ELECTRICAL SIGNATURES AND WATER ABSORPTIVITY OF A NEW INSULATION MATERIAL FOR HIGH VOLTAGE APPLICATION

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ELECTRICAL SIGNATURES AND WATER ABSORPTIVITY OF A NEW INSULATION MATERIAL FOR HIGH VOLTAGE APPLICATIONS

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To my beloved husband and son,

parent and family members,

lectures and friends,

Thanks for all the encouragement and supports

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ABSTRACT

Polymer composite material has been widely used as an outdoor insulation material due to its advantages such as low surface energy, light weight, good pollution performance (hydrophobicity properties) and shorter processing time. Nevertheless, most researchers are concerned about polymeric long-term performance. By optimizing the material formulation and design, long-term performance of polymeric insulation can be improved. Thus, to develop better insulation, it is important to determine the ageing performance, electrical characteristics and also physical characteristics of the polymeric material. In this research, new filler called Boehmite, AlO(OH) is added to the existing Polyvinyl Chloride (PVC) as a new polymer insulation material. The PVC is used as the base matrix. The effects of Silane Coupling Agent (SCA) were also studied. The polymer material was exposed to ageing process by conducting surface tracking and erosion resistance tests in accordance with BS EN 60587:2007. Surface flashover tests were conducted before and after the ageing test according to BS EN 60243-1:1998. Then, the material was further tested through permittivity and capacitance test before and after ageing tests. Water absorption test was also conducted in order to observe the hydrophobicity characteristics of the insulation material. The water absorption test is based on ASTM D570-98.A comparison was then made between the PVC with filler and PVC without filler based on the result obtained from the experiment. Results reveal that the formulations of 65% PVC and 35% filler and SCA 5g give the most promising results. It is a proof that the proposed material has the potential to be used as insulation material for high voltage application.

ABSTRAK

Bahan polimer komposit telah digunakan secara meluas sebagai bahan penebat luar kerana kelebihannya seperti tenaga permukaan yang rendah, ringan, prestasi terhadap pencemaran yang baik (ciri-ciri kalis air) dan masa pemprosesan yang lebih pendek. Walau bagaimanapun, kebanyakan penyelidik prihatin mengenai prestasi jangka panjang polimer. Dengan mengoptimumkan formulasi bahan dan reka bentuk, prestasi jangka panjang penebat polimer boleh diperbaiki. Oleh itu, untuk menghasilkan penebat yang lebih baik, adalah penting untuk menentukan prestasi penuaan, ciri-ciri elektrik dan juga ciri-ciri fizikal bahan polimer. Dalam kajian ini, pengisi baru dipanggil Boehmite, AlO (OH) telah ditambah kepada Polivinil Klorida sedia ada (PVC) sebagai bahan penebat polimer baru. PVC digunakan sebagai matriks asas. Kesan Agen Gandingan Silana (SCA) juga dikaji. Bahan polimer telah didedahkan kepada proses penuaan dengan menjalankan ujian pengesanan permukaan dan rintangan hakisan mengikut BS EN 60587: 2007. Ujian lompatan elektrik pada permukaan telah dijalankan sebelum dan selepas ujian penuaan mengikut BS EN 60243-1: 1998. Kemudian bahan kajian juga akan melalui ujian ketelusan dan ujian kemuatan untuk sebelum dan selepas ujian penuaan. Ujian penyerapan air juga dijalankan untuk melihat ciri-ciri kalis air bahan penebat. Ujian penyerapan air adalah berdasarkan kepada ASTM D570-98. Seterusnya, perbandingan telah dibuat di antara PVC dengan pengisi dan PVC tanpa pengisi berdasarkan keputusan yang diperolehi daripada kesemua eksperimen yang telah dijalankan. Keputusan menunjukkan formulasi 65% PVC dan 35% pengisi dan SCA 5g memberikan hasil yang paling menggalakkan. Ia adalah bukti bahawa bahan yang dicadangkan mempunyai potensi untuk digunakan sebagai bahan penebat untuk aplikasi voltan tinggi.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Tan δ	-	Tangent delta or dissipation factor
I_R	-	Resistive current;
I_C	-	Capacitive current;
ε	-	Permittivity;

LIST OF ABBREVIATIONS

PVC	-	Polyvinyl Chloride
HV	-	High Voltage
SCA	-	Silane Coupling Agent
BS	-	British Standard
ASTM	-	American Society for Testing and Materials
kV	-	kilo volt
HVDC	-	High Voltage Direct Current

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of study

High voltage system is widely being used in various applications including commercial industry, power system, medical industry and laboratories. In this era, these applications have become a necessity. In high voltage system, there are two important matters to be considered, which are the insulator and conductor. In any high voltage application where high voltage stress is being applied, it is vital that a better understanding on the insulation material deterioration properties is taken into account in considering the optimum design of the insulation system for increased reliability and safety. When the insulation system is good, the electrical application will also demonstrate good performance and longer life time [1].

From the year 1800 onwards, ceramics and rubbers have been used in insulators. Throughout its application for over a century, ceramics has testified itself to withstand the environmental ageing. Nevertheless, porcelain poses several limitations. Porcelain is very fragile, which means they are easily broken during handling and installation. However, there was a rapid development in different insulator types and designs, all with the same aim to increase their performance under contaminated conditions [2].

The industry of insulation material has been progressing tremendously by developing numerous insulation materials. Besides that, since in the early 1960s, polymeric composite has been used and also has been accepted widely in various areas involved in high voltage application, replacing ceramic insulation. Common applications of this polymeric insulation are insulators, surge arresters, bushing and bus bar insulation. In this study, a new insulation material derived from polymeric composite compounds for high voltage application are developed [3-5].

There are many advantages of using this polymeric insulation over ceramic insulation, namely polymer is more light weight, easily installed and also lower in cost. However, its major advantage is it possessed low surface energy and maintains good hydrophobicity. Hydrophobicity is the ability to repel water. It is a useful property which can be used in contaminated and heavily polluted area [6-8].

1.2 Problem Statement

Polymeric insulation have been in service for 40 years. However, the long-term performance of this insulation has been probed since then. The existing polymeric insulation materials for high voltage applications such Ethylene Propylene Monomer (EPM), Silicone Rubber (SIR), Ethylene Propylene Diene Monomer (EPDM), Ethylene Vinyl Acetate (EVA) or the mixture of SIR and EPM or SIR and EPDM demonstrated weakness such as low ageing performance which caused early degradation. This is due to the weaker bond that polymer materials has compared to porcelain (covalent bond versus ionic bond). Therefore they can age sooner and be vulnerable to change due to the stresses they are exposed to in service [6].

Service stresses such as corona discharge can cause chemical reactions on the polymer material’s surface. The presence of moisture and contamination slowly changes the properties of the insulation surface. The surface transform from hydrophobic to hydrophilic which allows the polymer surface to get wet and causes the increased flow of leakage current. Therefore, it is extremely important that the hydrophobicity of the insulation material's surface is maintained as hydrophobicity prevents water droplets from spreading on the insulation surface. This ability also will prevent the forming of tracking and erosion on the insulation surface during in wet conditions [6, 9].

Most research and studies pertaining to the improvement of polymeric insulation performance had been done where the main concerns still being focused on the long term performance of polymeric insulation. However, there are also researchers who have recognised the importance of hydrophobicity as the main emphasis in their studies. Most researchers simulated the actual field condition by continuously wetting the surface of the polymeric insulation with artificial contaminants. These studies observed the tracking and erosion on the surface of the samples after placing the sample under high voltage stress for long hours. Yet, most researchers came to conclude that hydrophobicity is a very important property as it greatly influences the performance of polymeric insulation [10, 11].

If the hydrophobicity is lost, it is necessary for the polymer to not pass the critically leakage currents that would lead to the formation of dry band. The formation of dry band can lead to insulation failure. It is known that hydrophobic surfaces present a higher resistance to leakage current flow rather than hydrophilic surfaces. Thus, the higher leakage of current and dissipation energy are required to initiate flashover. This is another advantage of polymeric insulation whereby it has higher flashover voltages than conventional porcelain insulator. Hence, it is also important that the study the electrical properties such as insulation resistance, dielectric strength and dissipation factor (tangent delta) are given due consideration. [12-14]

The common polymers used in most studies were EPDM, Silicone Rubber, EVA and even Polyolefin. This shows that polymeric insulation is flexible as the formulation of a sample can be modified to achieve the desired properties in acquiring good performance. Thus it is also crucial that the formulations, design and manufacturing process of the polymeric insulations are studied. As there is a lack of research that uses polymer Polyvinyl Chloride (PVC) as the base material, this study utilised the existing PVC with a newly introduced filler Boehmite (AlO(OH)) as well as a silane coupling agent to obtain a compatible compound.

Therefore, to avoid the occurrence of the problem that had been stated above, it is important that a new material with proper material selection is developed through a complex formulation and optimisation process to reach the desired results and performances.[4]

1.3 Objective of Research

The objectives of the research are:

i. To develop a new polymer material using PVC with Boehmite for high voltage outdoor application.
ii. To conduct ageing test and determine the electrical and physical characteristics of the material.
iii. To compare the properties of the new material (PVC with Boehmite) with the existing material (PVC).

1.4 Scope of Work

In order to achieve the objectives of this project, there are several scopes were outlined. The scopes of this project include:

i. Material that was used is from thermoplastic polymer.
ii. Parameter studied is the electrical and physical properties of the material. The electrical properties tested were tangent delta, capacitance, dielectric strength and insulation resistance, whereas

physical properties examined were water absorption, surface tracking and erosion resistance.

iii. The comparisons between the new material and existing material were made between electrical and physical properties.

iv. The tests were done in PBL's laboratory at the Institute of High Voltage and High Current, Faculty of Electrical Engineering, UTM.

1.5 Research Contribution

This research's contributions include:

i. the introduction of a new polymeric material as a solid outdoor high voltage application.

ii. reduction in early degradation of the insulation material.

iii. a starting point for research in the application of a new filler. The results obtained can be used for further studies.

1.6 Thesis Organisation

The results of the completed study are presented in five different chapters. Chapter 1 explains the basic and main structure of the whole study. The problem statements, objectives and the scope of the study are also discussed in this chapter. This chapter also describes the expected significance of the research.

Chapter 2 elaborates the literature review including previous research that were conducted on polymeric insulation, including the history of polymeric insulation, type of insulators that were used previously, materials and design of an insulator, advantages and disadvantages of the insulators, challenges faced by the insulators, the international standards that are related to the preparation of the material and recent works on the target material.

Chapter 3 discusses the methodology of this study. This chapter elaborates the preparation of the materials, the procedures and the setup of experiments involved as well as the parameters that were taken into consideration. The properties studied were dielectric strength, tangent delta, capacitance, insulation resistance, hydrophobicity as well as the physical properties such the tracking and erosion on the sample's surface

Chapter 4 discusses the result of the experiments. The results are analysed and discussed based on the electrical and physical properties respectively.

Chapter 5 concludes the whole study. The results of the experiments on the new material, namely on whether it can be withstand the high voltage application are summarised in this chapter. In addition, recommendations on future studies are also presented in this chapter.

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