POLYMER INSULATOR COATED BY ROOM TEMPERATURE VULCANIZATION FOR STRENGTHENING VOLTAGE WITHSTAND CAPABILITIES

FARAH ADILAH BINTI JAMALUDIN

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By

FARAH ADILAH BINTI JAMALUDIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Philosophy

July 2020

DEDICATION

To rise after each fall

Correct after mistaking

Improve after each fail

This work is dedicated to my beloved parents and husband for their endless support

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman : Mohd Zainal Abidin Ab. Kadir, PhD PEng CEng
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Non-ceramic type insulator, also known as polymer insulator has become an alternative to most power utilities worldwide due to its advantages. However, polymer insulator has some major drawbacks such as its material properties that are easily degraded and aging that results in unknown long-term reliability. Typical problems encountered by the polymer insulator during its years of service have included tracking and erosion of the shed that could lead to flashover, and chalking that can increase contamination accumulation on the shed or housing, and bonding and electrical failures due to interference between different materials. All these typical problems were due to prolonged exposure to atmospheric pollution, ultra-violet radiation (UV), rain and salt fog. Furthermore, being a tropical country with high lightning intensity, 70% of power outages in Malaysia are caused by lightning. Lightning strikes overhead power lines, causing surge over voltages and that affect performance of polymer insulators and lead to flashover and damage to the insulator or power lines. Under normal circumstances, the damaged polymer insulator will be replaced with a new one but it is labour-intensive and costly. Alternatively, in this research, new method of use, which is applying Room Temperature Vulcanisation (RTV) coating on polymer insulator surfaces in order to increase electrical performance of the insulator and also to restore a damaged insulator without the need to shut down the power lines. Previously, RTV coating method was widely used in outdoor porcelain and glass insulators to enhance electrical performance under pollution condition and increase their life span. Since there are no past measurements available for the polymer insulator, this research offers three different types of insulator configuration settings used in this work, namely, basic uncoated, and RTV types 1 and 2 coated insulators. All the insulators were tested under dry, clean-wet and pollution conditions under alternating and different lightning impulse voltage conditions. From the research, RTV-coated insulator was found to increase polymer insulator withstand capabilities up to 50% under pollution condition and reduce leakage current magnitude. From the study, application of RTV coating was found to be effective

for strengthening voltage withstand capabilities under alternating and lightning impulse voltages. RTV coating can be used to improve and protect the surface condition of the polymer insulator. This may help to improve the performance of the polymer insulator and increase its lifespan and power system reliability.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENEBAT POLIMER YANG DILAPISI OLEH BAHAN PEMVULKANAN SUHU BILIK UNTUK MENINGKATKAN KEUPAYAAN KETAHANAN VOLTAN

Oleh

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Penebat jenis bukan seramik atau dikenali sebagai penebat polimer telah menjadi alternatif kepada kebanyakan utiliti kuasa di seluruh dunia kerana kelebihannya. Walau bagaimanapun, penebat polimer mempunyai beberapa kelemahan utama seperti sifat materialnya yang mudah rosak dan penuaan yang menyebabkan jangka panjang yang tidak diketahui. Masalah tipikal yang dihadapi oleh penebat polimer semasa perkhidmatannya adalah pengesanan dan hakisan pada permukaan polimer yang boleh menyebabkan kegagalan elektrik, dan permukaan berkapur yang akan meningkatkan pengumpulan pencemaran di permukaan polimer, ikatan dan kegagalan akibat erbezaan bahan. Kesemua masalah ini disebabkan pendedahan yang lama di bawah pencemaran atmosfera, radiasi ultra violet (UV), hujan dan kabus garam. Selain itu, sebagai negara iklim tropika dengan kepadatan kilat yang tinggi, 70% gangguan kuasa di Malaysia disebabkan oleh kilat. Serangan kilat pada talian kuasa menyebabkan lonjakan voltan dan menjejaskan prestasi penebat polimer sehinggan boleh mengakibatkan *flashover* dan kerosakan pada penebat atau talian kuasa. Kebiasaannya, penebat polimer yang rosak akan digantikan dengan yang baru dan memerlukan tenaga kerja yang intensif dan mahal. Selain itu, dalam kajian ini, kaedah baru iaitu menggunakan salutan suhu bilik (RTV) pada permukaan penebat polimer untuk meningkatkan prestasi penebat elektrik dan juga untuk memulihkan penebat yang rosak tanpa perlu mematikan talian kuasa. Sebelum ini, kaedah ini telah digunakan secara meluas dalam penebat jenis porselin dan kaca untuk meningkatkan prestasi elektrik di bawah keadaan pencemaran dan meningkatkan jangka hayatnya. Ciri-ciri pelekat dan keupayaan untuk menindih kebocoran arus, mudah untuk digunakan dan dibersihkan atas talian adalah faktor utama penggunaannya di kalangan utiliti. Oleh kerana tiada lagi kajian yang dibuat untuk penebat polimer, dalam kajian ini, terdapat tiga jenis konfigurasi yang digunakan iaitu penebat tanpa salutan dan dibaluti oleh RTV jenis 1 dan 2. Semua penebat telah diuji di bawah keadaan kering, bersih-basah dan pencemaran di bawah keadaan voltan dedenyut yang berbeza polariti. Dari penyelidikan, penebat bersalut RTV didapati meningkatkan

keupayaan ketahanan voltan penebat polimer sehingga 50% di bawah keadaan pencemaran dan mengurangkan jumlah arus bocor. Dari kajian ini, salutan RTV didapati berkesan untuk menguatkan keupayaan menahan voltan di bawah voltan dedenyut. Lapisan RTV boleh digunakan untuk memperbaiki dan melindungi keadaan permukaan penebat polimer. Ini boleh membantu meningkatkan prestasi penebat polimer dan meningkatkan jangka hayat dan sistem kuas

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREAVIATIONS

AC	Alternating Current
BIL	Basic Impulse Insulation Level
DC	Direct Current
EPR	Ethylene-Propylene Rubber
FEM	Finite Element Modelling
FTIR	Fourier Transform Infra-Red
FRP	Fibreglass Reinforced Plastic
IR	Infra-red
IEC	International Electrotechnical Commission
LC	Leakage Current
NSDD	Non-Soluble Material Deposit Density
RH	Relative Humidity
RTV	Room Temperature Vulcanised
SDD	Salt Deposit Density
SiR	Silicone Rubber
TNB	Tenaga Nasional Berhad

CHAPTER 1

INTRODUCTION

1.1 Overview

In power lines, insulator plays an important role in providing insulation and mechanical support to the tower. An insulator is also used to separate the phase line conductors from each other and from the ground. An insulator is an essential part of the power transmission and distribution lines as the failure of an insulator will affect the performance of the power line and cause power outages and electricity service disruption. This failure will lead to economic losses as most of the industries depend on uninterrupted power supply [1]. Failure of the insulators is often associated with changes in service environment and pollution. An insulator can be classified into two categories: ceramic (porcelain and glass) and non-ceramic (polymer). Ceramic -type insulators such as porcelain or glass were widely used in the early years of development of high voltage transmission and distribution designs. Since the 1960s, polymer insulators have been introduced and become an alternative insulator option for use in power lines [2-3]. Many of the electricity providers in the world have opted for polymer insulators due to their advantages such as lower cost and lighter weight compared to conventional ceramic insulators, easy handling and installation, vandalism resistant, reduced breaking wear and tear of insulator housing, and low surface property also known as hydrophobicity characteristics that able to bead water and suppress leakage current on insulator surface. The presence of conductive and partially conductive layer on insulator surface dictates flashover [4-5]. Hence, hydrophobicity characteristics make polymer insulators perform better under contaminated conditions compared with ceramic insulators [6-8].

1.2 Problem Statement

Throughout the years of service, utilities providers and researchers have found some drawbacks of using polymer insulators, due ageing and degradation. From previous studies, most of the researchers found that electrical and environmental stresses were the main factors that contribute to ageing of polymer insulators. Electrical stress such as leakage current causes the formation of dry band arcing and lightning impulse could cause flashover. On the other hand, environmental stresses such as UV radiation, heat, humidity and pollution have been found to be significant contributing factors to polymer material degradation and ageing. In addition, since the structure of a polymer insulator consists of different materials such as polymeric housing, FRP rod and metal end fitting, interference between these materials makes the polymer insulator prone to electrical deterioration.

Moreover, in Malaysia, 70% of power outages have been due to lightning-caused surge overvoltage on the insulator and damages the insulator itself and causes failure of the overall power system [1][10-11]. Therefore, investigation of insulator withstand capabilities under lightning impulse is crucial to ensure reliability of power line system and improvement of power system reliability in Malaysia.

Ageing and material degradation phenomena of polymer insulators will potentially create significant impact on the performance of insulators if not properly being mitigated. Degradation of polymeric insulators causes losses in its hydrophobic characteristics, surface flaking, cracks, punctures on shed or housing and worse, allowing the moisture content to penetrate and affect the insulator core [5-9]. Normally, in these cases, the aged and damaged insulator will be replaced with a new one and it is labour-intensive and costly. Alternatively, with a new proposed method, applying RTV coating material on the polymer insulator can restore the damaged insulators on the live lines without the need to dismantle any parts. Figure 1.1 shows the examples of ageing and degradation of polymer insulators.

Figure 1.1 : Ageing and degradation of polymer housing [13]

RTV coating application method was widely used for porcelain or glass insulators to reduce the probability of flashover compared with other methods due to its good dielectric properties, flexibility over a wide range of temperatures, adhesion characteristics, improvement of immunity to de-polymerisation, faster application, and most importantly, the application can be made under energised condition [9-10]. RTV coating was known to increase the lifespan of the ceramic insulators. Reference [11] mentioned that RTV coating application on ceramic insulator could last up to 15 years. However, not many studies have focused on the performance in terms of voltage breakdown strength of the RTV coating application. In addition, the electrical properties of RTV coating materials need to be evaluated as the previous studies shows that the effect of RTV performances varies depending on its formulation. Moreover, to date, and to the best knowledge of this researcher, no studies or past measurement have been made of polymer insulators under lightning impulse condition. Following this study, more research needs to be done in terms of:

1. The effect of a lightning strike on the polymer insulator;
2. The effect on RTV coating materials and configuration on the polymer insulator.

1.3 Research Objectives

The purpose of this research was to investigate the effects of RTV coating on polymer insulator and evaluate its electrical performance and its withstand capability when exposed to electrical and environmental stresses. The main objectives of the research are:

1. To propose using two different types of RTV coating materials on the insulator surface to increase electrical performance of polymer insulator.
2. To evaluate the behaviour of coated insulator (using RTV coating materials) under alternating and impulse voltage and different weather conditions.
3. To evaluate the critical points of insulator profile by simulating electric field and voltage profile of the insulator.
4. To classify the electrical behaviour of coated insulator and to make recommendations.

1.4 Scope of work

i. Distribution polymer type insulators were used for this research. In the experimental works, three different configuration settings of insulator were used. The settings used were basic uncoated, coated with type 1 RTV silicone coating, and coated with type 2 RTV silicone coating.

ii. All these insulators were evaluated under three different conditions: dry, clean wet, and pollution. Each of the tests was conducted under alternating voltage and impulse.

iii. For verification purposes, the insulator was modelled in 3D using Anysys Software. Electric field and voltage profile were evaluated for each case.

iv. For this research, the behaviour of surrounding structures such as cross-arm, corona ring, and towers were excluded.

1.5 Thesis Organisation

This thesis consists of five chapters: Introduction, Literature Review, Methodology, Results and Discussion, and Conclusion. The outlines of individual chapters are as follows:

This **Chapter 1** presented the overview of the study, current issues and application of RTV coating materials on polymer insulator. The Problem Statement Scope and Limitations were also highlighted in this chapter. Objectives of this study were also presented.

Chapter 2 provides an extensive review of published literature on the subject of polymer insulator, including a study of the behaviour of polymer insulators when exposed to different currents, voltages and weather conditions. Previous works on polymer insulator pollution flashover and flashover mechanism are also presented. Types of pollution and severity level are also discussed in this chapter. A review of RTV silicone coating application of ceramic insulators and advantages are also discussed in this chapter.

Chapter 3 discusses the methodology used to achieve the research objectives. For experimental works, specimens are tested in a fog chamber under different service conditions. The 50% probability of flashover, U50 for each type of specimen setting will be evaluated. For each test, the breakdown voltage value and leakage current were recorded. Software modelling was used for verification purpose. The model was simulated according to specimen tested in experimental work. The behaviour of voltage and electric field of each case are evaluated.

Chapter 4 presents the analysis of the experimental and simulation results followed by discussion of these results, which are classified accordingly based on the insulator settings, weather conditions and impulse polarities. The trend of recorded results, and effects of coating on insulator withstand capability are discussed in this chapter.

Chapter 5 presents the general conclusion drawn from the findings in this study and outlines some recommendations for future research.

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