# THERMAL BEHAVIOUR ANALYSIS OF POLYPROPYLENE (PP) AND HIGH DENSITY POLYETHYLENE (HDPE) INSULATION MATERIAL UNDER IPT TEST

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**A report submitted**
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**DECLARATION**

I declare that this thesis entitled "THERMAL BEHAVIOUR ANALYSIS OF POLYPROPYLENE (PP) AND HIGH DENSITY POLYETHYLENE (HDPE) INSULATION MATERIAL UNDER IPT TEST is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : MUHAMMAD HAMIZAN BIN MAHMUD

Date : 5/7/2021

**APPROVAL**

I hereby declare that I have checked this report entitled "THERMAL BEHAVIOUR ANALYSIS OF POLYPROPYLENE (PP) AND HIGH DENSITY POLYETHYLENE (HDPE) INSULATION MATERIAL UNDER IPT TEST" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature : .....

Supervisor Name : Dr.Nor Hidayah Binti Rahim

Date : 5/7/2021

**DEDICATIONS**

To my beloved mother and father, Mahmud Bin Hamid and Anim Bte Bakar. Also to my sibling for their encouragemenet. Lastly, to everyone that directly or indirectly involved in this project

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First and foremost, I would like to thank Allah SWT for giving me this opportunity and giving me strength to go through challenging moments during the completion of this project due to this blessing, I have succeeded completing this project and gained new knowledge and experiences.

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My sincere appreciation also extends to all my colleagues and others who have aided at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members.

## ABSTRACT

In high voltage system, insulation plays main role in order to ensure the performance of high voltage equipment. Currently the polymer insulation material will be used in high voltage insulation system. PP and HDPE is type of polymer. It commonly uses as insulation material. However, due to the electrical, thermal and mechanical stress will affected the performance of high voltage insulation system. Therefore, in this project it is proposed to study the thermal behaviour analysis of PP and HDPE insulation material under Inclined Plane Tracking (IPT) test. In this project, the objective for this project to use the Inclined Plane Tracking (IPT) test as diagnostic tools of the thermal behavior of PP and HDPE, to acquire the thermal behaviors, temperature and tracking of PP and HDPE insulation material subjected to IPT test measurement., and to analyses the relationship of thermal behavior, temperature, and tracking length of PP and HDPE insulation material subjected to Inclined Plane Tracking (IPT) test measurement. According to BS EN 60587 standard, the IPT test was conducted. In this project the test voltage 3.5 kV used, and the test was conducted up to 6 hours. The thermal behaviour of PP and HDPE insulation material was investigated. From the result obtained, the thermal behaviour of PP is slightly brighter compare to HDPE because more heat and infrared radiation emitted and released upon PP insulator material compared to HDPE. Other than that, the temperature of PP has higher temperature compared to HDPE. It was verified by its operating temperature, which is operating temperature of PP is higher than HDPE. lastly, the result obtained for the tracking on both sample PP and HDPE show that both sample failed because the tracking has reaches the end point criterion, where surface tracking on the sample has reached more than 25mm. Consequently, IPT test measurement can be pratically used in order to use in insulation material testing especially investigating the thermal behaviour performance of material.

## *ABSTRAK*

Dalam sistem voltan tinggi, penebat memainkan peranan utama untuk memastikan prestasi peralatan voltan tinggi. Pada masa ini bahan penebat polimer akan digunakan dalam sistem penebat voltan tinggi. PP dan HDPE adalah jenis polimer. Ia biasanya digunakan sebagai bahan penebat. Namun, disebabkan oleh tekanan elektrik, terma dan mekanikal akan mempengaruhi prestasi sistem penebat voltan tinggi. Oleh itu, dalam projek ini dicadangkan untuk mengkaji analisis tingkah laku termal bahan penebat PP dan HDPE di bawah ujian Inline Plane Tracking (IPT). Dalam projek ini, objektif untuk projek ini menggunakan ujian Inline Plane Tracking (IPT) sebagai alat diagnostik tingkah laku terma PP dan HDPE, untuk memperoleh tingkah laku terma, suhu dan penjejakan bahan penebat PP dan HDPE yang menjalani ujian IPT pengukuran., dan untuk menganalisis hubungan tingkah laku termal, suhu, dan panjang penjejakan bahan penebat PP dan HDPE yang dikenakan pengukuran ujian Inline Plane Tracking (IPT). Menurut standard BS EN 60587, ujian IPT telah dijalankan. Dalam projek ini voltan ujian 3.5 kV digunakan, dan ujian dilakukan hingga 6 jam. Tingkah laku termal bahan penebat PP dan HDPE disiasat. Dari hasil yang diperoleh, tingkah laku terma PP sedikit lebih terang dibandingkan dengan HDPE kerana lebih banyak sinaran panas dan inframerah yang dikeluarkan dan dilepaskan pada bahan penebat PP berbanding dengan HDPE. Selain itu, suhu PP mempunyai suhu yang lebih tinggi berbanding HDPE. Itu disahkan oleh suhu operasinya, yang mana suhu operasi PP lebih tinggi dari HDPE. terakhir, hasil yang diperoleh untuk penjejakan pada kedua-dua sampel PP dan HDPE menunjukkan bahawa kedua-dua sampel gagal kerana penjejakan telah mencapai kriteria titik akhir, di mana pengesanan permukaan pada sampel telah mencapai lebih dari 25mm. Akibatnya, pengukuran ujian IPT dapat digunakan secara pratik untuk digunakan dalam pengujian bahan penebat terutama menyelidiki prestasi tingkah laku termal bahan.

**TABLE OF CONTENTS**

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| PP | - | Polypropylene |
| HDPE | - | High Density Polyethylene |
| mm | - | milimeter |
| kΩ | - | Kilo ohm |
| kV | - | Kilo volt |
| ml/min | - | Milileter per minute |

## LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

In electrical system, insulator is an important component. It is used electrical equipment to support and seperate electrical conductor without allowing current through themselves. In high voltage insulation system, polymeric material is the most commonly used as insulation material. Basically insulating material included into subcategories which is polymer and composites. For high voltage equipments such as powercables, insulators, transformer and others are some examples of polymer used. Due to the enviromental electrical, mechanical and thermal resistance in high voltage equipment it might causes the degradation of high voltage equipment. Those electrical ageing stresses such as mention before could lead to degration on the insulation of high voltage equipment by tracking and erosion especially upon the surface tracking properties

Therefore by conducting the Inclined Plane Tracking (IPT) test, the resistance to tracking which is the progressive degradation of a solid insulating material. A part erosion can be descibed as a loss of material during a leakage current or electrical discharge. Due to surface tracking for high voltage insulation material, this technique was usead before. Therefore by using the IPT test, the thermal performance of PP and HDPE could be investigated. So that, in this study , the thermal behaviour analysis of PP and HDPE insulation material will be observed according to the standard of BS EN 60587. Electrical insulating material used under severe ambient condition. This test methods for evaluating resistance to tracking erosion.

## 1.2 Project Motivation

Due to the effect of the environmental, mechanical, electrical and thermal stresses in high voltage insulation system, it might cause the degradation of insulation material. Therefore, this motivated to investigate the thermal behavior analysis of polypropylene (PP) and High-Density Polyethylene (HDPE) insulation material under Inclined Plane Tracking (IPT) test. Since of surface tracking that could lead to severity in surface condition of insulation which effect the electrical properties in high voltage system. This project is investigated by using the Inclined Plane Tracking (IPT) test according to the international standard BS EN 60587:2007.

## 1.3 Problem Statement

The degradation of material specifically leads to a deterioration in its insulating properties, it reduces dielectric strength. When it happens after a partial discharge, the insulator destroyed. Specifically, upon the thermal stress, the surface on insulation material could be degrade and damage upon surface tracking on that material. Therefore, this project necessary to understand and investigate the thermal behavior analysis of polypropylene (PP) and High-Density Polyethylene (HDPE) insulation material under Inclined Plane Tracking (IPT) test.

## 1.4 Objective

The objective of this project are as follows:

1. To use the Inclined Plane Tracking (IPT) test as diagnostic tools of the thermal behavior of Polypropylene (PP) and High-Density Polyethylene (HDPE).

2. To acquire the thermal behaviors, temperature and tracking of Polypropylene (PP) and High-Density Polyethylene (HDPE) insulation material subjected to IPT test measurement.

3. To analyses the relationship of thermal behavior, temperature, and tracking length of Polypropylene (PP) and High-Density Polyethylene (HDPE) insulation material subjected to inclined plane tracking (IPT) test measurement.

## 1.5 Scope of Project

The scope of project are:



1. Polypropylene (PP) and High-Density Polyethylene (HDPE) is used as insulation material.

2. Inclined Plane Tracking (IPT) test BS EN 60587 used as test to obtain the result.

3. To determine the temperature, tracking length and thermal behaviour on Polypropylene (PP) and High-Density Polyethylene (HDPE).

4. Preferred test voltage 3.5kV and flow rate 0.3 ml/min

5. To obtained the temperature, tracking length and thermography on Polypropylene (PP) and High-Density Polyethylene (HDPE) during time interval (every 30 minutes until 6 hour or sample fail)

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Polymer material is a solid insulation material that a widely used in high voltage engineering or its application. Due to the benefit of polymeric insulation material over the ceramic insulation material is one of the reasons why the ceramic insulation was replaced. Due to maintain and improve the quality of the power system, many research have been conducted to improve the performance of polymeric insulation material.

In this section, subtopic that will discusses about explanation of the theoretical background of polymer insulator. It also explains the type of material that were select, the surface tracking, testing method and equipment that use in IPT test.

## 2.2 Polymeric Insulation

Insulator is a material that keeps energy such as electricity, heat, or cold from easily transfer through it which mean it provide physically and electrically support for conductor by separate it from another conductor and object. There are three types of insulation material the usually use in electrical system network such as solid, gas and liquid. In this study, Polypropylene (PP) and High-Density Polyethylene (HDPE) has been selected as solid insulation material. Polypropylene (PP) and High-Density Polyethylene (HDPE) also known as polymeric insulation.

Now day, polymeric insulation material has become famous and widely use in electrical system compared to ceramic insulation because its performance and their lifespan that have been improved. Other than that, ceramic insulation was replace by polymeric insulation because it advantages such as hydrophobicity characteristic, installation and maintenance cost reduction, resistance to vandalism and contaminant performance improvement. Due to change of ceramic insulation to polymeric insulation, it was improving the quality and the performance of transmission and distribution systems.

In this research, Polypropylene (PP) is chosen to compare the performance properties with High Density Polyethylene (HDPE).

## 2.3 Polypropylene

Polypropylenes refer as PP that a form of thermoplastic. Polypropylene is similar to Polyethylene (PE) but PP is a harder compound. Comparison between Polyethylene and Polypropylene it can be operating in high temperatures which means it high melting point. And it also has high breakdown strength, that is good for increasing the voltage of the cable operate.

There are two type major of polypropylene which is homopolymer and copolymer polypropylene homopolymer contain only polypropylene monomer in a semi-crystalline solid form. Other than that, the other main application included a textile, pipes, packaging, automotive and electrical application. While polypropylene copolymer is divided into random copolymers and block copolymers produced by polymerizing of propene and ethane. Other than that, the properties of PP can be described by [1]:

- Semi-rigid
- Translucent



- Good chemical resistance
- Tough
- Good fatigue resistance
- Integral hinge property
- Good heat resistance

## 2.4 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) is a polymer based produced from monomer ethylene [2]. HDPE has crystallinity, large spherulite radius and little change in the dielectric constant and for this reason it has excellent insulation performance [3]. HDPE is other type of polymer besides PP that are most widely used in the world market, employed for electrical equipment, automotive engineering material, and packaging [4].

HDPE also capable of withstanding temperature of beyond 100 ℃, and its melting point points is 135℃. Other than that, the advantage of HDPE can describe by:

- High tensile strength
- Waterproof property
- Able to resist low temperature
- Relatively strong and stiff
- Low cost

## 2.5 Surface Tracking

There are many factors that cause the polymer insulation material to decrease their life performance. Tracking is the most factor of the failure of outdoor insulation performance, it a peculiar phenomenon that occurs on the surface of the insulation because of the creepage discharge. It develops from surface discharge activity is correlated with the flow of leakage current, especially in wet or contaminated environments. The impact of discharge varies with the surface field intensity, surface current magnitude and the state of discharge thereby induced, all of which are due to surface wetting and the degree of contamination [5]. Once tracking occurs, the surface electrical insulation property is lost completely, and it never recovers.

## 2.6 Inclined Plane Tracking (IPT) Test

Incline plane tracking test is a method for evaluate resistance to tracking and erosion under ambient condition using a liquid contaminant and inclined plane specimens based on BS EN 60587:2007 [6]. This test also was used to determined ranking of material in terms of tracking and erosion resistance and to select the suitable materials that can be use in insulator and other outdoor applications [7][8]. The result could obtain accurately by strictly follow the international standard procedures. The test method, dimension of test specimens, contaminant preparation process, step for conducting test, and electrical equipment is given by international standard [9].

Based on the Figure 2.1 show BS EN 60587:2007 international standard for schematic diagram for IPT. A specimen with dimensions of 50mm width × 120mm length and the thickness shall be 6mm is install between top and bottom electrodes at angle 45˚± 2˚ from the horizontal [6].

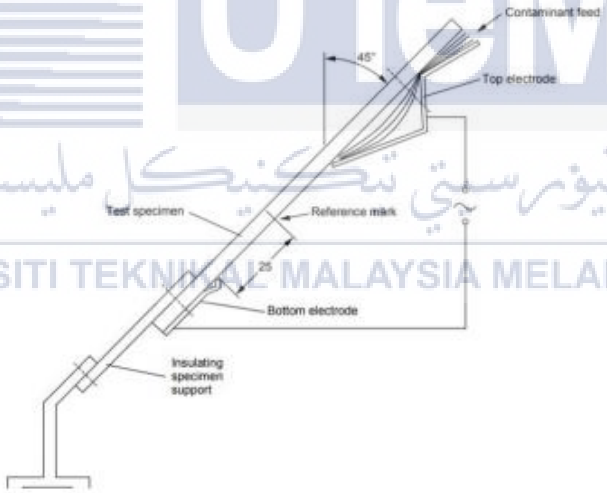


Figure 2.1 Setup for Inclined Planed Test [6]

Based on the international standard, there are four different test voltage levels that usually use for this test such as 2.5kV, 3.5kV, 4.5kV and 6kV. IPT test also have two methods to run this test such as:

Method 1: Constant tracking voltage

Method 2: Stepwise tracking voltage

For this study, method 1 were use and the test parameter base on the standard BS EN 60587:2007 need to follow as shown in Table 2.0. This method is the most widely used method as there is less need for continual inspection [6]. When contaminant flow in uniformly at the specific rate, by referring to Table 2.0, after circuit turned on and voltage raise to one of the suitable test voltages, 2.5kV, 3.5kV, or 4.5kV, which should be reaches within 10s max, and the timing device is started [8]. The result will be observed during 6 hours at the constant tracking voltage until all five specimens fail.

Table 2.1 Test Parameters [6]

| **Test voltage kV** | **Preferred test voltage for method 1 kV** | **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 |

## 2.7 IRISYS-4010 Thermal Imager

IRISYS – 4010 Thermal Imager is equipment that use in this study to measure the samples temperature and capture thermal imager of the samples. Figure 2.2 show the IRISYS-4010 Thermal Imager. Besides monitor temperature and thermal imager, IRISYS – 4010 equipment has some important specification to be used such as temperature range, radiometry, emissivity correction and accuracy [8]. After that, equipment has really decent temperature range from -10℃ to +250 ℃. With the information provided, it is clear that the equipment has a high sensitivity [10].


Figure 2.1 IRISYS - 4010 Thermal Imager

## 2.8 Summary of Literature Review

From the Figure 2.2 show the flow of summary literature review. The literature review starting with study on insulation material. On this topic, polymeric was focused and the PP and HDPE was uesd as sample in this project. After that, the study about trackinng that occur on the polymeric insulation. Lastly, IPT test was study and method 1 was udes in this project, which is constant tracking voltage.

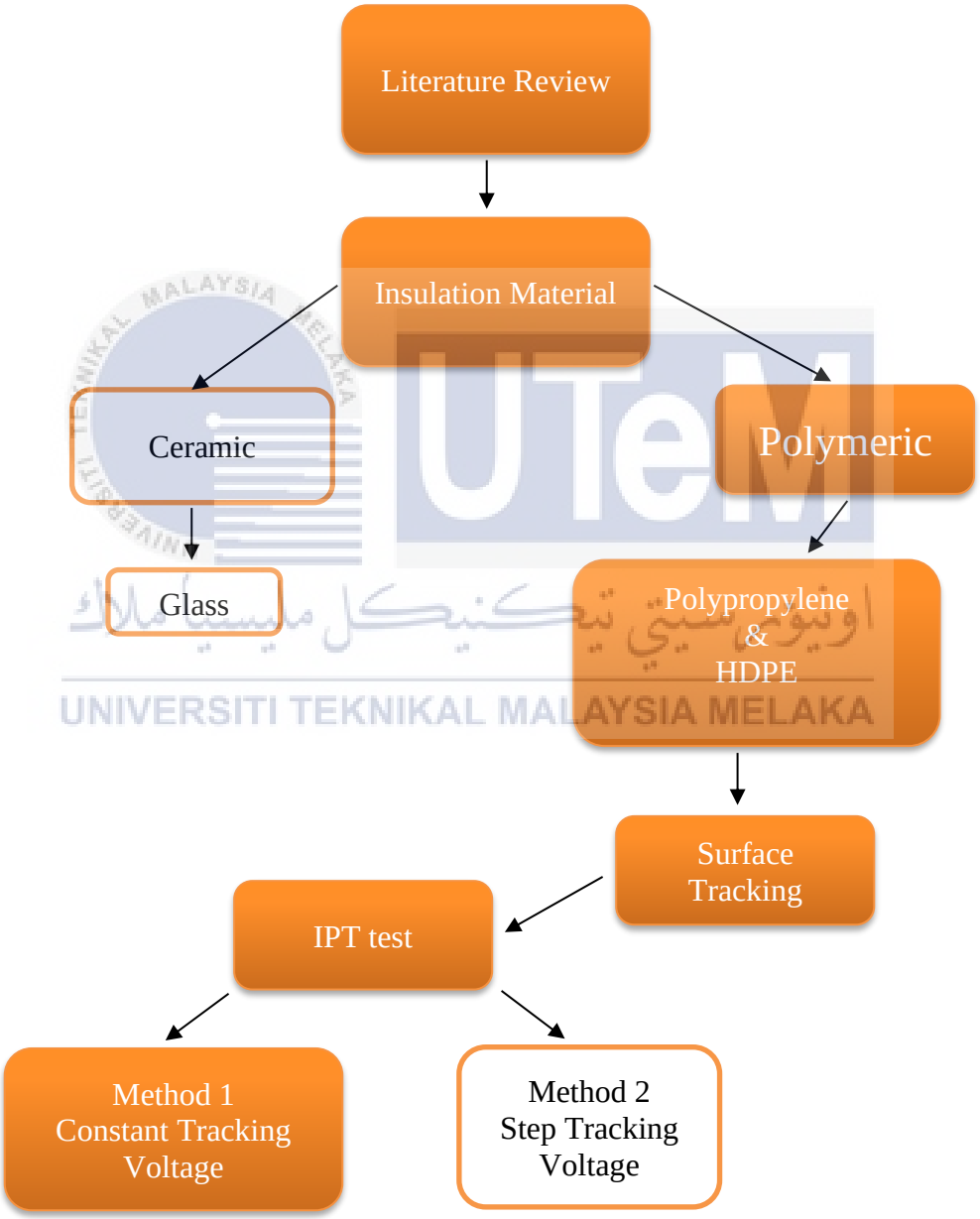


Figure 2.2 Summary of Literature Review