

LIGHTNING CHARACTERIZATION USING SHORT BASELINE
LIGHTNING SENSOR SYSTEM

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To my parents for their thirsty for knowledge, financial support, continuous
prayers among numerous best wishes for me,
I pray you harvest the fruits of your labour.
*“My Lord! Bestow Your Mercy on them as they
cherished me in my childhood”*

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ABSTRACT

Lack of accurate lightning strike details have continue to be resulting causes of disaster across the continent especially at regions with high isokeraunic level like Malaysia, Singapore, Indonesia to mention few among many despite their installed lightning protection. This natural phenomenon is associated with a very strong current discharge causing several damages to lives and properties, and still remain the main source of forest fire which leads to enormous economic losses from damaging of structures and facilities. However, researchers have been in search of how best to withstand this recurring phenomena because it is believed that the knowledge of its constituents have great role to play in the protection of lives and properties against the menace which can only be achievable via comprehensive design of sophisticated protection gadget. These basic parameters include the current amplitude, polarity of the charge transfer, number of stokes per flash, lightning characterized patterns with duration of some occurrences which plays important roles in scientific research, protection analysis as well as serves as warning notification. Several attempts had been made in studying these fundamentals of the lightning parameter which are mainly achieved through manual analysis by taking measurements directly from the oscilloscope with some analysed in MATLAB but lacking full automation and require lot of human effort thus, incorporates some forms of errors as well as other challenges due to the bulkiness of the data. The study therefore, develops and presents how the basic lightning parameter could be achieved using Labview computer-based program mainly to address all the challenges as well as provide long term measurement due to non-availability of commercialized software for the findings. However, this research analysis was based on threshold detection techniques using labview software for the development of automated analysing labview-based programs. The developed programs were evaluated with an automated analysis of some 30 captured lightning signal under Malaysia atmospheric condition and proven to be 20% more accurate when compared with its manually analysed results based on the present analytical techniques. For the characterized parameters, 18 lightning flashes (60%) fitted BIL model while 7 lightning flashes (23%) fitted BL model and 5 lightning flashes (17%) falls to have irregular model patterns. Also, further analysis on the detected BIL shows about 60% of the PBP trains occurs within time duration of 1-5 ms. And, its intermediate processes ranges mostly between 30-40 ms for 11 (60%) lightning flashes out of the 18 flashes characterized as BIL model type. However, newer version of the software was recommended as it is expected to have more advanced signal processing features which may likely include the missing signal pattern recognition block which will definitely provide better accuracy and efficiency.

ABSTRAK

Kekurangan butiran tepat kilat telah menyebabkan punca-punca bencana di seluruh benua terutamanya di kawasan-kawasan dengan tahap isokeraunic tinggi termasuk Malaysia, Singapura, Indonesia dan lain-lain negara, walaupun perlindungan kilat telah dipasang oleh mereka. Fenomena semulajadi ini dikaitkan dengan pelepasan arus yang sangat kuat yang menyebabkan beberapa kerosakan kepada nyawa dan harta, yang masih kekal sebagai punca utama kebakaran hutan seterusnya membawa kepada kerugian ekonomi yang besar dari segi kerosakan struktur dan kemudahan. Walau bagaimanapun, penyelidik telah mencari cara terbaik untuk menangani fenomena berulang ini, kerana dipercayai bahawa pengetahuan jujuk mempunyai peranan yang besar dalam perlindungan nyawa dan harta terhadap ancaman itu yang hanya boleh dicapai melalui reka bentuk menyeluruh alat perlindungan yang canggih. Parameter asas termasuk amplitud arus, kekutuban pemindahan cas, bilangan stoke per kilat, kilat dicirikan corak dengan tempoh beberapa kejadian yang memainkan peranan penting dalam penyelidikan saintifik, analisis perlindungan serta berfungsi sebagai pemberitahuan amaran. Beberapa percubaan telah dibuat dalam mengkaji asas-asas parameter kilat yang sebahagian besarnya dicapai melalui analisis manual dengan mengambil ukuran langsung daripada osiloskop dan diuji menggunakan MATLAB walaupun bagaimanapun kurang automasi penuh dan memerlukan banyak usaha manusia, iaitu dengan menggabungkan beberapa bentuk kesilapan dan cabaran lain adalah disebabkan oleh data yang banyak. Kajian ini menggunakan program berasaskan komputer LabVIEW untuk membentangkan bagaimana parameter kilat asas boleh dicapai terutamanya bagi menangani segala cabaran dan juga menyediakan pengukuran jangka panjang kerana ketidaksediaan perisian dikomersilkan untuk penemuan. Program yang dibangunkan telah dinilai dengan menganalisis automatik beberapa isyarat 30 kilat yang ditangkap di bawah atmosfera Malaysia dan terbukti 20% lebih tepat berbanding dengan hasilnya dianalisis secara manual berdasarkan teknik-teknik analisis ini. Bagi ciri-ciri parameter, 18 berkelip kilat (60%) model BIL dipasang manakala 7 berkelip kilat (23%) model BL dipasang dan 5 berkelip kilat (17%) mempunyai corak model yang tidak teratur. Selain itu, analisis lanjut mengenai BIL dikesan menunjukkan kira-kira 60% daripada kereta api PBP berlaku dalam tempoh masa 1-5 ms. Dan, proses yang terdekat antara kebanyakannya antara 30-40 ms selama 11 (60%) berkelip kilat daripada 18 flashes dicirikan sebagai BIL jenis model. Walau bagaimanapun, versi baru perisian ini disyorkan kerana ia dijangka mempunyai ciri-ciri yang lebih canggih untuk pemprosesan isyarat yang mungkin corak isyarat yang hilang boleh termasuk di dalam pengiktirafan blok yang pasti akan memberikan ketepatan dan kecekapan yang lebih baik.

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LIST OF ABBREVIATIONS

<i>AM</i>	-	Arithmetic Mean
<i>BIL</i>	-	Breakdown Intermediate Leader
<i>BL</i>		Breakdown Leader
<i>CG</i>	-	Cloud-Ground Discharge
<i>CID</i>	-	Compact Intra-cloud Discharge
<i>GM</i>	-	Geometric Mean
<i>GPS</i>	-	Global Positioning System
<i>ICC</i>	-	Initial Continuous Current
<i>IVAT</i>	-	Institut Voltan Arus Tinggi (Institute of High Voltage and High Current)
<i>LabVIEW</i>	-	Laboratory Virtual Instrument Engineering Workbench
<i>LF</i>	-	Low Frequency
<i>LIS</i>	-	Lightning Imaging Sensor
<i>MATLAB</i>		Mathematical Laboratory
<i>MDF</i>	-	Magnetic Direction Finder
<i>MoM</i>	-	Method of Moment
<i>OTD</i>	-	Optical Transient Detector
<i>PBP</i>	-	Preliminary Breakdown Pulses
<i>PC</i>	-	Personal Computer
<i>RAM</i>		Read Access Memory
<i>RMS</i>	-	Root Mean Square
<i>RS</i>	-	Return Stroke
<i>TL</i>	-	Transmission Line
<i>TOA</i>	-	Time Of Arrival
<i>TRC</i>	-	TRaCe
<i>UTC</i>		"Universel Temps Coordonné" (officially called Coordinated Universal Time)
<i>UTM</i>	-	Universiti Teknologi Malaysia

<i>VHF</i>	-	Very High Frequency
<i>VI</i>	-	Virtual Instrument
<i>VLf</i>	-	Very Low Frequency

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Dangerous meteorological phenomenon such as lightning have generated different thought among human leading to various forms of debates. Different mythologies impersonating the God of thunder and weather from the ancient time including that of Egypt (Typhon), China (Tien Mu) and India (Indra) to the ancient Greek times (Zeus) were all symbolized by lightning flash are the most famous ones. According to fossil evidence, Hardland, Hacker (1966) confirms the presence of lightning over 250 million years[1]. Also Scientists had play important role in the study of lightning on how charged particle are accumulated and their impacts. It was therefore discovered that lightning initiation are caused by forcefully separation between positive and negative charges caused by the ice in the cloud. This discovery is dated as far back as 10th June, 1752 when a famous scientist and inventor, Benjamin Franklin flew a kite during thunderstorm & discovered charges were collected in a Leyden jar as the kite got struck by lightning and this further encouraged him into further experiment on electrical nature of lightning thus led him to the invention of the present and widely accepted lightning rod for protection against lightning effects. And also showed that lightning originating from cloud are mostly negative in nature but sometimes have positive charges[2]. However, this natural phenomenon ‘lightning’ have been described by several researchers and scientists as the transient and high

current discharge associated with the migration of electric charges either between the atmosphere and earth or within different layers of the atmosphere in which both electrical and magnetic fields are produced. The primary source of this natural phenomenon is cloud ‘cumulonimbus’ which will further be explained in subsequent section. The existence of lightning has been recorded years before the evolution of human life which may have play important role in the science of earth. Millions of lightning activities are recorded at any instance of time with majority being cloud to ground discharges which involves the formation of channels carrying large current which poses danger to the earth surface.

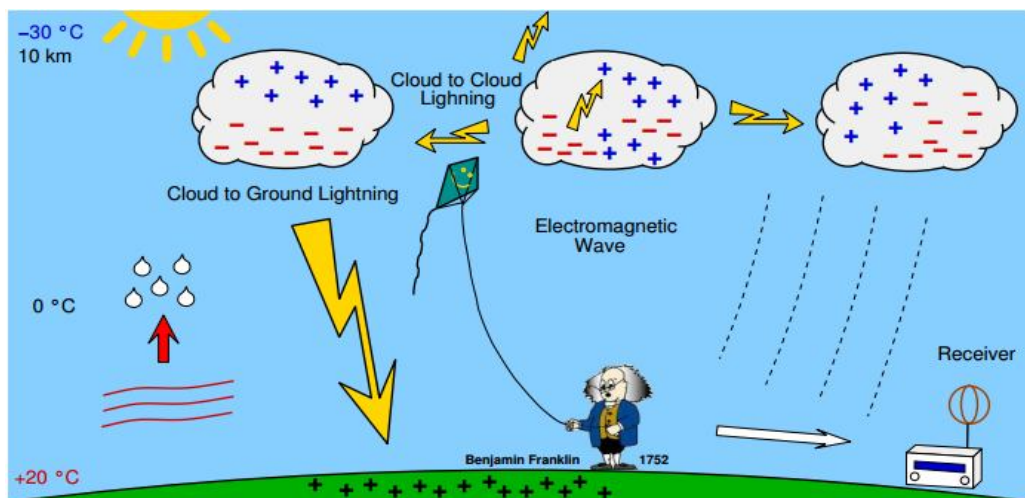


Figure 1.1: How natural phenomenon ‘lightning’ forms.

Lightning poses dangerous effects on both electronics and electrical equipment which are highly sensitive to electric and magnetic fields resulting from cloud to ground (CG) lightning which is the reason why it is regarded as a dangerous and disastrous natural atmospheric phenomenon. Detailed illustration on the formation of lightning activity is as shown in fig. 1.1. This natural phenomenon is associated with a very strong current discharge causing several damages to lives and properties, and still remain the main source of forest fire which leads to enormous economic losses from damaging of structures and facilities. Other most affected areas include

Electricity utility lines and substation accessories, aviation industries, transportation sectors, research institutes, metrology stations among others. Therefore, the use of lightning detection and locating systems for the determination of lightning parameters are of utmost important which senses this disastrous phenomenon prior to the event. Among the basic parameters provided by this lightning detecting systems include the current amplitude, polarity of the charge transfer, number of strokes per flash, amplitude of the electric current, lightning coordinates etc. and these are used for scientific research, protection analysis as well as serves as warning notification. Shielding failure resulting from lightning has been a major obstacle in operation of transmission system[3]. According to [4], over 50% of power systems failure in Japan are caused by lightning while about 40-70% of the total interruptions on high voltage transmissions line in china are due to lightning [5].

This phenomenon therefore, generates great concern to mankind due to its detrimental impact on safety, hazards and equipment failure as a result of direct lightning strikes on ground which leads to increasing research efforts on how to tackle the effect by improving on the detecting and protective systems against its effects. Fig. 1.2 gives the illustration of the initiation and discharge formation.

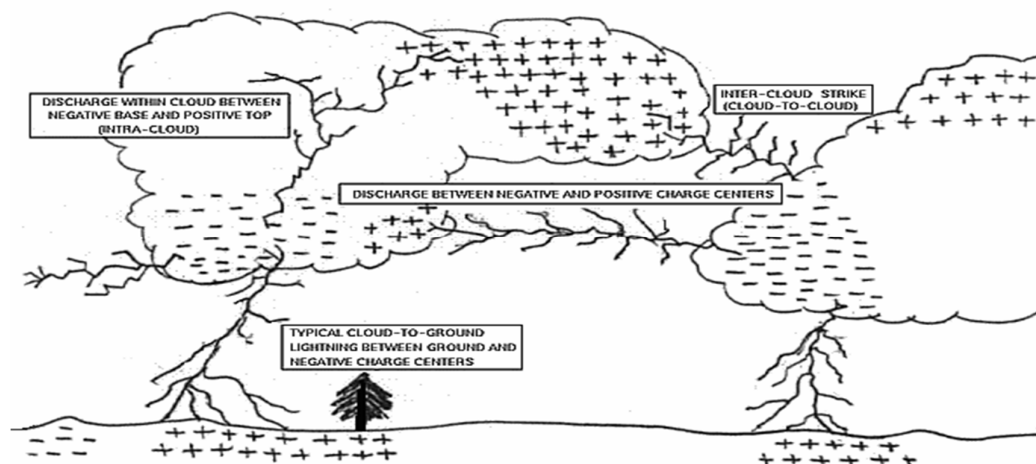


Figure 1.2: Lightning initiation and discharge formation.

However, this natural phenomenon ‘lightning’ have been described by several researchers and scientists as the transient and high current discharge associated with the migration of electric charges either between the atmosphere and earth or within different layers of the atmosphere in which both electrical and magnetic fields are produced. The primary source of this natural phenomenon is cloud ‘cumulonimbus’ is broadly explained in subsequent section. The existence of lightning has been recorded years before the evolution of human life which may have play important role in the science of earth. Millions of lightning activities are recorded at any instance of time with majority being cloud to ground discharges which involves the formation of channels carrying large current which poses danger to the earth surface. This report will however cover aspects on lightning with focus on how lightning parameters can be characterized for better enhancement of lightning protective systems.

1.2 Problem Statement

Among few research efforts on the characterization analysis of lightning discharges reviewed, non-availability of potential software for the analysis of the lightning activity was confirmed as authors all employed various manual techniques for their analyzed parameters. Also, there have been no automated/commercial program for the extraction of this important lightning parameters except the manual analysis via the human eye which incorporates high error percentage in provision of detailed statistical data as well as longer processing time duration and some difficulty in analyzing large amount of data among other challenges like inconsistency, non-efficient and yet, detailed information of this lightning activity is needed. Therefore, this information has an important role to play, as it guides these public in ensuring adequate protection against the detrimental natural phenomenon leading to an improvement in policy making regarding lightning occurrence by the government.

1.3 Aims of the research

The focus of the research will be aimed at developing labview computer-based program for the characterization of lightning discharge/return stroke.

1.4 Objectives of the Research

The main objectives of this study are outlined below.

1. Developing characterization of lightning discharge/return stroke using labview simulation software.
2. Provide detailed characterization of preliminary breakdown pulse trains in negative cloud to ground lightning discharge.

1.5 Scope of the Research

To achieve the objective of the research, the following will be the scope of study.

The research requires the setting up and installation of lightning detection system that will detect and record lightning strokes in form of electric field within a

predetermined location close to the IVAT Research Centre, Universiti Teknologi Malaysia, Skudai Campus, Johor, Malaysia.

The study will be limited to the use of labview computer-based software for the development of program for the characterization of the lightning discharge/return strokes.

The program developed will be expected to produce detailed characterization parameters for the lightning discharges/return strokes of set of detected and captured lightning signals.

Data (Parameters) produced from the set of captured signals using the developed labview-based program will be compared relatively with manual analysis so as to proof the effectiveness and efficiency as well as the accuracy of the developed program.

The outcome of the comparative analysis will therefore, be related to past literature and researches carried out across the world in order to justify the fundamentals for the future policy framework needed to be address for an enhanced design of lightning protection system and also possibility of developing lightning database.

1.6 Output/Benefits of the Research

The study will be beneficial in many respects. These include:

The study closes p the gap which leads to inherent error in the earliest lightning data analysis thus, provides more accurate parameters for the design of more sophisticated lightning protection and detection gadgets.

The developed labview-based program serves as good alternative to the existing manual analysis which aimed at lessen the difficulty in the task by seeking the advancement in technological development for an improved analysis.

The study exposes the inherit risk incorporated in the present day lightning protection and monitoring equipment.

The advantages of the study is highly beneficial to both the researchers and government in the advancement of the present findings and policy making on lightning issues on its citizenry.

1.7 Structure of the Report

The project is divided into five (5) chapters. The thrust of each chapter is summarised below.

Chapter one entails the general introduction of the subject matter which entails lightning activity, history of lightning discoveries, and its damaging consequences. This chapter also illustrates briefly the initiation, formation and importance of protecting lives and properties against this natural atmospheric phenomenon. The expected outputs and benefits of the research are mentioned and the chapter ends with an overview of the report arrangement.

Chapter two presents a detailed review of lightning discharges, how discharges are detected, measured and lightning flash components. Breakdown process with their characterized techniques were discussed. Critical highlights of various detection techniques, modelling type as well as lightning characterization techniques from the ancient time. And, it was concluded with measurement of the initial electric field with its constituents parameters.

Chapter three deals with the research design and methodology to be employed in carrying out the findings as highlighted. This covers the installation set-up of the lightning detection/monitoring system and also, the development of labview based program for the characterization and measurement of all the required lightning parameters. The chapter was concluded by highlighting the technique employed in the developed labview program with its flowcharts fully explained.

Chapter four presents the results and discussions of all the analysis carried out in the study with clear explanations of the findings. This analysis was based on the captured lightning signals which was automated analysed using the developed labview programs. The chapter exposes the effectiveness and efficiency of the developed program as its automated outputs were compared with the manual analysis of the same captured lightning signals. This was concluded with summarized statistical analysed results.

Chapter five gives the conclusion of the study based on the findings. The research objectives were revisited and both theoretical and practical contributions of the study were reported. Limitations to the study were also presented and necessary recommended are provided for the progress and actualization of any possible improvement on the tendency of achieving lightning database which will serve as information source centre for researchers and manufacturers of lightning related issues.

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