



**PERFORMANCE ANALYSIS IN MATERIAL  
SELECTION FOR SURFACE INSULATION  
CONDITION OF HIGH VOLTAGE APPLICATION**

**AZHAR BIN SULAIMAN**

**MASTER OF ELECTRICAL ENGINEERING  
(INDUSTRIAL POWER)**

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**Faculty of Electrical Engineering**

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**AZHAR BIN SULAIMAN**

**A dissertation submitted in partial fulfillment of the requirements for the degree of  
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**2014**



## DECLARATION

I declare that this dissertation entitled “Performance Analysis in Material Selection for Surface Insulation Condition of High Voltage Application” is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : .....

Name : Azhar Bin Sulaiman

Date : .....

## **DEDICATION**

A million praise towards to my beloved mother and late father, my family, my respectful supervisor, examiner and lecturer and to all my friends for their support and cooperation in helping me to complete the report.

Thanks to UTeM staff for their guidance and information given during my DISSERTATION. Their information helps me a lot in preparing the report.

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## ABSTRACT

High voltage insulation form an essential part of the high voltage electric power transmission systems. Any failure in the satisfactory performance of high voltage insulation can cause considerable loss of capital. The right material of insulator will perform optimization in production cost, maintenance cost and life time services. The performance of insulation materials can determine through the leakage current (LC) signal. That shows information of surface condition and pollution severity. Numerous of studies have been conducted to discover on insulation materials ageing in relation to surface condition, especially the correlation between LC harmonic components and deterioration of polymeric materials surface but still lack in analysis the performance of insulation materials specifically. This research presents the performance analysis of polymeric and non-polymeric insulation materials in contaminated condition using time frequency distribution (TFD). The selected materials are high density polyethylene, polypropylene and polystyrene as polymeric materials. Otherwise, glass is selected as a non-polymeric material. To demonstrate the performance of polymeric and non-polymeric insulation materials surface condition, LC signals is monitored and captured via non-standard inclined plane tracking (IPT) test. Then, the results are analyzed by using TFD which is spectrogram as a tool to diagnose and represent in time frequency representation (TFR). Parameters of signal are estimated from TFR to identify the LC signals patterns of the materials and to classify the surface condition via LC parameters. The findings of this research suggest that under contamination condition the insulating materials surface in certain voltage stress sustain several signals patterns as capacitive, resistive, symmetrical and unsymmetrical. The correlation between LC signal patterns and LC parameters is demonstrated the performance of insulating material surface conditions. Furthermore, this contribution can be applied for online monitoring and diagnosing erosion of insulation materials surface condition and it is very useful to the utility supplier. The conclusion can be drawn with approach of monitoring surface condition using TFD which is spectrogram is applied for analyze and demonstrate the performance of surface condition insulation materials.

## ABSTRAK

Penebatan voltan tinggi adalah salah satu bahagian penting dalam sistem penghantaran kuasa elektrik. Sebarang kelemahan pada penebatan voltan tinggi akan menyebabkan kehilangan kos modal yang banyak. Pemilihan bahan penebat yang tepat untuk aplikasi voltan tinggi dapat mengoptimumkan prestasi dari aspek kos penghasilan, kos penyelenggaraan dan jangka hayat penggunaan. Prestasi bahan penebat dapat ditentukan semasa isyarat kebocoran arus (LC). Ia menunjukkan maklumat mengenai keadaan permukaan dan tahap pencemaran. Banyak kajian yang telah dijalankan untuk mengenalpasti pencemaran bahan penebat dengan keadaan permukaan bahan penebat, terutama kolerasi antara komponen-komponen kebocoran arus selaras dengan kemerosotan prestasi permukaan bahan penebat polimer tetapi masih lemah dalam menganalisis prestasi bahan penebat secara spesifik. Penyelidikan ini meneliti prestasi bahan penebat polimer dan bukan polimer dalam keadaan tercemar dengan menggunakan teknik taburan kekerapan masa (TFD). Bahan-bahan yang dipilih di dalam kajian ini adalah 'high density polyethylene', 'polypropylene' dan 'polystyrene' sebagai bahan polimer. Manakala, 'glass' dipilih sebagai bahan bukan polimer. Tujuan kajian ini adalah untuk membandingkan prestasi permukaan bahan penebat polimer dan bukan polimer. Bentuk isyarat 'LC' dipantau dan direkodkan melalui kaedah ujian penjejak satah condong (IPT) tanpa mengikut standard spesifikasi masa. Kemudian, hasil keputusan dianalisis dengan menggunakan teknik TFD iaitu spectrogram sebagai alat menganalisa dan memaparkan dalam bentuk perwakilan tempoh dan frekuensi (TFR). Isyarat parameter dianggarkan daripada TFR untuk mengenalpasti corak tipikal bentuk gelombang isyarat bahan dan untuk dikelaskan mengikut keadaan permukaan melalui parameter-parameter kebocoran arus. Penemuan dalam penyelidikan ini mencadangkan dalam keadaan tercemar permukaan bahan penebat iaitu di tekanan voltan tertentu mengalami beberapa corak bentuk isyarat gelombang seperti 'capacitive', 'resistive', 'symmetrical' dan 'unsymmetrical'. Kolerasi antara corak-corak bentuk isyarat gelombang dan jumlah herotan gelombang (TWD) boleh ditakrifkan sebagai satu penunjuk keadaan hakisan permukaan bahan penebat. Tambahan pula dapatan ini boleh diaplikasikan untuk pemantauan dalam talian dan mendiagnosis hakisan permukaan bahan penebat dan sangat berguna bagi pembekal utiliti. Kesimpulannya, dengan pendekatan TFD pemantauan keadaan permukaan oleh spectrogram digunakan untuk menganalisa dan mengesahkan prestasi bahan-bahan penebat voltan tinggi.



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## LIST OF PUBLICATIONS AND EXHIBITIONS

### 1. International Conferences

**A. Sulaiman**, A. R. Abdullah, A. Aman, N. Norddin and N. Q. Zainal Abidin ,2013 ,  
*Performance Analysis of High Voltage Insulators Surface Condition Using Time-Frequency  
Distribution*, IEEE 7th International Power Engineering and Optimization Conference  
(PEOCO2013), 3<sup>rd</sup>-4<sup>th</sup> June 2013, Langkawi, Malaysia.

### 2. Exhibition

A. R. Abdullah, A. Aman, N. Q. Zainal Abidin and N. Norddin, **A. Sulaiman**, 2013 , has  
been awarded the *ITEX BRONZE MEDAL* for the invention ‘Online High Voltage Insulator  
Surface Condition Monitoring System’ at the 24<sup>th</sup> International Invention, Innovation &  
Technology Exhibition (ITEX 2013), 9<sup>th</sup>-11<sup>th</sup> May 2013, Kuala Lumpur, Malaysia.

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Introduction**

The insulators traditionally have been made from porcelain and glass. These materials have an outstanding insulating properties and weather resistance but have the disadvantages of being heavy, easily fractured and subject to degradation of their withstand voltage properties when polluted. However, these materials have over one century of service history and proven to resist environmental ageing and to be self-supporting and also being used in a wide variety of applications (Mackevich and Shah, 1997).

Instead, polymeric insulators are being accepted increasingly for use in outdoor installations by the traditionally cautious electric power utilities worldwide (Gubanski, 2005). The polymeric insulators outdoor improved the performance with light weight, lower construction and transporting cost, vandalism resistance, less gunshot damage, high strength to weight ratio-longer spans/new tower design, better contamination performance and improved transmission line aesthetics (Hall, 1993). However, early generation of

polymeric product is not considered the expected service life and until now users still have concerns about polymeric insulation materials performance. Therefore, the right material of insulator will perform optimization in production cost, maintenance cost and life time services. Besides that, insulation material products research will impact our everyday lives, environment and economy.

One of the indicators used to determine performance insulation materials is by leakage current signal. Leakage current (LC) signal provides information of polymeric and non-polymeric insulation surface condition and the pollution severity. It is the most efficient technique can be used to monitor the performance of insulation materials either online or offline. LC signal has a strong correlation on the surface condition and degradation of polymeric material. For this purpose, several methods to evaluate and predict materials performance based on LC measurements and one of them is the tracking and erosion test using incline plane tracking (IPT) test set-up (Gubaski, 1999).

This research work focuses on the performance analysis of insulation materials in order to demonstrate and verify the polymeric and non-polymeric insulation materials for high voltage application. Experimental for demonstrating and evaluating the performance of the selected materials as high voltage outdoor application must be complying with the international standard test specifically BS EN 62039:2007. This standard test is explicable in selection guide for polymeric materials for outdoor use under HV stress. In addition, the standard lists several references which relates to electrical and mechanical properties requirement that must be fulfilled for insulating materials in outdoor high voltage application.

In this analysis, characteristic LC signal is used as diagnostic tools to study and predict the insulation materials surface condition under electrical stress. Most previous studies used Fast Fourier Transform (FFT) to analyze the leakage current signal. Fast Fourier Transform (FFT) is useful to get the magnitude or phase of a number individual or band of frequencies. To resolve this problem, the analysis using time frequency distribution (TFD) such as spectrogram is used. Spectrogram performed to represent a three dimensional of the signal energy with respect to time and frequency. The analysis technique is motivated by the limitation of FFT to cater non-stationary signals which are spectral characteristics change in time. It is the result of calculating the frequency spectrum of windowed frames of the compound signal.

## **1.2 Problem Statement**

Any failure in the satisfactory performance of high voltage insulation can cause considerable loss of capital. Numerous studies and research activities are growing up for analyze the performance of insulation materials has been made. However, the research and development of high voltage outdoor insulation is still lack of studies in analysis and verified the performance of insulation materials surface condition specifically. Difficulty to detecting defective on insulation materials caused by lack of knowledge in its long term reliability and loss of hydrophobic that leads to tracking and erosion as well as to flashover under contaminant condition.

Hydrophobic is treated as the resistance to formation of conducting water tracks that increase leakage current, chances of flashover, and other deterioration effects. The superior contaminant performances of polymeric outdoor insulation materials were

regarded as the contribution of their hydrophobic surfaces. In other words, it is the formation of water beads on surface, which resist the flow of water in continuous conducting track (M Amin et al., 2007). Methods of hydrophobic measurements especially by leakage current (LC) were overviewed in this issues.

Numerous of studies have been conducted to discover on insulation ageing in relation to surface LC components, especially the correlation between LC harmonic components and the deterioration of insulation materials surface. Normally in previous works, LC is analyzing in time or frequency domains and mostly used Fast Fourier Transform (Krivda et al., n.d.). Fast Fourier Transform (FFT) is only suitable used for analysis of stationary signals and does not provide temporal information (Rioul, O. and Vetterli, 1991). Otherwise, LC signals are usually in non-stationary pattern especially during dry band condition and surface discharge, its mean FFT is not appropriate for non-stationary signal. Furthermore, the analysis of LC in polluted polymer insulator shows that FFT is fast in computation but possess limitations in resolution (Muniraj and Chandrasekar, 2009). It is tough to get timing info from a FFT. In fact, the FFT had a hard time telling whether things were going forward or backward. In time or frequency domain plot, it just gives half of the information about the signal. A time domain plot shows how a signal changes over time without notify "what" happened. Meanwhile, a frequency domain plot shows how much of the signal lies within each given frequency band over a range of frequencies without notify about the time it occurred.

### **1.3 Objectives of the research**

The following are the objectives of this research:

1. To analyze the performance of the polymeric and non-polymeric insulation materials surface condition for high voltage application using time frequency distribution.
2. To conduct test on high voltage insulation materials using Inclined Plane Tracking (IPT) test.
3. To demonstrate the performance of material surface condition for high voltage insulation materials using LC parameters.

### **1.4 Scope of work**

This research work focuses on the following scope:

1. High Density Polyethylene, polypropylene and polystyrene is thermoplastic polymeric material. Meanwhile, glass is non-polymeric material for tracking and erosion resistance.
2. Laboratory investigation is carried out on dielectric strength, tracking and erosion performance of the polymeric and non polymeric materials complying with non-standard test BS EN 60587-2007, to provide the information on suitability of the insulation materials for high voltage application as well as correlation between LC and surface condition of the materials.