“ I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references.”

Signature : ………………………………….

Name : Amirul Akmal Bin Abd.Rahman

Date : 11th June 2012

“ I hereby declare that I have read through this report entitle “Investigation On The Effect Of Transient Overvoltage On Electrical Cable” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

Signature : ………………………………….

Supervisor’s Name : Mr Zikri Abadi Bin Baharudin

Date : 11th June 2012

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ABSTRACT

Lightning strike to overhead electrical power cable or transmission line may cause the high effect of transient overvoltage which lead to permanent damages and affect the transmission line performance. These studies focus on the developing of lightning model as well as the cable model. PSCAD software is the main tools for the simulation works. Furthermore the effect of transient overvoltage to the cable with different parameters were observed by simulating and analyzing the proposed models. In addition, the pattern of the currents and voltages from different topologies and cable's parameters were analyzed when the lightning current wave shape of 8/20 was performed. It is found that the patterns of phases currents such as the peak current, the unwanted frequency and the surge duration signal were similar to each other under different parameters of the cable. Similarly, it is observed that the pattern of the phases voltage such as the peak current, the unwanted frequency and the surge duration signal were similar to each other under different parameters of the cable. In addition, we investigated the direct strike to the transmission line model for the cable under hot temperature (38 Celcius) especially in tropical location such as in Malaysia. It appears that the peak current, the unwanted frequency and the surge duration was similar to the standard value provided by the factory. In future, this project may initiate for the study of scheme protection planning base on available basic insulation level guideline.

ABSTRAK

Kilat pada kabel kuasa elektrik atau talian penghantaran boleh menyebabkan kesan yang tinggi voltan lampau yang fana yang membawa kepada kerosakan kekal dan menjejaskan prestasi talian penghantaran. Kajian ini memberi tumpuan kepada pembangunan model kilat serta model kabel. Perisian PSCAD adalah alat utama bagi kerja simulasi. Selain itu, kesan voltan lampau yang fana kabel dengan parameter yang berbeza telah dipatuhi oleh simulasi dan menganalisis model yang dicadangkan. Di samping itu, corak arus dan voltan dari berbeza topologi dan parameter kabel dianalisis apabila bentuk kilat gelombang semasa 8/20 telah dilakukan. Ia mendapati bahawa corak fasa arus seperti arus puncak, frekuensi yang tidak diingini dan isyarat lonjakan tempoh yang sama antara satu sama lain di bawah parameter yang berbeza kabel. Begitu juga, didapati bahawa corak voltan fasa seperti arus puncak, frekuensi yang tidak diingini dan isyarat lonjakan tempoh yang sama antara satu sama lain di bawah parameter yang berbeza kabel. Di samping itu, kita menyiasat mogok langsung kepada model talian penghantaran untuk kabel di bawah suhu panas (38 Celcius) terutama di lokasi tropika seperti di Malaysia. Ternyata bahawa arus puncak, frekuensi yang tidak diingini dan tempoh lonjakan adalah sama dengan nilai piawai yang disediakan oleh kilang tersebut. Pada masa depan, projek ini boleh memulakan untuk kajian asas perancangan perlindungan skim tersedia.

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t_{front}	-	Wave front time
t_{half}	-	Half amplitude time
I_o	-	Peak current
t	-	Lasting time of lightning stroke
α	-	Constant
β	-	Constant

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

In most cases of lightning strike, overhead power transmission cable is mostly exposed to the strike because of it location and placed. There are several problems cause by lightning on overhead transmission line and one of it is transient overvoltage. Lightning can cause permanent damage and affect cable performance at transmission line. In addition, different cable parameter will produce different effect of overvoltage on cable when it is strike by lightning. The cable strength withstand level is affected due to the direct lightning strike on the conductor and may cause the cable breakdown. Lightning strike will also contribute to the skin effect losses of the conductor and at the same time may cause a dielectric loss of cable the insulation. Therefore, is very important to study the effect of transient overvoltage to overhead transmission line to improve the transmission line performance and lightning protection.

1.2 Objective

Objectives of this project are to:

- Develop lightning and overhead transmission cable model using PSCAD software.
- Study the effect of lightning overvoltage to power transmission cable.
- Investigate the effect of different cable parameters and types to the performance of electrical cable when subjected to transient overvoltage due to lightning strike.

1.3 Scope

Scope of this project are:

- Development of lightning and electrical cable model using PSCAD software.
- Lightning model as a transient overvoltage source
- Design transmission line model for 132-kV for medium transmission line.

1.4 Thesis outcome

This report consist of 5 chapter. Chapter 1 discusses about the problem statement, objective, and scope of the project. Chapter 2 contains the literature review to be as a reference and it will be a guide line to complete this project. Chapter 3 is methodology. This chapter will explain every steps that required in order complete the project and it will be summarized in flow chart. Chapter 4 is the details, preliminary result and expected result that has been obtained and verified from the simulation and justification from previous research done by other researchers. Chapter 5 is a conclusion and will summarize the project outcome.

CHAPTER 2

LITARETURE REVIEW

2.1 Introduction

Literature review is done to understand the overall concept for single stroke lightning and conductor/cables model with several parameter using PSCAD software. A few different concepts and parameters is required to achieve the research objective. Furthermore, to accomplish the literature review, reference from several sources such as books, online searching, IEEE journals is required for analysis, collecting information, verification and validation process with the previous journal form others researcher must be done.

2.2 Lightning

2.2.1 Lightning Phenomenon

Lightning Strike is the discharge of electric charge accumulated in the clouds to the ground. Clouds accumulate typically certain electric discharge conducive conditions. Electric discharge occurs between the two for example clouds and ground, the negative charge, and in response the ground produces the counter charge: the positive charge, basically creating the shortest electrical path. In this situation and conditions include accumulated charge density, humidity in the air and it may enabling faster dielectric breakdown, ground elevation specifically to buildings, mountains, tall living things.[1].

2.2.2 Type of lightning discharge

A lightning discharge that commonly related to two object which is one the ground or not it is called a 'lightning strike'. The term 'stroke' or 'component stroke' apply only to component of cloud-to-ground discharge. For each stroke, there are two important parts which are downward leader and an upward return stroke. Upward return stroke usually involve a relatively low level 'continuing current' . Lightning strike that carrying a continues amount of current shows the transient process. The starting stroke for the lightning are started by 'stepped' leaders while the component stroke follow the previous form channel are started by 'dart' or 'dart-stepped' leader[2]. There are four different type of lightning discharge between cloud and ground have been discovered. The types are downward positive lightning, downward negative lightning, upward positive lightning and upward negative lightning.

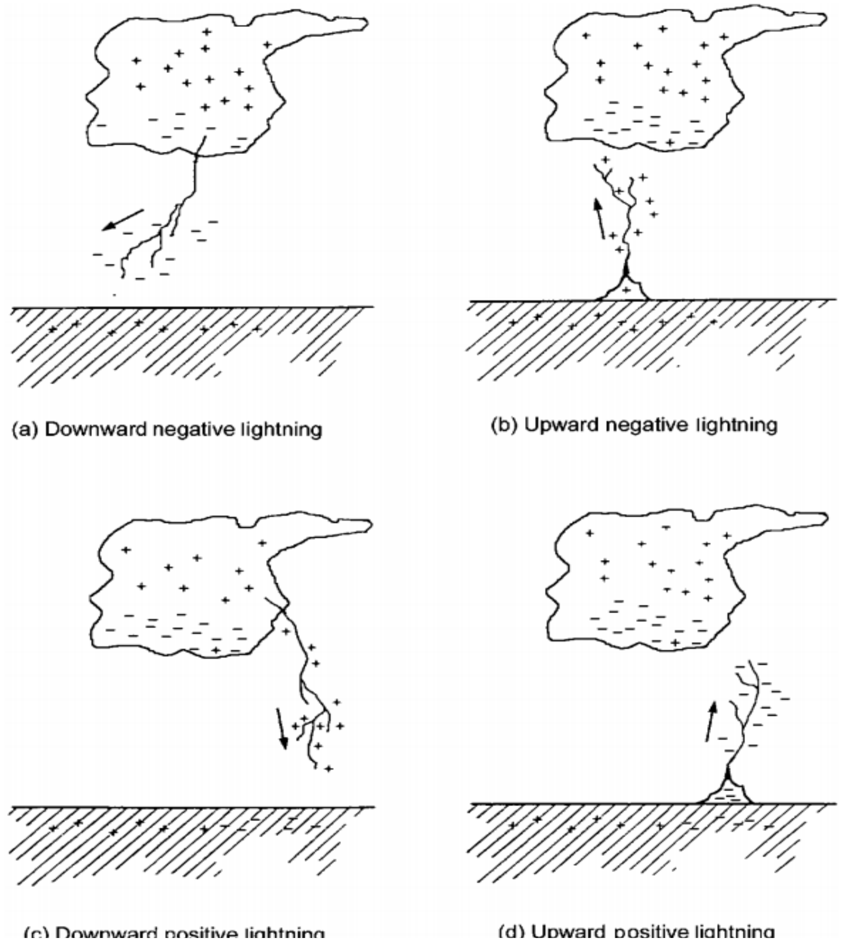

Figure 2.1 : Type of lightning[2]

Figure 2.1 shows four type of lightning which are a downward negative lightning, upward negative lightning, downward positive lightning, upward positive lightning. For all type of lightning, the discharge can be seen as effectively transferring cloud charge to the earth and usually called cloud-to-ground discharge. The common lightning flash that occurs is downward negative lightning with 90 percent or more in the global cloud-to-ground lightning, and another 10 percent or less then that might be cloud-to-ground discharge are from the downward positive lightning. Upward lightning discharge from upward negative lightning and positive lightning is still occurring, but it is not frequent and it is normally strike the tall object which is higher than 100m[2].

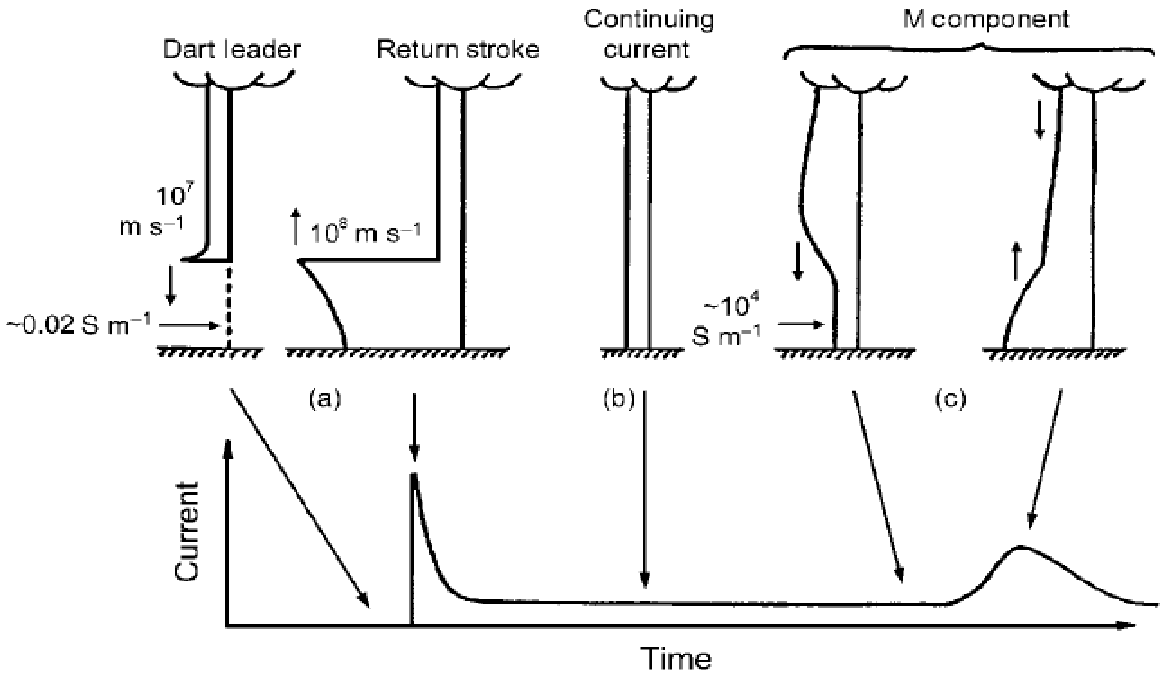

Figure 2.2 : Lightning current graph[2]

Figure 2.2 shows a lightning current graph illustrates the descending leader creates a conductive path between the cloud charge source and ground and produced negative charge along the path. The return stroke travels the other way with the same path which is from the ground moving towards the cloud charge sources and at the same time it neutralizes the negative leader charge. Picture (b) in figure 2.2 shows the continuous lightning current and it looks as a quasi-stationary arc between the cloud charge to the ground. Within that period, the normal duration raise up to hundred milliseconds and the arc current is tens to hundreds amperes. Picture (c) in figure 2.2 shows the M-component produce a continuous current and associated with luminosity. It shows that the M-component consists of two wave superposition propagating in opposite direction. M-component has a spatial front length of a kilometer, while the spatial waves length for the dart and return stroke wave are formed to be 10m to 100m. All channel conductivity in figure above is $10^4\ S\, m^{-1}$, except for the channel section between the dart-leader tip and the ground which is 0.02 S m^{-1}[2].

2.2.3 Lightning damaged

The total amount of damaged for every lightning strike to an object is depending on the characteristic of the lightning and also includes the properties of the object itself. When the lightning strike the a building, it produced a magnetic field because of the large amount of lightning current flows into the ground through the cable and wire started from the lightning rod at the top of the building. Because of the magnetic field generated from the lightning current, voltage is induced in the cable and electronics equipment, this will create a surge voltage. This cause damaged to the electrical and electronics equipment that is not protected. Furthermore, equipment that being placed at the ground, may generate induced voltage and buried electric lines by the surge current into the earth.

In other case, lightning strikes direct to the ground and raise the potential of the ground and surrounding area because the countering of charge or neutralization. The induced charge that generated from the lightning strike that charged the ground moves toward the lightning point and large ground current will flow due to the current surge.

Lightning may also affect to the electrical power lines. It happens when the lightning strike the ground near the power lines which will create an unbalanced electrostatic charge in overhead power lines which previously has a balanced in charge level. The damage to the power lines and the power equipment will occur due to the surge current because of the large amount of current flows.[3]

2.3 Modeling of Lightning

Single stroke lightning model can be represented by a double exponential model for single stroke by using double exponential will be selected for this project. Double exponential function can be determine using this equation (2.1) [4]:

$$i = I_o(\exp(-\alpha t) - \exp(-\beta t)) \tag{2.1}$$

where,

I_o : current amplitude of lightning stroke

α and β: constant

t : lasting time of lightning stroke

Referring from IEEE standard, the setting time for double exponential lightning model is 8μs X 20μs, it consist two times which is half time and front time. The half time value is 20μs and the front time value is 8μs

According to P.Liu et. al. from the journal 'Modeling Lightning Performance of Transmission System Using PSCAD' states that the setting time for front time and half time for double exponential model is 8μs X 20μs [4]. From the time setting, the α and β value can be obtained using equation 2.2 and 2.3 .

α = and β = is a constants.

$$t_h = \frac{\ln 2}{\alpha} \tag{2.2}$$

$$t_f = \frac{ln\,(\frac{\beta}{\alpha})}{\beta - \alpha} \tag{2.3}$$

I_o is the lightning stroke current amplitude.

From figure, when the simulation time is less than the threshold input of the comparator, then the comparator output a low level. Otherwise, a high level will be the output. Both of the low and high level will be used for the input control signal of the Two-Input Selector, Whose will be the signal connected to α, a delayed bi-exponential waveform, with the high level input, or the zero signal connected to β**,** with the low level input [4].

2.4 Conductor

An important issues that need to be highlighted and review in this project is the conductor. There are a few types of conductor and their parameter must be considered for this project[5]. Some of the characteristic are[6]:

i. conductor diameter
ii. weight per unit length
iii. conductivity of material
iv. cross-sectional area
v. modulus of elasticity
vi. rated breaking strength
vii. coefficient of thermal expansion
viii. cost of material
ix. maximum unload design tension
x. resistance to vibration and galloping
xi. surface shape or drag coefficient
xii. fatigue resistance

2.4.1 Type of Conductor

There are few types of conductor that has been use in transmission line. Each of the cable has their own characteristic and parameter to be use in particular transmission purpose. Some type of the cable is commonly use for transmission line[5]. The types of conductors are :

2.4.1.1 ACSR (Aluminum Conductor Steel-Reinforced)

This aluminum conductor steel reinforced is a type of conductor that very famous and it commonly used. This type of conductor has a form stranded conductor contain of one or more layer of hard drawn 1350 aluminum wire strain and a high-strength galvanized steel core. The reinforcing wire have to be at the centre core or it placed throughout the cable. Aluminum and galvanized coats are thin, it also applied in purpose to reduce corrosion of the steel wire. With numbers of stranding combination of aluminum and the steel that been placed, it might help the current carrying capacity for a long range and it stronger the mechanical strength characteristic for the cable to withstand the tension and the natural effect.

2.4.1.2 AAAC-6201(All Aluminum Alloy Conductor)

This all aluminum alloy conductor has a most perfect electrical characteristic with a conductivity of 52.5% IACS, it also has a great sag-tension characteristic with superior corrosion resistance compare to ASCR. In fact, it has the same current carrying capacity as ACSR conductor it has a better strength to weight ratio. The different between ACSR is it not consist a steel core. AAAC-6201 has a better electrical losses compared to ACSR conductor but the thermal coefficient of expansion is high. For the short circuit temperature of AAAC-6201, the ideal temperature to maintain the conductor must not be more than $340^{o}C$ to avoid dangerous conductor annealing.

2.4.1.3 AAC(All Aluminum Conductor)

This all aluminum conductor is made from not one, but several strand of 1350 alloy aluminum with the drawn from H19 temper. but aluminum 1350 has a slack whish is it has a minimum conductivity which is 61.2% IACS. and because of that characteristic that low strength to weight ratio, AAC limited use in transmission lines and rural distribution because of the life spans utilized. It normally use for the area that required a short with high conductivity because the advantage of great corrosion resistance.

2.4.1.4 ACAR(Aluminum Conductor-Aluminum Alloy Reinforced)

This conductor is a combination of 6201 aluminum and 1350 aluminum strand to provide a transmission conductor with a great balance of electrical and mechanical properties. This type of conductor make up from one or more layers of 1350-H19 aluminum strands helically wrapped with one or more 6201-T81 aluminum alloy wire. The conductor core consist one or more aluminum 6201 strands. The main advantage of this ACAR is this conductor is all strands may change between aluminum 6201 and EC, by that characteristic it allows the design of conductor with maximum balance between electrical and mechanical characteristic.

2.4.1.5 ACSR/AW(Aluminum Conductor, Aluminum-Clad Steel Reinforced)

This conductor has similar characteristic with the basic ACSR except the core wire consist a high strength aluminum-clad steel instead of galvanized steel. The aluminum-clad has a minimum thickness of 20 percent it overall normal wire radius. The conductor that consist a clad provides a more protection against corrosion than any others types of steel core wire, it suitable to be install in areas where the area has a high corrosion condition. Its strength and stress at 1 percent extension are less than that for Class A galvanized coated steel core wire. However, it has slightly lower in term of resistivity compared to galvanized steel core that may have a lower losses