FACULTY OF ELECTRICAL ENGINEERING

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FINAL YEAR PROJECT REPORT

THE CHARACTERIZATION OF NEGATIVE CLOUD-TO-GROUND LIGHTNING FLASHES IN MALAYSIA UNDER THE INFLUENCE OF POLLUTION

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Bachelor of Electrical Engineering (Power Industrial)

June 2015

"I hereby declare that I have read this full report entitled "**The Characterization of Negative Cloud-To-Ground Lightning Flashes in Malaysia under the Influence of Pollution"** and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Industrial)"

Signature : _____

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Date : 1 June 2015

THE CHARACTERIZATION OF NEGATIVE CLOUD-TO-GROUND LIGHTNING FLASHES IN MALAYSIA UNDER THE INFLUENCE OF POLLUTION

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I declared that this report entitled "**The Characterization of Negative Cloud-To-Ground Lightning Flashes in Malaysia under the Influence of Pollution"** is the result of my own research unless as cited in references. The report has not been accepted for any degree and not concurrently submitted in candidature of any other degree.

Signature : _____

Name : Muhammad Ridwan Bin Muhamad

Date : 1 June 2015

To my beloved mother and father

Rodizah Binti Samsudin

Muhamad Bin Mohd. Yatim

“Thank you for your patience and support”

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ABSTRACT

Lightning is one of the unpredictable natural phenomenon. Study on lightning is very important because engineers must know lightning characteristics before designing lightning protection systems. This study is focused more on return stroke which occurs in negative cloud-to-ground lightning flash. The characteristics of the negative cloud-to-ground lightning flashes in Malaysia are studied by analyzing electric field generated by the whole flash in nanoseconds resolution. Six out of fifty successive negative cloud-to-ground lightning flashes were selected as sample and analyzed. The measurement was recorded in Universiti Teknikal Malaysia Melaka (UTeM) during southwest monsoon period which is from April to May 2015. It was found that, total number of interstroke intervals has an arithmetic mean value of 76.38ms, a geometric mean value of 4.32ms and does not depend on return stroke order. Of the six negative cloud-to-ground lightning flashes, 83.3% have multiple strokes. In addition, the minimum and maximum peak amplitude of first return stroke (RS) are 0.33 and 1.22V respectively. The mean and geometric mean of peak amplitude for first return stroke (RS) that have been recorded were 0.79 and 0.73V. The percentage of single-stroke flashes was 16.7%, while the mean numbers of strokes per flash and maximum number of stroke per flash were 3 and 5, respectively.

ABSTRAK

Kilat adalah satu fenomena yang tidak dapat diduga. Kajian terhadap kilat sangat penting kerana jurutera mesti mengetahui ciri-ciri kilat sebelum merekabentuk sistem perlindungan kilat. Kajian ini lebih fokus terhadap pulangan strok yang berlaku dalam kelip kilat negatif awan ke darat. Ciri-ciri kelip kilat negatif awan ke darat di Malaysia dikaji dengan menganalisa medan elektrik yang dihasilkan oleh keseluruhan kilat dalam resolusi nanosaat. Enam daripada lima puluh berturutan kelip kilat negatif awan ke darat dipilih sebagai sampel dan dianalisa. Pengukuran direkodkan di Universiti Teknikal Malaysia Melaka (UTeM) ketika monsun barat daya iaitu daripada April sehingga Mei 2015. Kajian ini telah mendapati bahawa, jumlah selang antara strok mempunyai nilai purata aritmetik sebanyak 76.38ms, nilai purata geometrik sebanyak 4.32ms dan tidak bergantung kepada susunan pulangan strok. Daripada enam kelip kilat negatif awan ke darat, 83.3% mempunyai berbilang strok. Di samping itu, nilai minimum dan maksimum amplitud puncak strok pulangan pertama masing-masing adalah 0.33 dan 1.22V. purata dan purat geometrik puncak amplitud untuk strok pulangan pertama yang telah dicatatkan adalah 0.79 dan 0.73V. Peratusan berkelip tunggal strok adalah 16.7%, manakala purata bilangan strok per kelip dan bilangan maksimum strok per kelip masing-masing adalah 3 dan 5.

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LIST OF ABBREVIATIONS

Al	-	Aluminium
ALDIS	-	Austrian Lightning Detection and Information System
Cd	-	Cadmium
Cu	-	Copper
CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
Cr	-	Chromium
CG	-	Cloud-to-ground
CCN	-	Cloud condensation nuclei
EFM	-	Electric field mill
Fe	-	Ferum
HCL	-	Hydrogen chloride
H_2S	-	Hydrogen sulfide
NLDN	-	National Lightning Detection Network
NOx	-	Nitrogen oxide
O_3	-	Ozone
Pb	-	Plumbum
PCB	-	Printed circuit board
PM_{10}	-	Particulate Matter

RS	-	Return stroke
SO_2	-	Sulfur Dioxide
Zn	-	Zinc

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CHAPTER 1

INTRODUCTION

1.1 Background of Project (Motivation and Significance of Project)

The first study of the effect of urban area on the enhancement of the cloud-to-ground (CG) lightning activity over and downwind of cities has been initiated through literature published by [1]**.** Then, several studies have been conducted to study the effect of an urban area on the initiation and enhancement of CG lightning by researchers [2, 3, 4, 5, 6, 7, 8, and 9]. The study found that summer thunderstorms were locally enhanced in the city of St. Louis [10] and researchers reported that urban effects have caused convective precipitation anomalies in the city of Mexico [11]. Apparently, human activities have contributed to an increase of concentration of air pollution in urban area and also caused a thermodynamic effect due to differential heating of the city surface [7]. As a result, pollution over the cities can raise the concentration of cloud condensation nuclei (CCN) and this may affect the characteristics of the negative cloud-to ground lightning flashes such as the number of strokes per flash and interstroke intervals (time separation between strokes). For the reason, characteristics combined with the relationship between air pollution over cities in Malaysia are beginning to be of interest to researchers for the purpose of weather forecast and the designing of lightning protection systems. For example, a researcher [12] found that the failure mode of surge-protective devices deployed in power systems depends on the number of strokes per flash and interstroke intervals. This study contends that the number of strokes per flash and the interstroke intervals are every important parameter to consider in coordinating the circuit breakers in power distribution systems.

1.2 Problem Statement

In Malaysia, industrial activity that contributes high pollution appeared in Penang, Perak, Selangor and Johor [13]. Some studies in U.S.A, Spain and Brazil claim that pollution may enhance the lightning activity by providing highly negative charge at negative charge center [2]. The statement mention as above have no clear evidence to prove. Therefore, it is crucial to conduct lightning measurement in Malaysia in order to investigate the impact of air pollution against the enhancement of lightning activities.

1.3 Objectives

The objectives of conducting this project are as follow:

1.3.1 To develop a hardware for measuring electrostatic field (slow field changes) and radiation field (fast field changes) generated by lightning flash.

1.3.2 To analyze statistical information on electric field produced by negative cloud-to-ground lightning flashes.

1.3.3 To perform comparative study against cloud-to-ground lightning flashes in Malaysia and Spain under the influence of pollution.

1.4 Scope of the Project

This project will focus on identification of negative cloud-to-ground lightning flashes in Malaysia in which the lightning measurement is performed at Faculty of Electrical Engineering in Universiti Teknikal Malaysia, Melaka (UTeM). In this project, software named PROTEUS is used to design and simulate circuit for measuring lightning wave. Upon completing the circuit, it will be transferred to PCB board before combining it with complete hardware. The hardware consists of parallel plate antenna, fast field circuit, operational amplifier at interest frequency of 80MHz and oscilloscope which is used for the measurement of electrostatic field and radiation field. The important parameters concerned in this project include number of strokes per flash, interstroke intervals (time separation between strokes), peak amplitude of lightning wave captured and other statistical information of the lightning flash such as mean, geometric mean and standard

deviation. Besides that, air pollutant data provided by Clean Air Innitiative-Asia Secretiarat and the study of Luis Rivas Soriano and Fernando de Pablo from University of Salamanca, Spain are used to compare the cloud-to-ground lightning flashes in Malaysia and Spain under the influence of pollution, respectively.

1.5 Report Outline

This report consists of five chapters.

Chapter 1:- In this chapter, there will be explanation about background of project (motivation and significant of project), problem statement, objectives and scope of the project.

Chapter 2:- The literature review will be given on important facts about lightning and will focus on the characteristic of ground flashes. Those facts are obtained from papers, journal, articles, reference book and others.

Chapter 3:- It will review about the methodology of project which encompasses the development of project devices, simulation of circuit for verification and flow chart of project.

Chapter 4:- For this chapter, there is description of analysis and discussion of result obtained from the lightning measurement activity.

Chapter 5:- Finally, this chapter provides conclusion and summary of the research. Last but not least, there will be recommendation for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Related Works

This chapter presents related work in this field.

2.1.1 Lightning Forming Process

The first process in the generation of lightning is charge separation [14]. There are two hypotheses describing the process: Polarization mechanism hypothesis and electrostatic induction hypothesis. For polarization mechanism hypothesis by which charge separation occur still be the subject for researchers and this hypothesis has two components. Firstly, falling droplets of ice and rain become electrically polarized as they fall through the atmosphere's natural electric field. Secondly, colliding ice particles become charged by electrostatic induction. Ice and super-cooled water are the keys to the process. Violent winds buffet tiny hailstones as they form, causing them to collide. When the hailstones hit ice crystals, some negative ions transfer from one particle to another. The smaller, lighter particles lose negative ions and become positive; the larger, more massive particles gain negative ions and become negative.

According to the electrostatic induction hypothesis charges are driven apart by as-yet uncertain processes. Charge separation appears to require strong updrafts which carry water droplets upward, super-cooling them to between -10 and -20 °C. The collision between water with ice crystals to form a soft ice-water mixture is called graupel. Then, the collisions result in a slight positive charge being transferred to ice crystals and a slight negative charge to the graupel. Updrafts drive lighter ice crystals upwards, causing the cloud top to accumulate increasing positive charge. The heavier negatively charged graupel falls towards the middle and lower portions of the cloud, building up an increasing negative charge. Charge separation and accumulation continue until the electrical potential

becomes sufficient to initiate lightning discharges, which occurs when the gathering of positive and negative charges forms a sufficiently strong electric field. There are several additional hypotheses for the origin of charge separation. According to one such hypothesis, charge separation is initiated by the ionization of an air molecule by an incoming cosmic ray.

2.1.1.1 Leader Formation

After the induce charge separation happen, the upper part of cloud becomes positively charged and the lower part of the cloud become negatively charged. Thus, the negative charge at the base of cloud induces a positive charge on the ground. In the thundercloud, there are negatively charged mixed water and ice region that causes an initial bipolar discharge or path of ionized air. The discharge path of ionized are called leaders. Meanwhile, the negative charge leaders are called “stepped leaders”, travels towards the ground in forked pattern. The progression of stepped leader start to increase slowly which may continue for several tens to several hundreds of milliseconds to approach the ground. At this initial phase, there are relatively small electric current (tens or hundreds of amperes) and usually the leader is almost invisible compared to the subsequent lightning channel. When a stepped leader approaches the ground, the positive charges on the ground enhance the electric field. In Heinz Kasemir first theory [15], he states that the electric field is highest on trees and tall buildings. If electric field is strong enough, a conductive discharge called a positive streamer can develop from these points. As the field increases, the positive streamer is attracted to the stepped leader and a channel moves up to meet it. Once they connect, a strong current propagates upwards as a brightly visible return stroke. As a result, the surrounding air is superheated to $20{,}000^{0}$C and rapid expansion takes place, producing a shockwave which is heard as thunder. This form of lightning is called cloud-to-ground lightning.