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STUDY ON DIFFERENT TYPES OF SURGE ARRESTER FOR 132kV OVERHEAD TRANSMISSION LINE IN SHIELDING FAILURE ANALYSIS

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This report is submitted in partial fulfilment of requirement for the degree of Bachelor in Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

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I declare that this report entitle “Study on Different Types of Surge Arrester for 132kV Overhead Transmission Line in Shielding Failure Analysis” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

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Date	:	....

To my beloved family

ACKNOWLEDGEMENT

In the name of Allah, the most Gracious and most Merciful

Praise be to Allah, Lord of universe for His bounties bestowed upon us, Peace be to the Prophet Muhammad s.a.w the sole human inspiration worthy of imitation. Alhamdulillah all praise be to Allah S.W.T the Almighty for giving me the strength, guiding me in my final year project undertaken.

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ABSTRACT

Transients overvoltage caused by lightning is considered a major source of disturbances in high voltage transmission line systems. Lightning that consume an extreme high density of current, high capacity of voltage and transient electric discharge occurred on the transmission lines that travel towards the terminal or substation may lead to severe damages, particularly to the expensive electrical equipment. When the transient overvoltage due to lightning occurred at the phase conductor of the transmission line, the phenomena called shielding failure. Study on the shielding failure is crucial in order to evaluate the performance of transmission line as the lightning strokes terminate on the phase conductor of the transmission line. Metal Oxide Surge Arrester is used to limit the voltage across the equipment terminals in the presences of a surge on the system. In this project, the transmission line, lightning strike and surge arrester are modelled using PSCAD software. Three different types of surge arrester are modelled which are the IEEE model, Pincetti model and Fernandez Diaz model. It is found that the IEEE model is the best surge arrester model when injected more than 10KA current impulses of 8/20us since it have almost similar value of the residual voltage with the manufacture data tested result. The IEEE model was selected to apply to the 132kV transmission line in order to evaluate shielding failure phenomena. The result obtained show that the IEEE model succeeds to provide the optimum protection to the 132kV transmission line during lightning strike.

ABSTRAK

Transient voltan tinggi yang disebabkan oleh kilat dianggap sebagai sumber utama berlakunya gangguan di dalam sistem talian penghantaran voltan tinggi. Kilat yang terdiri arus berketumpatan tinggi dan voltan berkapasiti tinggi berlaku pada arah terminal atau pencawang boleh membawa kepada kerosakan yang teruk, terutamanya untuk peralatan elektrik. Apabila lebihan voltan disebabkan oleh kilat berlaku pada konduktor fasa talian penghantaran, fenomena ini dipanggil *shielding failure. K*ajian terhadap fenomena *shielding failure* adalah penting untuk menilai prestasi talian penghantaran di mana strok kilat akan tamat pada konduktor fasa di talian penghantaran. Fungsi penangkap kilat dengan mengehadkan voltan untuk merentasi terminal pada peralatan apabila berlakunya surge pada sistem. Projek ini menggunakan perisian PSCAD untuk memodelkan talian penghantaran, strok kilat, penangkap *surge*. Tiga jenis penangkap *surge* yg dimodelkan adalah model IEEE , model Pincetti dan model Fernandez Diaz. Kajian mendapati bahawa model IEEE adalah yang model penangkap *surge* terbaik apabila disuntik dengan 10kA arus impuls 8/20us. Ini kerana model IEEE mempunyai nilai voltan *residual* yang hampir sama dengan data pembuatan. Model IEEE telah dipilih untuk melindungi talian penghantaran 132kV semasa fenomena *shielding failure*. Keputusan yang diperolehi menunjukkan bahawa model IEEE berjaya untuk memberikan perlindungan yang optimum kepada talian penghantaran 132kV semasa strok kilat terhasil.

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LIST OF ABBREVIATION

TOV	-	Temporary Overvoltage
CFO	-	Critical Flashover Voltage
MSL	-	Multiple Stroke Lightning
SSL	-	Single Stroke Lightning
SA	-	Surge Arrester
MCOV	-	Maximum Continous Operating Voltage
IEEE	-	Institute of Electrical and Electronics Engineers

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Natural phenomena like lightning occurs almost everyday in the world. This could cause the travelling waves between the devices connected to the transmission line. Lightning causes the temporary increment of voltage in the transmission line system and this could harm the insulator of the line and devices connected to it. In order to maintain failure rate at the lowest level, it is necessary to provide the high quality and avoiding damages to the electrical equipment. Plenty of studies regarding the performance of the transmission line system has been conducted [1].

Protecting the transmission line against the lightning stroke can be achieved by designing the suitable surge arrester to maintain good performance of the transmission line system. It is important to explore the importance of this study since the lightning overvoltage is one of major concern for insulation design of protection in power system equipment. The phenomena happen whenever lightning strike at the top of tower, lightning current flows down to the bottom of the tower and this cause the voltage to increase and eventually result in Backflashover [2].This also happen when the lightning stroke does not terminate at the tower or shield wire but on the phase itself, this phenomenon called Shielding Failure [3]. Both of the cases will damage the equipment connected to the transmission line itself. Since the high frequency range associated with the lightning, the suitable of model are necessary to analyse and the simulation of studies require detailed in modelling of network component, which include the towers and also lightning component itself.

The purpose of this project is to investigate the shielding failure phenomena on transmission line and determine which the best option for surge arrester installation. This simulation tools used in this project are PSCAD/EMTDC. The simulation result will be obtained by injecting different magnitude of lightning current at the tower of transmission line. This also includes evaluating the implementation of several types of surge arrester which comprise of surge arresters from IEEE Frequency – dependant model, Pincetti Model and Fernandaz-Diaz model on the 132kV overhead transmission line.

1.2 Motivation

Lightning has been one of the important problems for the insulation designs in power system and it still the main cause of outages of transmission and distribution lines. A complete awareness of the parameters of the lightning strike is essential for the prediction of the severity of the transient voltages generated across power equipment either by a direct strike to the power line or by indirect stroke. Since the lightning travelling waves cause the temporary increase in voltage to the transmission line system, it is necessary to analyse such increase in voltage in order to design the surge arrester that necessity for the application and the performance of the transmission line system

1.3 Problem Statement

Lightning interruption has become a major problem for electrical power system. The lightning caused the interruption by shielding failure and backflashes. The installation of surge arrester possible to reduce direct stroke to the phase conductor, but this does not necessarily mean that the line will have perfect lightning performance. The studies will show the application of surge arrester consume a better performance than shield wire and thus will improve the transmission line performance due to lightning [2].

1.4 Objectives

The objectives of this project are stated as follows:-

i. To model 132kV Overhead Transmission Line by using PSCAD for shielding failure analysis.
ii. To model several types of surge arrester, the IEEE frequency-dependant model, Pincetti model and Fernandez-Diaz model for 132kV Overhead Transmission Line.
iii. To analyse and select the most accurate model of surge arresters based on the comparison between the simulation result and the datasheet.

1.5 Scope of Work

Based on the project milestone, this project focused on:-

- The model of the transmission line system is conducted in simulation tools called, PSCAD.
- The modelling of 132kV Overhead Transmission Line which include modelling of transmission tower and stroke of lightning current
- Modelled on three different types of surge arrester model which are IEEE model, Pincetti Giannettoni model and Fernandez-Diaz model.
- Evaluate the transmission line performance due to shielding failure.
- Concern about the effectiveness of surge arrester installation on transmission line system

1.6 Thesis Outline

This report comprises into five chapters. These five chapters include the literature review, introduction, methodology, simulation result, analysis and discussion also concluded with conclusion and recommendation part.

Chapter 1 briefly explain in the introduction of the project and these include the project background, motivation, problem statement, scope of work and thesis outline. Chapter 2 explicate the literature review on this project, for example the theories on lightning phenomena, fundamental on surge arrester and transmission line parameter.

Chapter 3 interpreted on the process and methodology of the project in order to achieve the objective of the project. This chapter includes the method of developing the surge arrester, lightning stroke using PSCAD simulation. This section summarises in flowchart.

Chapter 4 consist of the results and discussions. This includes the lightning stroke simulation and surge arrester model injected with three different of lightning strike magnitude. The result then presented in table to compare with the manufacturer datasheet. The discussion on comparison was made to select the best model to implement in 132kV Overhead Transmission Line.

Lastly, Chapter 5 concludes on the works and studies that have presented in previous four chapters. This chapter also includes some recommendation for future development.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Protecting the overhead transmission line against lightning strikes is one of the crucial tasks to secure the electrical power system since the lightning phenomena is main causes of faults in overhead transmission lines. Performance of the power system are mainly depends on the performance of transmission lines which continues operation of transmission lines without sudden outages is severely important not only for the system stability but also the efficiency of power delivery. The lightning performance of overhead lines can be measured by the flashover rate, usually presented as number of flashover by 100km and year [1].

In Malaysia, Tenaga Nasional Berhad has implemented the installation of line surge arrester for the transmission line lightning performance improvement since 1995[4]. Line arresters are usually installed on all phase conductors of one circuit of the double circuit. In this project, the line arresters are installed on the tower of the considered 132kV line. Several lines of surge arrester installation parameters are studied to improve the performance of the transmission lines [4], [5].

2.2 Lightning

Lightning occur almost about every day in the world. Lightning also more prevalent in tropical region, for example South East Asia. According to United State National Lightning Safety Institution reported that Malaysia was ranked at the top of lightning activities in the world. It is stated in the report that the average-thunder day level for Malaysia's capital Kuala Lumpur within 180 - 260 days per annum [6]. This interruption of high number of power outages due to lightning owing to the high isokeraunic level that to be found in Malaysia. The isokeraunic level is estimated approximately around 200 thunderstorm days a year and the lightning ground flash density is about 15-20 strike per km^2 per year [5].

Lightning consume an extreme high density of current, high capacity of voltage and transient electric discharge. The transient discharges of static electricity are needed to re-establish on electrostatic equilibrium within the storm environments [7]. It is need to be concerned that Malaysia located near the equator and therefore it is categorized as prone to experienced high lightning and thunderstorm activities. Malaysian Meteorological Services has indicated that thunders possibly can occur almost 200 days a year in Malaysia. Thunderstorms caused merely between 50% and 60 % of the transient tripping in the distribution networks and transmission for Tenaga Nasional Berhad (TNB). The main reason could be short of precise and consistent lightning data in Malaysia to enable trough studies on lightning and its mitigation [4].

Lightning generated when the charges separates within the cloud due to the electric breakdown of the air from high electric fields. The facts shows that when the thunder clouds are charged, the temperature of the cloud is usually below -20°C where the negative charge is located at the lower part of it. The originally positive charged region at the base of the cloud usually stated at 0°C of temperature [8].

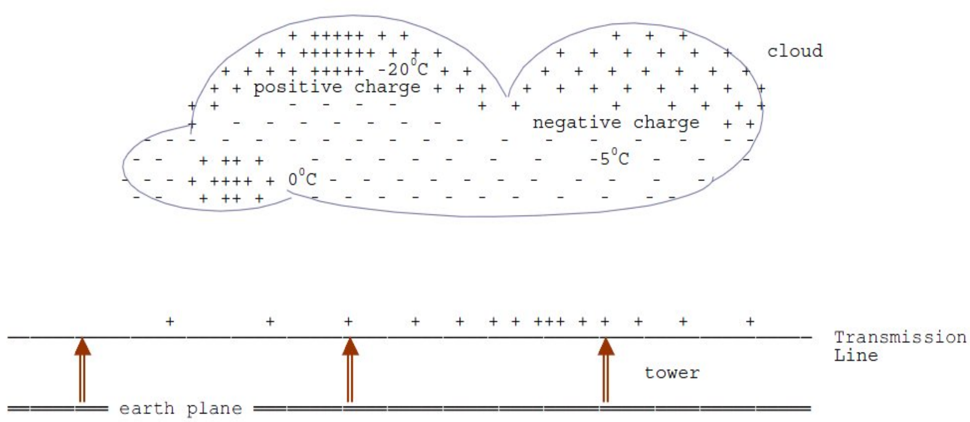

Figure 2.1 Induced charges on transmission line

When the lightning discharge occurs at the lower portion of the cloud, the air starts to break down in steps and it is called stepper leader. The sufficient field intensity on the earth for upward steamer to form and link to the remaining gap occur is when the stepper leader is approached to 15m to 50m down to earth. It is proportional since the charged develops follow as stepper leader progresses get closer to the ground. If the more positive charge collects on the earth, the short upward leader extends to meet the downward negative stepper leader

Thunder happens when high intense of pressure wave exists due to interaction between the downward leaders and upward leader. Based on previous research, the impulse current due to return stroke can flow from minimum as 20kA and may exceed to 200kA. It is also estimated the propagation of return stroke happens around 20% of speed of light by releasing charge and develop a current of tens of thousands of ampere peaking in a few microsecond [5]. If the second leader propagates continuously stroke again to the earth, this subsequent leader stroke will propagates to existed energised channel called dart leader.

The heavy current during the stroke that is only being considered when comes to urge calculation. During this time, the waveform are represented by a double exponential of the form in Equation 2.1[9].

$$i = I(e^{-\alpha t} - e^{-\beta t}) \qquad (2.1)$$

With the wavefront times of 0.5-10us, and the wavetail times of 20-200 us. (Average lighning current waveform would have a wavefront of the other of 8us and a wavetail of the order of 20 us) [10].

2.3 Lightning Effect on Transmission Line

2.3.1 Shielding Failure Flashover

The charged clouds are always discharges directly to the transmission line. If the lines get struck at a long distance from a station or substation, the surge will flow along the line in directions, shattering insulators and might be wrecking poles until the total energy of the surge is spent. When the lightning strike on phase conductor, the current magnitude and the natural frequency of the stroke causes the voltage surge to be propagated equally in both directions from the point of the strike occurred. The term of Shielding Failure use to describe when the lightning stroke to the phase conductor. Most of the unshielded line, all strokes to the line are shielding failures. But not all shielding failure results in insulator string flashover. Flashover across the insulator string occurs when the value of overvoltage are higher than the critical flashover voltage (CFO). The lightning stroke current for particular conductor can be calculated by using Equation 2.2 [8].

$$I_c = \frac{2 * (CFO)}{Z_{surge}} \tag{2.2}$$

$$Z_{surge} = 60 ? \overline{\ln\frac{2h}{r}\ln\frac{2h}{R_c}} \tag{2.3}$$

Where:

CFO: lightning impulse negative polarity critical flashover voltage

Z: conductor surge impedance;

h: the average of conductor height;

r: the conductor radius;

Rc: the corona radius of the conductor at a gradient of 1500kV/m(m) [8];