa yang lama menjadi punca utama masalah ini. Bahan polimerik ini adalah jenis hydrophobic dimana ia air tidak melekat padanya berbanding dengan kaca seramik yang bersikap hydrophilic. Projek ini telah dilakukan dengan membina IPT untuk menilai nilai rintangan pada prestasi permukaan dan penghakisan pada frekuensi berbeza. Di antara kelebihan penggunaan IPT ialah IPT lebih cepat, kaedah pembelajaran yang bagus, memerlukan pemerhatian yang mendalam dan kaedah ujian yang murah berbanding dengan prosedur ujian yang lain. Kaedah yang dijalankan semasa projek ini adalah membuat litar pada perisian LabVIEW, memberikan nilai voltan yang tetap iaitu 3.5 kV tetapi nilai pemboleh ubah di mana frekuensi diubah dari 50 Hz hingga 1 kHz. Data direkod dan spesimen dikaji dan dianalisis dari segi kesan ke atas pengesanan di permukaan dan prestasi penghakisan.

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LIST OF SYMBOLS

SYMBOL	TITLE
HV	High Voltage
HDPE	High Density Polyethylene
PP	Polypropylene
IPT	Inclined Plane Test
BS	British Standard
AC	Alternating Current
DC	Direct Current
Hz	Heartz
KV	Kilovolts
PVC	Polyvinyl Chloride
mm	Milimeter
ρ	Density
TFD	Time Frequency Domain
LC	Leakage Current

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CHAPTER 1

INTRODUCTION

1.1 Research Background

As to prevent the current flow to undesired paths, the insulation play an important role to keep the high voltage (HV) applications running well. Although the type of insulation had been used since 1900's, it is still under study and improvement. It involves the development of designing the insulator, material of insulation, development of practical monitoring and measurement [1]. Material for the insulation on outdoor and indoor is still under study and recent development of an insulation that are used ceramic and non-ceramic type. Material can be classified into 3 type of measuring ageing from diagnostic properties which are mechanical properties, chemical properties and electrical properties.

For electrical properties, the material can be test by the dielectric strength, resistivity and tracking and erosion. Tracking and erosion mostly test for outdoor used. Polymeric type of material was selected to be tested in this study because of its advantages compared to non-ceramic insulation. Among them are low surface energy and hydrophobicity surface properties [2]. Polymeric insulation is good resistance against vandalism damage, less cost and lighter in weight. Although this polymeric insulation had been used over 50 years, the questions still exist regarding to their lifetime performance. Therefore, the focus of this research is to study the life performance on surface tracking and erosion performance of polymeric insulation material with different frequency behaviour according to BS EN60587.

1.2 Project Motivation

This project has been motivated by the several previous studies and experimental. On the previous research, this test has been conducted under non material test. To complete the project, this polymer insulation has been test on surface and erosion tracking using different frequency behaviour.

Because of its advantages, the polymeric material seems become the imperative material proportionate from porcelain and glass fibre. Thus, this polymeric material now replacing the porcelain and glass usage in the transmission line and distribution industry.

1.3 Problem Statement

On previous study, the IPT test were conducted comply with the standard BS EN60587-1 which is using AC supply of 3.5 kV and 50 Hz of frequency. In the real world application, the AC supply and the frequency might be different. Hence, the aim of this project is to study the ageing by surface tracking and erosion performance on different frequency behaviour. What is the effect if different frequency is used on the polymeric insulation?

1.4 Objectives

In this study, the main objective to be achieved is:

1. To conduct different frequency and standard tracking and erosion test for polymeric insulation material.
2. To observe and compare the physical result of different frequency and standard test on surface tracking and erosion performance of polymeric material.

1.5 Scope of Works

The scope of work will be focused on:

1. International standard on tracking and erosion test according to BS EN60587-1 is complied.
2. The range of frequency to be tested are between 50 Hz to 1 kHz.
3. Material to be studied is polypropylene (PP)
4. Method 1 is the selected method for this test.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this segment, a few studies have been directed in regards to following and disintegration of the polymeric protection material test. The stream of studies begins from the sort of polymeric protection, caught up with the element influenced in polymeric protection, which is focused on surface tracking and erosion due ageing factor. Numerous studies have been led to comprehend the instruments of ageing, build up benchmarks for the testing of quickened ageing in research. Furthermore investigation strategies to demonstrate the debasement and the components of ageing of polymer materials utilized as a part of protection. From the past examination, the testing for surface tracking and erosion has been set up by utilizing a few test which one of that is IPT (inclined plane test). In general of the study has utilizing the standard BS EN 60587 in light of the fact that this standard has meet the specification and the aftereffect of the test is demonstrated as a substantial result.

2.2 Insulation Materials

Electrical insulator must be utilized as a part of electrical framework to avert undesirable stream of current to the earth from its supporting focuses. It is the most important material in the high voltage industry. The separator assumes an imperative part in electrical system. Insulator is a high resistive way through which for all intents and purposes to ensure the current disable to flow through it and also along these lines make it almost difficult to direct an electric current affected by an electric field. There are 3 sorts of insulating material which comprise of gas, fluid and solid or composites. This insulator appears differently in relation to different materials, semiconductors and conduits, which transmit electric current all the more effortlessly. The property that distinguishes of this insulator is its resistivity.

Based on the study for this project, a large amount of organic and inorganic materials had been used. Thus, high voltage insulation material can be classified into 3 groups which is organic materials, inorganic materials and synthetics polymers. There are numerous good insulating material can be used for protective coating on electrical wire and cables such as glass, rubber, PVC, asbestos and paper [3][4]. Therefore, the electrical insulation is stressed by several factors that is:

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i. Dielectric
ii. Thermal
iii. Mechanical
iv. Chemical
v. Radiations

Ecological conditions, for example, temperature, dampness, weight can modify the dielectric properties of an electrical system prompting its disappointment because of not sufficient properties or corruption under that particular ecological condition. Hence, polymeric insulation material are picked as a result of its particular favourable circumstances, contrasted with the ceramic insulators.

2.3 Polymeric Insulation

Polymeric insulation is a hydrophobic type of insulation which means it is water repellent. Compared to ceramic material that is hydrophilic. But the limitations of the polymeric material is life performance. There are several ways to decide their life performance. Previous studies shows that, surface tracking and erosion on polymeric insulator can be displayed by utilizing leakage current [5]. Surface tracking and erosion had been test by using inclined plane test (IPT) method according to BS EN60587-2007 is directed on polymeric insulation.

Polymeric composite insulations were introduced in service for outdoor distribution and transmission for more than four decades. In high voltage insulation, there are three classes of polymeric material which are epoxy resins, hydrocarbon elastomers and silicone elastomers [6]. Polymeric material can be divided into two groups consists of thermoplastic and thermosetting. For this study, thermoplastic is selected for its low melting temperatures property. Thermoplastic consists of Polypropylene (PP) and High Density Polyethylene (HDPE).

Many research had been done on this polymeric insulation to improve its lifespan and performances. This is because of its physical and economic especially. Due to the advantages of the polymeric insulation compared to the ceramic insulation, it has replaced the use of ceramic insulation in the high voltage industry. Some of the advantages are [7]:

i. Low surface energy
ii. Better contamination performance
iii. Light in weight
iv. Easy to handle
v. Easy transportation and installation

For this study, PP is selected as a material under study because its properties that fulfil the requirements.

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2.4 Polypropylene

There were two type of this thermoplastic polymers which is polyethylene (PE) and polypropylene (PP). Both of this properties had different in term characteristics of resistivity on temperature, moisture and chemical. Polypropylene (PP) has a good resistance to organic solvents, degreasing agents and electrolytic attack. Compare to polyethylene (PE), PP has lower impact strength. Despite the fact that polypropylene not good at receiving an impact, the reaction on temperature and tensile strength is better than PE. In addition, Polypropylene (PP) is one of flexible polymers and does not retain water. It is more hydrophobic which is unequipped for dissolving in water. The advantages of the polypropylene as below [8] [9]:

i. Lightweight
ii. High tensile strength, high heat resistance and impact resistance
iii. Non-toxic and non-staining
iv. Good dielectric properties
v. Resist chemical and stress cracking
vi. Easily fabricated

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2.5 Factors Affected In Polymeric Insulation

All material that had been used for insulation in high voltage industry will had their factor to lead to problems on the transmission line or distribution. Therefore, in this research the factors that affect the performance of the polymeric insulation are ageing, water treeing, electrical trees and contaminant factor. For this study, ageing factor is the main factor that affected the life performance of the polymeric insulation.

2.6 Ageing

The major problems that lead to failure of an insulator is ageing. Ageing which can cause either surface tracking or erosion. Both of this defect can affected the life performance of the polymeric insulator. Ageing is a factor when the life performance of the insulator is reduce or failure due to any changes in the chemical, mechanical and electrical properties of the polymeric materials [10]. It consists in the degradation with time of one or several properties. Ageing is one of the factors that affect life performances of insulation material and will meet failure when the polymer encounter several type of stress which are electrical, environment, mechanical, heat, and weather pollution [11]. Surface tracking and erosion are the method to test the life performance of the polymeric insulation.

2.7 Surface Tracking and Erosion

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Surface tracking and erosion one of the failure factor of the type insulation. It will decrease the long term performance for the insulation. Based on the study, surface tracking execution and erosion could be monitored by a leakage current behaviour. Surface tracking is where the physical state of the polymer insulation had some problems where when the thermal and electrical energy change from dry band arcing. This happen when the energy changes had limit the durability of the insulator which can lead to decomposition. Meanwhile, erosion happened when the insulator encounter loss of material because of leakage current and electrical discharge happened [12] [1]. According to BS EN60587, surface tracking and erosion is apply to study the effect of this ageing performance.

2.8 Surface Tracking and Erosion Performance Test

The best ways to investigate about the ageing of polymeric insulation is by examined the insulation material that is polypropylene under the actual area situation. Unfortunately, the time taken for the effects of this aging will take a long period of time. Therefore, surface tracking and erosion test consenting to BS EN 60587-2007 are led, at that point leakage current recurrence parts is utilized as an analytic apparatus for their surface condition checking and degradation seriousness. Basically, there are also other test can be conducted to test this surface tracking and erosion that is tracking wheel dust, fog test and salt fog test. All of the test are based on standard and each test have their own objective and purpose on getting the results [13]. For this study, IPT was chosen because of its advantages and it fulfil the requirement needed. The advantage of performing this test are because it is economical and all the material is provided. Furthermore, the results found within a short term period. Unfortunately, by using this procedure will make the researcher experienced in difficulty to determining the initial tracking voltage. Based on the study, a test to carry out performance of insulating material has been made. Table 2.1 has shown the important properties of material and minimum requirement of polymeric insulation.

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Table 2.1: Important properties and minimum requirement of polymeric insulation [14]

Property	Minimum Requirement	Test Standard
Resistance to tracking and erosion	1A3,5b	IEC 60587*
Tear strength	>6N/mm	ISO 34-1*
Volume resistivity	>10MΩ	IEC 60093*
Breakdown field strength	10kV/mm	IEC 60243-1*
Water diffusion test	Voltage test -12kV-1min or tan δ<0.2	IEC 62217* IEC 60250*
Arc resistance	>180 s	IEC 61621*

2.9 Inclined Plane Test (IPT)

The inclined plane test on surface tracking and erosion is one of popular testing procedure to evaluating the surface tracking and erosion on polymeric insulation material. Based on standard BS EN60587:2007, the sample of polymeric insulator must be in rectangular shape with the size of 120 x 50 x 6 mm. The sample are place at 45 degrees angle according to the standard stated. Conductive solution (ρ = 3.95Ω.m) is dripping on a filter paper and streaming down the specimen towards the ground electrode where dry band arcing for the most parts happens [15]. Base on previous study, this test is conducted in the lab where the variable transformer has been used where on the other hand, the secondary voltage can be adjusted according to standard values (0-6kV) with a rated current not less than 0.1 A for each specimen. Then, the transformer will be through to the fixed resistor and connected to upper electrode that been tide with the specimen. The lower electrode is connected to ground. The peristaltic pump acts as a medium to flow the contaminant flow rate at the upper electrode. Figure 2.1 has shown the IPT test experimental setup.

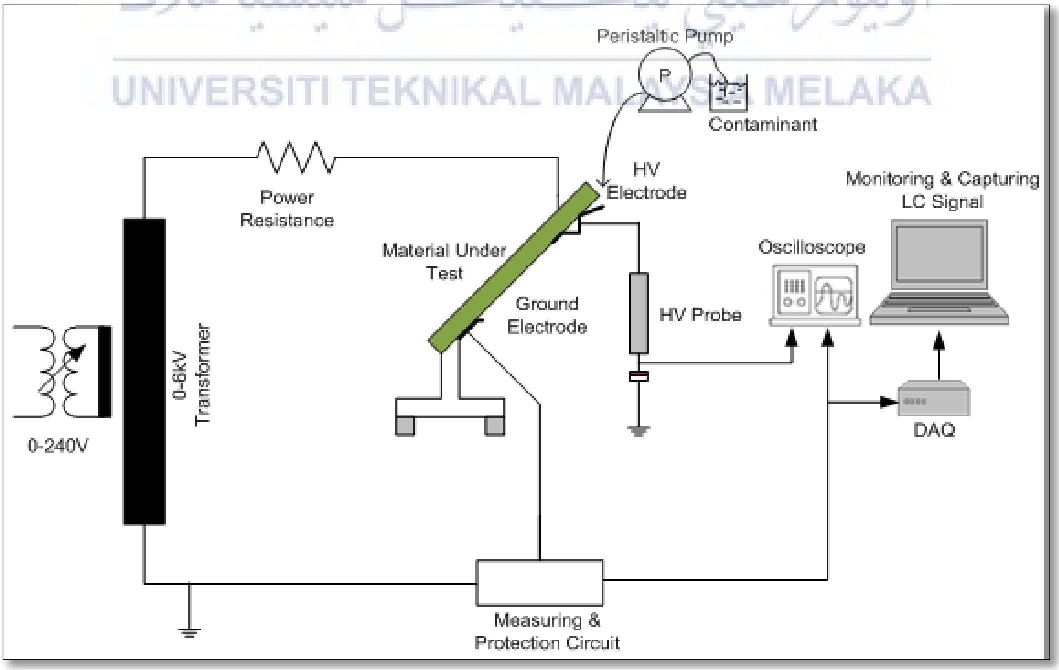

Figure 2.1: Inclined Plane Test Setup based on BS EN60587:2007 (IPT)

2.10 Standard Test Method in IPT

Standard test procedure according to BS EN60587 is used to analyse the validation results of surface tracking and erosion performance of polymeric insulation material. The international standard had fixed two methods for evaluation of insulating materials. The two methods is to make sure the insulating materials can be use under severe ambient condition at power frequencies of 45 Hz to 65 Hz. This method can be verify by measuring the resistance of surface tracking and erosion, using contaminant and inclined plane test specimens. The two methods are describe as below [15]:

i. Method 1: constant tracking voltage
With the contaminant flowing uniformly at the specific rate, switch on and raise the voltage to one of the preferred test voltage which should be reached within a maximum of 10 seconds, and start the timing device. The voltage should be maintain for 6 hours. If the test were conducted again with the different voltage either high or low, each of the test need a further set of five specimens that shall be tested for each selected voltages. The consistent tracking is the most elevated voltage withstood by all the specimen for 6 hours without problems.

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ii. Method 2: stepwise tracking voltage
By selecting a starting voltage that able to multiple of 250 V, failure would not occur sooner than the third voltage step but a preliminary trial test may be necessary. The contaminant flowing uniformly at the specified rate, switch on and raise the voltage to the selected value. Maintain the voltage for 1 hour and increase by multiple of 250 V for each subsequent hour until failure. As the voltage is increases, the contaminant flow rate and resistance value of the series resistor is increased according to Table 2.1. The stepwise tracking voltage is the highest voltage withstood by all the five specimens for 1 hour testing without failure.

Table 2.1: Standard test parameter

Test voltage kV	Preferred test voltage for method 1	Contaminant flow rate ml/min	Series resistor, resistance kΩ
1.0 to 1.75	-	0.075	1
2.0 to 2.75	2.5	0.15	10
3.0 to 3.75	3.5	0.30	22
4.0 to 4.75	4.5	0.60	33
5.0 to 6.0	-	0.90	33

2.11 Polymeric Surface Tracking and Erosion on Frequency Behaviour

On the past research, glass is chosen as non-polymeric and Polypropylene (PP) as the polymeric insulation material. Surface tracking and erosion test had been done by following the standard BS EN 60587-2007 are conducted on these materials and information obtaining by using the Lab View project is utilized for leakage current (LC) data. By the parameters that has been establish, the order of surface tracking is made. As a result, the leakage current contain non-static signal. From this, it can be reasoned that time frequency domain (TFD) is suitable devices for surface condition observing. The investigations of leakage current are based on frequency domain and time-frequency representations are directed. As conclusion, the surface state of polymeric insulation material state can be divided precisely by utilizing spectrogram [5] [16].

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2.12 Conclusion

As conclusion, based on the previous study shown that polypropylene (PP) insulation material are able to be used for outdoor insulation because of its physical characteristics and the advantages. The PP is selected because this insulation material passed all the test according to method 1 in BS EN60587 standard. According to standard, the results of the observation will become valid as it had been stated on the standard. If the test conducted based on non-standard procedure, the result can't be proven as a valid result because it is not follow the standard.

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2.13 Summary

Figure 2.2 has shown the summarization of literature review from previous work of tracking and erosion test by following to the BS EN60587 standard.

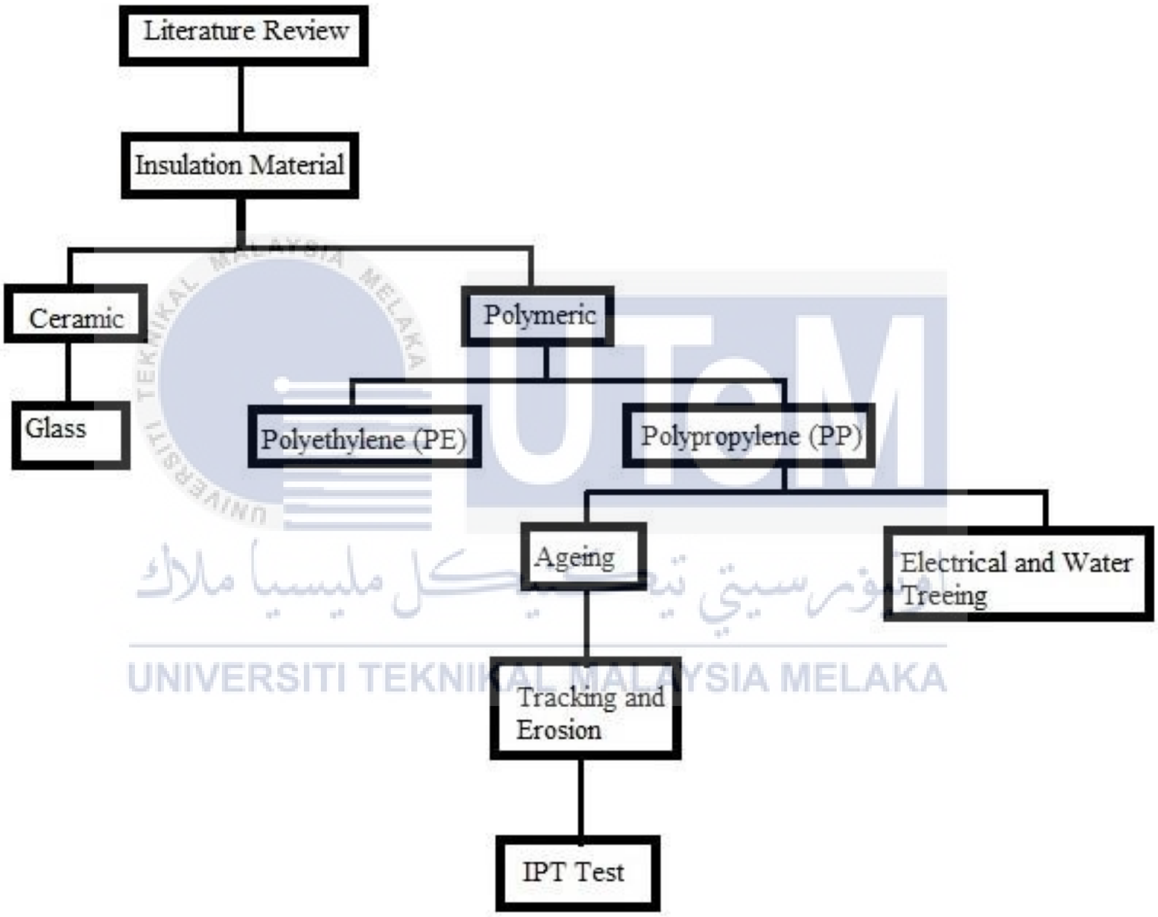

Figure 2.2: Summarization of literature review

CHAPTER 3

METHODOLOGY

3.1 Introduction

Based on the objective and scope stated of this project which is to study the effect surface tracking and erosion under different frequency by referring to BS EN 60587 standard as a test method. In this section, every step from the early progress until the result is gain according to the surface of the specimen shown a tracking and erosion effect.

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3.2 Overall Flow Chart of Methodology

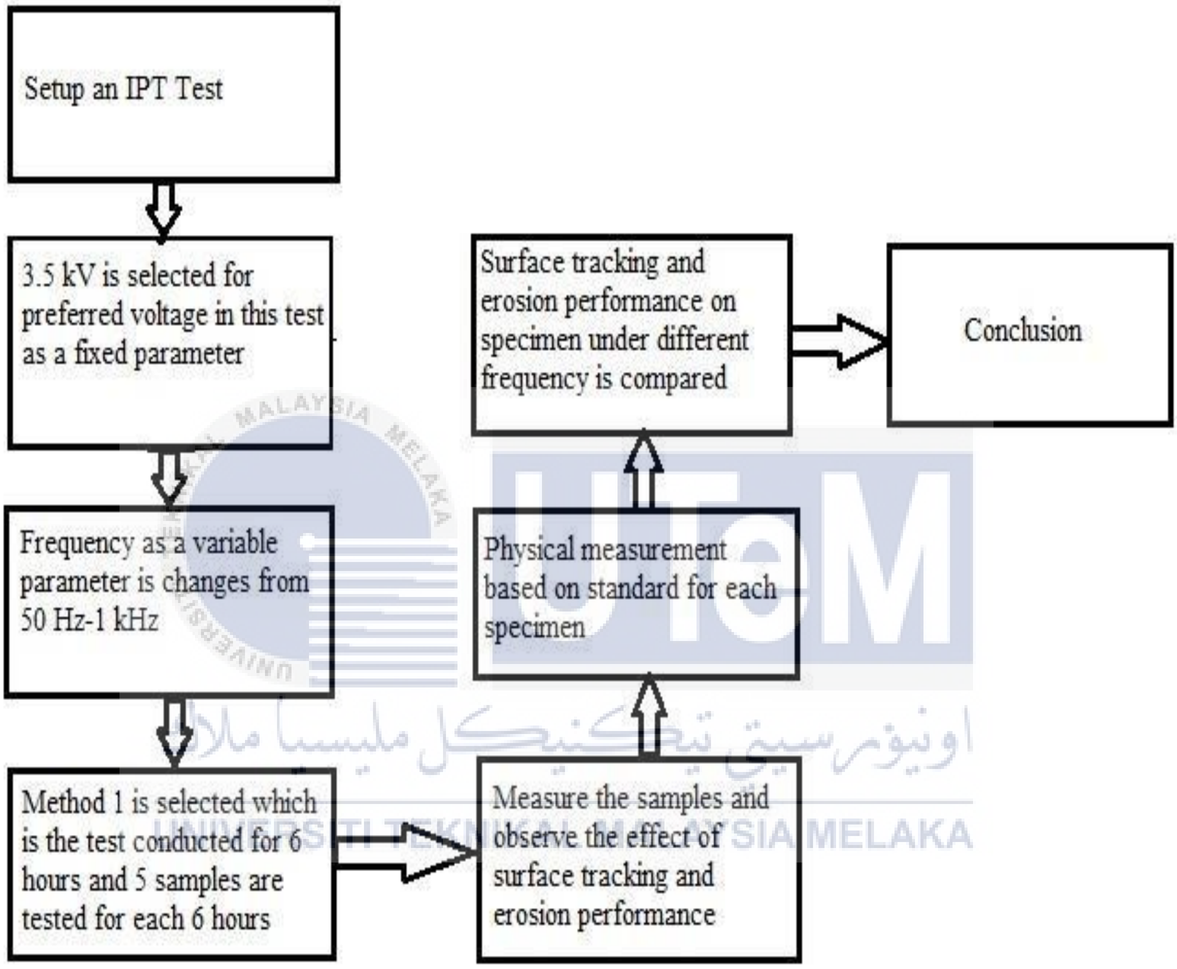

Figure 3.1: Overall Flow Chart of Methodology

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3.2 PP Specimen

Based on standard state that the size dimension of the specimen should be at least 50mm x 120 mm with the thickness 6mm as shown in figure 3.2

Figure 3.2: Standard size of specimen

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The specimen had been supply to student as to save time on making the specimen from the starting until it is done. Before starting the test, the specimen need to be drilled according to the standard BS EN 60587 measurement. The specimens shall be drilled as shown in Figure 3.3 to attach the top and lower electrodes. Figure 3.4 shown the specimen being drill before it can be used to the IPT test.

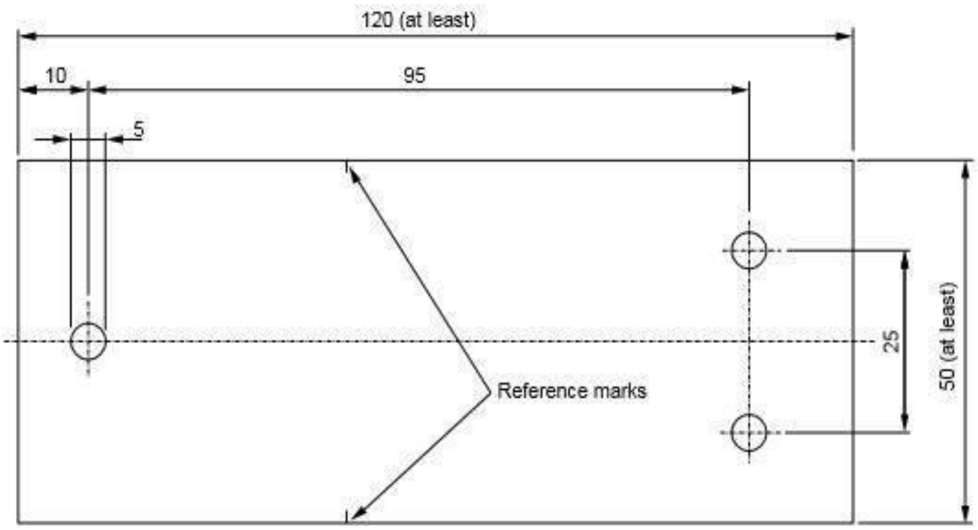

Figure 3.3: Test specimen with holes for fixing electrodes

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Figure 3.4: Specimen to be perforation

3.3 Preparation of Contaminant

According to BS EN 60587, ammonium chloride (NH4CL), Triton X-100 and distilled water (Figure 3.5) are mix together to becoming a contaminant. NH4CL is a crystalline salt where it is acidic and soluble in water as shown in Figure 3.6. Triton X-100 as shown in Figure 3.7 is known as chemical compound that is nonionic surfactant that has a hydrophilic polyethylene oxide chain where act as a wetting agent to solubilize something. To prepare the composition of contaminant, based on the standard BS EN 60587 stated that NH4CL should be by mass analytical quality of 0.1% ± 0.002% and 0.02% by mass of Triton X-100 in distilled water.

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Figure 3.5: Distilled Water

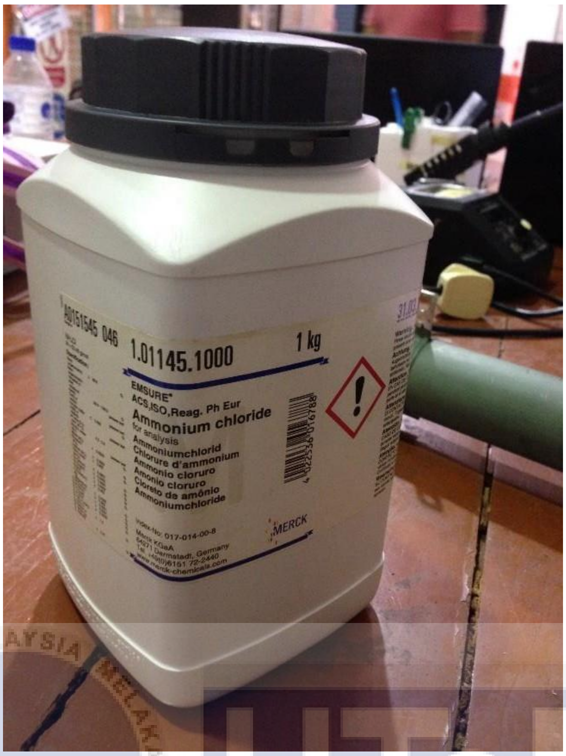

Figure 3.6: Ammonium Chloride (NH4CL)

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Figure 3.7 Triton X-100

The standard resistivity value of the contaminant is 3.95 mΩ ± 0.05 mΩ. Conductivity meter is used to measure the value of the contaminant resistivity level as shown in Figure 3.8. Based on the standard, the unit for the contaminant level is in resistivity unit, but the conductivity meter unit is in mS/cm. Therefore, a calculation has been made to convert the unit of mS to resistivity where:

$$\frac{1}{�} = �$$

$$\frac{1}{3.95 m\Omega} = 0.253\ �/m$$

$$0.253 \frac{s}{m} = 0.253\ x\ \frac{1000}{10} = \ 2.53\ \ m�/cm$$

Figure 3.6 has shown the value of conversion in conductivity meter according the standard value.

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Figure 3.8: The conductivity value of contaminant

3.4 Peristaltic Pump

The peristaltic pump is used to measure and control the contaminant flow rate in rpm as shown in Figure 3.9. According to standard, the parameter of the contaminant flow rate is in ml/min. To meet the requirement of the standard, conversion is done by using calculation and measurement. For 1 rpm, the measure value is equal to 0.05 ml/min. One flask is used to measure and record the flow rate. Then, the value is compared to calculation method where:

3rpm = 0.65 ml/min

X rpm = 0.30 ml/min

rpm = 1.4rpm

UTeM
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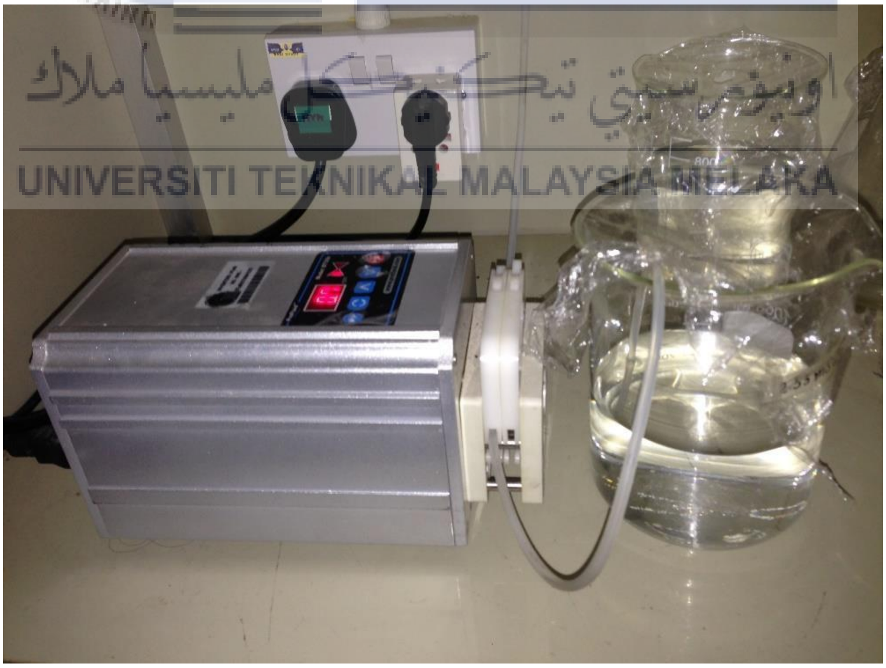

Figure 3.9 Peristaltic Pump

3.6 Function Generator

Function generator is the main device to varying the frequency used for the test. It function as a supply where the signal waveform is generate based on the parameter injected by the function generator. The signal waveform display either on the oscilloscope or computer must be the same as the value of the frequency and voltage has been supply. If the waveform signal is differ from the value injected from the function generator, then it must be a problem with the coding. Next, if the problem occur on the oscilloscope, probably the probe or the connection is incorrect. For this test, the frequency is vary by using this function generator where the frequency is variable parameter. The input voltage from the power amplifier is set to 3.5 kV by using this function generator. The power amplifier input can reach up to 30 kV but for this test, only use 3.5 kV. Therefore, the reading of the input voltage is measure by using digital multi meter where it is connected to the power amplifier.

3.7 IPT Test Setup

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Inclined Plane Test setup is the test had been used to evaluate surface tracking and erosion performance of polymeric insulation. The IPT had been setup as shown in Figure 3.10 and 3.11. The components and device used in this setup are:

1) Power Supply
2) Power Amplifier
3) Power Resistor
4) Specimen
5) Frequency Generator
6) Measuring Unit (shunt resistance, protection device)

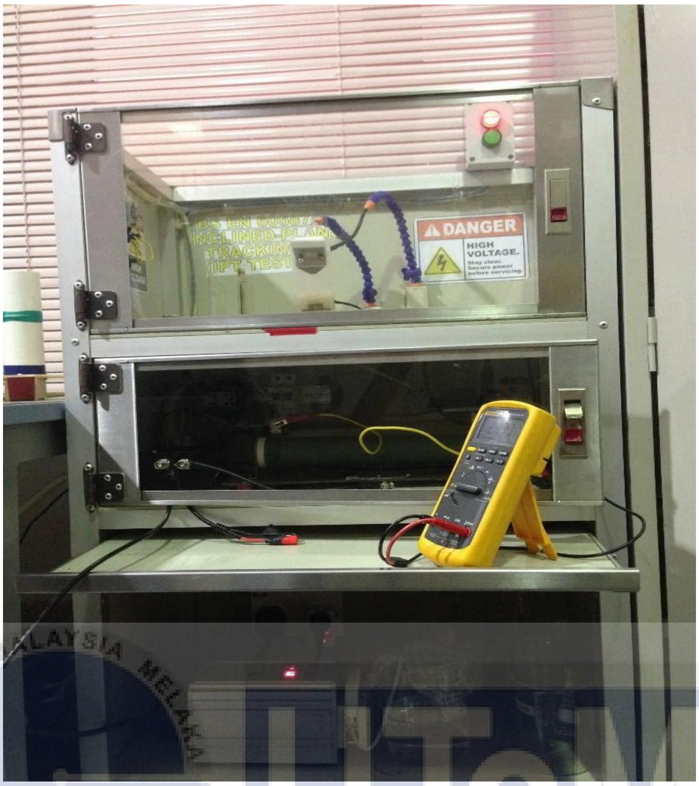

Figure 3.10: IPT setup

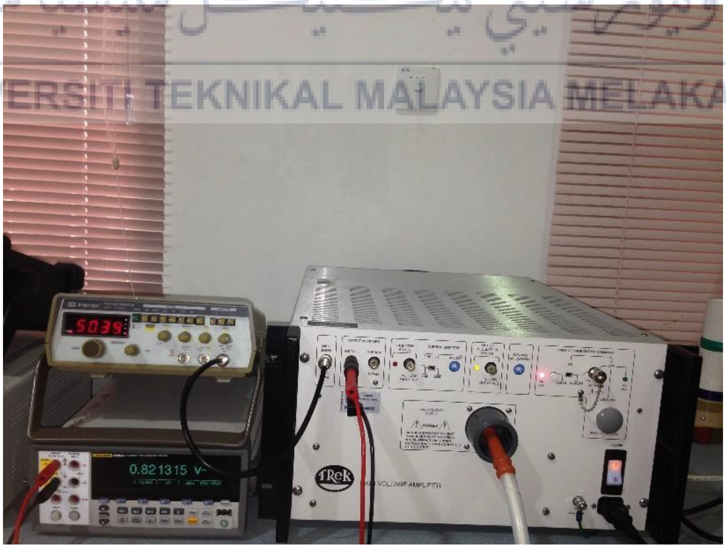

Figure 3.11: Power Amplifier, Function Generator and Digital Multimeter

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From the supply, 240 V is connected to power amplifier which can varied on how much preferred high voltage according to the standard parameter. The power amplifier can be varied from 0 to 30 kV. But according to standard, the preferred voltage only maximum at 6 kV. Table 3.1 shown the parameter according to BS EN 60587 standard. The preferred voltage in this test is 3.5 kV. The high voltage supply is connected to the High Voltage (HV) probe (Figure 3.12), where the HV probe act as capacitive voltage divider which it is mainly used to measure the value of the high voltage side from the transformer. The HV probe ratio is 1000:1. Figure 3.13 shown the position of the specimen and the contaminant shall flow from the quill hole of the top electrode and not from the sides or the top of the filter-paper.

Table 3.1: Test Parameter

Test voltage kV	Preferred test voltage for method 1	Contaminant flow rate ml/min	Series resistor, resistance kΩ
1.0 to 1.75	-	0.075	1
2.0 to 2.75	2.5	0.15	10
3.0 to 3.75	3.5	0.30	22
4.0 to 4.75	4.5	0.60	33
5.0 to 6.0	-	0.90	33

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The power resistor is connected in series with the high voltage power supply as to prevent overload current in the circuit when the high voltage side is directly connected to the zero potential ground if the connection or the specimen has become totally conductor. As preferred voltage used is 3.5 kV, then the power resistor value used is 22 kΩ as shown in Table 3.1. Then, the circuit connected with the specimen that had been installed at 45° as stated in the standard. The specimen is connected between the HV electrode and the ground electrode as shown in Figure 3.11. Next, the contaminant flow rate that should be at 0.3 ml/min at 3.5 kV which is equal to 1.4 rpm in the peristaltic pump parameter.

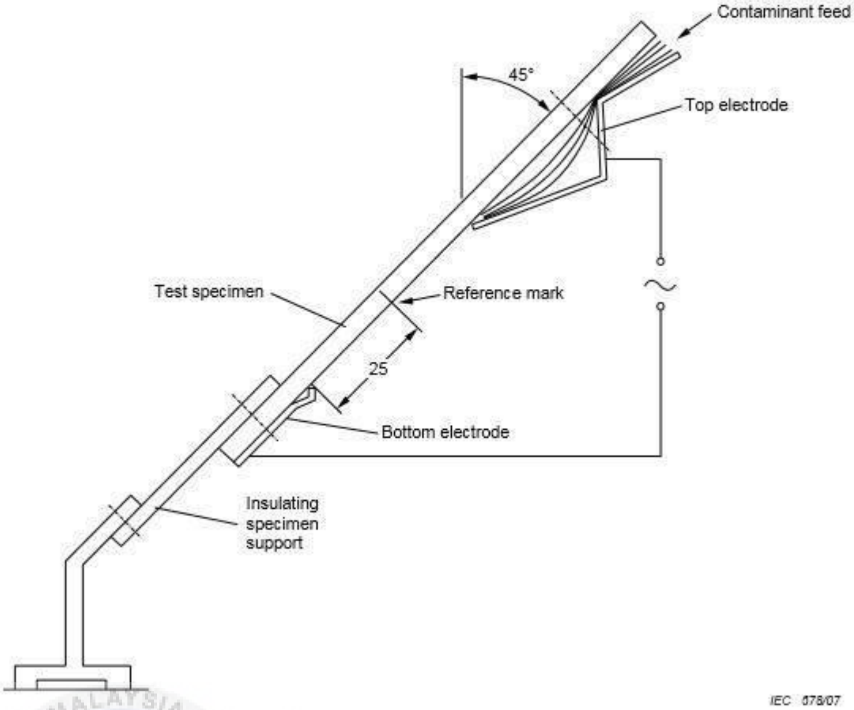

Figure 3.12: Schematic, Test assembly

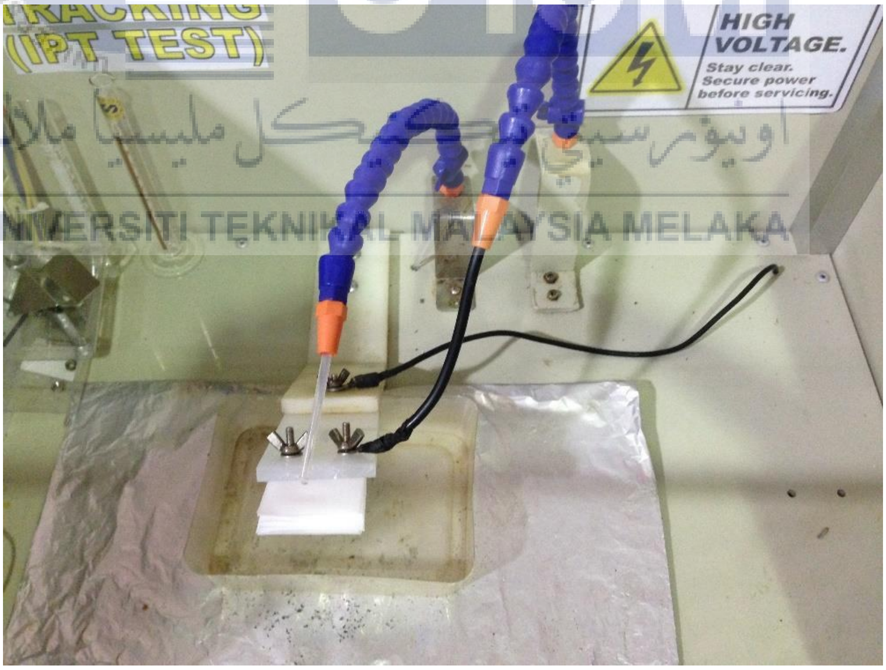

Figure 3.13: Contaminant drop from top

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3.7.1 Method 1: Application of Constant Tracking Voltage

Test Method 1 has been chosen in this experiment as to study the aging problem due to surface tracking and erosion under different frequency as to comply BS EN 60587 standard. All the parameter is fixed referring to Table 3.1 where the voltage is 3.5 kV, power resistor is 22 kΩ and the contaminant flow rate is 0.3 ml/min. The parameter that is varied is the frequency, where the value used is 50 Hz, 500 Hz, 1 kHz and 5 kHz. The test is conducted for 6 hours. Five set of test is conducted for one frequency behaviour. The surface tracking and erosion performance is observed during the test occurred.

3.8 IPT Start Procedure

Before starting the test, some procedure needs to be follow as a safety precaution.

1. Check all the probe connection at the high voltage is well connected.
2. Make sure the specimen installed on the IPT according to the standard.
3. Switch on all the equipment.
4. Vary the input value of the high voltage using frequency generator where it is connected to the power amplifier and the output voltage at the HV probe is the preferred voltage.
5. Start the flow rate contaminant until the contaminant drop to the filter paper.
6. Method 1 is apply for 6 hours of testing.

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3.9 Physical Measurement

After 6 hours of testing, the specimens were collected for physical measurement on the surface tracking and erosion performance. The tracking is measured by using a digital caliper. The tracking is measure from the lower electrode to the end of the tracking effect on the surface of the specimens. For this measurement, criterion B is selected as a method to determine the end point. As been stated for criterion B, the end point is reached when the track reaches a mark on the specimen surface 25 mm from the lower electrode or when a specimen shows a hole due to intensive erosion or the specimen ignites. Then, the measurement data is recorded which are tracking and the maximum depth of erosion reported in the classification. For example a maximum erosion depth of 0.5 mm as 1 A 3.5 – 0.5 where 1 stand for the Method 1 used, and A stand for the criterion selected and the number is the measurement that has been measured. Figure 3.14 shown the tracking on the surface of the specimen is measure by using a digital caliper. The tracking and the depth of the erosion is recorded.

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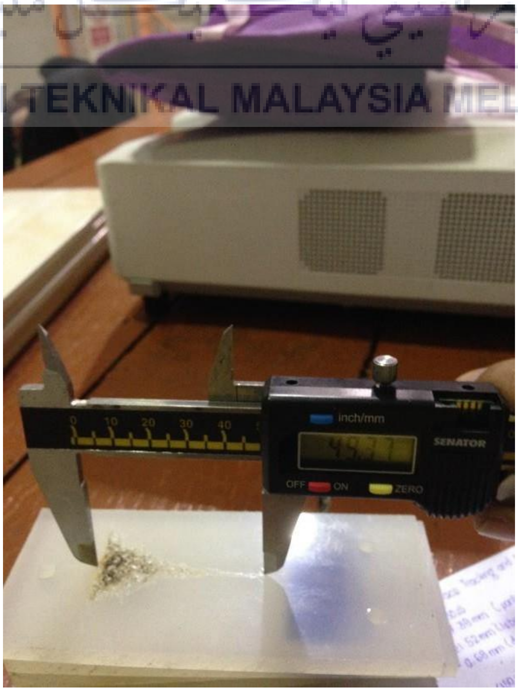

Figure 3.14: Physical measurement on the specimens

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter will show the results gain during the experiment was conducted and the data is collected then analyse. The data have been collected by using LabVIEW software. The specimen surface is observed and analyse after 6 hours of testing. The result is compared between different frequency which is 50 Hz, 500 Hz and 1 kHz as a variable parameter and the effect of the surface of the specimen by tracking and erosion performance. Thus, discussion is made by using the results.

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4.2 Data Observation

On this experiment, 3.5 kV has been selected as a fixed parameter preferred test voltage as well as the power resistor is 22 kΩ and the contaminant flow rate is 0.3 ml/min is used. For standard frequency parameter test which is 50 Hz, the tracking has reached a mark on the specimen surface 47.38mm from the lower electrode. This means the specimen considered has failed the test according to criterion B.

To pass the test based on standard, the tracking path need to be shorter than 25 mm after 6 hours of testing. As in technically result, for 50 Hz is 1 B 0.68. Figure 4.1 has shown the specimen surface of 50 Hz (standard) testing.

Figure 4.1: Specimen tested with standard 3.5 kV with 50 Hz frequency

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The other specimens had been test using different frequency while the input voltage is fixed 3.5 kV. Table 4.1 has shown the results of five specimens being test according to Method 1 with the measurement of tracking path on the surface of the specimens and Table 4.2 shown the depth of erosion result of the last test.

Table 4.1: Result of five specimens being test

	Tracking Path Measurement (mm)				
Frequency (Hz)	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
50	47.30	47.28	47.43	47.34	47.38
500	49.89	50.56	50.77	50.69	50.74
1000	51.04	51.21	51.27	51.17	51.19

Table 4.2: Depth of Erosion Result

Frequency (Hz)	Depth of Erosion (mm)
50	0.68
500	2.85
1000	3.42

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Based on the Table 4.1, all the results is observed and clearly shown that all the specimens has failed the test. As shown in Figure 4.2, where 500 Hz is used, the surface tracking is longer than 50 Hz and the depth of erosion clearly can be seen. For 1000 kHz, the tracking path is longer than the other two specimens and the erosion is deeper than 500 Hz specimen as shown in Figure 4.3. Hence, the higher frequency selected, the more effects occurred on the surface of the specimens by tracking and erosion. From all the observation and analysis on the specimens, all the specimens has failed the test according to criterion B.

Figure 4.2: Specimen tested with standard 3.5 kV with 500 Hz frequency

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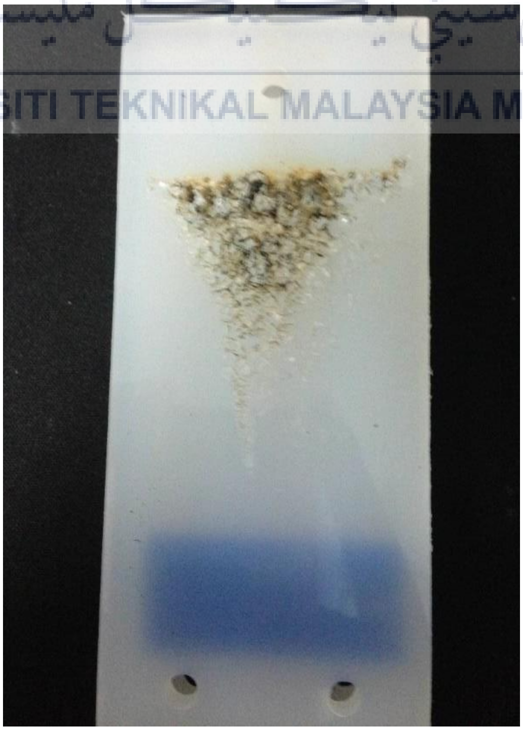

Figure 4.3: Specimen tested with standard 3.5 kV with 1 kHz frequency

4.4 Overall Discussion

Based on the data analysis and observation that had been recorded, the frequency behaviour on polymeric insulation will affect the surface tracking and erosion performance on the specimen. In the other word, the higher the frequency selected, the more visibility the effects on the specimens. From the result collected, the highest frequency selected which is 1 kHz is the worst on the surface tracking and erosion performance compared to 50 Hz and 500 Hz.

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CHAPTER 5

CONCLUSION

5.1 Conclusion

The objective of this research is to study the effect of surface tracking and erosion performance on polymeric insulation on different frequency behaviour according to BS EN60587. All the objective have been achieved. The preferred voltage selected is 3.5 kV and the frequency is a variable parameter in this test. As a conclusion, the higher the frequency used in this test, the worst effect of the specimen in surface tracking and erosion performance that happened. From the test conducted, all the test had failed according to criterion B on the standard requirements where the surface tracking and erosion performance on the specimen during the test occurred seems to be more than 22 mm each frequency supply to the test. Based on observation and analysis during the test, the higher frequency supply, the more vibration and humming produced from the HV electrode and this could lead to existence of heat energy that will lead to surface tracking and erosion on the specimens [16].

5.2 Recommendations

Outside noise or disturbance probably one of the factor that will affect the output of the test and this cannot be avoided no matter in what condition. So, to overcome this disturbance or noise, the IPT test needs to be enclosing properly to get the best results where it can be more accurate when minimize the effect of all minor disturbance or noise. Further studies is needed to overcome this issue.

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