UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE INVESTIGATION OF THUNDER FOR PROFILING THE TYPE OF LIGHTNING

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor of Electrical Engineering Technology (Industrial Power) with Honors.

by

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ABSTRAK

Kilat awan-ke-darat adalah sejenis kilat yang diklasifikasikan sebagai kilat yang paling bahaya di antara kilat-kilat yang lain yang mampu memusnahkan harta benda dan berbahaya kepada kehidupan dimana boleh menyebabkan kecederaan dan kematian. Masa-ke-guruh merupakan salah satu kaedah untuk menentukan jarak kilat dengan menentukan beza masa di antara sinaran kilat dengan bunyi guruh yang lebih perlahan dengan kelajuan 300 m/saat berbanding dengan kelajuan kilat. Kaedah ini telah dilaksanakan dengan menggunakan dua teknik ukuran: bidang radiasi elektrik jalur lebar dan akustik guruh rakaman isyarat. Kenyaringan 120db bunyi guruh itu dikesan oleh omnidirectional electret mikrofon. Masa yang berlalu antara sensor digunakan untuk mengira jarak kilat. Perisian WaveStudio 7.7.2.3 (Lecroy) dan perisian XViewer 1.81 (Yokogawa) yang digunakan untuk kerja-kerja analisis. Berdasarkan keputusan, purata jarak adalah antara 0.4km dan 4km. Daripada projek ini, ia telah ditemukan bahawa data daripada saluran akustik mempunyai beberapa voltan teraruh yang mungkin dari pergerakan cas positif pada tanah. Data daripada bunyi akustik boleh digunakan secara langsung untuk menentukan jarak kilat sebagai masa pertama bermula voltan yang dihasilkan yang mempunyai korelasi dengan standard lejang kembali pertama. Ini maklumat yang berguna boleh dilaksanakan ke dalam sistem yang boleh menentukan jarak kilat secara automatik untuk tujuan keselamatan.

Kata kunci: **Jarak Kilat; Medan Elektrik; Masa-ke-Guruh; Antena; Mikrofon; Beza Masa**

ABSTRACT

Cloud-to-ground lightning is one type of lightning which classified as the most dangerous among lightning that destroy properties and harmful to life that may cause injuries and death. Time-to-thunder is one of method to determine the distance of lightning by determine the delay time between lightning radiation and thunder sound as the thunder much slower with speed of 300 m/sec compared to lightning. This concept was adapted by using two measurements techniques: broadband electric radiation field and the acoustic signal recording thunder. The 120db loudness of the thunder sound was detected by omnidirectional electret microphone. The time elapse between sensors was used to calculate the lightning distance. The WaveStudio 7.7.2.3 (Lecroy) and XViewer 1.81 (Yokogawa) software used for analysis work. Based on result, range of distance was between 0.4km and 4km. From this project, it was founded that the data from acoustic channel have some induced voltage which might be from positive streamer at the ground. The data from acoustic sound can be used directly to determine the lightning distance as the first begin time of induced voltage have correlation with standard first return stroke. This useful information can be implemented into a system which can determine the lightning distance automatically for safety purpose.

***Keywords*= Lightning Distance; Electric Field; Time-to-Thunder; Antenna; Microphone; Time Elapse.**

DEDICATION

To Allah, my beloved parents, supervisor and friends.

ACKNOWLEDGEMENT

In the Name of Allāh, the Most Gracious, the Most Merciful

Thanks to Allah, finally I was completed this project and the final report on the subject of Projek Sarjana Muda (PSM) after being worked hard from last semester until the end of this semester.

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLE

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

Hz	-	Hertz
%	-	Percentage
ns	-	nano second
sec	-	second
km	-	kilo meter
V	-	Volt
µsec	-	micro second
LPCR	-	Low Positive Charge Region
C	-	Coulomb
°C	-	Celcius
kA	-	kilo Amphere
BIL	-	Breakdown, Intermediate, Leader
ms	-	milli second
CG	-	Cloud-to-Ground
ms^{-1}	-	Speed
α	-	Alpha
NCG	-	Negative Cloud-to-Ground
PCG	-	Positive Cloud-to-Ground
P	-	Positive
N	-	Negative
GC	-	Ground-to-Cloud
CA	-	Cloud-to-Air Lightning
CC	-	Cloud-to-Cloud Lightning
K	-	Kelvin
γ	-	Gamma
J	-	Joule
dt	-	time different
N	-	Newton
dB	-	Decibel

Ω	-	Ohm
F	-	Farad
UTeM	-	Universiti Teknikal Malaysia Melaka
USB	-	Universal Serial Bus
DC	-	Direct Current
AC	-	Alternating Current
PWM	-	Pulse Width Modulation
PC	-	Personal Computer
IC	-	Integrated Circuit
τ		Torque

CHAPTER 1
INTRODUCTION

1.1 Introduction

In this chapter, it will concise all the primary subject of the project that consist the project background, problem statement, objective, project scope, important of project and significant study. All of the information is relevant to the project.

1.2 Project Background

Lightning is the natural phenomena cause by a discharge of electrical energy that is develops in thundercloud. During thunderstorm, many process occur which lead in developing electric charge in various part of cloud. Some of the processes involve are vertical winds and different water droplets size. During the process of charging the cloud, it will achieve where the cloud is strong enough to discharge it charges that result as stroke of lightning. Figure 1.1 shows the type of thundercloud charge that normally occurs on cloud and how it is discharge. There are many type and name of lightning that are cloud-to-ground lightning, ground-to-cloud lightning, intra-cloud lightning, cloud-to-cloud lightning, ball lightning, heat lightning, Staccato lightning, Anvil Crawler, Bolt from the Blue, cloud-to-air lightning, bead lightning, ribbon lightning, sheet lightning, and sprites, but cloud-to-ground is the most famous lightning occur towards ground which be classified as the most dangerous lightning activity that give harm to human and properties.

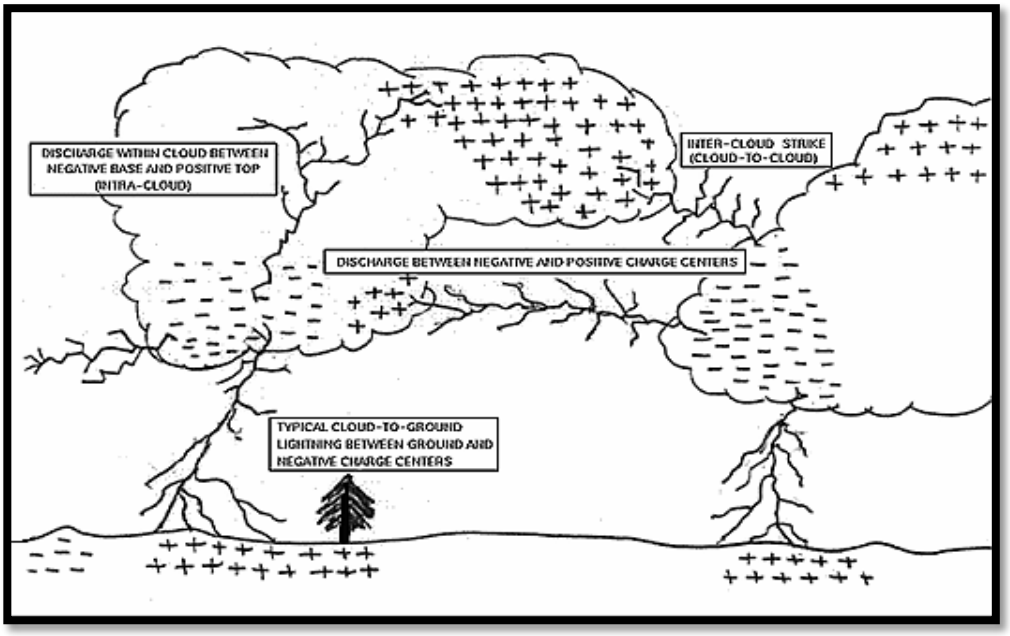

Figure 1.1: Type of Thundercloud Charge adapted from (Jerauld 2003b)

Thunder is the acoustic emission associated along after the lightning discharges. Thunder signatures have been analysed by many scientists that aim for understanding the energy emitted, asymmetric channel and localization of lightning channel (Bodhika et al. 2014). Thunder is the result of sudden expansion of the air along the lightning channel due to extremely high in temperature of the lightning channel. The sudden increase in pressure and temperature from lightning will produce rapid expansion of the air surrounding and within a bolt of lightning. The shock wave generated by the lightning transfer the thunder signal within a couple of meters from its source. Large amplitudes of thunder signatures are usually associated with the return stroke stage with the highest amplitude in lightning profile (Bodhika et al. 2011). The time-to-thunder method was one of method to determine the strike distance which aiming for the time lapse of both events (Ibrahim & Malek 2010). Thunder waves generated by lightning cloud-to-ground flash are considered to be one of strong natural sound source. Even though the strongest thunder signatures are generated at the return stroke stage, thunder signals generated at other events also can be strong enough to be record using a sensitive system (Bodhika et al. 2011). Electric fields generated by lightning events recorded through wide band from 20 kHz to 20 MHz measurements have been analysed using Fourier methods by many

researchers in the past that was very accurate method to determine the sound of thunder (Sonnadara et al. 2006).

1.3 Problem Statement

A thunder profile from lightning generation is not well understood. However, some study had identified a certain of sound from the thunder can inform a certain type of lightning that is usually cloud-to-ground lightning. Therefore it was a good idea to enhance the understanding the relationship of thunder and the type of lightning profile. In real life, lightning was among the most dangerous natural disasters. There are 100 lightning strikes every second on earth that have enough power to destroy everything within no time. So, the information from both lightning and thunder sound were very important to determine the time elapse between these two events. Besides that, antenna was detected and collected all electromagnet and electric field from surrounding such as thermal noise, electronic noise from receiver circuit input and radiated electromagnetic noise such as electrical machinery. Microphone also will collect man-made noise that was range in nano second (ns) which was very small that result not fixed the thunder profile. Apart from that, the time lapse after a lightning flash to hear thunder sound also not fixed as the lightning occur with many distances. So, something need be change to make sure the time elapse between lightning and thunder is below than 9.00 sec that surely 3 km distances of lightning as 1 km refer to 3 sec (Uman 2001).

1.4 Objective of Project

The objectives of this project were to ensure all the methods to complete this project in order to achieve the aims of this project. Therefore, there are some objectives need to be achieved at the end of this project before it is considered as successfully project. The objectives of this project are:

a) To understand the formation concept of thunder and the lightning.
b) To identify the type of sensor used for detecting electric field from lightning and thunder sound.
c) To measure times elapse between first return stroke and thunder sound using oscilloscope.
d) To analyze the waveform of thunder sound produced for profiling the lightning

1.5 Scope of project

The scope of project should be parallel to the objectives. The concept of the thunder and lightning formation need to be study for understanding the basic concept of the formation by using article, books, Internet and many source related. In this project, hardware needs to be prepared that are the combination between electric field sensor which is parallel plate antenna and thunder sound sensor which is omnidirectional outdoor microphone. From this two sense elements, it can determine the time elapse between lightning and thunder event as the lightning occur first and followed by the sound of thunder. The lightning type for this research are focus more towards negative cloud-to-ground lightning which is classified as the most dangerous lightning type which destroy properties and harmful to life that may cause injuries and death. The Teledyne LecroyHDO4024 used for electric field data logging while DL850 Yokogawa Recorders used for thunder sound waveform data logging. Besides that, output from antenna that detects the electric field need to be verify whether it is certainly a lightning signal profile that occur during return stroke by analyse the profile. As the thunder sound profile are not well understood, research and analyse of this waveform need to be done for profiling the type of this waveform.

1.6 Importance of project

Nowadays, thunder sound become one of the informative source on determine the distance of lightning. Based on past research, the lightning distance can be determined by using magnetic and electric field radiation from lightning with combination of audible and infrasonic sound from thunder. By using both data of lightning peak time that are sure to be first return stroke and thunder sound will get time elapse between this event. Based on time elapse, distance from the lightning strike which known as return stroke can be determined. This data then lead for future work which can be used for safety purpose.

1.7 Significant Study

Based on US National Lightning Safety Institute, Malaysia was categories as the third highest lightning activity around the world. Lightning at Malaysia most occur during inter-monsoon period in April, May, September and October. Based on recorded data, Malaysia experienced an average of 180 to 260 thunderstorm day a year after Indonesia with 322 and Columbia which between 275 to 320. Besides that, lightning also can be classify as one of the worst natural killer which causing at least 25,000 deaths worldwide each year. The important of this project then will determine time-to-thunder which can determine the distance of lightning. Based on past research about time-to-thunder method used to measure the distance of lightning, the lightning profile during return stroke are negligible as the data taken only the peak voltage during lightning activity. So, it is very important to study the profile of the lightning during return stroke and also the thunder sound profile. This both data can be used for future work which can be analysing for making a system for a safety purpose.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In this chapter, it provides the discussion about the formation of lightning and thunder. This includes the discharge process and also upward and downward moving process. Besides that, common type of lightning also explain with the type of thunder sound heard. Time-to-thunder method also being explain with also the distance of thunder can be detected. Generation of thunder also explain with acoustic energy and frequency spectrum. The process of measurement for lightning and thunder are also will be described in detail.

2.2 Formation Concept

2.2.1 Lightning

The most general sources of lightning are thundercloud, which is formed by cumulonimbus. Essentially, thundercloud structure was found to be tri-polar electrostatic which is divided into 3 part that are positive charge uppermost region which also known as net positive charge, followed by negative charge region which known as net negative charge which located at middle level nearly bottom of cloud, and continue with an additional small pocket of positive charge located at the bottom of the cloud which also known as Low Positive Charge Region (LPCR). Based on the Figure 2.1 below that shows the thundercloud with the position of the tri-polar electrostatic in the thundercloud which adapted from measurement achieve by (Malan 1963).

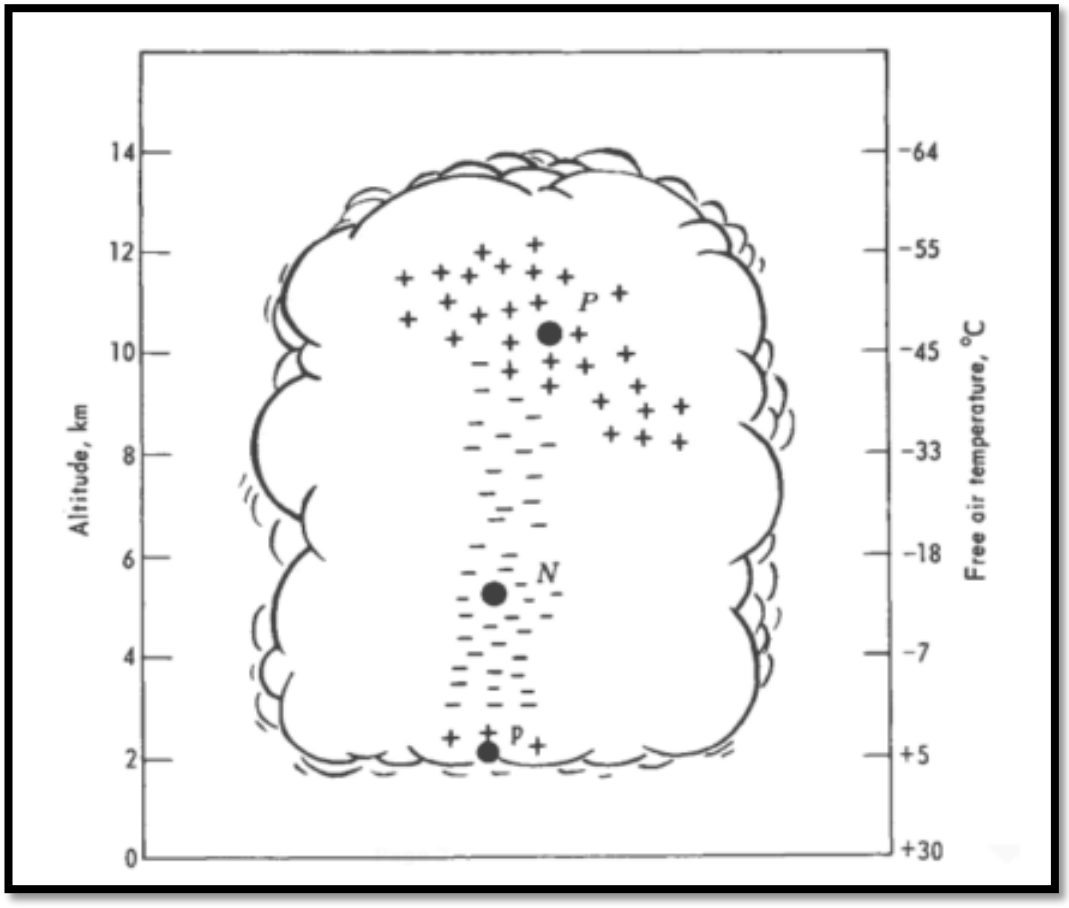

Figure 2.1: South African charge distribution in thundercloud according to Malan (1963) P – Positive charge uppermost region, N – negative charge region and P – Low Positive Charge Region (LPCR) adapted from (Uman 1969).

Lightning are occur when present of electric discharge between positive and negative charges that attract and collide each other then will produce an electric sparking. It is initially occur in cloud which contain water particle and ice particle as the higher the cloud locate will decrease the temperature. This both particles more likely being charging as it positive charge force upward by warm air current and negative charge move downward due to gravity. When particle are being charged, positive charge will move upward while negative charge move downward on the centre of cloud. Based on past study, balloons have been used as instrument through each 8 thunderstorms in England. The result from this experiment show that +4C is present at height of 1.5 km, -20C at 3km and +24C at 6km (Uman 2001). Once charge has been separated, it cause the unbalanced of electrical

charge that the positive and negative will attract each other to form a neutralise condition. Positive charge from ground will move upward toward cloud to form a pathway. Once these pathways are completely formed, spark will form to neutralize the both charge.

As the negative charge only move downward, the air particle from surrounding will heat up. This temperature of spark after heat up the surrounding airs are at almost 20,000 °C and it is rapidly heats the air to create a shock wave. Then, this lightning spark will form with variation type of lightning. Based on the Figure 2.2 below show the major lightning type happen which are more focus to be study as it is more practical when this type of lightning always cause injuries and death among human, disturbances in power and communication system besides it also create starter ignition of forest fire.

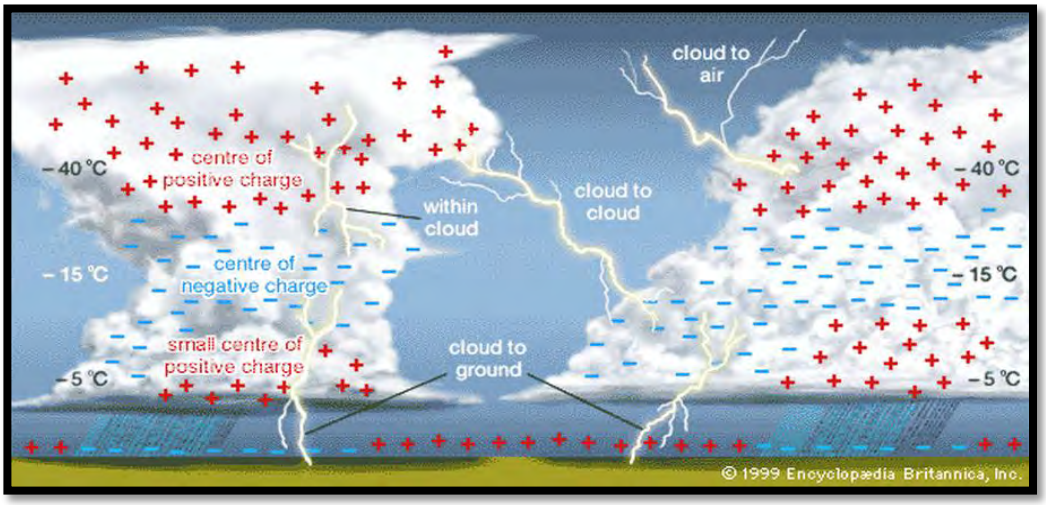

Figure 2.2: Type of major lightning occur adapted from (http://lightningformrslittle.weebly.com/uploads/1/4/4/2/14427904/2309004.gif?91)

2.2.1.1 The Lightning Discharge Process

Lightning are known as transient with high in current electric discharge where the length path are measured in kilometres (km). The general causes of lightning are electric charge that separated in

thunderstorm cloud that also known as cumulonimbus. Besides that, not all lightning activities occur during thunderstorm. Lightning also have been found during many natural disaster activities such as volcano eruptions, sandstorms, heavy snowstorm, extremely forest fires and surface nuclear detonation that are capable to develop lightning (Uman et al. 1972)(Anon n.d.)(Colvin et al. 1987). Based on Figure 2.3 below, it is show that volcano eruption at Sakurajima Volcano can developed electric discharge that produced lightning.

Figure 2.3: Volcano eruptions at Sakurajima Volcano in southern Kyushu, Japan (2013) adapted from (http://www.mymodernmet.com/profiles/blogs/martin-rietze-japan-sakurajima-volcano-eruption/)

Berger (1978) has been classifying possible lightning that can occur between the cloud-to-ground into four different types. The types are in terms of the direction of motion whether it is upward or downward, and the sign of charge whether it is positive or negative charge of the step leader that initiates the discharge. Based on the Figure 2.4, category (a) lightning types are downward negative lightning that are the most typical cloud-to-ground lightning. It is about 90% global ground flashes are the flows of negative charge to ground. This initiate when the negative charges are moving downward

as a step leader that lower the charge to earth ground. The first return stroke current is about 30Ka that can be three to five stroke within one flash (Rakov & Huffines 2003).While category (b) are the type of downward positive lightning which are very rarely that only 10% of cloud-to-ground flash. This type of flash will rise to a larger currents and larger positive charge transfer than their more numerous counterparts compared to negative ground flashes. Category (c) that is upward negative lightning have positively charged step leader that move upward to the lowers negatively cloud charges. Categories (d) that is upward positive lightning which negatively charge are moving upward towards the lowers positive cloud charge. Based on lightning observations at Mt. San Salvatore in Switzerland determine that 75 % to be negative upward flashes with only about 11 % were negative downward, and the remaining 14 % were classed as positive upward flashes adapted from (Berger 1975.

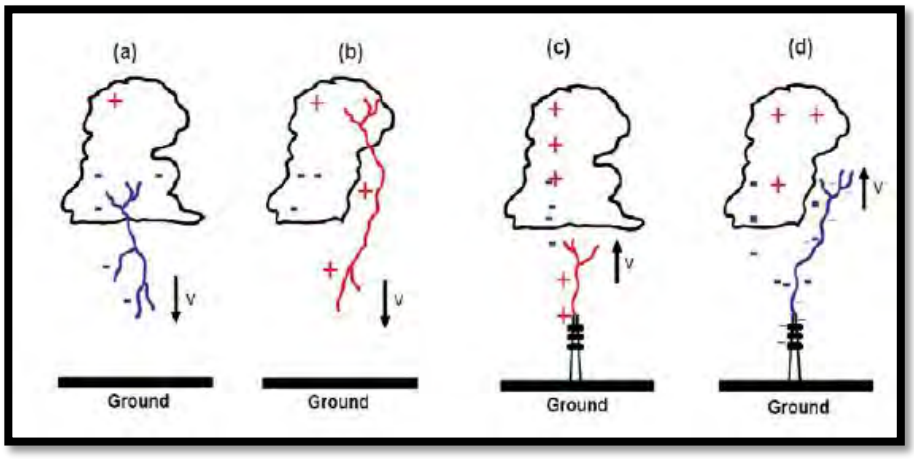

Figure 2.4: Four major category type of lightning adapted from (Berger K. 1978) (Jerauld 2003b)