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Faculty of Electrical Engineering

INSULATOR SURFACE CONDITION MONITORING SYSTEM FOR LEAKAGE CURRENT ANALYSIS

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INSULATOR SURFACE CONDITION MONITORING SYSTEM FOR LEAKAGE CURRENT ANALYSIS

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A thesis submitted
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DECLARATION

I declare that this thesis entitle "Insulator Surface Condition Monitoring System For Leakage Current Analysis" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date	:	....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for award of Master of Science in Electrical Engineering.

Signature	:	....
Supervisor Name	:	Dr. Abdul Rahim Bin Abdullah
Date	:	....

DEDICATION

To my beloved mother and family

ABSTRACT

There are several ageing factors that affect the long term performance of insulating material such as electrical stress, biological attack, and outdoor weathering contamination. Leakage Current (LC) is one of the key methods of measuring the insulator surface conditions which can cause tracking, erosion and flashover. Hence, an automated monitoring system is needed to reduce diagnostic time, rectify severity and ensure quality of insulator performance. This research presents the development of leakage current monitoring system to analyse insulator surface condition using Time-Frequency Distribution (TFD). To develop the system, a pre-information of the leakage current signal analysis is needed. Many previous researchers used Fast Fourier Transform (FFT) method for the analysis which gives spectral information; but it has some limitations in non-stationary signal, for example it does not provide temporal information. In this research, spectrogram is used to analyse the leakage current signals that consist of multi-frequency components and magnitude variations. From the Time-frequency representation (TFR) obtained using the time-frequency distribution, parameters of leakage current signal are calculated such as instantaneous of root mean square (RMS) current, fundamental RMS current, total harmonic distortion, total non-harmonic distortion, and total waveform distortion. The leakage current signals have different states such as capacitive, resistive, symmetrical and unsymmetrical waveforms that classifies the surface condition of the polymeric insulation. Tracking and erosion tests based on BS EN 60587-2007 standard are developed and constructed to capture the set of those leakage current states. Then, the leakage current signals are captured and transfer to personal computer using data acquisition system (DAQ) for monitoring and storing purpose. Graphical User Interface (GUI) is developed using Visual Basic (VB) for the real time analysis of the leakage current for insulator surface condition monitoring system. At the end of this research, the developed system shows that it is appropriate and reliable to implement the leakage current monitoring system for determining the leakage current characteristic of insulating surface condition.

ABSTRAK

Terdapat beberapa faktor yang memberi kesan penuaan prestasi jangka panjang dari bahan penebat seperti tekanan elektrik, serangan biologi, dan pencemaran luluhawa luar. Kebocoran Arus adalah salah satu daripada kaedah utama mengukur keadaan permukaan penebat yang boleh menyebabkan pengesanan, hakisan dan jambatan kilat. Oleh itu, satu sistem pemantauan automatik diperlukan untuk mengurangkan masa diagnostik, memperbaiki tahap penebat dan memastikan kualiti prestasi penebat. Kajian ini membentangkan pembangunan sistem pemantauan kebocoran arus untuk menganalisis keadaan permukaan penebat menggunakan Taburan Masa Frekuensi (TFD). Untuk membangunkan sistem ini, pra-maklumat analisis isyarat arus kebocoran diperlukan. Ramai penyelidik sebelumnya telah menggunakan Fourier cepat ubah (FFT) iaitu kaedah yang memberikan maklumat spektrum kepada analisis kebocoran arus, tetapi ia mempunyai beberapa batasan dalam isyarat tidak seimbang, misalnya ia tidak dapat memberi maklumat yang sementara. Dalam kajian ini, spectrogram digunakan untuk menganalisis isyarat arus kebocoran yang terdiri daripada komponen multi-frekuensi dan variasi magnitud. Dari Perwakilan Frekuensi Masa (TFR) yang diperoleh dengan menggunakan taburan masa-frekuensi, parameter isyarat arus bocor dikira, seperti arus bocor punca min kuasa dua (RMS), arus bocor RMS, jumlah herotan harmonik, jumlah herotan bukan harmonik, dan jumlah herotan bentuk gelombang. Isyarat arus bocor memiliki corak yang berbeza seperti kapasitif, rintangan, simetri dan bentuk gelombang simetri yang mengklasifikasikan keadaan permukaan penebat polimer. Penjejakan dan hakisan ujian yang mengikut konsep BS EN 60587-2007 dibina bagi menangkap set corak kebocoran arus. Kemudian, isyarat kebocoran arus ditangkap dan dipindahkan ke komputer peribadi yang menggunakan sistem perolehan data (DAQ) untuk memantau dan menyimpan. Pengguna grafik muka (GUI) dibangunkan dengan menggunakan Visual Basic (VB) untuk analisis masa sebenar arus bocor untuk sistem pemantauan keadaan permukaan penebat. Pada akhir kajian ini, sistem tersebut menunjukkan ianya sesuai dan boleh dipercayai untuk melaksanakan sistem pemantauan kebocoran arus untuk menentukan ciri-ciri kebocoran arus keadaan permukaan penebat.

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

HV	-	High Voltage
PVC	-	Polyvinylchloride
LC	-	Leakage Current
FFT	-	Fast Fourier Transform
TFD	-	Time Frequency Distribution
IPT	-	Inclined Plane Tracking
RMS	-	Root Mean Square
THD	-	Total Harmonic Distortion
TnHD	-	Total non-Harmonic Distortion
TWD	-	Total Waveform Distortion
TFR	-	Time Frequency Representation
VB	-	Visual Basic
GUI	-	Graphic User Interface
TNB	-	Tenaga Nasional Berhad
DC	-	Direct Current
HVDC	-	High Voltage Direct Current
EAP	-	Early Aging Period
TP	-	Transition Period
LAP	-	Late Aging Period
FT	-	Fourier Transform
DFT	-	Discrete Fourier Transform
STFT	-	Short Time Fourier Transform
Hz	-	Frequency unit, Hertz

ADC	-	Analogue to Digital Converter
NI-DAQ	-	National Instrument Data acquisition
USB	-	Universal Serial Bus
V	-	Volts
PP	-	Polypropylene
UTeM	-	Universiti Teknikal Malaysia Melaka
DAQ	-	Data Acquisition
P.U	-	Per-unit System

LIST OF SYMBOLS

$w(t)$	-	Observation window
f_s	-	Sampling frequency
f_0	-	Fundamental frequency
h	-	Harmonic
t_s	-	Sampling period
n	-	Integer
$I_{RMS}(t)$	-	Instantaneous Root Mean Square Current
$I_{1RMS}(t)$	-	Instantaneous Root Mean Square Fundamental Current
$I_{THD}(t)$	-	Instantaneous Total Harmonic Distortion
$I_{TnHD}(t)$	-	Instantaneous Total non-Harmonic Distortion
$I_{TWD}(t)$	-	Instantaneous Total Waveform Distortion

LIST OF PUBLICATIONS

1. Publications

N. Q. Zainal Abidin, A. R. Abdullah, N. Norddin, A. Aman (2013). “Online Surface Condition Monitoring System using Time Frequency Distribution on High Voltage Insulator." Australian Journal of Basic and Applied Sciences.

Norddin, N., A. R. Abdullah, N. Q. Zainal Abidin, A. Aman (2013). "High Voltage Insulation Surface Condition Analysis using Time Frequency Distribution." Australian Journal of Basic and Applied Sciences.

N. Norddin, A. R. Abdullah, N. Q. Z. Abidin, and A. Aman, “Automated Classification System for Polymeric Insulation Surface Conditions” Engineering Letters. (Accepted for IAENG Journal).

2. Proceeding International Conferences / Seminar

Zainal Abidin, N. Q., A. R. Abdullah, et al. (2013). Online surface condition monitoring system using time-frequency analysis technique on high voltage insulators. Power Engineering and Optimization Conference (PEOCO), 2013 IEEE 7th International.

Abidin, N. Q. Z., A. R. Abdullah, et al. (2012). Leakage current analysis on polymeric surface condition using time-frequency distribution. Power Engineering and Optimization Conference (PEOCO) Melaka, Malaysia, 2012 Ieee International.

Abidin, N. Q. Z., A. R. Abdullah, et al. (2012). Online Leakage Current Monitoring System using Time-Frequency Distribution on High Voltage Insulator. Power and Energy Conversion Symposium (PECS 2012). Melaka, Malaysia.

Norddin, N., A. R. Abdullah, et al. (2013). Polymeric insulation surface condition analysis using linear time frequency distributions. Power Engineering and Optimization Conference (PEOCO), 2013 IEEE 7th International.

Sulaiman, A., A. R. Abdullah, et al. (2013). Performance analysis of high voltage insulators surface condition using Time-Frequency Distribution. Power Engineering and Optimization Conference (PEOCO), 2013 IEEE 7th International.

Abdullah, A. R., N. Norddin, et al. (2012). Leakage current analysis on polymeric and non-polymeric insulating materials using time-frequency distribution. Power and Energy (PECon), 2012 IEEE International Conference.

Norddin, N., A. R. Abdullah, et al. (2012). Leakage Current Analysis of Polymeric Insulation using Linear Time Frequency Distribution. Power and Energy Conversion Symposium (PECS 2012). Melaka, Malaysia.

3. Exhibition

PECIPTA **Silver** Medal for the the invention **Online High Voltage Insulator Surface Condition Monitoring System** at the International Conference and Exposition on Invention of Institutions of Higher Learning PECIPTA 2013 in 7-9 Nov, Kuala Lumpur, Malaysia.

Awarded **ITEX bronze medal** for the invention “Online High Voltage Insulator Surface Condition Monitoring System” at the 24th International Invention, Innovation & Technology Exhibition ITEX 2013 Kuala Lumpur, Malaysia from 9th-11th May 2013.

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview of Research Background

Two of the most important components in high voltage (HV) engineering or its applications, are conductors and insulator. Conductors are used to carry current to the desired paths while insulators prevent the flow of currents in undesired paths, as shown in Figure 1.1 (Ronald and Duccan, 2004). The principal media of insulation used for insulators are gases, vacuum, liquid, solid, or a composite (combination). Among them, solid dielectric materials are used in all kinds of electrical apparatus and devices to insulate the current carrying part from one another when they operate at different voltages.

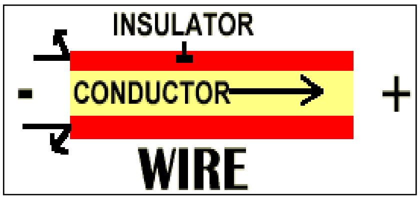

Figure 1.1 General illustration of insulator

Leakage current will flow through the protective ground conductor to ground. One of the main contributors that leads to the occurrance of leakage current is the contamination on the surface of the insulators. Measurement of leakage current is one of most critical steps to find information on how to minimize the flashover caused by pollution insulators, and better if it requires additional information from measurements and analysis of the pollution (Ramirez et al., 2012). For leakage current performance, one factor that should be controlled is the flashover mechanism due to dry band formation on the surface. Basically, leakage current signal that leads to surface flashover consists of capacitive current, resistive current, non-linear current and non-linear with discharge current (Bollen and Gu, 2006). Measurement of the leakage current such as amplitude, pulse, accumulated charge and discharge duration has been used to provide information on degradation (Fernando and Gubanski, 1999c). For this reason, measurements of leakage current are often performed in order to evaluate the performance of the material surface condition.

Incline Plane Tracking (IPT) test that complies to the BS EN 60587-2007 standard is conducted on polypropylene polymeric to simulate a set of different leakage current patterns; from capacitive state, resistive state, symmetrical and unsymmetrical state. Leakage current is normally analysed in frequency domains, and the fast Fourier transform (FFT) is commonly used for transformation technique. However, leakage current signals are usually in non-stationary pattern especially during dry-band condition and surface discharge. Therefore, to overcome these limitations, time frequency distribution (TFD) is used.

Time frequency distributions (TFDs) are developed to represent time-varying signal jointly in time and frequency representation (TFR) (Radil et al., 2007). Non-stationary signals in electrical engineering brings a challenges for signal processing which serves the idea for applying joint time frequency representations. Conventional techniques that are currently used for signal monitoring are based on visual inspection of voltage and current waveforms. In this research, an automated signal classification system using spectrogram analysis is developed to identify, classify as well as provide the information of the signal.

1.2 Motivation of Research

High voltage insulators form an essential part of the high voltage electric power transmission systems. Any failure in the performance of high voltage insulators will result in considerable loss of capital, as there are numerous industries that depend upon the availability of an uninterrupted power supply. The importance of the research on insulator pollution has been increased considerably with the rise of the voltage of transmission lines since outdoor insulators are being subjected to various operating conditions and environments.

Surface discharge is a common electrical discharge that normally occurs on outdoor insulators under wet and contaminated conditions. The surface of the insulators is covered by airborne pollutants due to either natural or industrial pollutants, or mixed between the two. Contamination on the surface of the insulators enhances the chances of flashover. Under dry conditions the contaminated surfaces do not conduct any leakage current, and thus contamination is of little importance in dry periods (Gorur and Olsen, 2006). As the surface become moist due to rain, fog or dew, the pollution layer becomes conductive because of the presence of ionic solids. Pollution flashover, ageing, tracking and erosion that observed on insulators used in high voltage transmission, is one of the most important problems for power transmission. These kind of pollutions are very complex problem due to several reasons such as modelling difficulties of the insulator complex shape, different pollution density at different regions, non-homogenous pollution distribution on the surface of insulator and unknown effect of humidity on the pollution (Dhahbi-Megriche and Beroual, 2000).

The performance of insulators under polluted environment is one of the guiding factors in the insulation coordination of high voltage transmission lines. On the other hand,