LIGHTNING CHARACTERISTICS OBSERVED BY LIGHTNING DETECTION SYSTEM (LDS) ALONG KLMK – PROI 275 kV TRANSMISSION LINE

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ABSTRACT

A cloud-to-ground lightning activity data collected by a Lightning Detection System (LDS) along the 275 kV transmission line KLMK-PROI in year 2004 to 2005 from Seremban to Melaka has been investigated. The LDS are installed by TNB Research Sdn Bhd (TNBR) in 1994. Annual lightning days are acquired and ground flash density maps are constructed from the database. Lightning parameters such as, polarity, ground flash density and peak lightning current were analyzed with the lightning data collected by LDS. The lightning data was analyzed using FALLS (Fault Analysis and Lightning Location System) software. It is found that the negative lightning is observed more than the positive lightning. Also found that the value of peak current either negative or positive polarity is about 30 kA. The performance of LDS, especially detection efficiency, was evaluated using the data obtained from transmission line fault and lightning activities along transmission line. It is found detection efficiency is 93.38%.

ABSTRAK

Tujuan penyelidikan ini adalah untuk menyelidik aktivi-aktiviti kilat dari awan ke bumi dengan data yang dikumpulkan oleh Sistem Pengesan Kilat (LDS) di sepanjang talian penghantaran KLMK – PROI 275 kV dari Seremban ke Melaka bagi tahun 2004 hingga 2005. Sistem Pengesan Kilat ini telah dipasang oleh Tenaga Nasional Research Sdn Bhd (TNBR) pada tahun 1994. Data tahunan kejadian kilat dan peta-peta ketumpatan pancaran kilat ke bumi diperolehi daripada pengkalan data TNBR. Parameter-parameter kilat seperti polariti, ketumpatan pancaran kilat ke bumi dan arus puncak dianalisis daripada data yang dikumpul oleh Sistem Pengesan Kilat. Data ini dianalisis dengan menggunakan perisian FALLS (Fault Analysis and Lightning Location System). Daripada penyelidikan, di dapati polariti kilat negatif adalah melebihi polariti kilat positif. Juga di dapati purata nilai arus puncak adalah 30 kA. Untuk prestasi Sistem Pengesan Kilat, terutamanya kecekapan pengesanan telah dinilai dengan menggunakan data kesalahan kilat dan data aktiviti kilat di sepanjang talian penghantara itu. Di dapati, nilai kecekapan pengesanannya adalah 93.38%.

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LIST OF ABBREVIATIONS

CG	-	Cloud-to-Ground
DE	-	Detection Efficiency
FALLS	-	Fault Analysis and Lightning Location System
GAI	-	Global Atmospheric Inc
GC	-	Ground-to-Cloud
GPS	-	Global Positioning System
IC	-	Inter Cloud
IKL	-	Iso-Keraunic Level
IMPACT ESP	-	Improved Accuracy from Combined Technology Enhanced Sensitivity and Performance
KLMK	-	Kelemak
LDS	-	Lightning Detection System
LFOR	-	Lightning Flashover Rate
LPATS IV	-	Lightning Positioning And Tracking System
MDF	-	Magnetic Direction Finders
MV	-	Megavolts
NLDN	-	National Lightning Detection Network
PROI	-	Paroi
TNBR	-	Tenaga Nasional Research Berhad
TOA	-	Time of Arrival

CHAPTER I

INTRODUCTION

1.1 Background

Lightning is a natural phenomenon that may impose disastrous effects on human and industrial equipment. Approximately 9 million lightning strikes hit the earth everyday with 100 strikes per second at any given time. One lightning bolt can contain 100 million volts and up to 100,000 amperes. Typical strikes will generate temperature of 30,000 Kelvin which is five times hotter than the sun's surface.

All the lightning activities in Malaysia have been monitoring and recorded by Tenaga Nasional Research Sdn. Bhd (TNBR) using the Lightning Detection System (LDS) which is installed at 7 different places across the peninsular Malaysia. The main objective of LDS is to detect the lightning activities occurring across the National grid in real time. It is also used to gain better understanding on lightning phenomena at this region and also to assess and mitigate the lightning impact on power distribution and transmission system.

In the past decade, modern lightning location systems have been installed worldwide for monitoring lightning activities. These systems collect information on lightning co-ordinates, lightning peak current and number of strokes per flash, etc. Today they are becoming an indispensable daily operation tool for electric power utility providers.

Lightning data collected by lightning location systems are increasingly used by power utility providers for the effective design, operation and maintenance of transmission lines. Real-time data together with online information of line components, for example, are used to speed the restoration of systems and to minimize the damage to utilities and customers. Peak lightning current is a crucial parameter in the design of power lines and substations.

In many cases, an accurate knowledge of this lightning parameter is unknown to design engineers, but it can be built up with the lightning data collected by a lightning location system. Ground-flash density is considered as the most important parameter in evaluating the performance of a transmission line against lightning. It is normally obtained using magnetic steel bars, or lightning flash counters.

The lightning location system is capable of providing a direct measurement for estimating this parameter. When using lightning data for daily operation of utilities, performance of a lightning location system is of interest. The performance is characterized by detection efficiency (DE). It is evaluated with different methods currently, such as video observation of cloud-to-ground lightning activities in a selected site, and utilization of transmission line fault data, etc.

The first method was applied in the evaluation of the United States of America National Lightning Detection Network (NLDN). Both detection efficiency and location accuracy were calculated using a large data set of video observation of lightning activities in the vicinity of Albany, New York during the summers of 1993, 1994 and 1995. It was found that the overall flash DE reached 67%, 86% and 72% in 1993, 1994 and 1995, respectively; and the overall stroke DE reached 67% and 47% in 1994 and 1995, respectively (Chen, S.M, 2002).

The second method was tried by Hokuriku Electric Power Co. in Japan. Both detection efficiency accuracy in the Hokuriku area were evaluated using the data of transmission line faults recorded between November 1993 and October 1996. The detection efficiency of Hokuriku Electric Power Co. LLS was about 80% in summer and about 60% in winter (Chen, S.M, 2002).

In Malaysia, Lightning Detection System (LDS) is used to detect cloud-to-ground (CG) flashes. The LDS is a combination of Magnetic Direction Finders (MDFs) and Time of Arrival (TOA) sensors. The LDS records the location, time, polarity, peak amplitude, and multiplicity of CG flashes.

A lightning detection coverage for TNBR in Malaysia using the LDS which consists of five IMPACT ESP sensors and two LPATS IV sensors achieving uniform and highly accurate lightning coverage. It collects data not only throughout Malaysia, but extending outward well beyond TNBR's region of interest for early storm warning. This LDS is installed by TNBR in 1994. Network communication is achieved through TNBR's desired communication network by connecting all these TNBR sites.

This thesis presents an investigation into cloud-to-ground lightning activity data collected by a Lightning Detection System (LDS) along the 275 kV transmission line KLMK-PROI in year 2004 to 2005 from Seremban to Melaka. Annual lightning days are acquired and ground flash density maps are constructed from the database. Lightning parameters such as, polarity, ground flash density and peak lightning current were analyzed using the lightning data collected by the LDS. The performance, including detection efficiency was evaluated using the data obtained.

1.2 Objectives

The objectives of the project are:

1. To investigate and observed characteristics of cloud-to-ground (CG) lightning activity in tropical area using lightning detection system along KLMK-PROI 275 kV transmission lines from 2004 to 2005.

2. To find out the detection efficiency of lightning location system on the KLMK-PROI 275 kV transmission lines.

1.3 Scope

The scopes of the project are described below:

1. The investigation of the characteristics of cloud-to-ground lightning activity in tropical area are based on the data from TNBR's LDS on KLMK-PROI 275 kV lines for year of 2004 to 2005, employing the combination of MDF and TOA techniques with seven stations.

2. The data observed and analyzed are within 1km radius of KLMK-PROI 275 kV transmission lines located in Melaka and Negeri Sembilan.

3. The parameters to be analyzed are lightning polarity, peak current distribution and flash density.

4. The project will also find out the detection efficiency of lightning location system on the KLMK-PROI 275 kV transmission line.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Malaysia, as many other tropical countries, experiences high frequency of lightning incidents. However, there are few reports on the characteristics of lightning in this region. S.M. Chen *et. al* (2002) had presented the lightning performance, including detection efficiency and location accuracy. It was evaluated with the data of the recorded lightning faults on 110, 220 and 500 kV transmission lines in 1997-1999 obtained at Guang Dong in China. Lightning parameters, such as thunderstorm days, ground-flash density and peak lightning current were estimated with the lightning data collected by Guang Dong Lightning Location System (GDLLS).

Meanwhile, E.B Shim *et. al* (2002) described the LPATS system in Kepco, Korea. They obtained the statistical distribution of lightning current parameters, the Iso-Keraunic Level (IKL) map from 1996 to 2001 and calculated the Lightning Flashover

Rate (LFOR) for 154 kV/345 kV transmission tower which has double circuits or four circuits in one tower.

T. Shindo *et. al* (1998) also had presented a could-to-ground lightning occurrence for the year between 1992 to 1995. The analysis is done using the data obtained with nine different lightning location systems in Japan. A total of more than 2 million lightning strokes are observed for the four years and the number of annual lightning strokes is closely related to the weather conditions in summer.

Chen. S.M and Fan.L.M (2002) have investigated into cloud-to-ground lightning activity data collected by a lightning detection system in the Guang-Dong Province, the southernmost in China. The lightning days are compared with annual thunderstorm days collected by the Guang Dong Meteorological Agency, and a weak correlation is noted.

Another group of researcher, Hidayat. S *et. al* (1999) also have investigated characteristics of lightning in the tropics. An observation using a lightning detection network has been carried out on the Java Island (Indonesia) since February 1994, employing the combination of MDF and TOA techniques with four stations. Analysis on the collected data revealed high lightning flash density around the Java Island, especially during the rainy season.

Lightning characteristic observed by the LPATS-III network for 5 consecutive years from 1996 to 2000 on the Java Island, Indonesia also have been reported by Hidayat. S *et. al* (2002). Performance of Megavolts (MV) distribution system in Jakarta recorded for the same period is analyzed in the relation with the lightning activity.

The loss of a system due to a lightning strike in a conventional power generating station, would only have economic consequences. Narinder. K. T (2001) has studied the effects of lightning strikes on reactor trips or misoperation of the equipment from January 1984 through September 2000. From this study, he found that most of the lightning strikes operated the over voltage protection devices for the control rod drive system.

2.2 Lightning Process

2.2.1 Sources of Lightning

Most research on the electrical structure of clouds has focused on the cumulonimbus, the familiar thundercloud or thunderstorm, because this type of cloud produces most of the lightning. There have been limited studies of the electrical properties of other types of clouds such as stratus, stratocumulus, cumulus, nimbostratus, altocumulus, altostratus, and cirrus clouds that might potentially produce lightning or, at least, long (1 to 100 m) sparks (Uman M.A, 1994).

The classic model for the charge structure of a thundercloud was developed in the 1920's and 1930's from ground-based measurements of both thundercloud electric fields and the electric field changes that are caused when lightning occurs. In this model, the thundercloud forms a positive electric dipole as shown in Figure 2.1 and Figure 2.2; that is, a primary positive charge region is found above a primary negative charge region.

By the end of the 1930's, Simpson and co-workers (Uman M.A, 1994) had verified this overall structure from measurements made with sounding balloons inside clouds and had also identified a small localized region of positive charge at the base of the cloud. Subsequent measurements of electric fields both inside and outside the cloud have confirmed the general validity of this double-dipole structure.

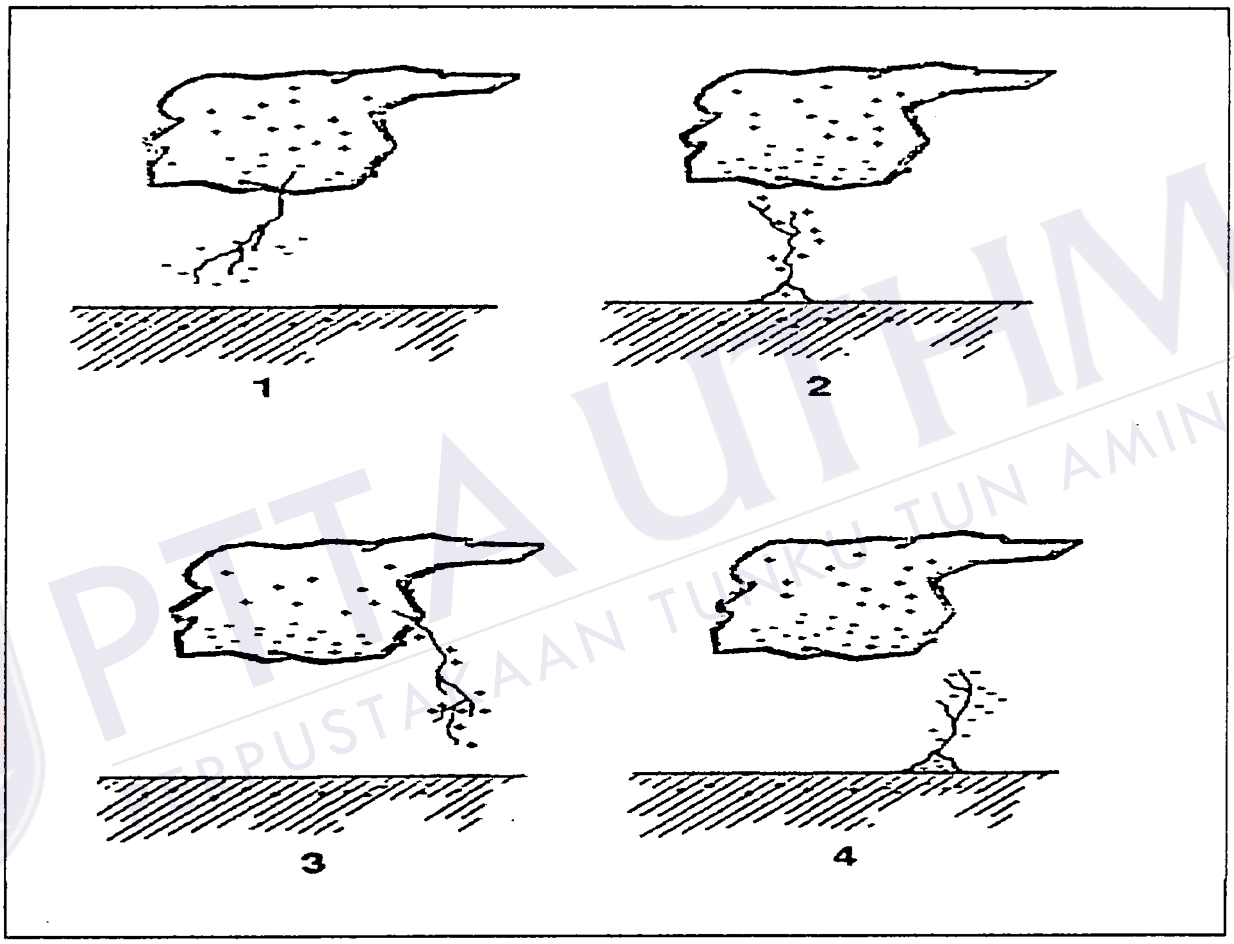

Figure 2.1: Thundercloud charge distribution and categorization of the four types of lightning between cloud and ground.

2.2.2 Natural Lightning

Lightning is a transient, high-current discharge whose path length is measured in kilometers. Well over half of all flashes occur wholly within the cloud and are called intracloud (IC) discharges. Cloud-to-ground (CG) lightning has been studied more extensively than other forms of lightning because of its practical importance (for instance, as the cause of injuries and death, disturbances in power and communication systems, and the ignition of forest fires) and because lightning in the clear air below the cloud base is more easily studied with optical techniques.

Cloud-to-cloud and cloud-to-air discharges occur less frequently than either IC or CG lightning. All discharges other than CG are often combined under the general term cloud discharges. Four different types of lightning between cloud and Earth have been identified, the ways by which these are initiated being shown in Figure 2.1. CG flashes initiated by downward moving negatively-charged leaders probably account for about 90% of the CG discharges worldwide (Figure 2.1, category I), while less than 10% of lightning discharges are initiated by a downward-moving positive leaders (category 3).

Ground-to-cloud discharges are also initiated by leaders of either polarity that move upward from the Earth (categories 2 and 4). These upward-initiated flashes are relatively rare and usually occur from mountain peaks and tall man-made structures. The number of cloud-to-ground flashes per square kilometer per year has a maximum of 30 to 50, and a typical over-land value of 2-5. Between 10 and 20 million CG flashes strike the continental United States annually. Worldwide there are about 100 total (cloud and ground) flashes per second for a worldwide average flash density of about 6 km^2 per year.

2.2.3 Negative Lightning

A negative CG discharge (Figure 2.1, category 1) begins in the cloud and effectively lowers some tens of coulombs of negative charge to Earth. The total discharge is termed a flash (as is the total discharge for other types of lightning). Flash durations are typically about half a second. A flash has several components, the most significant being three or four high-current pulses called strokes. Each stroke lasts about a millisecond, and the separation between strokes is typically several tens of milliseconds. Lightning often appears to "flicker" because the human eye can just resolve the individual pulses of luminosity that are produced by each stroke.

The sequence of luminous processes that are involved in a typical negative CG flash is shown in Figure 2.2. The stepped leader initiates the first return stroke after it propagates downward in a series of discrete steps. The stepped leader is itself initiated by a preliminary breakdown within the cloud, although there is no agreement about the exact form and location of this process. High-speed photographs show that leader steps are typically 1 μs in duration, tens of meters in length, and that the pause time between steps is 20 to 50 μs. A fully developed stepped leader can effectively lower 10 C or more of negative charge toward the ground in tens of ms. The average downward speed of propagation is about 2×10^5 m/s. The average leader current is between 100 and 1000 A. The leader steps have peak pulse currents of at least 1 kA. During its progression toward ground, the stepped leader produces a downward-branched geometrical structure.

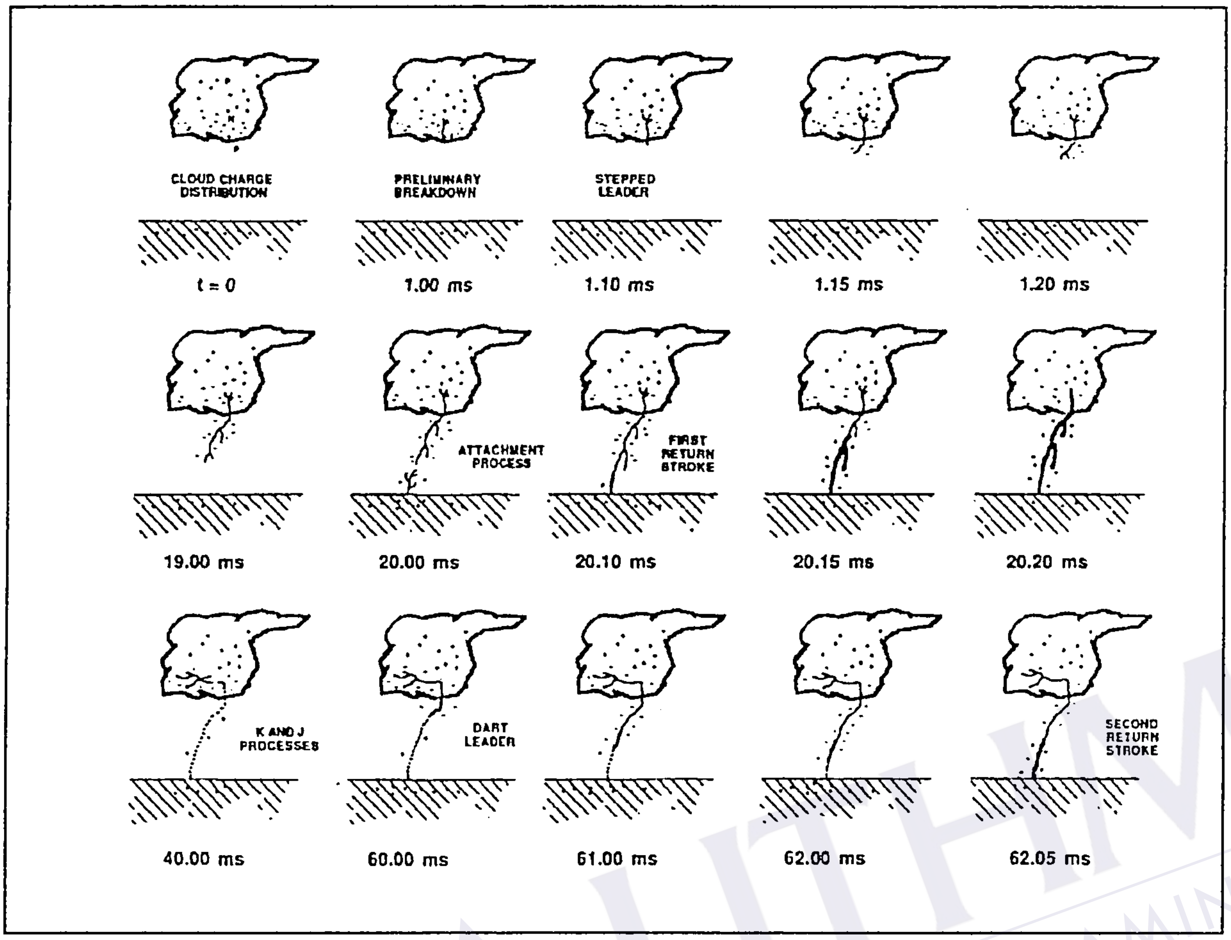

Figure 2.2: Various processes that make up a negative CG lightning discharge.

The potential difference between the lower portion of the negatively charged leader and the Earth has a magnitude in excess of 10^7 V. As the tip of the leader nears ground, the electric field at sharp objects on the ground or at irregularities on the surface increases until it exceeds the breakdown strength of air. At that time, one or more upward-moving discharges are initiated from those points, and the attachment process begins. When one of the upward-moving discharges contacts the downward-moving leader, some tens of meters above the ground, the leader is effectively connected to ground potential. The leader channel is then discharged by an ionizing wave of ground potential that propagates up the previously charged leader channel. This process is the first return stroke.

The electric field across the difference in potential between the return stroke, which is at ground potential, and the channel above, which is near cloud potential, is what produces the additional ionization. The upward speed of a return stroke is typically one-third to one-half the speed of light near the ground, and the speed decreases with height. The total transit time between ground and cloud is on the order of 100 μs. The first return stroke produces a peak current of typically 30 kA at the ground, with a time from zero to peak of a few microseconds. Currents measured at the ground decrease to half the peak value in about 50 μs, and currents of the order of hundreds of amperes may flow for times of a few to several hundred milliseconds.

The rapid release of return-stroke-energy heats the leader channel to a peak temperature above 30 000 K and produces a high-pressure channel that expands and creates the shock waves that eventually become thunder. The return stroke effectively lowers to ground the negative charge originally deposited on the stepped leader channel including all the branches, as well as other negative cloud charge that may become available at the top of the channel.

When the return-stroke current ceases, the flash, including various discharge processes within the cloud, may end. In that case, the lightning is called a single-stroke flash. On the other hand, if additional cloud charge is available, a continuous dart leader can propagate down the residual first-stroke channel and initiate another return stroke. During the time between the end of the first return stroke and the initiation of a dart leader, so-called J- and K-processes occur in the cloud. The J-process involves charge motion in the cloud on a tens of milliseconds time scale, while the K-process moves charge on a time scale ten times shorter. The dart leader has a peak current of 1 kA or more and lowers a total charge on the order of 1 C at a speed of about 3 x 10^6 m/s.

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