SURFACE DISCHARGE ANALYSIS OF HIGH VOLTAGE GLASS INSULATOR USING ULTRAVIOLET PULSE VOLTAGE

SAIFUL MOHAMMAD IEZHAM BIN SUHAIMI

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

MAY 2017

Specially dedicated to

my father and mother, Suhaimi Bin Mat and Norieziam Binti Che Din

my siblings, Qistina Nurqaisum, Syaiful Muhd Qawiem and Muhammad Qarafix

and last but not least my families, lecturers and also my friends

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my supervisor, Dr. Nor Asiah Muhamad and external co-supervisor, Dr. Nouruddeen Bashir Umar for their continuous encouragement and sharing knowledge throughout my study. In addition, I would also like to express appreciation to my co-supervisor, Dr. Noor Azlinda Ahmad for sharing her knowledge in guiding and assisting me during my study.

I wish to thank Universiti Teknologi Malaysia and Ministry of Higher Education Malaysia (MOHE) for awarding me the scholarship to pursue my study and granting us the research grant, Fundamental Research Grant Scheme (FRGS), which supported this research as part of my study.

Special gratitude goes to all the staff of Institute of High Voltage and High Current (IVAT), UTM for their assistance in the experimental setup. Moreover, I would like to thank postgraduate students of IVAT especially Novizon, Aulia, Nur Faizal Kasri, and Zulkifli Azman, for their technical support and thoughtful concern.

Finally yet importantly, I am forever indebted to my parents, my families and my friends whom have supported emotionally and financially.

ABSTRACT

Contaminated and aged transmission line insulators are susceptible to flashover during service, due to temporary or permanent loss of their insulating properties, resulting in power system failure. Surface discharges are precursors to flashovers. To pre-empt the occurrence of flashover incidents, utility companies need to regularly monitor the condition of line insulators. Recent studies have shown that monitoring of ultra-violet (UV) signals emitted by surface discharges of the insulators is a promising technique. This study presents a method of detecting impairment on contaminated and aged insulators during surface discharge activities, by using UV pulse voltage method. For verification, time and frequency domain of the UV signals for a group of insulator samples with varying contamination levels and degree of ageing have been analysed. Experimental result shows that a strong correlation exists between the frequency components of the UV signals and discharge intensity levels under varying contamination levels and degree of ageing. As the contamination levels increases, the discharge levels of the insulator samples also intensifies, resulting in the increase of total harmonic distortion (THD) and fundamental frequency of the UV signals. Frequency components of the UV signals have been employed by using MATLAB simulation to develop a technique based on artificial neural network (ANN) to classify the flashover prediction based on the discharge intensity levels of the insulator samples. The results of the ANN simulation show 87% accuracy in the performance index. This study illustrates that UV pulse detection method is a potential tool to monitor insulator surface conditions during service.

ABSTRAK

Penebat talian penghantaran tercemar dan berusia yang terdedah kepada lampau kilat ketika dalam perkhidmatan disebabkan oleh kehilangan ciri-ciri penebatan sama ada kekal atau sementara, mengakibatkan kegagalan sistem kuasa. Nyahcas yang terhasil pada permukaan penebat adalah petanda awal kejadian lampau kilat. Bagi memastikan kejadian lampau kilat tidak berlaku, syarikat utiliti perlu sentiasa memantau keadaan penebat garis. Kajian terbaru menunjukkan bahawa pemantauan isyarat ultra ungu (UV) yang dihasilkan oleh permukaan penebat merupakan satu teknik yang berkesan. Kajian ini membentangkan satu penyelidikan terhadap isyarat UV pada penebat-penebat tercemar dan berusia yang dikesan semasa aktiviti nyahcas permukaan menggunakan kaedah denyut UV. Untuk pengesahan, masa dan frekuensi domain isyarat UV untuk sekumpulan sampel penebat dengan pelbagai tahap pencemaran dan darjah penuaan telah dianalisa. Keputusan ujikaji menunjukkan bahawa satu pertalian yang kuat wujud antara komponen frekuensi isyarat UV dan aras keamatan nyahcas yang berbeza-beza di tahap pencemaran dan darjah penuaan. Apabila tahap pencemaran dinaikkan, aras keamatan nyahcas penebat meningkat dan ini mengakibatkan peningkatan dalam herotan harmonik seluruh (THD) isyarat UV dan frekuensi harmonik asas. Komponen frekuensi isyarat UV telah dikaji dengan menggunakan simulasi MATLAB bagi membangunkan satu teknik berdasarkan rangkaian neural buatan (ANN) untuk mengelaskan ramalan lampau kilat berdasarkan aras keamatan nyahcas penebat. Keputusan simulasi ANN menunjukkan ketepatan 87% dalam indeks prestasi. Kajian ini menunjukkan bahawa kaedah pengesanan denyut UV merupakan satu alat yang berpotensi untuk memantau keadaan permukaan penebat semasa dalam perkhidmatan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

AC	-	Alternating current
AI	-	Artificial Intelligence
ANN	-	Artificial Neural Network
DC	-	Direct Current
ESDD	-	Equivalent Salt Deposit Density
FFT	-	Fast Fourier Transform
HV	-	High Voltage
LC	-	Leakage Current
NaCl	-	Sodium Chloride
PC	-	Personal Computer
PD	-	Partial Discharge
RMS	-	Root Mean Square
THD	-	Total Harmonic Distortion
TNB	-	Tenaga Nasional Berhad
UV	-	Ultraviolet

LIST OF SYMBOLS

R	-	Resistance
I	-	Current
V	-	Voltage
C	-	Capacitance
U	-	Source Voltages
Q	-	Output Signal
S_a	-	Salinity
V	-	Volume
A	-	Area of Insulator washed
σ_{20}	-	Conductivity of suspension connected to $20\ °C$
θ	-	Temperature of suspension
b	-	Temperature constant
V_h	-	Harmonic Voltage
h	-	Harmonic Number
f	-	Frequency
T	-	Time
V_i	-	Injected Voltage
V_{p-p}	-	Peak-to-peak voltage

V_{min}	-	Minimum normalized value
V_{max}	-	Maximum normalized value
D	-	Input value of data
D_{max}	-	Maximum input value of data
D_{min}	-	Minimum input value of data

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Transmission lines are one of the most important parts of power system. They play a paramount role as electrical components for the transfer of large amount of electricity from generation to distributions. There are three main parts in electrical supply system, namely, generation, transmission, and distribution [1]. Figure 1.1 shows a typical power system, from generation to distribution. These parts each have different functions. However, for electricity to be supplied efficiently from the power plant to customers, reliable insulators that can effectively insulate the lines from the transmission towers are needed in the system. Also, the electrical losses need to be considered. Every type of insulator has its own limit to withstand electrical stress [2, 3]. There are levels of electrical strength for each insulator used in transmission line systems.

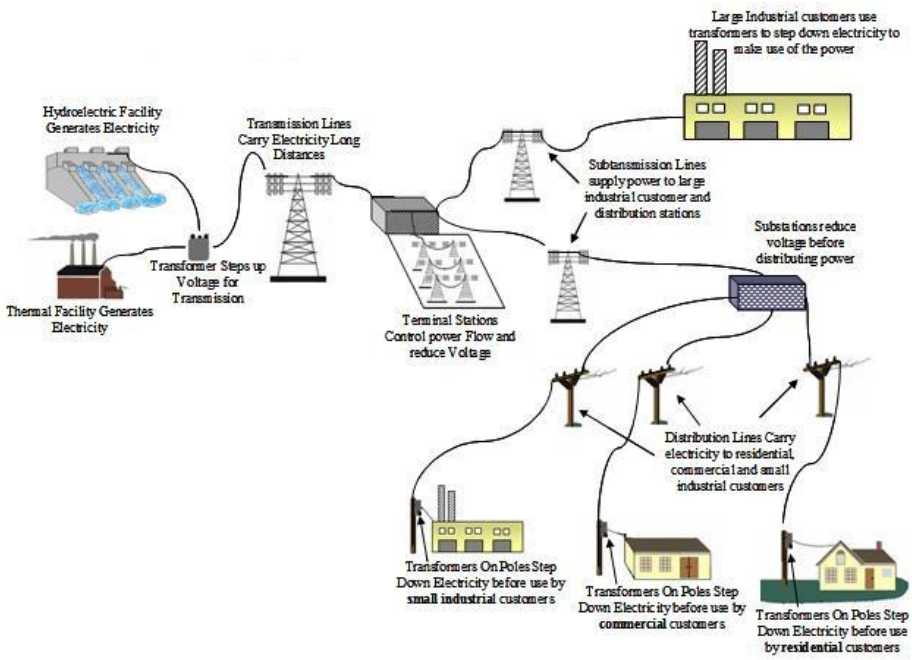

Figure 1.1 Electricity Supply System Schematic [4]

Transmission line insulators are susceptible to contamination flashover and thus a source of power system failure. The energy transferred through the transmission line is usually at its highest level to avoid losses since it is transferred over a long distance. Thus, the insulators that are used in a transmission lines need to have adequate insulation for that particular voltage level. Although the insulators have been designed for that voltage level, environmental factors need to be considered as they affect the insulators' performance [5].

The environment is one of the main causes of insulator flashover and breakdown in power systems. Aerosols and pollutants deposited on the surface of the insulators cause reduction in insulator surface resistance thereby leading to the flow of leakage current. This subsequently leads to the formation of surface discharges on the surface of the insulators. Figure 1.2 shows a typical flashover incident on a string of glass insulator.

Figure 1.2 Flashover Occurrences [6]

Since the environment in which the insulators operate cannot be controlled, electricity supply companies carryout maintenance services to prevent or reduce the surface discharges from developing into a flashover. The maintenance methods usually practiced by the utilities company are either breakdown maintenance or periodic maintenance. For breakdown maintenance, the maintenance is carried out after a breakdown incidence has happened in the system. This makes the cost of the maintenance very high because of the damage caused due to the breakdown. Periodic maintenance, on the other hand, is a type of maintenance that is carried out periodically (from time to time). However, nowadays researchers are studying and developing methods to predict the insulators' surface condition during their operation to prevent flashover occurrences. Such kind of maintenance method is called predictive maintenance. In such cases, the surface discharges that develop on the surface of insulators which are precursors to flashover incidences can be monitored.

Insulator surface discharge need to be monitored closely over time since the pollution around the insulators are unpredictable. The various methods that have been used to detect surface discharges include infrared method, ultrasonic method, acoustics method, leakage current method and ultraviolet method with some of the methods having their pros and cons [7-9]. By detecting the discharge that happens on the surfaces of the insulators, the flashover can also be predicted and thus reduce power system failure.

Studies have shown that surface discharges on the surface of insulators emit UV radiation [10]. UV radiation can be detected in many source such as sunlight, electric discharge and special light (mercury-vapour lamp, back light) [11]. These UV radiations have different wavelengths. The UV radiation from electrical discharges such as corona have a waveband of 280 nm – 400 nm, while few others range from 160 nm to 180 nm [12]. These wavebands are also known as the solar blind region.

Many researchers have studied the UV radiation emitted from electrical discharge using UV Image method [13, 14]. This method is reliable since it can detect and pinpoint the discharge location though very expensive when used in the fields. However, other inexpensive UV signal detection methods have been proposed. One of these methods is the UV pulse method. This method involves the detection and measurement of the UV pulses due to UV radiation emitted by the insulator surface discharges. This method has been shown to be a promising.

1.2 Problem Statement

There are many types of discharge detection methods being studied in the past to monitor insulator surface discharges with new methods introduced from time to time. The most common methods that have been reported are leakage current (LC) method, infrared method, and acoustics method. These methods have their own advantages and drawbacks. LC method nowadays is not the preferred detection method for insulators surface discharges due to its accuracy of the detection and the method involves direct contact measurement which is undesirable to utility companies. For Acoustics detection method, it is mostly used for partial discharge detection but is immune to electromagnetic interference [8, 15, 16]. Ultrasonic detection method is sensitive to the background noise. Although it can easily locate discharges, it has a poor sensitivity and sound attenuation. Infrared method is mostly related to temperature detection and it is difficult to use during hot and sunny day which affecting the detection accuracy [17]. Recently, measurements on the ultraviolet signals emitted during insulators surfaces discharges have been shown to be a good method to detect surface discharge from insulator transmission line. Studies by [18] have shown that this method could locate the discharge area with relatively high accuracy. The method also has high sensitivity that makes the detection more accurate and reliable than other method. In addition, it is a non-contact method.

There are two methods employed in the detection of the ultraviolet signals emitted by the surface discharges, the ultraviolet pulse method and ultraviolet imaging method. Nowadays, researchers have been narrowing their research on UV ray detection for UV imaging method. There have been many studies regarding detection of surface discharges using UV images [13, 14]. This is because this method is very easy to use by utilities and it is a non-contact detecting method. In this method, focus is on the UV image of the insulator surface in service. The image is studied so that it can provide information regarding the discharge stage from the UV images that are emitted on the insulators' surface. Numerous studies have been conducted related to characterization and pattern recognition of the UV signals using the UV image method.

With regards to the UV pulse method, most of the studies have been limited to detection and measurement of the UV pulse signals of the insulator surface discharges. Studies pertaining to characterization and pattern recognition of the UV pulse signal in relation to surface condition of the insulators are lacking. Table 1.1 shows the past study on the condition monitoring of the transmission line insulator using UV method (UV pulse and UV Image) for pollution, environment factor and ageing.

Table 1.1: Past study related to UV pulse and UV Image method

Study	**Insulator Surface Condition**			
	Pollution and Environment Factor		**Ageing**	
	UV Pulse	UV Image	UV Pulse	UV Image
Detection	Numerous	Numerous	None	Very Few
Characterization	Very Few	Numerous	None	Very Few
Pattern Recognition	None	Numerous	None	Very Few

1.3 Objectives of Study

1. To detect and measure the UV signals during UV emission due to discharge activities on the surfaces of contaminated and aged insulators
2. To study and classify the UV pulse signals magnitude and harmonic of varying surface discharge intensities of contaminated aged insulators.
3. To find performance index of insulator discharge intensities with respect to insulator surface condition using artificial intelligence of in-service transmission line insulators.

1.4 Scope of Study

The scopes for this research are as follows:

1. Laboratory investigations are carried out on field-aged ceramic insulators artificially contaminated.
2. Artificial Neural Network is employed for pattern recognition of insulator surface discharge intensities for insulator surface condition monitoring.

1.5 Significance/Contribution of Study

The contribution of this research is as follows:

1. Characterization of UV pulse signals from UV radiation emitted during insulator surface discharges in relation to varying degree of insulator contamination level and ageing.
2. A technique to monitor surface discharge of the insulators by using artificial intelligence.

1.6 Thesis Organization

This thesis is organized as follows:

Chapter 2 is about literature review related to this study. Previous studies related to this work are presented. Various insulator surface discharge detection methods are presented, with the comparisons made to highlight their pros and cons.

Chapter 3 describes the research methodology and equipment used during the experiment. Details about the experiment flow and data collection are also discussed.

Chapter 4 consists of the discussion on experimental results. The results analysis on the include UV signal waveforms in time and frequency domain under various insulator surface conditions vis-à-vis contamination level and degree of ageing. Also, results on flashover prediction using ANN are also presented.

Chapter 5 presents the overall conclusion on the research outcome. Recommendations for future work in this area are also discussed.

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