INVESTIGATION ON THE RELATIONSHIP BETWEEN LIGHTNING FLASHES AND RAINFALL RATE IN MALACCA

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INVESTIGATION ON THE REALTIONSHIP BETWEEN LIGHTNING FLASHES AND RAINFALL RATE IN MALACCA

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DECLARATION

I declare that this report entitled Investigation on the Relationship Between Lightning Flashes and Rainfall Rate in Malacca is the result of my work except for quotes as cited in the references.

Signature : ……………………………………

Author : ARIFFIN BIN HERMAN

Date : 11 January 2022

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 the award of Bachelor of Electronic Engineering with Honours.

Signature	:	…………………………………
Supervisor Name	:	Dr Norbayah Binti Yusop
Date	:	19 January 2020

DEDICATION

This final project is dedicated to my beloved mother, sibling, all members of my family. They were always there for me through thick and thin and give the best advice that I needed.

To my supervisor who always guide and gave supports to me completing this final project, Dr Norbayah Binti Yusop

To my lecturer who teach me to understand more about lightning flashes which help me a lot to understand this research., Dr Mohd Riduan Bin Ahmad

Also, to all my fellow friend who always there to help me, give ideas to solve problem and for the immeasurable support that I needed to complete this project.

ABSTRACT

Severe storm that happens is often followed by a flash flood with capability of producing excessive rainfall. Severe storm that occurred may produce lightning when there is an electrical discharge occurs during the storm. On 11 August 2020 and 20 October 2021, a severe storm happened at Malacca causing serious damage and many people are affected. The incident was happened so sudden and the collected data during that day is not yet studied. Hence, the first objective of this study is to classify the types of lightning flashes. The second objective is to analyze the type of lightning flashes emitted from the storm and the third objective is to analyze the relationship between lightning flashes and rainfall rate. The data that present is Electric Field Mill (EFM), Fast Antenna System (FA) and weather radar. The lightning analysis shows that there are five lightning flashes type that recorded, which is +CG, -CG, IC, +NBE and -NBE. From the two storms, there are total of 1356 lightning flashes. Storm on 11 August 2020 recorded 1024 lightning flashes with IC (436) is the majority and the minority is -NBE (6), where storms on 20 October 2021 recorded a total of 332 lightning flashes recorded with IC (122) has the highest value and -NBE (5) also has the lowest value. The EFM value is vary for the two storms, the storms on 11 August recorded 9.80 kV/a as the highest value and the storm on 20 October 2021 recorded 3.20 kV/a as the highest value. On 20 October 2021, the radar data show that the highest rainfall rate is 80 mm/h, and the reflectivity is 53 dBZ. From the data, it is known that heavy rainfall is occurred. The weather radar show that heavy rain is occurring from Jasin to the whole area of Malacca. The storm on 11 August 2021 recorded 50mm/h rainfall rate and the reflectivity is 50 dBZ. The data also shown that heavy rainfall occurred during that day. The radar shows the rainfall moved from Masjid Tanah to whole area of Malacca. From the two storms, IC have the highest number of lightning flashes that occurred and -NBE has the lowest number of lightning flashes. From the rainfall rate and reflectivity of both storms, IC is the one that leading to the occurrence of heavy rainfall. Where -NBE with the lowest number is the indicator before the heavy rainfall to occur.

ABSTRAK

Ribut teruk yang berlaku selalunya diikuti dengan banjir kilat yang mampu menghasilkan hujan yang berlebihan. Ribut teruk yang berlaku mungkin menghasilkan kilat apabila terdapat pelepasan elektrik berlaku semasa ribut. Pada 11 Ogos 2020 dan 20 Oktober 2021, ribut teruk berlaku di Melaka menyebabkan kerosakan teruk dan ramai orang terjejas. Kejadian itu berlaku secara mengejut dan data yang dikumpul pada hari tersebut masih belum dikaji. Oleh itu, objektif pertama kajian ini adalah untuk mengklasifikasikan jenis-jenis kilat. Objektif kedua adalah untuk menganalisis jenis kilat yang dihasilkan daripada ribut dan objektif ketiga adalah untuk menganalisis hubungan antara kilat dengan kadar hujan. Data yang hadir ialah Electric Field Mill (EFM), Fast Antenna System (FA) dan radar cuaca. Analisis kilat menunjukkan terdapat lima jenis kilat yang direkodkan iaitu +CG, -CG, IC, +NBE dan -NBE. Daripada dua ribut itu, terdapat sejumlah 1356 kilat. Ribut pada 11 Ogos 2020 merekodkan 1024 kilat dengan IC (436) adalah majoriti dan minoriti ialah -NBE (6), di mana ribut pada 20 Oktober 2021 mencatatkan sejumlah 332 kilat yang direkodkan dengan IC (122) mempunyai nilai tertinggi dan -NBE (5) juga mempunyai nilai terendah. Nilai EFM adalah berbeza untuk kedua-dua ribut, ribut pada 11 Ogos mencatatkan 9.80 kV/a sebagai nilai tertinggi dan ribut pada 20 Oktober 2021 mencatatkan 3.20 kV/a sebagai nilai tertinggi. Pada 20 Oktober 2021, data radar menunjukkan kadar hujan tertinggi ialah 80 mm/j, dan reflektiviti ialah 53 dBZ. Daripada data, diketahui bahawa hujan lebat berlaku. Radar cuaca menunjukkan hujan lebat berlaku dari Jasin ke seluruh kawasan Melaka. Ribut pada 11 Ogos 2021 merekodkan kadar hujan 50mm/j dan reflektiviti ialah 50 dBZ. Data juga menunjukkan bahawa hujan lebat berlaku pada hari tersebut. Radar menunjukkan hujan bergerak dari Masjid Tanah ke seluruh kawasan Melaka. Daripada dua ribut itu, IC mempunyai bilangan kilat kilat tertinggi yang berlaku dan -NBE mempunyai bilangan kilat kilat paling rendah. Daripada kadar hujan dan pemantulan kedua-dua ribut, IC adalah yang membawa kepada kejadian hujan lebat. Di mana -NBE dengan nombor terendah adalah penunjuk sebelum hujan lebat berlaku.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Flash flood has been a natural disaster that give the human civilization many troubles now days and the past century. The worst is, it does not choose where and when to happen, it just does. This natural disaster has caused many people lost their place to live and lost their family members and friend. The problem with flash flood is, it cannot be predicted.

On 18 August 2020 and 20 October 2021, a severe storm and heavy flash flood has occurred in Malacca and affected many places. The storm on 18 August 2020 cause damage to the area of Malim, Batu Berendam and Klebang while the storm on 20 October 2021 affects the area of Taman Bukit Beruang Utama and Kampung Asam Kumbang Bemban. The storms cause people lost their place to stay and causing serious damage. The incident was happened so suddenly and the lightning data and rainfall rate data from the thunderstorm has not been analyze. The correlation between the electric field mill, lightning flashes and rainfall rate data also not been discovered.

1.2 Objectives

This research is aimed to study the data which is electric field mill, lightning flashes and rainfall rate that collected from the storms that occur on 11 August 2020 and 20 October 2021. There are three main objectives for this research, there are:

i. To classify the types of lightning flashes

ii. To analyze the type of lightning flashes emitted from the storm

iii. To analyze the relationship between the lightning flashes and rainfall rate

1.3 Scope of Work

The storms that will be study in this research is on 11 August 2020 and on 20 October 2021. The location of the collected data use is in Malacca and the duration is vary for each storm. The duration for storm on 11 August 2020 is from 04:00:00 to 14:00:00, while the duration for storm on 20 October 2021 is from 12:00:00 to 18:00:00. For this project, the data used is EFM, lightning data and rainfall rate. The lightning data is collected by using the EFM sensor and FA system which installed at University Teknikal Malaysia Melaka (UTeM), while the radar data is obtained from the Malaysia Meteorological Department (MMD). The classification and analysation of the lightning flashes will be carried out using the PicoSCope software. Rainfall data also studied based on the colour code of the radar data. The data that collected will be display in the form of bar chart, several graph, and tables. Electric field variance will be plotted using Matlab and display in the form of signal. Based on the collected data, the correlation between the electric field, lightning flashes and rainfall rate can be determined.

1.4 Project Significant

There are few significant that will be obtain from this research. The first significant is, this research will help other people to understand more about the lightning flashes. The second significant is, help others to understand the correlation of lightning flashes and rainfall rate to how it causes flash flood.

1.5 Thesis Outline

This thesis consists of five main chapters. Chapter 1, it will be introducing about the storm that occur on 11 August 2020 and 20 October 2021. It also briefs explanation about the study of lightning flashes and flash flood. Chapter 1 also contains about problem statement of the project, objectives, scope of work, project significant and the thesis outline.

Chapter 2, present the literature review of the project. This chapter mainly focused about the previous studies that has been done by previous researcher. But the paper that is used is only the one that have connection to this project. It starts with the introduction to the lighting flashes, follow by explanation about the type of the lightning flashes that use in this project.

Chapter 3 describes the methodology on how the project can be completed. This chapter explains about the software use to analyze the lightning. Using this software, the lightning can be classified according to its type. The process of data collection also consists in this chapter. A flowchart also created as a guide to complete this project step by step from start until completing the project.

Chapter 4 discuss on the results and discussion. For this part, more detailed explanation about the flashes type, characteristic and data that got from the lightning. EFM data and rainfall rate data will also present. It also contains the analysis data about the correlation of lightning flashes and rainfall rate. The discussion will be about the relationship between lightning flashes and rainfall rate from the two storms that have been studied.

Chapter 5 is the last chapter and it consist of present the conclusion and future works of this project. It will give the summary and overview of the whole project objectives. This chapter also give the things that can be added to make this project even better in the future.

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction

Lightning is created from the thunderstorm. Thunderstorms happen because of these few things that is moisture, warm air at the surface of the earth and lifting medium like draft and wind. A vertical updraft forces warm, moist air upward, where it condenses and cools, generating cumulonimbus clouds. With the rising of these clouds into freezing temperatures, the moisture condenses into ice particles. Little bits of ice break off as they meet and bounce off each other, creating electrical charges. The sum of these numerous electrical chargers causes a collision, which results in a bolt of lightning.

Floods are mainly caused by severe thunderstorms that produce a large amount of rain in a short period of time. Because thunderstorms normally develop, mature, and dissipate in few hours, there is a need to create approaches to monitor strong thunderstorms using data with a high temporal resolution. According to Defer et al. (2005) lightning observations provide a possibility of monitoring regional thunderstorm activity continuously in remote regions of the Mediterranean and Europe [1].

In many countries, flash floods are one of the most serious natural dangers, resulting in severe loss of life and economic damage. Flash floods are one of the most serious meteorological hazards that can occur anywhere and at any time. As it happens, it takes a lot of lives and causes a lot of damage. The most common cause of flash floods is severe thunderstorms.

For this research, it more focus on the storm event that occur on 11 August and 20 October 2021 at Malacca. The storm causing series of damage at various place in and affected many people. The worst affected location for the storm occurs on 11 August 2020 is Malim, Batu Berendam, Taman Merdeka Permai and Klebang. While the worst affected place for storm on 20 October 2021 is in Taman Bukit Beruang Utama, Melaka Tengah and Kampung Asam Kumbang Bemban, Jasin. Several cars also were also damaged and drowned by the flash flood and many reports were made to public department such as “Jabatan Bomba dan Penyelamat” where people asking for help. Both storms happened so suddenly and because of that the collective data which collected on that day is not yet study and analysed. The involved data is Electric Field Mill (EFM), Fast Antenna System (FA) and weather radar.

Not just that, lightning is an electrical discharge that occurs during thunderstorms. There are few types of lightning that focus on this study that is Intra-Cloud (IC), Narrow Bipolar Event (NBE) which consist of +NBE and -NBE, and Cloud to Ground (CG) which consist of +CG and -CG. Each of this lightning has its own characteristic. This characteristic is the one that been used to classify the lightning. In Malaysia, the common type of lightning flashes is CG, and most of the time -CG occurrence is higher than -CG.

In this work, two storms on 11 August 2020 and 20 October 2021 in Malacca will be analysed. The data used from the electric field mill (EFM), Fast Antenna System (FA) and weather radar. All this data will be analyzed and process throughout this project and the correlation will be made. By analyzing and correlated all the data, it can be used to help in understanding how the storms causes the flash flood and the data also can be used to predict the event before occurs in the future.

2.2 Types of Lighting Flashes

For this study, it focusses on several types of lightning. First is Cloud to Ground (CG), CG is divided into two types. That is positive cloud to ground (+CG) flash and negative cloud to ground (-CG) flash. Next is Intra-cloud (IC), intracloud flash does not have any positive and negative. The last one is Narrow Bipolar Event (NBE). Just like cloud to ground, this narrow bipolar event also has two types. One is positive narrow bipolar event (+NBE) and other is negative narrow bipolar event (-NBE)

2.2.1 Intra-Cloud (IC)

Intra-cloud (IC) lightning is by far the most common type. Based on research made by Shao et al. (1996), cloud to ground lightning typically occurs between the main negative charge region and ground, while intracloud lightning normally occurs between the main negative and upper positive charge regions [2]. Because the channels of intra-cloud lightning are usually obscured from view by the cloud, the understanding of intra-cloud discharges has lagged that of cloud to ground discharges, to the point that not even the basic features of the structure and development of intra-cloud lightning have been understood [3].

The intra-cloud flash is associated with the major negative and upper positive storm zones at the lower and upper levels. In the classical bilevel structure, relatively few radiation events were in lower, the main negative charge level, in comparison to the upper, positive charge region based on [1]. But according to Krehbiel et al. (199)

such intra-cloud flashes had an inverted polarity bilevel structure in which the lower and upper levels correspond to the main positive and negative regions in the storms, respectively [4].

Study based on Nag et al. (2010) stated that most studies treat the channel of intra-cloud lightning discharge as horizontal or vertical when studying the discharge characteristics of intra-cloud lightning discharge [5]. However, in nature, intra-cloud lightning discharge paths are frequently sinuous and branched, which shows a clear fractal aspect [6]. From Wan et al. (2018), with the growth in the horizontal scale of the cloud, the fractal dimension of the discharge channel grows exponentially [7]. This is because the larger the cloud's horizontal scale, the stronger the thundercloud's background electric field in the simulation zone, and the more breakdown locations and breakdown directions available in the discharge. This will increase the randomness of the discharge, which will result in a proportionate rise in the number of branches and fractal dimension of the discharge channel.

2.2.2 Narrow Bipolar Event

Narrow bipolar event (NBE) is also known as Narrow Bipolar Pulses (NBPs) or Compact Intracloud (CID). These narrow bipolar events are a type of intracloud lightning discharge initially founded by Le Vine [8] and characterize by its narrow electromagnetic waveforms (10-20 us) and strong radiation in the HF and VHF radio bands [8-11].

NBE has two polarities, which is negative and positive [12]. Previous research stated that negative NBE are mostly at higher altitudes than positive NBE [13,14]. In terms of thunderstorm normal charge distribution, the findings in Wu et al. (2012) show that positive NBE form between the primary negative charge layer and the upper positive charge layer, whereas negative NBE form between the upper positive charge layer and the screening charge layer [14]. According to prior research in Wu et al. (2013) of NBE statistics, the number of positive NBE in a single thunderstorm is usually more than the number of negative NBE [15].

Based on Jacobson et al. (2005) and Suszcynsky et al. (2003), in Florida, extensive research on the climatic context of NBE revealed a substantial link between NBE rates and regular lightning flash rates [16,17]. So, stronger storm will produce higher percentage of NBE while weaker storm produced less than stronger storm or no NBE at all. From the research done by Wiens et al. (2003) showed that only a few storms, including two strong storms, produced the majority of NBE in the Great Plains, while most storms did not create any NBE [18].

NBPs is usually being reported to occur in isolation. However, in recent observation, NBP seems detected with the CG flashes. The research in Lyu et al. (2019) and Bandara et al. (2019) also show that +NBE are now known to initiate some IC flashes and -NBE are known to initiate some CG flashes [19,20]. The Florida thunderstorm also give the same observation, where 6% of the NBPs is part of the CG flash [21]. Based on Esa et al. (2014), 39.3% of NBPs (57 single NBPs and 6 Multiple NBPs) have been observed to be part of the CG and IC flashes [22].

From research done by Esa et al. (2014), most lightning flashes except NBE have been observed to start with a series of bipolar pulses known as Initial Breakdown (IB) [23,24]. Narrow bipolar event is a type of flash that does not have a visible IB process and is thought to be released by a quick positive streamer that initiates the IB process [25]. Because of that, NBE is dependent on the latitude [26].

Based on the data by Bandara et al. (2021), 31 +NBE altitudes varied from 10.1–15.3 km, where other three higher altitude -NBE occurred at 12.7, 15.0, and 15.7 km altitude [27]. This result is almost the same with previous research where the altitude of +NBE are usually lower than -NBE [28].

2.2.3 Cloud to Ground

Cloud to ground (CG) are the most common type of lightning. Commonly know from previous research, almost 90% of CG lightning are -CG flashes while the balance 10% are the +CG [29,31]. Based on result from Yusop et al. (2019), there were 2,019,923 flashes recorded [32]. This data consists of 43.01% +CG and 56.99% −CG flashes. The +CG that recorded were quite significant and the ratio between -CG and +CG were also high compared to previous research that has been done in other places. For example, in Chan et al. (2018), the data recorded 201,296 lightning events. From that data, the percentage of +CG is 21.91% and -CG is 78.09% [33].

Some researchers have done some research on the charge structure that will cause +CG lightning. According to William et al. (2001), there were some hypotheses that proposed about the charge structure, that could generate +CG lightning [34]. One of the hypotheses is from Brook et al. (1982) and Curran et al (1992), which is tilted charge hypotheses [35,36]. Strong high-level wind shear, they hypothesized, would cause the dipole or triple charge configuration to tilt. The upper positive charge zone will be unprotected by the middle negative charge region and will discharge directly to earth.

CG is one of the lightning that has been observed to begin with series of bipolar pulses known as Initial Breakdown (IB) [23,24]. From study done by Zikri et al. (2018), initial breakdown pulses (radiation field) have the following characteristics, that is bipolar shape, duration of IB pulses ranges from 10 to 200 seconds, and the process usually begins with a few small pulses, progressing to the largest pulse, and finally ending with a decreasing amplitude in the last pulse [37]. In Gomes et al. (1998), studied has been done in Sweden and Sri Lanka about the IB process preceded the first Return Stroke [38]. The studied found that in Sweden, all 41 –CG flashes were preceded by the IB process, whereas in Sri Lanka, only 9 out of 47 –CG flashes from tropical storms were preceded by the IB process.

Based on data obtain summer thunderstorms are known to create negative cloud-to-ground (-CG) flash, which is thought to account for 90% of all cloud-to-ground (CG) flash worldwide [39]. However, in some stages and in some places of some severe thunderstorms, the positive cloud-to-ground (+CG) flash that neutralized positive charge in the cloud would occur. The findings of the experiments reveal that +CG lightning neutralizes more charge than -CG lightning.

The continuous current of -CG lightning generally reaches about 100 amps. But the continuous current of +CG lightning generally reaches about 1000 amps, which exceeds the continuous current of -CG lightning by one order of magnitude [40]. As a result, when compared to -CG lightning, +CG lightning is more prone to produce serious lightning mishaps such forest fires and oil depot explosions. As a result, more and more emphasis is being dedicated to +CG lightning research.

2.3 Lightning Correlation With Flash Flood

Examining lightning activity during flash flood occurrences helps to better comprehend the complicated hydro-meteorological conditions [41]. The concept that precipitation estimates generated from lightning observations can be utilized as a short-term forecast system of intense precipitation drives a lot of precipitation and lightning observation correlation research. This was supported by Carter et al (1976) since the lightning activity precedes the precipitation evolution [42].

Many researchers have made the correlation of the lightning and severe rainfall as their subject. For example, Petrova et al. (2014) found that based on the present study the flash density cannot be used directly for estimation of precipitation in the Mediterranean area [43]. But the strong relationship between rain rate and averaged flash density throughout the continental area during the summer implies that the processes that cause precipitation and lightning are the same. According to Iordanidou et al. (2016), there is at least one station with hourly rain over 5 mm/h for most of the lightning clusters [44]. For the specific radius of 30 km, when there are more than 150 flashes in a cluster, the correlation between lightning and precipitation surpasses 80%.

Lightning activity maps the position of a thunderstorm's convective center, which is where the most rain falls. The microphysical and dynamical processes within the clouds are intimately related to lightning activity in thunderstorms. As a result, much research conducted in various geographical regions support the association between the time evolution of lightning and rain in thunderstorms, as well as the similarity in their spatial distribution. An increase in rain often corresponds to an increase in lightning activity in the great majority of the thunderstorms analyzed. Cloud-to-ground (CG) flashes are most encountered adjacent to the strongest precipitation [42,45-51].

Simultaneously, multiple studies have found that the occurrence of +CG lightning is linked to convection development intensity, precipitation, and other factors. Research by Reap et al. (1989) say that the frequency of +CG lightning is frequently associated with the thunderstorm's rapid expansion stage [52]. Statistic shown in research by Macgorman et al. (1994) that the thunderstorms, which generate more +CG lightning, tend to develop into the severe thunderstorms [53]. Some researchers have discovered that thunderstorms dominated by +CG lightning frequently produce huge hail [53,54].

2.4 Variability of Lightning Flashes

Weather monitoring, such as rainfall and lightning activity, has improved over the years, from a visual approach of counting lightning flashes to the use of technology such as sensors and radar [55]. A better knowledge of the thunderstorm might be attained with the advancement of equipment technology for observing precipitation and lightning activity. Severe thunderstorms are instances of dangerous severe convective weather. Thundering convection and non-thundering convection can both cause storms and severe weather.

Study from Yusop et al. (2019) use two type of lightning detection technology which is World Wide Lightning Location Network (WWLLN) and Boltek Lightning Detector (LD-350). The WWLLN system recorded a high number of lightning strikes for January and February with 3936 and 4282 strikes but record a lower strike for the rest of the month which is 2000 strikes. LD system record a higher number of strikes on February, March, and April around 30704252, 43671872 and 45511286 strikes. While the rest of the month record a value less than 240000. LD system efficiency is six thousand times higher that WWLLN system [56]

Based on Ahmad et al. (2015), the research uses a three different properties broad-band antenna. The first is with 500 μs and 15 ms decay time constant while the other two is connected to a circuit tuned to 3 MHz which is a high frequency and 30 MHz which is a very high frequency. The research shows that Negative NBPs became less common as latitudes increased, whereas positive NBPs were more common. Malaysia (45%) had a substantially greater percentage of negative NBPs than Sweden (35%) in respect to all of the discovered NBPs (20 percent). Furthermore, in Malaysia (5.4 percent), the ratio of negative NBP events in relation to all lightning flashes was substantially greater than in Sweden (0.03 percent) [57].

From research done by Wooi et al. (2016), there is 104 negative lightning flashes with 277 negative return strokes were observed within 10–100 kilometres of the measurement station during the monsoon season in Johor. With an average multiplicity of 2.6 strokes per flash, multiple strokes account for 73 percent of the observed flashes. For first return strokes, the arithmetic mean (AM) of the initial peak electric field and the AM of the initial peak electric field derivative are 21.8 V/m and 11.3 V/m/ms. The initial peaks of the electric field and its derivative are larger for the first return strokes than for subsequent return strokes. This study explores the characteristics of the electric field created by negative lightning due to a lack of statistical data in the tropical area, notably in Malaysia. In order to enhance lightning finding systems or lightning protection, the characteristics of negative lightning should be investigated further [58].

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, it describes more about the instrument data and software used for the data collection. There is electric field mill (EFM), fast electronic antenna system (FA), weather radar and PicoScope software. The PicoScope is used analyze and classified the lightning according to its type.

3.2 Research Flow Chart

For this research, the data are collected from the two storms that occur at Malacca on 11 August 2020 and 20 October 2021. The duration of the storm are differ and the total collected data will also be different. The data that present in both storm are eelctric field mill, fast antenna system and rainfall rate. Figure 3.1 shows the process flow of this research.

In classification of the lightning, PicoScope is use to view the lightning flashes that capture using the fast antenna system. By studying the shape and characteristic of the signal, it can be classified to its own classes. Rainfall rate data are determined based on the colour code of the weather radar. Weather radar are provided in CAPPI format to make sure it can be easily study. Radar can be used to calculate rainfall rates as well as radar reflectivity so that the intensity of the rainfall can be determined. Using the correct formula, the reflectivity value is obtain using the rainfall rate value.

After that, all the data will be plot using the Matlab. The data is interpreted in the form of graph and bar chart. Using the data, the realtionship between lightning flashes and rainfall rate will be develop.

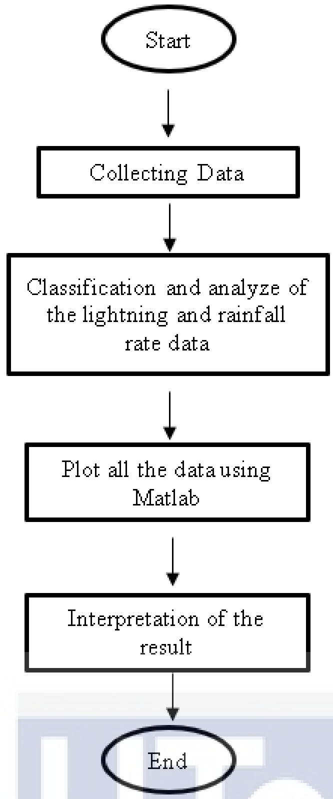


Figure 3.1: Process Flow of the Research

3.3 Data Collection

In this research, the data that will be used are electric field mill, lightning flashes and radar data that collected from the storms that occur on 11 August 2020 and 20 October2021. There are two types of lightning data that is collected form the electric field mill (EFM) and fast antenna system (FA). The duration of the collected data is differed for each storm. The duration for lightning data and radar data for storm on 11 August 2021 is collected from 04:00:00 to 14:00:00. For the storm on 20 October 2021, the lightning data durations are from 12:00:00 to 18:00:00 and the radar data duration are from 10:00:00 to 19:00:00. The radar data is provided by the Malaysia Meteorological Department (MMD and in the format of CAPPI.

3.4 Electric Field Mill (EFM) System

In this research, there are few types of data that used. There are the EFM data, lightning flashes data and rainfall rate data. All the data first will be study and analysed. For EFM data, it already been recorded by the EFM sensor. EFM data is plotted using the Matlab software. The plotted graph will show the characteristics of the EFM data that recorded.

The EFM sensor was located at University Teknikal Malaysia Melaka (UTeM), which was located at N 2°18'59.04" latitude and E 102°19'15.1176" longitude in Peninsular Malaysia. The EFM sensor will detects lightning on a regular basis and triggers graphical display warnings on a PC or laptop when it is detected. The software will reset to a green state if no lightning is detected during the preset time and the electric field levels fall below the defined values [59]. The status is "All Clear." It is shown in the Figure 3.2 and Figure 3.3.

The EFM display software sought to establish and maintain a network link with remote computers to transport data from the field mill to them. Differences in atmospheric energy data can be noticed in a variety of ways depending on the weather. This program allows you to see real-time electric field data in connection to an alarm annunciator, amplitude range selection, time range selector, and other geographical elements of interest. In the EFM display software both the history graph and the current field reading can be seen.

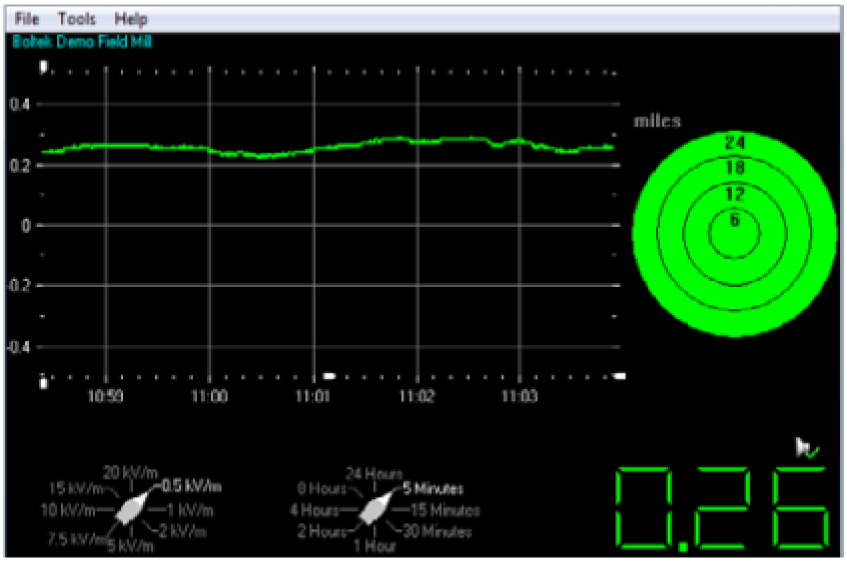


Figure 3.2: All clear status [59]

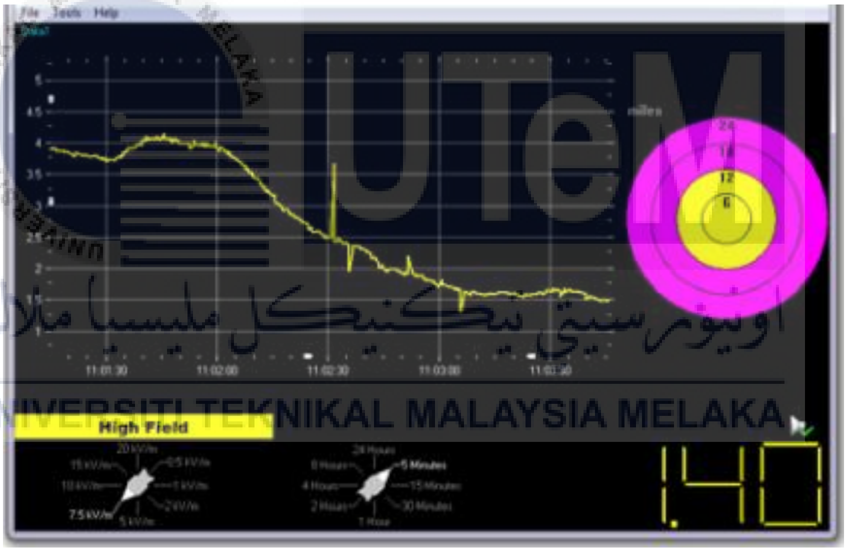


Figure 3.3: Lightning and High Field Alarm Active [59]

3.5 Fast Antenna (FA) System

The FA system is used to record the lightning flashes. FA system is a well-known and reliable method of measuring lightning. Many previous studies have used data for analysis purposed [60]. The data from FA system will be analyze using the Picoscope software. From there, the types of lightning will be classified according to their own characteristic such as Cloud-to-Ground (CG), Intra-Cloud (IC), and Narrow Bipolar Event (NBE) based on the waveform that view in the Picoscope.

According to Sabri et al. (2018), the FA system have decay time constant of 13 ms and 1 s and a VHF sensor (bandwidth 40-80 MHz) with centre frequency of 60 MHz [61]. The observation system is located at the Universiti Teknikal Malaysia Melaka (UTEM), Malacca, Malaysia (2.314077° N, 102.318282° E). Figure 3.4 shows the equipment needed to install the antenna system and Figure 3.5 shows how it installed at UTeM. Figure 3.6 shows the example of lightning data that recorded using the FA system.

For lighting data, first it will be classify using the PicoScope software, after that the total value for each type also will be obtained. All the obtained data will be interpreted in the form of graph also using the Matlab. Rainfall rate data is also same, first the rainfall rate for every 10 minutes will be determined by studying the colour of cloud. After that, using the respective formula, the reflectivity data will be obtained based on the rainfall rate data. All the value obtain will also interpreted in the form of graph by using Matlab.

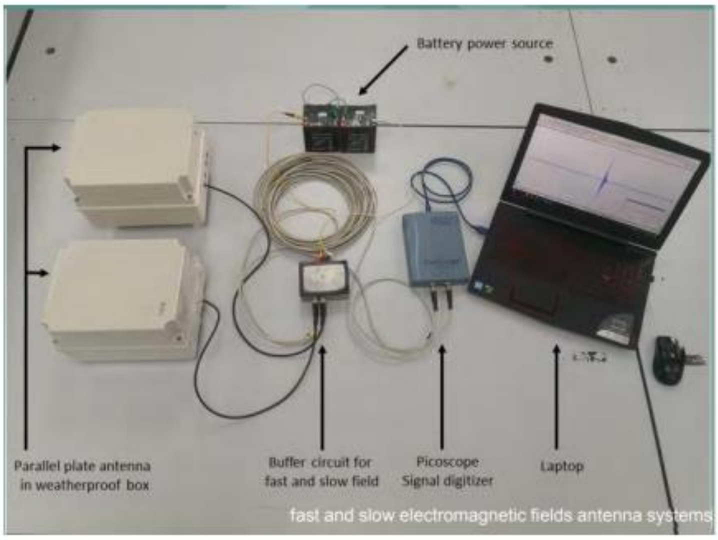


Figure 3.4: FA System Equipment

Figure 3.5: FA System at UTeM

FA_ (9)	20/10/2021 12:28 PM	PicoScope data file	12,195 KB
FA_ (10)	20/10/2021 12:30 PM	PicoScope data file	12,584 KB
FA_ (11)	20/10/2021 12:31 PM	PicoScope data file	16,443 KB
FA_ (12)	20/10/2021 12:39 PM	PicoScope data file	16,420 KB
FA_ (13)	20/10/2021 12:46 PM	PicoScope data file	16,565 KB
FA_ (14)	20/10/2021 12:48 PM	PicoScope data file	16,422 KB
FA_ (15)	20/10/2021 12:52 PM	PicoScope data file	16,209 KB
FA_ (16)	20/10/2021 1:01 PM	PicoScope data file	16,077 KB
FA_ (17)	20/10/2021 1:02 PM	PicoScope data file	16,064 KB
FA_ (18)	20/10/2021 1:10 PM	PicoScope data file	16,244 KB
FA_ (19)	20/10/2021 1:11 PM	PicoScope data file	16,250 KB
FA_ (20)	20/10/2021 1:12 PM	PicoScope data file	16,346 KB
FA_ (21)	20/10/2021 1:12 PM	PicoScope data file	16,222 KB
FA_ (22)	20/10/2021 1:13 PM	PicoScope data file	16,198 KB
FA_ (23)	20/10/2021 1:14 PM	PicoScope data file	16,188 KB
FA_ (24)	20/10/2021 1:15 PM	PicoScope data file	16,323 KB
FA_ (25)	20/10/2021 1:15 PM	PicoScope data file	16,304 KB
FA_ (26)	20/10/2021 1:16 PM	PicoScope data file	16,251 KB
FA_ (27)	20/10/2021 1:17 PM	PicoScope data file	16,244 KB
FA_ (28)	20/10/2021 1:18 PM	PicoScope data file	16,508 KB

Figure 3.6: Example of Data Recorded by FA System

3.6 Weather Radar

The radar data is record in CAPPI format and generated by the system in every 10 minutes. CAPPI was chosen because of its ability to display high-resolution images that can be studied and analyze easily. Radar can be used to calculate rainfall rates as well as radar reflectivity. Rainfall rate obtained from the radar data is based on the colour code of the cloud. Figure 3.7 shows the example of radar data in the format of CAPPI. Weather radar cannot identify the rate of rainfall directly. The rainfall rate, R (mm/h), can only be estimated by comparing the radar reflectivity, Z (mm^6/m^3) to the rainfall rate, R (mm/h).

Rainfall rates were proportional to raindrop volume, but reflectivity was proportional to drop diameter divided by the sixth power. Using the formula $Z=aR^b$, where a and b are constant. According to the Marshall-Palmer (MP), $Z=200R^{1.6}$. The value Z then need to be change to dB by using dBZ=10 log 10, where dBZ is the reflectivity value [62].

To define the rainfall capacity, the reflectivity values were used. Usually, with reflectivity value less than 35 dBZ, it was defined as light rain. When the reflectivity value is range from 35 to 50 dBZ, it defined as moderate rain. While heavy rain is defined when the reflectivity value is more than 50 dBZ. For value equal or higher than 55 dBZ is used for identifying hail.

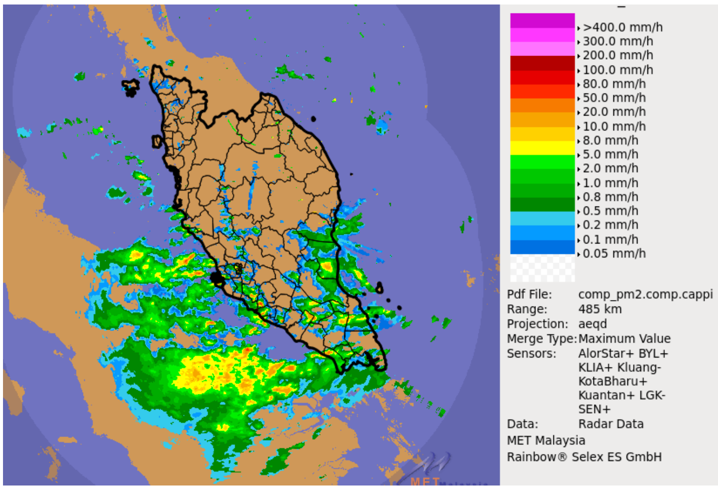


Figure 3.7: Weather Radar Data

3.7 Classify the Lightning

In order to classify the types of lightning is not easy. There are few types of lightning flashes need to be understood their characteristic. that must be known. The name called IC, +CG, -CG, +NBE and -NBE. Not just that, the lightning data signal is captured in two second time frame, so it is not impossible to have many signals. By using this signal, the lightning can be analyzed and classified using the PicoScope software.

Where there are many signals, zoom in to the triggered point first. Start from there, determine the lightning that is there on the triggered point. After that, go through all the signal one by one and determine the class of lightning for each of the signal. To classify IC is very easy, this is because IC often start from the negative charge. IC also has a small signal compared to the other and have many returns stroke.

Figure 3.8 shows the example of IC and it have many signals. Every signal must be classified and analyze thoroughly because maybe there are more than two types of lightning there.

Figure 3.8: Example of IC

Figure 3.9 is the zoom in figure for Figure 3.8. The lightning data must be zoom in like this at the triggered point so that the shape of the signal can be seen clearly, and from here the type of lightning can be determined. As seen in Figure 3.8, the signal start from negative. It also has few returns stoke. So, it deduces that the type of lightning is IC.

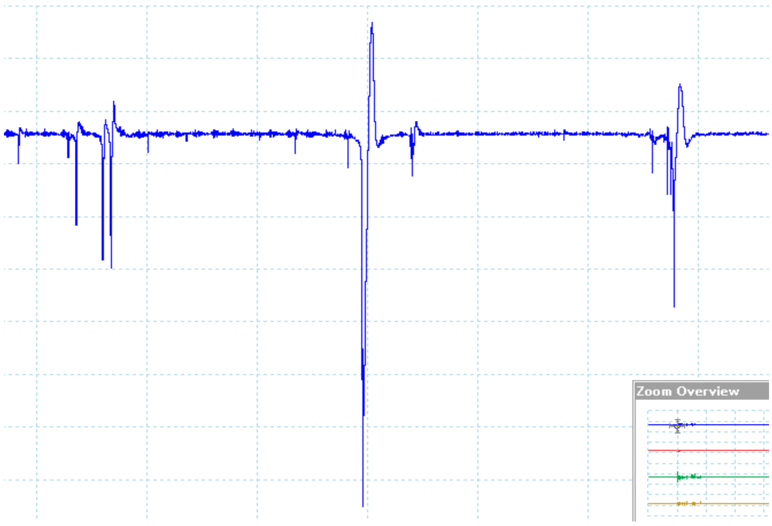


Figure 3.9: Example of IC

For the NBE is much easier to classify compared to the IC type. This is because NBE does not have a return stroke. It just stands alone. But NBE has two types that is +NBE and -NBE.

Figure 3.10 shows the example of NBE. The signal shows that the data is stand alone and does not have any return stroke. So, it most likely to be NBE. But, before determined the type, the data must be zoom in first so that the shape of the graph can be seen clearly. The type of lightning cannot just be determined from seeing the zoom out figure, this is because the graph maybe different when zoomed in. So that is why, it must be analyze thoroughly.

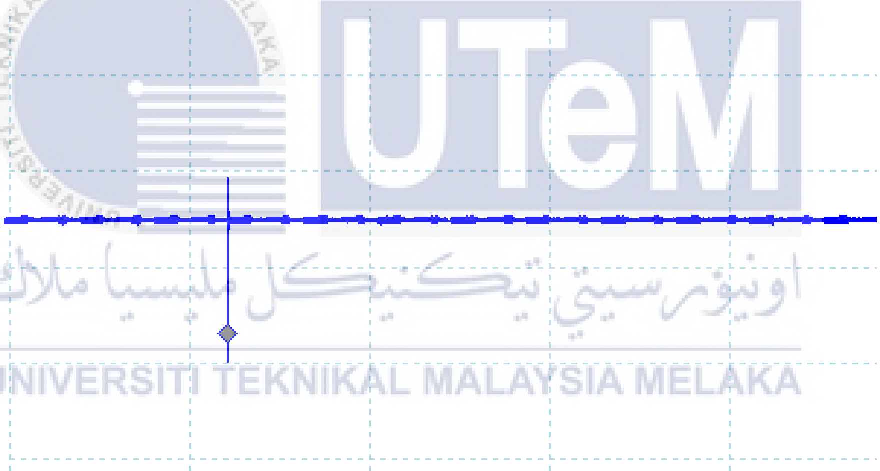


Figure 3.10: Example of NBE

After the data zoomed in, the graph is seen clearly in the Figure 3.11, and the type of lightning can be determined easily. The type of lightning for this data is NBE, to be more accurate it is +NBE because the graph starts from the bottom which is negative value.

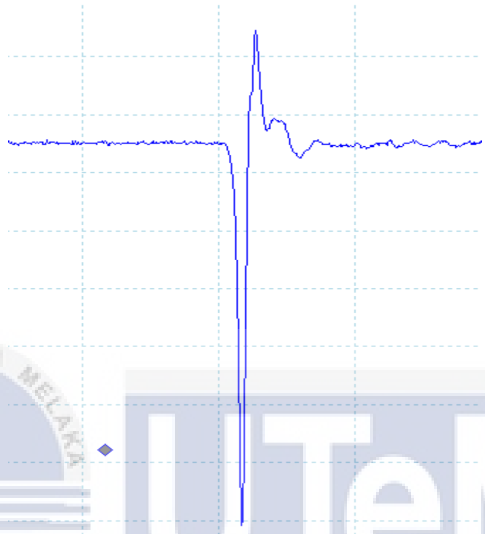


Figure 3.11: Example of +NBE

Figure 3.12 is the example of -NBE. This is because the graph starts at positive, so the type is -NBE. -NBE is just the reverse of +NBE

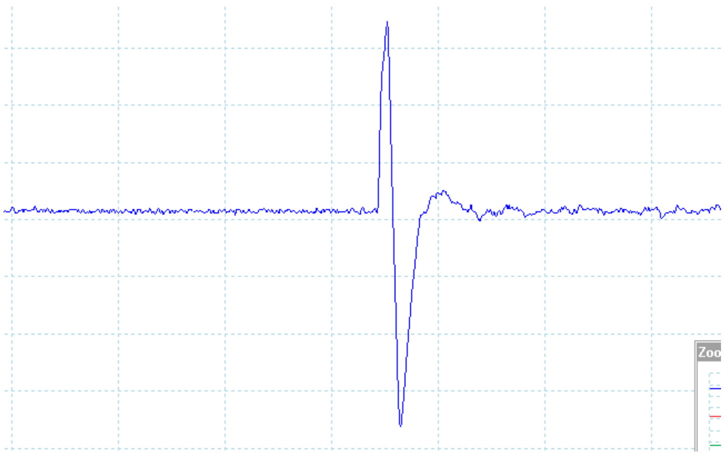


Figure 3.12: Example of -NBE

To classify CG is the same as other, but to determine the data as CG, it must fulfill few criteria. That is has a stepped leader, initial breakdown and return stroke [38].

From the Figure 3.13, it shows that there are a few signals. To identify is correctly, the sample must be zoom in first in the triggered point to see the clear shape of the graph. For another signal also need to be zoom in and check thoroughly.

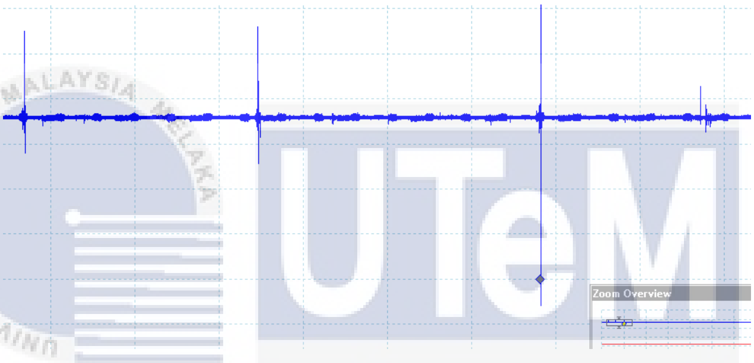


Figure 3.13: Example of CG

From the Figure 3.14, there is an example of initial breakdown that can be found in the lightning data especially -CG.

Figure 3.14: Example of Initial Breakdown

After found the initial breakdown, there is possibility that this signal is CG. After zooming in at the triggered as shown in Figure 3.15, the signal shown the noise like at front of the graph is the stepped leader of the signal and at the back is few returns stroke. So, this data is -CG. It is negative because it starts from the top which is the positive value.

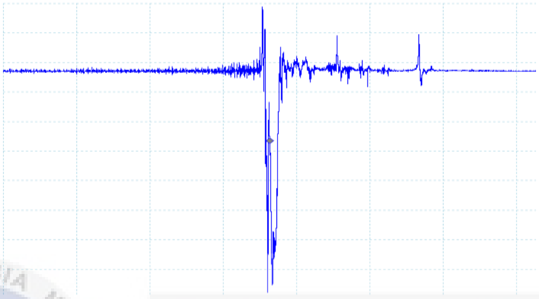


Figure 3.15: Example of -CG

For +CG, it is just the inversed of the -CG. At the front, there is stepped leader and the back there is few returns stroke but not as many as -CG. Usually, +CG has not more than four return strokes. Figure 3.16 show the example of +CG that has been found in the lightning data. As shown, it has the negative polarity which is the inverse for -CG which has the positive polarity.

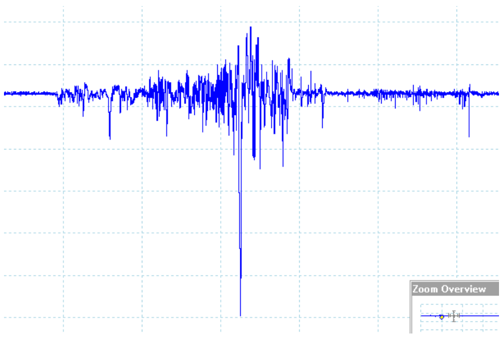


Figure 3.16: Example of +CG

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, it will describe all the result that has been obtained from the EFM, FA system and weather radar. Analysis will be made based on the analyze of lightning type, electric field change, number of return strokes, lightning flash rate, lightning strike rate, rainfall rate, radar reflectivity and location of the thunderstorm occur. From the collected data also, a discussion about their relationship between lightning flashes and rainfall rate will be investigated.

4.2 The Variation of Electric Fill Mill

Based on the Figure 4.1, the graph shows the electric field variance recorded from 12:00:00 to 19:00:00 on 20 October 2021 in Malacca. The graph show that there is only one storm that occur during this time. The storm was occurred from 12.00:00 to 18.00:00

At the early stage of the storm, the value of EFM is very small which is around 0.4 kV/m. The small value indicates that the early lightning occur at the early stage of the storm is a bit far from the EFM sensor located at UTeM. The highest EFM value recorded at 14.50:00 around 3.2 kV/m. There is also other high value, but it did not past the value of 3.2 kV/M. During 14.00:00 to 15.00:00, the highest value of electric field state that the lightning was detect being away from the position of the EFM sensor.

Figure 4.2 shows electric field variance recorded from 04:00:00 to 16:00:00 on 11 August 2020 in Malacca. According to Figure 4.1, there is two storms that occur during 04:00:00 to 14:00:00. The first storms occurred from 05:00:00 to 06:59:59, while the seconds storms occurred from 07:00:00 to 14:00:00.

The first storm recorded a very small number of electric field change, that is 0.75 kV/m recorded on 06:15:50. The small value means that the storm occurs a bit far from the sensor that located in UTeM. A higher number of electric field change is recorded during the second storm, which is 9.8 kV/m. That value is the highest electric field change obtained during that day. Higher value means that the storm occur is not far from the sensor located at UTeM.

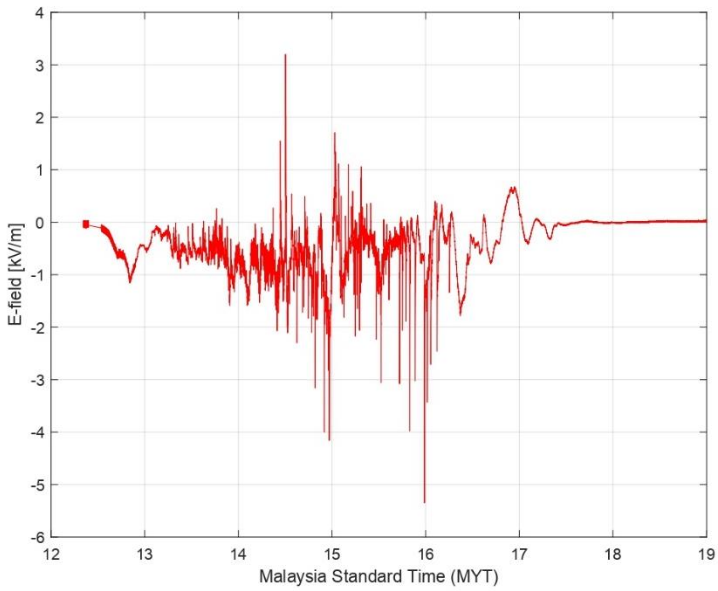


Figure 4.1: Electric Field Variance Recorded on 20 October 2021

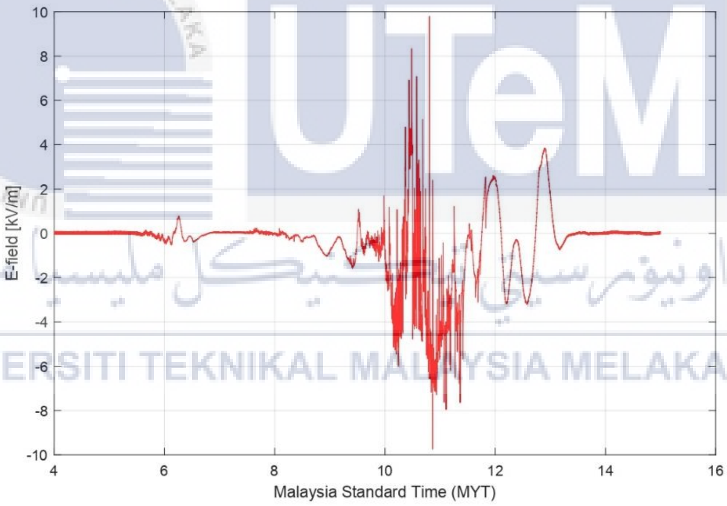


Figure 4.2: Electric Field Variance Recorded on 11 August 2020

4.3 Analysis of Lightning Flashes

Based on Figure 4.3, it shows the types of the lightning flashes and the number of lightning flashes that detected by the FA system. On 20 October 2021, the total lightning flashes recorded is 332. The highest number of lightning flashes that occur on 20 October 2021 was IC, with 122. The minimum number of lightning flashes was -NBE with only five. For CG type, there was 118 lightning flashes have been recorded. Around 74 out of 118 lightning flashes was +CG and the rest is -CG.

Figure 4.3 also shown the total number of lightning flashes that recorded on 11 August 2020. The total lightning flashes recorded that day is 1024, where IC has the highest value with 436 lightning flashes and -NBE has the lowest value with only 6 lightning flashes. For CG, there are total of 337 lightning flashes capture. From 337 lightning flashes, -CG recorded 310 lightning flashes and the rest is +CG lightning flashes.

Figure 4.4 shows the number of return stroke for +CG and -CG that captured on 20 October 2021. Based on Figure 4.4, there were total of 118 CG flashes that recorded by the FA system and the highest number of return stroke also different for -CG and +CG. The total lightning flashes for -CG is 44, where the highest return strokes number is 14 and the lowest is one. Majority of the lightning flashes has four return strokes which were 10 lightning flashes. Figure 4.4 also shows the return strokes for positive CG which has total of 74 lightning flashes. The majority number of return strokes were one which were 43 lightning flashes, while the minority number is four return strokes which were four lightning flashes from the total of 74 lightning flashes.

In addition, Figure 4.5 shows the flash rate during 12:20:00 to 18:00:00 on 20 October 2021 in Malacca. During this time, the highest flash rate was 58 flashes per 10 minutes. Based on the figure, the evolution of the flash rate is no uniform which first it increases until the highest peak which is 58 flashes at 14:00:00 – 14:10:00, then it declined. Afterward, the flashes become unstable and started to increase and decrease rapidly. Then, the flash rate begins to weaken period.

Figure 4.6 shows the flash rate for the storms that occur on 11 August 2021. The flash rate is recorded from 04:00:00 to 14:00:00. The maximum flash rate that recorded was 218 flashes per 10 minutes. The development of flashes per 10 minutes is not constant, where it increases and decrease until it reaches the highest peak. After that, the flash rate continued to increase and decrease rapidly until it begins the weakening period.

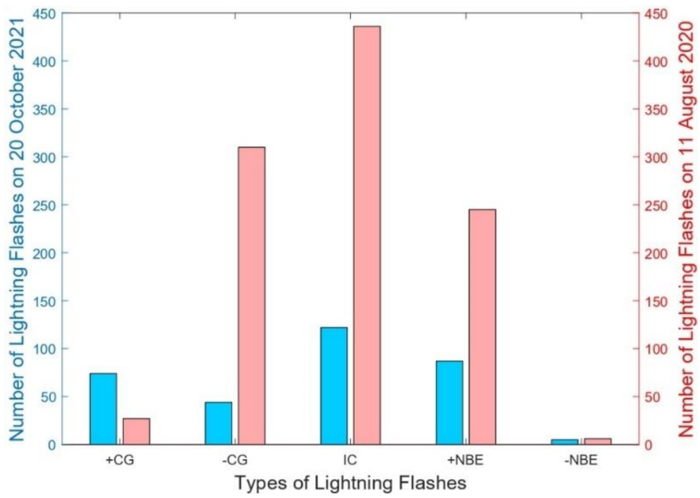


Figure 4.3: Total Lightning Flashes for Two Storms

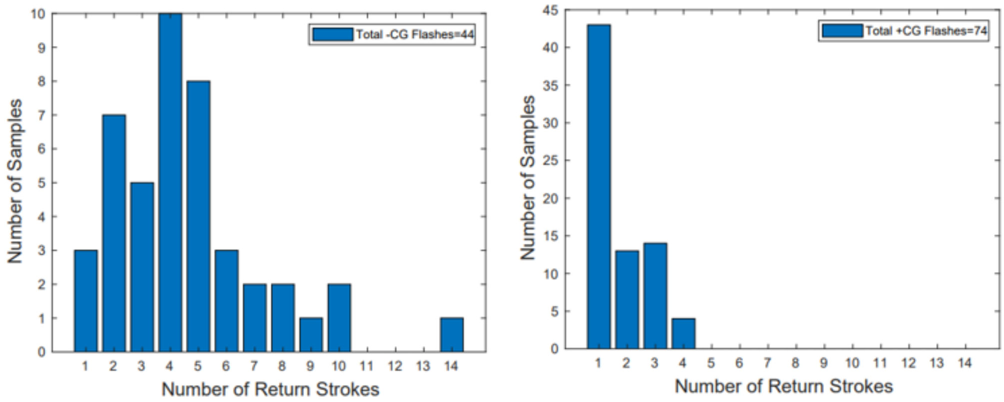


Figure 4.4: Number of Return Strokes on 20 October 2021

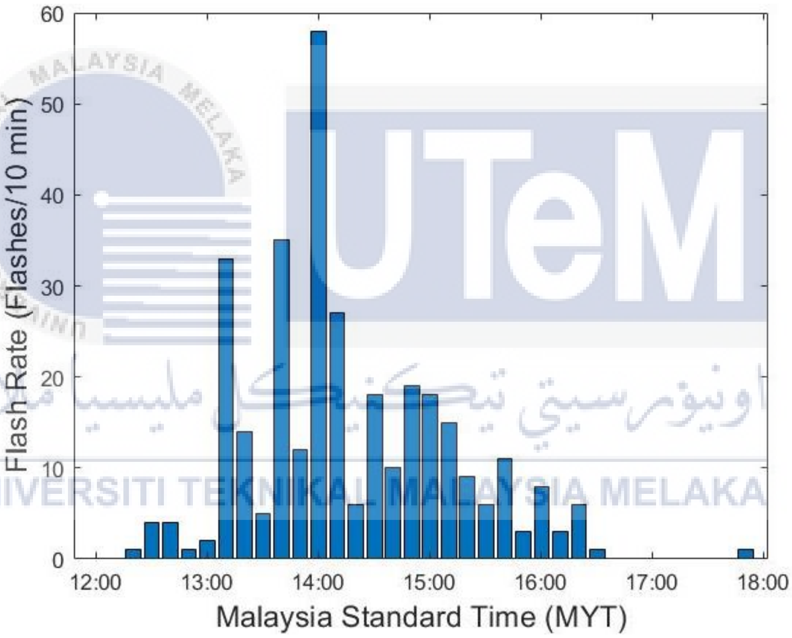


Figure 4.5:Flash Rate on 20 October 2021

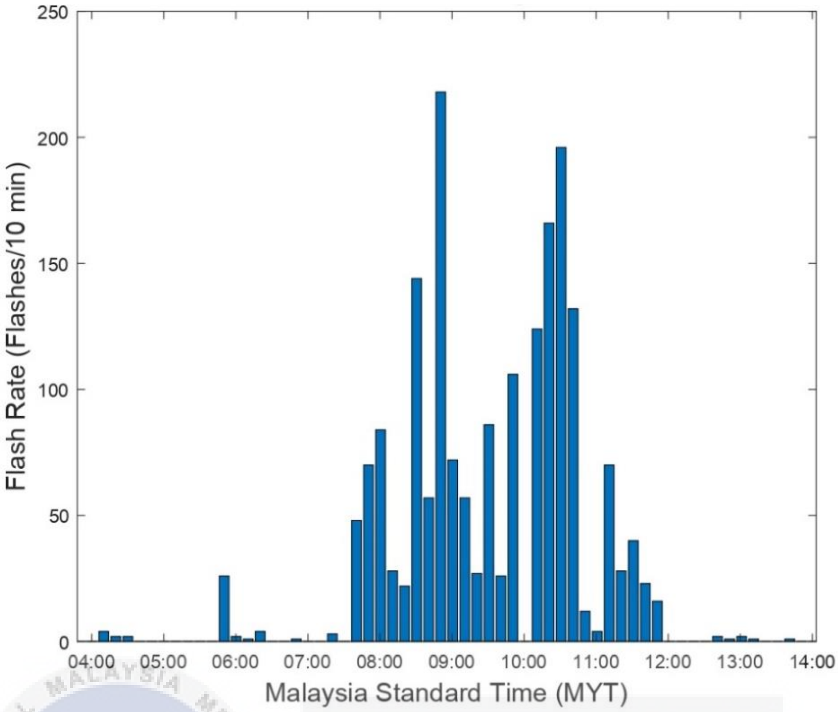


Figure 4.6: Flash Rate on 11 August 2020

4.4 Analysis of Rainfall Rate and Reflectivity

Figure 4.7 shows the rainfall rate recorded 20 October 2021.The minimum rainfall rate occur is 0.05 mm/h and the maximum is 80 mm/h. At the beginning of the storm, there rainfall rate value is not high, and the reflectivity value also show a small value. From the data, there was light rain occurred at the beginning of the storm.

The maximum rainfall rate occurred three times which first and second happened at the early stage of the thunderstorm at 11:50:00 and at 1:00:00to 1:10:00. At this time also, the reflectivity data also revealed that it reaches the highest value which 53 dBZ. Based on the reflectivity value shown in Figure 4.9, it is known that heavy rain was occurred at that time. Besides that, based on the CAPPI radar data, the location of the rainfall was moved in Alor Gajah to Melaka Tengah, and it keep moving to the direction of Jasin. It is shown in Figure 4.12.

The third times rainfall rate reach 80 mm/h is at 02.50:00 to 3.20:00. The reflectivity data also shown that the reflectivity value reach 53 dBZ at this time. So, at this time, heavy rain also occurred. As shown the CAPPI radar data, at this time, the location of the rainfall was occurred at the whole area of Malacca and moved to Jasin, the place that affected the most by the heavy rain.

Figure 4.8 shows the rainfall rate recorded on 11 August 2020. The maximum rainfall rate occurred only one time which happened around 09:30:00 to 11:00:00. The maximum value reach was 50 mm/h, and based on Figure 4.10, it's also shows at that time the reflectivity value also reaches the maximum for that day which is 50 dBZ. During this time, heavy rainfall was occurred. Figure 4.14 shows the radar data for the cloud movement during this time. It moves from Masjid Tanah and then whole area of Malacca.

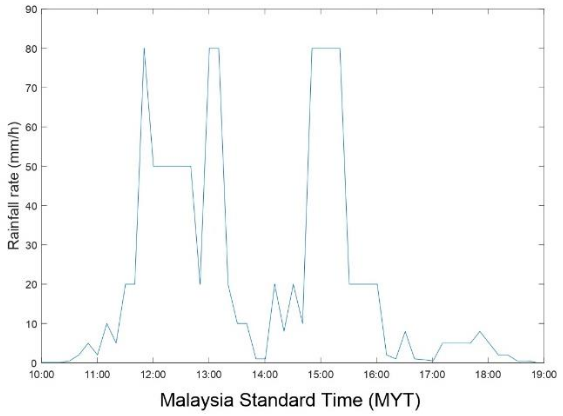


Figure 4.7: The Rainfall Rate Recorded on 20 October 2021

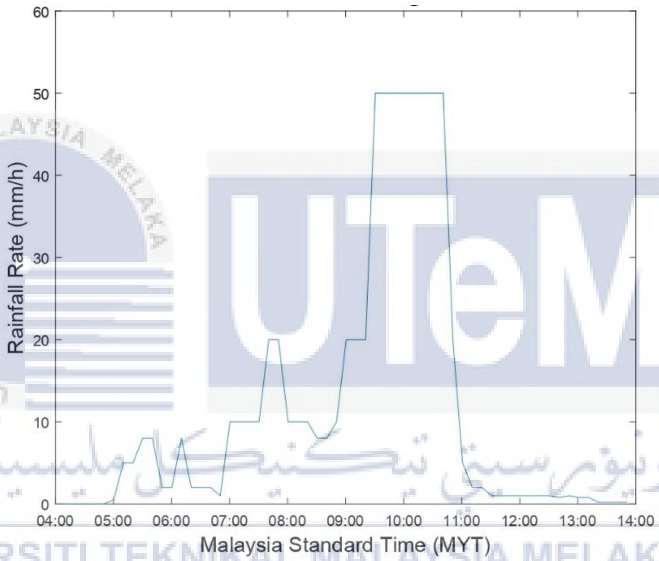


Figure 4.8: The Rainfall Rate Recorded on 11 August 2020

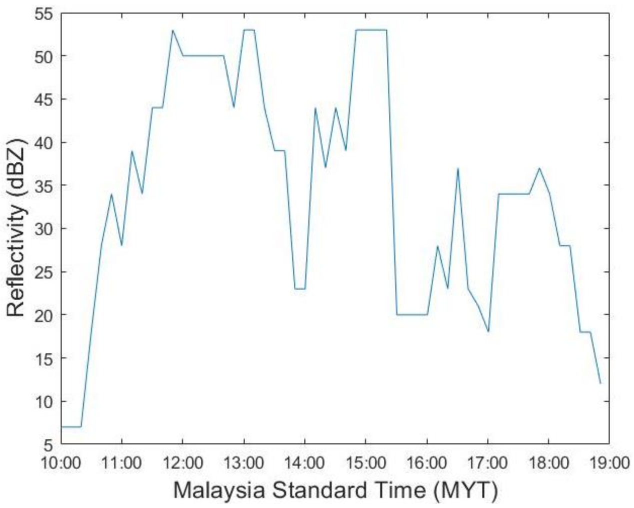


Figure 4.9:The Reflectivity Recorded on 20 October 2021

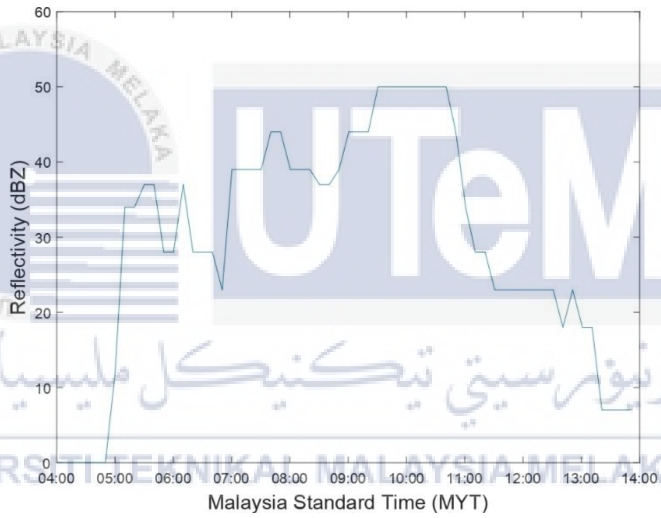


Figure 4.10: The Reflectivity Recorded on 11 August 2020

4.4.1 Development of Cloud

This happened at the early stage of the storm that occur on 20 October 2021. From Figure 4.11, it can be seen at 10.30:00 the cloud is started to form it shape. And as the time goes on, the cloud become bigger. This form of cloud is developed near Alor Gajah and moving in the direction to Melaka Tengah.

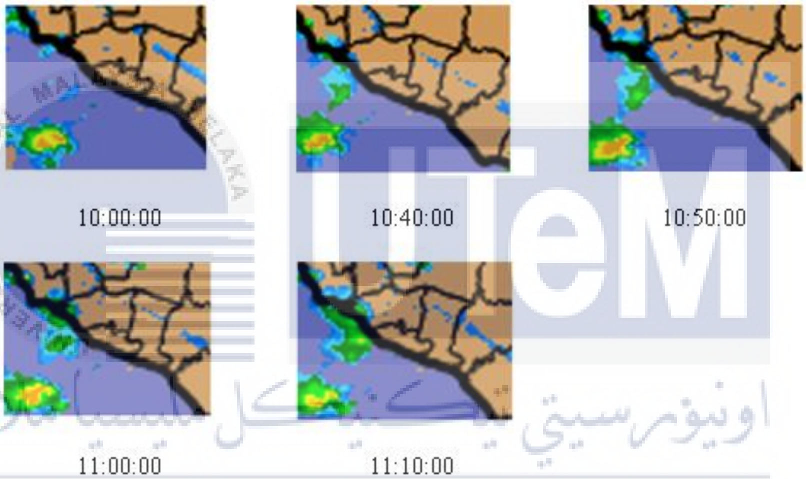


Figure 4.11: Cloud Development from 10:30:00 to 11:10:00

4.4.2 Development of Cloud During Highest Rainfall Rate

Figure 4.12, present the development of cloud reach the highest rainfall rate at the early stage of the storm on 20 October 2021 from 12:20:00 to 13:10:00. It reaches the highest 13.00:00 to 13.10:00 where the value of rainfall is 80 mm/h and at the same time, reflectivity data also reach it highest value. The cloud is moving from Alor Gajah to the direction of Melaka Tengah and Jasin.

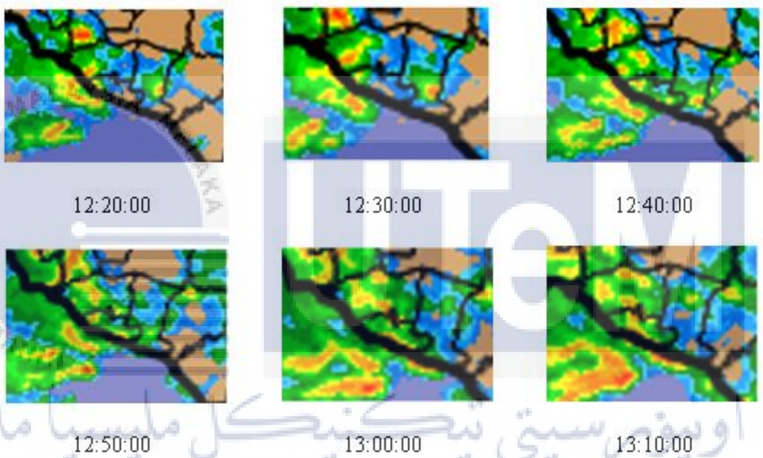


Figure 4.12: Radar Data from 12:20:00 to 13:10:00

Figure 4.13 shows the radar data on 20 October 2021 when the electric field variance reaches its highest value which is at 14:50:00. At this time also, the radar data show that the highest rainfall rate also happened here. It happened from 14.50:00 to 15.00:00 where the rainfall reaches the value of 80 mm/h and at the same time, the reflectivity data also reach the maximum value. During this time, heavy rain is occurred all around Malacca and especially Jasin, as seen in the CAPPI figure.

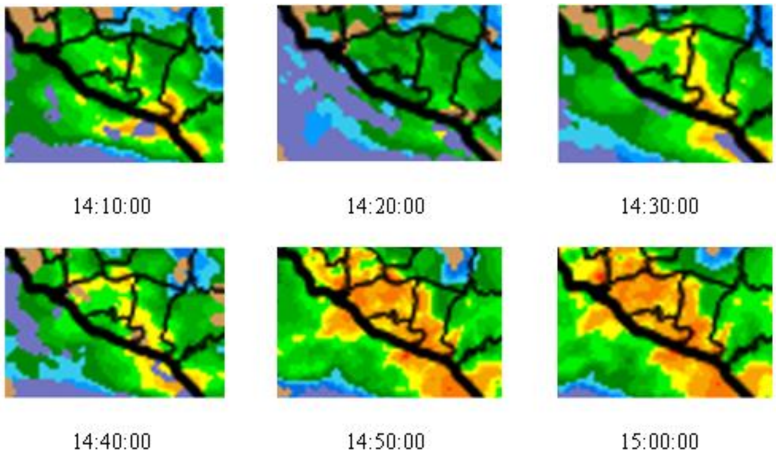


Figure 4.13: Radar Data from 14:10:00 to 15:00:00

From the Figure 4.14, it shows the radar data on 11 August 2020, when the rainfall rate reaches the highest value. It happened from 09:30:00 to 10:20:00. The rainfall rate recorded at this time is 50 mm/h and the reflectivity is 50 dBZ. From the data, it is known that heavy rainfall occurs at this time. The cloud movement is from Masjid Tanah and whole area of Malacca.

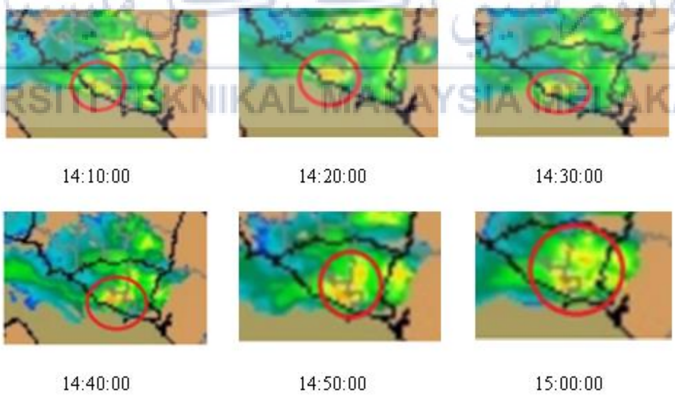


Figure 4.14: Radar Data from 09:30:00 to 10:20:00

4.5 Discussion

4.5.1 Relationship Between Electric Field Variance, Lightning Flashes, Rainfall Rate and Reflectivity

The correlation was made based on the analysis result in section 4.2,4.3 and 4.4. The important part was start from electric field variance, to lightning flashes and rainfall rate based on the CAPPI radar. Based on Figure 4.1 and Figure 4.2, it shows the data obtained from the EFM sensor that were installed at UTeM. From the Figure 4.1, there were only one thunderstorm that occur on 20 October 2021, that is from around 12:00:00 to 18:00:00 where the thunderstorm end. The highest electric field variance that recorded is 3.2 kV/m, which recorded around 14:50:00.

The data then divided to two parts, which before the electric field change reach its maximum value, which is from 12:00:00 to 14:49:59 and after the electric field change reach its maximum value, which is from 14:50:00 to 18:00:00. Based on Figure 4.15 shows there were total of 230 lightning flashes that recorded. From the total of 230 lightning flashes, the highest occurrence of lightning flashes is +NBE which is 86, and the lowest occurrence were -NBE which is 5. The flash rate that recorded were 58 flashes per 10 minutes.

For rainfall data, the highest data that recorded from 12:00:00 to 14:40:59 by the weather radar is 80mm/h, which is the highest value for the rainfall rate data. At this time also, the reflectivity data also produce the highest value which is 53 dBZ. Based on the value of rainfall rate and reflectivity data, it shown that heavy rain was occurred during the time before electric field variance reach its highest value. From the CAPPI data, it shown that the rainfall was moved from Alor Gajah to the direction of Melaka Tengah and Jasin.

Figure 4.16 shows the lightning flashes that recorded from 14:50:00 to 18:00:00 and there are 102 lightning flashes that recorded. The highest lightning flashes that occurred during this time is +CG with total of 55 lightning flashes and the lowest lightning flashes that recorded is +NBE. There were none lightning flashes detected for -NBE. The maximum flash rate recorded for this time is 21 lightning flashes per 10 minutes which occurred at 14:50:00, the same time as the electric field variance reach its maximum value. Then after 16:30:00, which was the late stage of the thunderstorm, the flash rate dropped to the lowest until it reaches 0 flashes per 10 minutes. The last flash rate that recorded were one at 17:50:00.

Besides that, the maximum rainfall rate detected by the weather radar during this time was also 80 mm/h. The reflectivity data also shown the highest value which is 53 dBZ. This was happened at 14:50:00 to 15:20:00. Based on the rainfall data and reflectivity data, heavy rain was also occurred at this time. The CAPPI data also shown where the rainfall moved. This time, the rainfall was occurred at Jasin and moving to the whole area of Malacca.

Figure 4.2 shows that there two storms that occur on 11 August 2020. The first storm occurred from 05:00:00 to 06:59:59. The electric field variance recorded in the first storm is 0.75 kV/m. Figure 4.17 shows the number of lightning flashes that capture during this time. There are total of 33 lightning flashes, where the highest value is +NBE with 21 lightning flashes and the lowest value is -NBE with only one lightning flashes. The flash rate record during this time is 26 flashes per 10 minutes. The rainfall rate value recorded for the first is only 8mm/h with the reflectivity value is 37 dBZ. From the value of rainfall rate and reflectivity, light rain was occurred during the first storm.

Figure 4.18 shows there are total of 980 lightning flashes detected during the second storm. The highest value is IC with 429 lightning flashes and the lowest value is -NBE with four lightning flashes. Second storm record a very high flash rate, which is 218 flashes per 10 minutes. After that, the flash rate decrease and reach zero flash per 10 minutes. The maximum rainfall rate recorded during this second storm is much higher that the first storm. It recorded 50mm/h for rainfall rate and 50 dBZ for reflectivity. Based on the value of rainfall rate and reflectivity, heavy rainfall was occurred during the second storm. The cloud movement was from Masjid Tanah to whole are of Malacca.

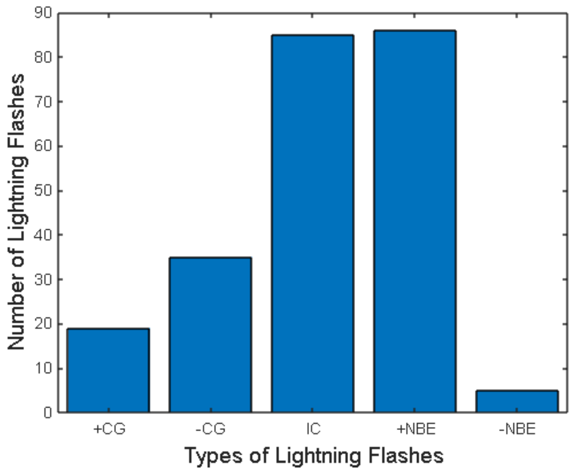


Figure 4.15: Lightning Flashes Captured on 12:00:00 to 14:49:59

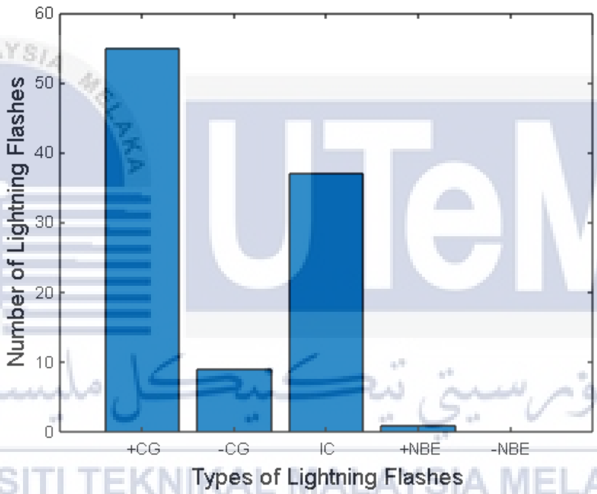


Figure 4.16: Lightning Flashes Captured on 14:50:00 to 18:00:00

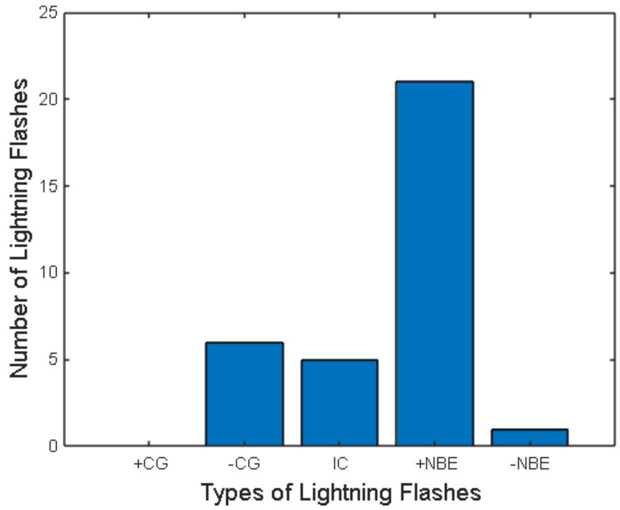


Figure 4.17: Types of Lightning flashes Capture on 05:00:00 to 06:59:59

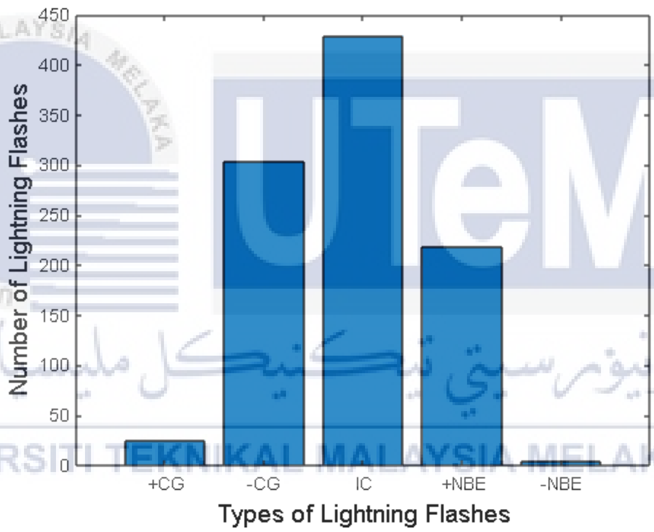
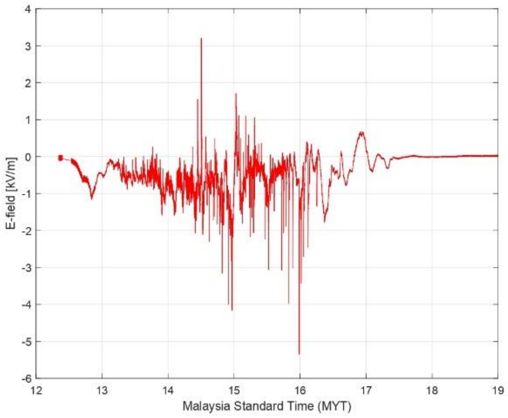


Figure 4.18: Types of Lightning flashes Capture on 07:00:00 to 14:00:00

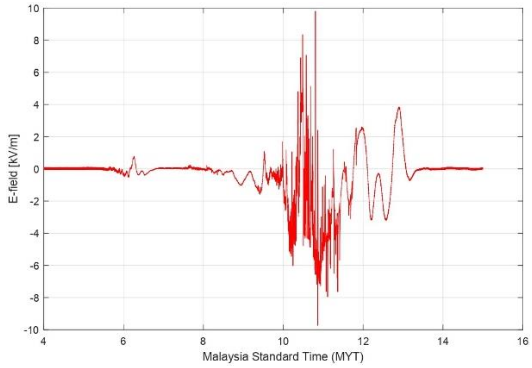
Table 4.1: EFM, Rainfall Rate, Flash Rate and Reflectivity for Two Storms

20 October 2021	11 August 2020

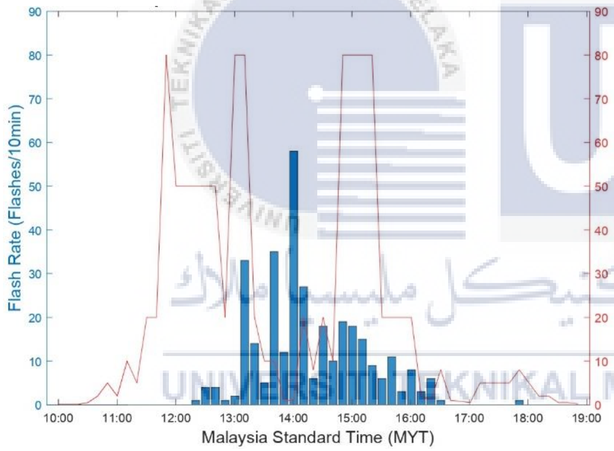
20 October 2021



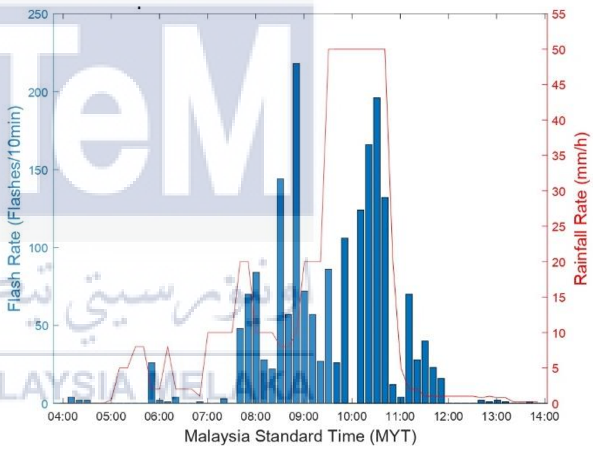
11 August 2020



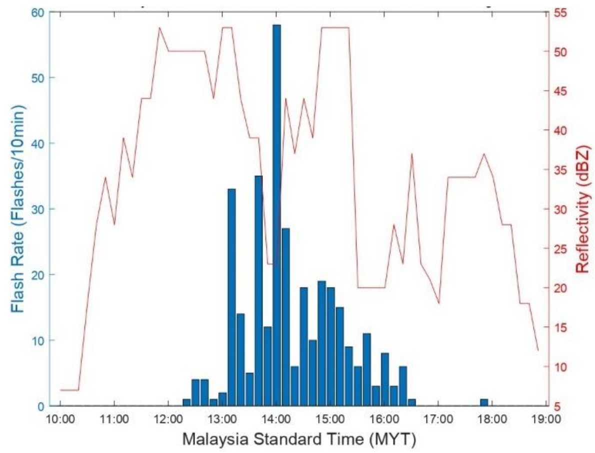
20 October 2021



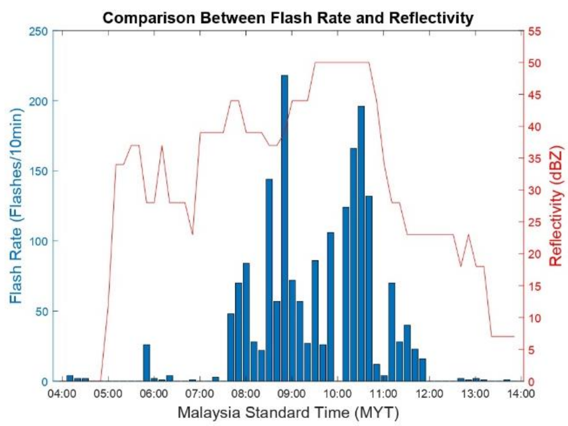
11 August 2020



20 October 2021



11 August 2020



4.5.2 Comparison Between Two Thunderstorms

The storms have been analysed on 11 August 2020 and the second 20 October 2021 in Malacca. Based on the electric field variance, there are two storms detected occur on 11 August 2020. The first storm duration was not very long, but it recorded a total of 33 lightning flashes. The +NBE is the majority types with 33 lightning flashes and +CG is the minority with zero lightning flashes. The rainfall rate and reflectivity recorded a small value, based on the data it is known that light rain is occurred during the first storm that occur from 05:00:00 to 06:59:59 Am.

The second storm take a longer time than the first one, it occurred from 07:00:00 to 02:00:00. There are more total of 980 lightning flashes recorded during this time and a majority types of lightning flashes was IC with 429, and the minority is -NBE with only four lightning flashes. The rainfall rate and reflectivity recorded the highest value for this second storm. Based on the value of rainfall rate and reflectivity, heavy rain was occurred during the second storm.

For storm occurred on 20 October 2021 was from 12:00:00 to 18:00:00. Although the time the storm occurred is six hours, it provides a satisfying result. From the storm results, it produces a total of 332 lightning flashes and the majority type is IC with total of 122 lightning flashes and the minority is -NBE with five lightning flashes. Rainfall rate data and reflectivity shows the highest value during this time, and it is known from the data that heavy rainfall was occurred.

From the results, it shows that the number of IC flashes has the highest recorded throughout the observation during heavy rainfall. The reading of rainfall rate and reflectivity shows heavy rainfall occur. Second is, the minority types of lightning flashes that occur is -NBE. From the result, -NBE didn't contribute much to the occurrence of heavy rainfall and only act as indicator before heavy rainfall occur.

Table 4.2: Comparison Between Two Storms

Thunderstorms Date	11 August 2020		20 October 2021
Data Type	First Storm	Second Storm	
Storm Duration	05:00:00 to 06:59:59	07:00:00 to 14.00:00	12:00:00 to 18:00:00
Highest EFM value (kV/m)	0.75	9.80	3.20
Total +CG Flashes	0	25	74
Total -CG Flashes	6	304	44
Total IC Flashes	5	429	122
Total +NBE Flashes	21	218	87
Total -NBE Flashes	1	4	5
Lightning Flashes Total	33	980	332

Majority Type of Lightning Flashes	+NBE	IC	IC
Maximum Flash Rate (Flashes/10min)	26	218	58
Maximum Rainfall Rate (mm/h)	8	50	80
Maximum Radar Reflectivity (dBZ)	37	50	53
Intensity of Rainfall	Light Rain	Heavy Rain	Heavy Rain
Movement of Rainfall	Klebang to Ayer Keroh after that to Alor Gajah	Masjid Tanah and then whole area of Malacca	Alor Gajah to Melaka Tengah after that Jasin and whole area of Malacca.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion

In this research, there three objectives that included and all the objectives have been achieved. The first objective is to classify the types of lightning flashes. Two storms event occur on 11 August 2020 and 20 October 2021 in Malacca has been used to classify the types of lightning flashes.

By using the PicoScope software, the lightning data can be view in the form of signal. There are some parameters to distinguish their types such as the shape and polarity of the signal must be seen thoroughly. From the two storms, there are three major types of lightning that have been classified. There are Narrow Bipolar Event (NBE), IntraCloud (IC) and Cloud to Ground (CG). For NBE and CG, each of the type has two polarities, which is -CG, +CG and -NBE, +NBE. Therefore, there are total of five types of lightning flashes that has been classified.

The second objective is to analyse the types of lightning flashes emitted from the storm. A total of 1356 lightning flashes have been recorded from the two storms. The storms on 11 August 2020 recorded a huge number of lightning flashes around 1024 flashes. The majority types are IC with total of 436 lightning flashes and the minority is -NBE with only 6 lightning flashes. The lightning data from that storm is analyse from 04:00:00 to 014:00:00 and two storms have been detected during the period. However, the storms that occur on 20 October 2021 recorded 332 lightning flashes with the majority of the lightning types was IC with 122 flashes and -NBE with only five flashes. The lightning data is analysed from 12:00:00 to 18:00:00. All the lightning flashes emitted from the storm has been analysed.

The third objective is to analyse the relationship between the lightning flashes and rainfall rate. The result shows the thing that stand out from both storms is the majority types of lightning, where IC is the majority type of lightning flashes for both storms. From the data of rainfall rate and reflectivity, majority of IC is leading to the occurrence of heavy rainfall in area that the lightning flashes strike. Where -NBE with the lowest number is the indicator before the heavy rainfall to occur.

5.2 Recommendation for Future Works

As seen from the result, there are total of 1356 lightning flashes that captured on 11 August 2020 and on 20 October 2021. Unfortunately, there are still have some limitation can be improved by implementing another method and recommendation for the future works.

The first recommendation using pattern or image recognition when classifying the lightning data. Instead of PicoScope software, it’s better to develop a Convolutional Neural Network (CNN) for classification the lightning flashes that captured according to its own classes. In this case, the neural network has made significant progress in pattern recognition, allowing for the effective classification of raw lightning data. Using CNN also will save many times to classify the lightning data. So, instead of using PicoSope, it better to develop a neural network for recognition of the lightning pattern.

Next, it is better to analyse more storms that causes by the flash flood in the future. By analysing on more storms, it means the scope of the data is much bigger and more can be study and analyse. Studying more data can be really useful in this research, it is because the accuracy of the result obtained will become precise and more data means more comparison can be done and the more accurate relationship can be investigated.

The weather radar data that used is also not very accurate. This is because, the rainfall rate determination is only based on the estimation of colour code generated from the cloud. Instead of using weather radar, it’s better to change it to microwave attenuation method to determine the rainfall rate. The data is accurate because it's verified by the rain detectors deployed at the weather stations and it can give a huge range of information.

The way to detect the lightning also needs to be change, in this research EFM sensor is used. Instead of using EFM, it is better to use other method, such as the TOA system. TOA system is the Malaysia high precision lightning detection and warning alert system. TOA system has the support of MetraWeather with high detection efficiency and location accuracy. TOA system is better and has more advantage compared to the EFM sensor.

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