UNIVERSITI PUTRA MALAYSIA

SIMULATION AND ANALYSIS OF LIGHTNING BACKFLASHOVER FOR THE 132 KV KUALA KRAI–GUA MUSANG TRANSMISSION LINE USING PSCAD

JUNAINAH BINTI SARDI

SIMULATION AND ANALYSIS OF LIGHTNING BACKFLASHOVER FOR THE 132 KV KUALA KRAI–GUA MUSANG TRANSMISSION LINE USING PSCAD

By

JUNAINAH BINTI SARDI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

June 2009

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfillment of the requirement for the degree of
Master of Science

SIMULATION AND ANALYSIS OF LIGHTNING BACKFLASHOVER FOR THE 132 KV KUALA KRAI–GUA MUSANG TRANSMISSION LINE USING PSCAD

By

JUNAINAH BINTI SARDI

June 2009

Chairman : Mohd. Zainal Abidin Ab Kadir, PhD

Faculty : Engineering

Lightning has been a major concern to the power system researchers as it may cause damage to the connected electrical equipment especially to the transmission line. One of the event that will cause lightning overvoltage and most likely to occur is backflashover. For that reason, one study has been carried out where values of backflashover rate (BFR) on a transmission line and probability of transformer damage at substation are observed due to backflashover. A sample of worst performance of transmission line in Peninsular Malaysia i.e. 132 kV Kuala Krai-Gua Musang transmission line data was obtained from Tenaga Nasional Berhad (TNB) for the purpose of backflashover analysis. Power System Computer Aided Design, PSCAD software was used to model integral part of transmission line components such as insulator gap, tower and footing resistance followed by doing the backflashover simulation and analysis. Besides that, the effects of line parameters such as ground resistance, soil resistivity, tower surge impedance, tower

height and number of shield wires in lightning performance study were also investigated. Findings from backflashover analysis of Kuala Krai-Gua Musang transmission line using PSCAD imply that the values of backflashover rate (BFR) and probability of transformer damage are influenced by the values of line parameters. Right selection of line parameters may reduce BFR and probability of transformer damage, thus improve the transmission line performance. Findings of this research can be useful guideline towards high voltage transmission line design and planning in Malaysia.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Sarjana Sains

SIMULASI DAN ANALISIS PEMERCIKAN API KILAT UNTUK TALIAN PENGHANTARAN 132 KV KUALA KRAI-GUA MUSANG MENGGUNAKAN PSCAD

By

JUNAINAH BINTI SARDI

Jun 2009

Pengerusi : Mohd. Zainal Abidin Ab Kadir, PhD

Fakulti : Kejuruteraan

Kilat telah menarik perhatian pengkaji sistem kuasa kerana kilat boleh menyebabkan kerosakan kepada perkakas-perkakas elektrik yang berkenaan terutama talian penghantaran. Salah satu fenomena yang sering berlaku dan boleh menyebabkan kerosakan pada talian penghantaran adalah pemercikan api. Oleh itu, satu kajian telah dijalankan di mana tahap pemercikan api (BFR) di talian penghantaran dan kebarangkalian berlakunya kerosakan pengubah di pencawang utama yang disebabkan oleh pemercikan api diukur. Satu sampel data talian penghantaran yang mempunyai prestasi terburuk iaitu talian penghantaran 132 kV Kuala Krai–Gua Musang telah diambil dari Tenaga Nasional Berhad bertujuan untuk menganalisa fenomena pemercikan api. Perisian Power System Computer Aided Design, PSCAD digunakan untuk membentuk model-model yang sesuai bagi komponen-komponen dalam talian penghantaran seperti celah penebat, menara dan rintangan kaki menara diikuti dengan

melaksanakan simulasi dan analisis pemercikan api. Selain itu, kesan parameter talian seperti rintangan kaki, kerintangan tanah, galangan pusuan menara, tinggi menara dan bilangan wayar pelindung terhadap prestasi kilat di talian penghantaran dikaji. Hasil analisis pemercikan api terhadap talian penghantaran Kuala Krai-Gua Musang menggunakan PSCAD menunjukkan bahawa nilai tahap pemercikan api (BFR) dan kebarangkalian berlakunya kerosakan pengubah adalah dipengaruhi oleh nilai parameter talian Pemilihan parameter talian yang betul boleh mengurangkan BFR dan kebarangkalian berlakunya kerosakan pengubah seterusnya memperbaiki prestasi talian penghantaran. Hasil penyelidikan ini boleh dijadikan panduan yang berguna dalam mereka dan merancang pembinaan talian penghantaran voltan tinggi di Malaysia.

ACKNOWLEDGEMENTS

I would like to express my sincere thanks and appreciations to:

My supervisor, Dr. Mohd. Zainal Abidin Ab Kadir, for his understanding and encouragement, and for his invaluable guidance throughout this work. His technical knowledge and sympathetic manner have helped me to make this project possible.

A special thanks to my co-supervisors, Dr. Hashim Hizam and Dr. Wan Fatinhamamah Wan Ahmad for their comments and advices in this project.

Universiti Teknikal Malaysia Melaka for financial assistance.

My husband, Khirman Md Kamal, my daughter, Az Zahra and my son, Aqil Azhad for sharing the difficulties and for being patient and understanding throughout the course of this study. Last but not least, my parents and my mother in law for their support and love.

APPROVAL

I certify that an examination committee met on June/09/2009 to conduct the final examination of Junainah binti Sardi on his Master of Science thesis entitled "Simulation and Analysis of Lightning Backflashover for 132 kV Kuala Krai-Gua Musang Transmission Line using PSCAD" in accordance with University Putra Malaysia (higher degree) act 1980 and University Pertanian Malaysia (higher degree) regulations 1981. The committee recommends that the candidate be awarded the relevant degree.

Members of the examination committee are as follows:

Norman Mariun, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Ishak Aris, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Norhisam Misron, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Ismail Musirin
Associate Professor
Faculty of Electrical Engineering
Universiti Teknologi MARA
(External Examiner)

_____

BUJANG KIM HUAT, Ph.D
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of University Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Mohd. Zainal Abidin Ab Kadir, PhD
Lecturer
Faculty of Engineering
University Putra Malaysia
(Chairman)

Hashim Hizam, PhD
Head of Department Electrical and Electronic Engineering
Faculty of Engineering
University Putra Malaysia
(Member)

Wan Fatinhamamah Wan Ahmad, PhD
Lecturer
Faculty of Engineering
University Putra Malaysia
(Member)

HASANAH MOHD. GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 11 September 2009

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently submitted for any other degree at UPM or at any other institutions.

_____

JUNAINAH BINTI SARDI

Date: 16 September 2009

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BFR	Backflashover rate
DE	Disruptive Effect
CIGRE	International Council on Large Electric Systems
IEEE	Institute of Electrical and Electronic Engineers
IEC	International Electrotechnical Commission
VT	Volt-time
LPM	Leader Progression Model
OGHW	Overhead Ground Wire
CFO	Critical Flashover
PSCAD	Power System Computer Aided Diagram
CSMF	Continuous System Model Functions
SW	Simple Switch Model
EMTDC	Electromagnetic Transient Direct Current
BIL	Basic Lightning Insulation Level

CHAPTER 1

INTRODUCTION

1.1 Research Overview

Insulation coordination is a selection of the insulation strength consistent with expected overvoltages to obtain an acceptable risk of failure. One of the events that may cause outage and most likely to occur is backflashover. Backflashover may occur when lightning stroke terminates on overhead ground wire or transmission tower. A stroke that terminates, forces currents to flow down the tower and out on the ground wires. Thus, voltages are built up across the line insulation. If these voltages equal or exceed the line critical flashover (CFO), flashover will occur [1]. Study on backflashover is very important in evaluating lightning performance as majority of lightning strokes terminate on shield wire than phase conductor. This is also due to most overhead transmission line are equipped with overhead ground wire [2].

Backflashover analysis was done to a 132 kV overhead transmission line connecting 132 kV Kuala Krai substation and 132 kV Gua Musang substation through rural area of Kelantan state. This line was chosen as it demonstrates the worst line performance in Peninsular Malaysia with high ground flashes density [2]. Lightning Detection System Lab (LDS), TNB Research records an average ground strokes densities of the area in the range of 6 to 20 strokes/km^2/year and the mean multiplicity of lightning strokes

observed is three [2]. Note that, these observations are made between Jan 2004 to July 2007.

PSCAD-EMTDC was used in this research for the purpose of backflashover simulation and analysis. This software is chosen because of its freedom to model compared to any end user software. It also provides the flexibility of building custom models, either by assembling those graphically using existing models, or by utilizing an intuitively designed Design Editor [3].

1.2 Problem Statement

Typically on many overhead transmission lines, lightning is the main cause of unscheduled interruptions especially for line of 275kV and below. For the last five years of failure mode analysis on TNB's overhead line tripping data, it was found that the common cause of tripping is lightning strikes [4].

Table 1.1 shows tripping records from TNB Research for Kuala Krai–Gua Musang 132 kV double circuit line due to lightning (Jan 2004 – July 2007) [2]. For the period of three and half years, the line has experienced 13 trippings which is equivalent to a flashover rate of 4.19/100 km/year with 12 of these trippings are double circuit trippings.

Table 1.1 Tripping Records for Kuala Krai–Gua Musang 132 kV Double Circuit Line Due to Lightning (Jan 2004 – July 2007) [2]

No.	Date	Time	Line
1.	12/06/2004	18:55	1&2
2.	01/05/2005	18:05	2
3.	04/06/2005	05:15	1
4.	28/09/2005	21:37	1&2
5.	03/10/2005	17:14	1&2
6.	07/10/2005	18:04	1&2
7.	07/10/2005	18:05	1&2
8.	09/10/2005	19:11	1&2
9.	29/10/2005	23:59	1&2
10.	14/11/2005	18:44	1&2
11.	15/11/2005	16:25	1&2
12.	02/09/2006	17:05	1&2
13.	02/06/2007	15:53	1&2

Lightning overvoltage at transmission line is caused by two events, backflashover and shielding failure. For that reason lightning performance of transmission line is measured by the sum of backflashover rate (BFR) and shielding failure flashover rate (SFFOR) with most of lightning overvoltage were due to the backflashover [5]. This is also due to many transmission lines which are equipped with shield wires to intercept lightning from strikes the phase conductors. As the impact, it can cause damage to electrical equipments at substation especially transformer.

Method used to estimate lightning performance of transmission line especially backflashover rate must cope with many uncertainties and parameters such as lightning current, ground flash density, tower structure, tower footing impedance, coordination

gap type and corona. Results from the estimation can be a guideline for transmission line designer to design the reliable transmission line or/and improve the design of lightning protection at the line. Low accuracy of estimated lightning performance of the line may reduce the transmission line efficiency and quality.

1.3 Objectives

Objectives of this research are to:

1) Model typical Malaysia's 132 kV transmission line using PSCAD software.
2) Estimate the backflashover current and backflashover rate (BFR).
3) Estimate probability of transformer damage at substation.
4) Investigate the effect of line parameters to the lightning performance of transmission line.

1.4 Scope of Work

Scope and limitation of the research work are:

1) This research only includes the first stroke of the lightning. As far as the severity of voltage across the insulators is concerned, subsequent strokes in the same flash are no worse than the first stroke. Subsequent strokes create more insulator voltage but at shorter times where the insulator strength is higher [6].
2) Non linear influence of corona is not included in the method of estimating backflasover rate. This exception follows CIGRE which totally neglects all effects of corona [7].

3) This research only focus on 132 kV overhead transmission line but the model of transmission line components can be used for any high voltage overhead transmission line simulation and analysis. Note that only parameters of the transmission line and substation are different as these parameters are depending on the level of voltage.

1.5 Significance of the Research

During the data collection and analysis, it was discovered that the major problem faced by TNB was due to the lightning strike [4]. Figure 1.1 shows the world map of keraunic level for which Malaysia lies near the equator where it is characterized by the high lightning and thunderstorm activities. Data from the Malaysian Meteorological Services Department indicates that Malaysia has an isokeraunic level of more than 200 thunder-days per year. While, the average, median and maximum peak discharge currents of the first return stroke in Malaysia are 37kA, 32.4kA and 352kA, respectively [8].

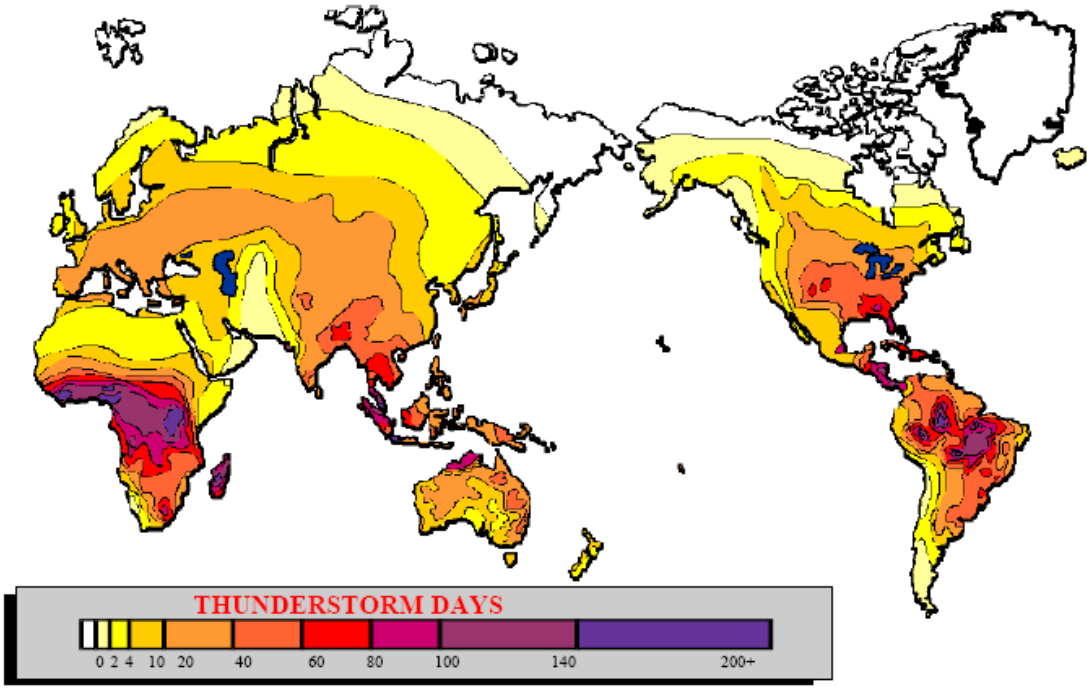

Figure 1.1. World Map of Keraunic Level [8]

Hence, it is important to understand the phenomena and characteristic of a lightning as lightning cannot be prevented and it can only be intercepted or diverted to a path that will, if well designed and constructed, reduce the damage on the transmission line. Each year, lightning strikes cause millions of dollars in damage for utilities and their customers, including transmission line failure.

The methods used for estimating the lightning performance of transmission lines show several approaches to a real life engineering problem that is ill-defined. Precise constants are rarely known and are often not really constant, input data is difficult to be described mathematically except in idealized ways, and outputs may be depictabled only by probabilities or average values. By its nature, lightning is difficult to study and model