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ELECTRICAL PERFORMANCE OF POLYMER-TYPE INSULATORS UNDER VARIOUS SERVICE AND LIGHTNING VOLTAGE CONDITIONS

MUHAMMAD SYAHMI BIN ABD RAHMAN

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By

MUHAMMAD SYAHMI BIN ABD RAHMAN

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman: Professor Mohd Zainal Abidin Ab. Kadir
Faculty: Engineering

Nowadays, the usage of polymer insulators are increasingly popular in the power systems and their outdoor application has resulted in the exposure to the various service conditions such as weather, pollution and lightning conditions. This study expanded previous researches by considering on the effects of wetting and pollution, i.e. clean-fog and salt-fog on the breakdown strength, voltage, electric field intensity and current density performance of a 10 kV polymer insulator under lightning impulse voltage. A set of experimental (based on IEC 60507) and simulation works revealed that the breakdown strength of insulator has significantly reduced under wet and pollution conditions where 21.18% and 53.33% of reduction was recorded, respectively due to the increase of surface conduction.

Besides, the effect of insulator inclination under wetting and different pollution conditions were considered through both lab measurements and finite element modelling. The results indicated that the performance of insulator reduced up to 18.33% and the changes of electric field intensity around the insulator has been one of the factors. It should be mentioned that the inclination of insulator is one of the major problems in the electrical utilities due to line mechanical forces and the deficiency of the equipment itself. The reduction factor of U_{50} which is obtained from the study can be useful during the planning stage of the distribution line.

The effect of lightning induced voltage on the electrical performance of polymer insulator was studied in this thesis, as it is one of the major factors for interruption of distribution lines in Malaysia. Note that the lightning induced voltage is due to the coupling between lightning electromagnetic fields and line condutors. The behaviours of electric field and voltage distribution in different parts of the insulator under lightning induced voltage condition were considered where the effects of pollution thickness, different pollution profile and humidity were investigated. It is expressed that the thickening of surface pollution can significantly increase the electric field intensity and current density for at most 62.17%. This study also found that the electric field increases due to the formation of the dry-band. Meanwhile, the increase in air humidity has been responsible to increase current density stress on the insulator surface.

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

PRESTASI ELEKTRIKAL PENEBAT JENIS POLIMER DALAM PELBAGAI KEADAAN SERVIS DAN VOLTAN KILAT

Oleh

MUHAMMAD SYAHMI BIN ABD RAHMAN

November 2016

Pengerusi: Professor Mohd Zainal Abidin Ab. Kadir
Fakulti: Kejuruteraan

Pada masa kini, penggunaan penebat polimer semakin popular dalam sistem kuasa dan aplikasinya di luar mendedahkannya kepada pelbagai keadaan persekitaran. Kajian ini telah mengembangkan kajian terdahulu dengan mengambil kira mengenai kesan basah dan pencemaran iaitu kabut bersih dan kabut garam pada medan elektrik dan profil voltan penebat polimer 10 kV bagi kes voltan kilat. Satu set kerja eksperimen dan simulasi telah mendedahkan penurunan nilai pecah voltan penebat insulator dalam keadaan basah adan pencemaran dimana penurunan masing-masing sebanyak 21.18% dan 53.33% telah direkod dipercayai disebabkan oleh peningkatan konduktiviti pada permukaan penebat itu.

Selain itu, kesan kecondongan penebat terhadap pepalang dalam keadaan basah dan pencemaran yang berbeza telah dipertimbangkan melalui kedua-dua ukuran makmal dan simulasi yang berasaskan FEM. Keputusan telah menunjukkan prestasi penebat menurun sehingga 18.33% dan perubahan medan elektrik di sekeliling penebat telah dikenalpasti sebagai salah satu antara faktor penyebab. Perlu dinyatakan bahawa kecondongan penebat adalah salah satu masalah utama dalam utiliti elektrik kerana daya kuasa mekanikal dan masalah peralatan itu sendiri. Faktor penurunan U_{50} yang diperolehi dari kajian ini boleh diguna ketika merancang litar pengagihan.

Kesan voltan teraruh kilat pada prestasi elektrik penebat polimer telah dikaji dalam tesis ini dimana voltan teraruh kilat adalah salah satu faktor utama dalam gangguan talian pengagihan di Malaysia. Perlu dinyatakan bahawa voltan teraruh kilat adalah disebabkan oleh gandingan antara medan elektromagnetik kilat dengan konduktor pengagihan. Prestasi medan elektrik dan voltan pada bahagian-bahagian yang berbeza di sepanjang penebat dalam keadaan voltan teraruh kilat dipertimbangkan dan dimana kesan-kesan penebalan pencemaran, kepelbagaian profil pencemaran dan kelembapan udara telah dikaji. Ia menunjukkan bahawa penebalan pencemaran di permukaan penebat boleh meningkatkan medan elektrik dan arus tertumpu sehingga 62.17%. Kajian ini juga telah menunjukkan bahawa kelembapan udara bertanggung jawab untuk meningkatkan arus tertumpu pada permukaan penebat disebabkan oleh peningkatan konduktiviti di persekitaran, dimana ia mungkin mempengaruhi penuaan penebat.

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I certify that a Thesis Examination Committee has met on (…….....) to conduct the final examination of Muhammad Syahmi Bin Abd Rahman on his thesis entitled "**Experimental and Simulation Works to Determine Electrical Performance of 10 kV Polymer Insulators Due to Lightning Impulse Voltage Under Various Service Conditions**" 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.

Members of the Thesis Examination Committee were as follows:

Mohd. Amran b. Mohd. Radzi, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Wan Fatinhamamah bt. Wan Ahmad, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohamad Kamarol bin Mohd Jamil, PhD
Associate Professor,
School of Electrical & Electronics Engineering
Universiti Sains Malaysia
(External Examiner)

(Zulkarnain Zainal, PhD)
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia
Date:

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

Mohd Zainal Abidin Ab. Kadir, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Gorakanage Arosha Chandima Gomes, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Jasronita Jasni, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Mahdi Izadi, PhD
Research Fellow
Faculty of Engineering
Universiti Putra Malaysia
(Member)

_____
ROBIAH BINTI YUNUS, PhD
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Signature: _____

Name of Member of Supervisory Committee: Gorakanage Arosha Chandima Gomes, PhD

Signature: _____

Name of Member of Supervisory Committee: Jasronita Jasni, PhD

Signature: _____

Name of Member of Supervisory Committee: Mahdi Izadi, PhD

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREAVIATIONS

AC	Alternating Current
BIL	Basic Impulse Insulation Level
DC	Direct Current
DU	Diendorfer-Uman
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
MTLE	Modified Transmission Line with Exponential Decay
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 Background of Study

In the early times, high voltage insulators were mostly constructed using basic materials such as ceramic or porcelain or glass. However, due to the material properties, porcelain and glass insulator are easily wetted which in turn forms a continuous water film on the hydrophilic surface. As a result, leakage current starts to increase leading to power outage due to system tripping. This ultimately causes a very high economic loss to the nation and country [1-3].

In recent times, the polymeric or composite material such as Silicon rubber (SiR) and Ethylene-Propylene rubber (EPR) are widely used to produce insulators to overcome problems demonstrated by the traditional materials [4, 5]. They are known to have superior properties and well known for highly durable in the presence of heavy pollution, vandalism, excellent in electrical properties and lower in weight to the withstand voltage ratio [6].

However, during its service life, the polymer insulator may deteriorate due to inevitable environmental, mechanical and electrical stresses where the combination of environmental and electrical stresses are the common causes of insulator failure. Therefore, previous researchers have tried to study the behaviour of insulator under various service conditions by adapting the relevant standards such as IEC 60507, IEC 60815 and IEC 60383 [7-9]. However, in insulator study, there are a plenty of separated conditions such as weathering, pollution and mechanical influences which can be explored, since it might affect the performance of insulators in many ways.

1.2 Problem Statement

Polymer insulators play an important role in the medium voltage lines where 70% of line outages are due to the failure of line insulators. Several factors are known to influence the electrical performance of the polymer insulators. Among the factors are weathering and pollution where they may reduce the insulator performance. Several studies [10-12] have been done on the effects of weather and pollution on the polymer insulator, but in the case of medium voltage polymer insulator with low leakage distance, no significant studies are available in the literature. Therefore, the aim of this study is to observe the effects of air humidity, wetting and pollution condition on the electrical performance of a 10 kV insulator under lightning impulse voltage.

The inclination of insulator with respect to the cross-arm frequently reported by electrical utilities are due to the mechanical forces on the line and problems in the

installation of the insulator as shown in Figure 1.1. Moreover, the insulator angle with respect to the cross-arm may affect the values of electric fields and also increase the chances of electrical breakdown. Consequently, investigating the effects of insulator inclination (with respect to the cross-arm) to the values of electrical breakdown under wetting and pollution conditions is one of the purposes of conducting this study.

The lightning induced voltage on the medium voltage lines is one of the common causes of failures in distribution lines. It is due to coupling between lightning electromagnetic fields and line conductors [13]. There are no significant studies in the literature that has considered the effect of lightning induced voltage on the performance of medium voltage insulator under different weather and pollution conditions. In that regard, the last target of this study is on the evaluation of electrical performance of a 10 kV insulator under lightning induced voltage impulse conditions.

Figure 1.1: The inclination of insulator during the operation

1.3 Research Objectives

The aim of this work is to investigate the electrical performance of a 10 kV polymer insulator under lightning impulse voltage conditions. The objectives to be fulfilled upon finishing this study are listed as follows:

1. To investigate the effect of wetting and pollution on the electrical performance of a 10 kV polymer insulator under lightning impulse voltage condition.
2. To investigate the effect of insulator inclination with respect to the cross-arm under wetting and pollution condition through lab measurement and FEM modelling.
3. To evaluate the effect of lightning induced voltage on the electric field intensity and current density profiles of a 10 kV polymer insulator.

1.4 Scope and Limitations

The scope and limitation of this study has been summarised into several points as follow:

1. The polymer insulator is selected based on typical insulator which is used in distribution system.
2. The simulation model focuses only on an insulator component, which partially includes a part of the cross-arm and line conductor.

1.5 Thesis layout

This thesis is divided into five chapters which covers the introduction, literature review, methodology, results and discussion, and conclusion. Each chapter is chronologically presented based on the work that was carried out.

Chapter 1 presents the overview of the study to introduce ideas on the application of insulator in medium voltage field. The problem statement which leads to this study are explained while the limitations on the previous study are highlighted. This chapter also list all the aims of the study which serves as the basis for developing the whole research. The scope of work and some limitation during the study are also explained.
Chapter 2 discusses details on the literature review based on some previous work. Generally, in this chapter, the basic types and structure of insulator are reviewed. The current and relevant issues on the insulator study are also highlighted. In addition, the polymer insulator including the basic function, structure, material properties and its behaviour under several environmental condition are explained comprehensively. Finally, several standards on insulator testing technique, environmental properties and electrical principles were reviewed.

In the Chapter 3, the chronology of the study was technically explained in detail while guidelines for conducting the study were presented. FEM based software used in the study was also described in full with basic setting and the limitation of the modelling are discussed to a certain extent. This chapter also provides the parameters used for conducting the study.

Chapter 4 elaborates the performance of the polymer insulator under wetting, pollution and inclination conditions with consideration of lightning impulse voltage and induced lightning voltage. The results obtained from the analysis are then utilized to clarify the performance of polymer insulator.

Chapter 5 summarizes the findings of the study based on the objectives and problem statements of the research. Meanwhile, some recommendations were provided for future work on improving the insulator performance against the service environment.

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BIODATA OF STUDENT

The author was born in Kota Bharu, Kelantan, Malaysia on 30th November 1991. He completed his Bachelor of Electrical & Electronic Engineering degree in Universiti Putra Malaysia with second class upper in 2014. Currently he remained at Universiti Putra Malaysia and pursuing Master of Science in Electrical Power Engineering under the Department of Electrical and Electronic Engineering. While pursuing his Master degree, he had been tutoring courses including, Computer Programming, Microprocessor Technology and Power Electronics laboratory.

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