UNIVERSITI PUTRA MALAYSIA

INVESTIGATION ON THE ELECTRICAL PERFORMANCES OF A 10 kV POLYMER INSULATOR WITH SURFACE MOSS DEPOSITION

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By

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INVESTIGATION ON THE ELECTRICAL PERFORMANCES OF A 10 kV POLYMER INSULATOR WITH SURFACE MOSS DEPOSITION

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Chair : Mahdi Izadi, PhD
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The polymer insulator is known for its superior insulation performance due to its hydrophobicity and has been widely used in power systems especially for distribution networks. In sustaining this upper hand status, several extensive studies have been undertaken in evaluating and investigating the relationship between hydrophobicity and the electrical performance of polymer insulator with pollution severity, weather and ultraviolet (UV) effects. For a tropical country such as Malaysia, the issue of the formation of moss deposited on the insulator surface as a part of pollution severity should be considered. In this study, a 10 kV polymer insulator was selected as a case subject with moss deposition on the surface. Its electrical performance was studied and compared with a clean polymer insulator through Maxwell and HFSS software simulation under both steady state and impulse voltage conditions. In addition to this study, both insulators were tested under different environmental conditions and voltage profiles in a fog chamber. The results showed that the deposited moss on the surface had a direct effect on the voltage breakdown values and that the moss can reduce the electrical stability of a power line especially a core contaminated polymer insulator under polluted air. These findings have significant implications for distribution network systems, especially in areas with a high probability of moss formation. It would be wise to take this information into account when designing any new line projects or improving existing networks by setting the proper insulation level.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENYIASATAN PRESTASI ELEKTRIK 10 kV PENEBAT POLYMER DENGAN PEMENDAPAN LUMUT DI ATAS PERMUKAAN

Oleh

FARAH ASYIKIN ABD RAHMAN

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Penebat polimer dikenali sebagai penebat yang berprestasi tinggi disebabkan oleh sifat kalis airnya dan ia telah digunakan secara meluas dalam sistem kuasa terutama di bawah rangkaian pengagihan. Justeru, dalam usaha mengekalkan prestasi ini, beberapa kajian menyeluruh telah dilakukan dalam menilai dan menyiasat hubungan antara sifat kalis air dengan prestasi elektrik penebat polimer di bawah ketegaran pencemaran, cuaca dan kesan UV. Untuk negara tropika, isu pemendapan lumut pada permukaan penebat adalah tambahan kepada isu pencemaran yang perlu dipertimbangkan juga. Dalam kajian ini, penebat polimer 10kV telah dipilih sebagai kes subjek kepada isu pemendapan lumut tersebut. Prestasi elektriknya dikaji dan dibandingkan dengan penebat polimer bersih melalui simulasi perisian Maxwell dan HFSS di bawah keadaan mantap dan voltan dedenyut. Sebagai tambahan kepada kajian ini, kedua-dua penebat telah diuji di bawah keadaan persekitaran yang berbeza dan profil voltan di dalam ruang kabus. Keputusan menunjukkan bahawa lumut yang disimpan di permukaan mempunyai kesan langsung ke atas nilai pecahan voltan dan ia dapat mengurangkan kestabilan elektrik talian kuasa, terutama pada penebat yang mempunyai pemendapan lumut pada teras ketika di dalam udara tercemar. Penemuan ini mempunyai implikasi yang ketara untuk sistem rangkaian pengagihan terutama di kawasan dengan kebarangkalian pembentukan lumut yang tinggi. Adalah bijak untuk mengambil kira notasi ini apabila merancang sebarang projek pengagihan baru atau memperbaiki rangkaian sedia ada dengan menetapkan tahap penebat yang betul.

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Above all I thank Allah s.w.t; the author of knowledge and wisdom; for giving me the strength and ability to complete my Master Degree.

I thank you all.

I certify that a Thesis Examination Committee has met on (.....) to conduct the final examination of Farah Asyikin Abd Rahman on her thesis entitled "Investigation On The Electrical Performances Of A 10 kV Polymer Insulator With Surface Moss Deposition" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREAVIATIONS

BIL	Basic Impulse Insulation
Creepage distance	Level Leakage Distance
SDD	Salt Deposit Density
NSDD	Non-Soluble Material Deposit Density
ε_r	Relative Permittivity
σ	Bulk Conductivity
%RH	Percentage of Relative Humidity
E	Electric Field
J	Current Density
LC	Leakage Current
SiR	Silicone Rubber
FEM	Finite Element Method

CHAPTER 1

INTRODUCTION

1.1 Research Overview

An insulator is an essential component in power transmission and distribution networks as it serves as a mechanical support for power lines. The outdoor insulators also act as front line protection by preventing any unwanted flow of current to earth via the supporting structure. However, this feature is dependent on the rate of environmental pollution deposited on the surface of an insulator, which tends to mask its performance. There are at least six known factors of environmental pollution, namely, temperature, UV radiation, altitude, rain, icing and pollution. Thus, this study has been tasked to seek enlightenment concerning the influence of environmental pollution on the electrical performance of an outdoor polymer insulator under a lightning impulse voltage.

Distribution insulators are widely used in Malaysia in 33 kV, 11 kV and 400/230 V distribution networks. Nonetheless, in certain parts of Johor and Perak, the distribution voltage may also include 22 kV and 6.6 kV [1],[2]. Currently, Tenaga Nasional Berhad (TNB), Malaysia's largest electricity utility company and one of the largest in the region [3], operates and maintains 1245 km of 11 kV, 1156 km of 22 kV and 5285 km of 33 kV bare overhead lines [4],[5]. The insulators used in these medium and low voltage distribution networks in Malaysia are currently made of ceramic, glass and polymer [6],[7]. These outdoor insulators are employed on lines that pass through transverse areas of urban and rural parts and inescapably into a 20,456,000 ha of forest in the country, which inevitably subjects the insulators to environmental stresses and pollution stresses [8]-[14], adding to the existing stresses of the line in the form of electrical and mechanical stresses [11],[15]. These stresses can lead to the insulators suffering issues which can cause their performance to deteriorate [9],[11],[13]. Environmental stresses such as rain, ultraviolet radiation, temperature and humidity variations are rated as important contributing factors to this deterioration [11],[13]. Unfortunately, all of these elements are experienced in Malaysia.

Malaysia is positioned near to the equator line at 1° to 7° North latitude and 100° to 120° East longitude [16] and is characterised by an equatorial climate. High temperatures that are likely be uniform throughout the year, high humidity, relatively moderate winds and abundant rainfall are all characteristics of this kind of climate. Malaysia has a low variation in temperature at typically 2 °C throughout the year with the range of a minimal average of 22 °C to 24 °C and a maximum average of 29 °C to 33 °C per month [16]. On the other hand, due

to the equatorial location, the humidity is relatively high and lies between 70 to 90 %. A further effect of the geographical location and topographical nature of Malaysia results in seasonal monsoon winds and causes the level of solar radiation received to fluctuate as the clouds absorb the sunshine and reduce the insolation. The daily average of solar radiation in Malaysia comes to 4500 kWh/m^2 [16]. With such harsh exposure and stresses upon the insulators, they will eventually age and the performance of these outdoor insulators will reduce.

1.2 Problem Statement/Motivation

The influence of bio-contamination on the electrical performance of a polymer insulator is an interesting topic that has been studied by many researchers, especially from countries with a tropical climate. Bio-contamination thrives well in this kind of climate. Malaysia has it all - high rainfall, high humidity, intensive sun radiation and elevated temperature which are especial conditions that make biological growth within the territory more probable. Consequently, it is important to consider the local bio-contamination issue when designing new power lines.

A number of reports have surfaced from Uruguay, Tanzania, Sri Lanka, Germany, USA (Texas, Georgia, and Florida), Columbia, Japan and Sweden [17]-[21] concerning visible greenish, blackish and sometimes brownish spots on the surface of a polymer insulator, causing a drop in the withstand level of the wet and dry flashovers and an increase in the leakage current [18],[20],[22]. These spots have subsequently been identified as algae, lichen, moss, mould or fungal growth [17]-[20], which are biological-contamination-types typically found in a tropical environment with high rainfall, high humidity, intensive sun radiation and elevated temperature [17]-[18],[20]. When these bio-contaminates colonise the surface of the insulators, they will impeded the drying of the surface and there is a possibility of increasing the degradation of the insulators through deposit enzymes [18],[21]-[22]. The research gap among previous research refers to considering the abovementioned case under lightning conditions.

Many reports have cited the effects of these bio-contaminates, and yet researchers are still unclear as to how much the growth of these contaminates can affect the performance of polymer insulators under high humidity conditions, let alone under natural field conditions. Thus, it is necessary to perform thorough research and share the findings with the community of researchers.

Malaysia has high rainfall, high humidity, intensive sun radiation and elevated temperature. All these conditions encourage biological growth within the

territory. Further, the occurrence of lightning in Malaysia is among the highest levels recorded in the world [23]. Therefore, considering the effect of bio-contamination materials on the surface of a polymer insulator in terms of the electrical performance of the insulator under impulse lightning voltage conditions can be helpful to increase the stability level of the line. This research considers the case from both the experimental and simulation points of view and the results will be explained and discussed accordingly.

1.3 Objectives

The aim of this study is to evaluate the electrical performance of a 10 kV polymer insulator with moss deposited on the surface under lightning impulse conditions. The objectives are listed as follows:

1. To model and simulate polymer insulators with surface moss in both steady state and lightning condition under various air conditions.

2. To investigate the electric field behaviour and voltage distribution of the abovementioned insulators.

3. To examine the electrical breakdown and measured the leakage current the abovementioned insulator under positive lightning impulse voltage and various air conditions.

1.4 Scope Of Work/Limitations

The scope and limitations of this study are listed as follows:

1. A 10 kV polymer insulator was studied.

2. A lightning impulse voltage was used in studying the electrical performance of the abovementioned insulator under lightning conditions.

3. Surface moss was generated (moss deposition on the insulator surface) under natural conditions.

4. Parameter for moss has been obtained from experimental works.

5. A limitation in modelling an edge rounded structure of the polymer shed and surface moss in HFSS and Maxwell software interface resulting in different values of tetrahedral mesh for each drawing and therefore influenced the outcome results.

1.5 Thesis Layout

The layout of the written thesis is as follows:

1. **Chapter 1 – Introduction**

This chapter briefly discusses insulators, lightning and the associated environmental pollution that led to the motivation to take up research in terms of studying polymer insulator performance including deposited moss under lightning conditions. The summary of the research includes the objectives and limitations.

2. **Chapter 2 – Literature Review**

This chapter reviews past research that has significant connection to this study. The associated research literature concerns the classification of insulators, the physics of lightning and its standards as well as the effects of environmental factors on the performance of polymer insulators.

3. **Chapter 3 – Methodology**

Chapter 3 touches on the methodology of the experimental and simulation works in achieving the ultimate objective of this study, namely the electrical performance of a 10 kV polymer insulator under lightning conditions with moss deposition on the insulator surface.

4. **Chapter 4 – Results And Discussion**

In this chapter, the experimental and simulation results corresponding to the objectives of this study are presented and discussed accordingly.

5. **Chapter 5 - Conclusion**

In this final chapter, a summary of the results is expressed and the relevance to the application side is presented. Moreover, recommendations and potential future works are proposed.

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