UNIVERSITI PUTRA MALAYSIA

BACKFLASHOVER RATE OF UNDERBUILT 33 KV DISTRIBUTION OVERHEAD LINE UNDER LIGHTNING CONDITION

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By

ZAWATI BINTI MOHD NAWI

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

November 2012

DEDICATION

This thesis is dedicated to my parent,

Siti Meriah binti Mohamed and Mohd Nawi bin Awang,

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

BACKFLASHOVER RATE OF UNDERBUILT 33 KV DISTRIBUTION OVERHEAD LINE UNDER LIGHTNING CONDITION

By

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November 2012

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 and distribution line. One of the most event is backflashover that will cause lightning overvoltage. For that reason, one study has been carried out where values of backflashover rate (BFR) on underbuilt transmission structure with characteristic of distribution line and provide the optimum placement of line arresters on phases at the tower of a distribution line to protect the line from overvoltage events. The purpose of this project is to model a 33 kV overhead distribution line for insulation coordination studies in which the investigation only focused on an underbuilt on transmission structure where the tower is also used for distribution system where the system voltage, characteristic and insulation strength are based on distribution system. A sample of worst performance underbuilt transmission structure in Peninsular Malaysia i.e. 33 kV Pantai Remis to Trong distribution line data was obtained from Tenaga Nasional Berhad (TNB).

Power System Computer Aided Design, PSCAD software was used to model underbuilt distribution line components such as footing resistances, tower, insulator gap, arrester followed by doing the backflashover simulation and analysis. Besides that, the effects of line parameters such as ground resistance, soil resistivity, tower height, number of shield wire and placement line arrester on phases at the tower in lightning performance study were also investigated. Findings from backflashover analysis of Pantai Remis – Trong line using PSCAD imply that the values of backflashover rate (BFR) and also the best place to install line arrester are influenced by the values of line parameters. Right selection of line parameters may reduce BFR and the best place for installation line arrester, thus improve the distribution line performance. Findings of this research can be useful guideline towards high voltage transmission and distribution overhead line design and planning in Malaysia.

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

KADAR PEMERCIKAN UNTUK TALIAN PENGAGIHAN DALAM PEMBINAAN 33 KV DI BAWAH KEADAAN API KILAT

Oleh

ZAWATI BINTI MOHD NAWI

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Kilat telah menjadi kebimbangan utama kepada para penyelidik sistem kuasa kerana ia boleh merosakkan peralatan elektrik yang disambung terutamanya talian penghantaran dan pengagihan. Salah satu peristiwa yang paling banyak berlaku ialah lampau kilat di mana akan menyebabkan berlakunya kerosakan. Atas sebab itu, satu kajian telah dijalankan di mana nilai kadar pemercikan (BFR) pada menara struktur penghantaran yang masih dalam pembinaan dengan ciri-ciri talian pengagihan dan menyediakan aturan yang terbaik bagi kedudukan penyekat talian pada fasa sesuatu menara pada talian atas untuk melindungi garisan daripada berlakunya voltan pusuan. Tujuan projek ini adalah untuk permodelan 33 kV talian pengagihan yang dalam pembinaan bagi kajian penyelarasan penebat yang mana siasatan hanya tertumpu kepada binaan ke atas struktur penghantaran yang masih dalam pembinaan di mana menara yang digunakan itu adalah untuk sistem pengagihan dan kekuatan,

ciri-ciri dan penebat voltan sistem adalah berdasarkan sistem pengagihan. Satu sampel struktur prestasi terburuk dalam binaan penghantaran di Semenanjung Malaysia iaitu 33 kV talian Pantai Remis - Trong data telah diperolehi daripada Tenaga Nasional Berhad (TNB).

Sistem Komputer Kuasa Reka Bentuk Berbantukan, perisian PSCAD telah digunakan untuk permodelan komponen talian pengagihan itu sebagai landasan ketahanan, menara, celah penebat, penyekat diikuti dengan melakukan simulasi pemercikan api dan analisis. Selain itu, kesan parameter baris seperti rintangan tanah, tanah berkerintangan, ketinggian menara, nombor wayar perisai dan penempatan penyekat sejajar dalam kajian prestasi kilat juga disiasat. Hasil daripada analisis pemercikan api Pantai Remis - Trong menggunakan PSCAD membayangkan bahawa nilai kadar BFR dan juga tempat terbaik untuk memasang talian penyekat dipengaruhi oleh nilai-nilai parameter. Pemilihan parameter baris yang betul boleh mengurangkan BFR dan kedudukan terbaik untuk penyekat talian pemasangan, seterusnya meningkatkan prestasi talian pengagihan. Hasil penyelidikan ini boleh menjadi garis panduan yang berguna ke arah pengagihan voltan tinggi dan rata garis rekabentuk dan perancangan di Malaysia.

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I certify that a Thesis Examination Committee has met on (insert the date of viva voce) to conduct the final examination of **Zawati bin Mohd Nawi** on her **degree** thesis entitled **"Backflashover Rate of Underbuilt 33 kV Distribution Overhead Line Under Lightning Condition"** in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The committee recommends that the student be awarded the Master of Science.
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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 Universiti Putra Malaysia or at any other institution.

ZAWATI BINTI MOHD NAWI

Date: 27 November 2012

TABLE OF CONTENTS

		Page
DEDICATION		i
ABSTRACT		ii
ABSTRAK		iv
ACKNOWLEDGEMENT		vi
APPROVAL		vii
DECLARATION		ix
LIST OF TABLES		xiii
LIST OF FIGURES		xiv
LIST OF ABBREVIATIONS		xvii

CHAPTER

1	**INTRODUCTION**	1
	1.1 Research Background	1
	1.2 Problem Statement	3
	1.3 Research Aim and Objectives	5
	1.4 Scope of Work	6
	1.5 The Significance of the Research	7
	1.6 Thesis Layout	10
2	**LITERATURE REVIEW**	12
	2.1 Insulation Coordination for a Power System	12
	2.2 Lightning Incidence	12
	2.2.1 Keraunic Level	14
	2.2.2 Ground Flash Density (GFD)	16
	2.3 Overvoltage	16
	2.3.1 Lightning Overvoltage	18
	2.3.2 Switching Overvoltage	19
	2.3.3 Temporary Overvoltage	20
	2.4 Lightning Performance on an Overhead Distribution Line	20
	2.4.1 Contamination on an Overhead Line	21

2.4.1.1 Types of Contaminant 21
2.4.1.2 Test Method 24
2.4.1.3 Types of Insulator 25
2.5 Insulation Flashover Mechanisms 29
2.5.1 Induced Voltage 29
2.5.2 Shielding Failure (SF) 30
2.5.3 Backflashover (BFO) 31
2.6 Lightning Performance Parameters 34
2.6.1 Lightning Stroke 34
2.6.2 Overhead Line Tower 35
2.6.3 Tower Footing Resistance Model 41
2.6.4 Leader Progression Model 42
2.6.5 Line Arrester 44
2.7 Lightning in Malaysia 46
2.8 Summary 47

3 RESEARCH METHODOLOGY 48
3.1 Introduction 48
3.2 PSCAD Software 52
3.3 Development of Models of the Pantai Remis -Trong Line using PSCAD Software 54
3.3.1 Modelling of a Lightning Stroke 55
3.3.2 Modelling of Overhead Distribution Lines 59
3.3.3 Modelling of a Tower 63
3.3.4 Modelling of Tower Footing Resistance 66
3.3.5 Modelling of the Insulator Coordination Gap 66
3.3.6 Modelling of a Metal Oxide Surge Arrester 68
3.3.7 Modelling of Crossarms 71
3.4 Description of Pantai Remis – Trong Line 72
3.5 Description of Simulation Model 75
3.6 Descriptions of Case Study 79
3.6.1 The Base Case 79
3.6.2 Effect of Tower Parameters on BFR 80

3.6.3 Line Arrester Placement 81
3.6 Summary 83

4 RESULTS AND DISCUSSSION 84
4.1 Backflashover Rate (BFR) Analysis 84
4.1.1 Base Model Analysis 85
4.1.2 Sensitivity Analysis 87
4.1.2.1 Soil Resistivity, ρ and Ground Resistances, R_g 87
4.1.2.2 Tower Height 90
4.1.2.3 Insulator Pins 93
4.1.2.4 Shield Wire 95
4.1.3 Placement of Line Arresters 97
4.2 Recommended Model 101
4.3 Summary 103

5 CONCLUSION 105
5.1 Conclusion 105
5.2 Recommendation for Future Study 107

REFERENCES 108
APPENDICES 115
BIODATA OF STUDENT 119
LIST OF PUBLICATIONS 120

LIST OF TABLES

Table		Page
1.1	Tripping Record for 33 kV Overhead Line between Pantai Remis and Trong Line	4
2.1	Classes and Shapes of Overvoltage – Standard Voltage Shapes and Standard Withstand Tests	17
2.2	Comparison between Typical Distribution Line and Underbuilt Transmission Structure for 33 kV	40
2.3	Parameter K and E_o for Different Configurations and Polarity	43
2.4	Types of Arrester Model	46
2.5	Yearly Lightning Strokes Counts	47
3.1	Segment Cross Section Details of Pantai Remis Trong Line for Phase Conductor and Ground Wire	63
3.2	V-I Characteristics for (a) A_0 and (b) A_1	70
3.3	Parameter Design for Each Selected Tower	74
3.4	Line Details	75
3.5	Key Parameters Used in Modelling Backflashover Rate to 33 kV System	77
3.6	Details for Base Model	80
3.7	Backflashover Analysis by Parameter Exchange	81
3.8	Ground Resistance, R_g variation Soil Resistivity, ρ	81
4.1	Summary of Simulation Works	84
4.2	The Base Model (TNB Malaysia) Backflashover Rate	86
4.3	Critical Current at Various R_g and ρ	90
4.4	Tower Height Effect	92
4.5	Quantitative Values for the Graph in Figure 4.4	94
4.6	Quantitative Value Obtained from Figure 4.5	97
4.7	Case 1	99
4.8	Case 2	100
4.9	Recommended Model for Pantai Remis – Trong Line	103
4.10	Simulation Result for Recommended Model	103

LIST OF FIGURES

Figure		Page
1.1	Definitions of CFO and BIL	2
1.2	Map of Pantai Remis – Trong Line	5
1.3	Observation of Thunderstorm Day per Year at Selected Cities Throughout Malaysia	7
1.4	Ground Flash Density for PPU Pantai Remis to PPU Trong	8
1.5	GSD Map for Years 2004 - 2007	9
2.1	Concave Waveform (I_{100}= Peak Current Magnitude, t_f = 1.67 (t_{90} - t_{30}) = Front Time, t_t = Tail Time)	13
2.2	Typical Major Causes for MVOH System Breakdown in TNB Malaysia	14
2.3	Types of Lightning	18
2.4	Statistical Impulse Withstand Voltage	19
2.5	Minor and Serious Damage to Insulators	23
2.6	Damaged Insulators caused by Flashovers	24
2.7	Two Styles of Low - Voltage Porcelain Insulator	26
2.8	Insulators: (a) Post Type and (b) Pin Type	26
2.9	Typical Insulator Units and Insulator Sets. (a) Shackle Insulator; (b) Pin Insulator; (c) Post Insulator; (d) Normal Cap and Pin Unit; (e) Anti-fog Cap and Pin Unit; (f) Aerodynamic Cap and Pin Unit; (g) Insulator Set (Single String); (h) 500 kV Vee Insulator Set; (i) Composite Pin Insulator on 11 kV Line (Courtesy of EA Technology Ltd, Capenhurst)	28
2.10	Shielding Failure Process	31
2.11	General Concept of Backflashover when Lightning Strikes to a Tower	32
2.12	Schematic of a Lightning Strike to a Tower	33
2.13	Diagram Showing How Lightning Strikes Cause Overvoltage and Flashover on Overhead Distribution Lines	33
2.14	Generalized Waveshape of a Lightning Strike	35

2.15	Outlines of Typical TNB Transmission Towers	36
2.16	Typical Steel Towers	37
2.17	Surge Impedance for a Tower Depending on Structural Details	38
2.18	Different Tower Models (a) Distributed Tower Model (b) Multistory Tower Model	38
2.19	Breakdown Phenomenon of Rod - Rod of an Air Gap	42
2.20	Schematic Representation of the Magnitude of Voltages and Overvoltages in a High Voltage Electrical Power System versus Duration of Their Appearance	44
2.21	Schematic Views of Arresters	45
3.1	Flow of Work	50
3.2	Sub Flowchart for Details Parameter Used in Modelling an Underbuilt Overhead Distribution Line	51
3.3	PSCAD Graphic User Interface to EMTDC	54
3.4	Waveform of Probability of Exceeding Crest Current	56
3.5	Waveform of Lightning Stroke Current Steepness	57
3.6	Developed Model of a Lightning Stroke	58
3.7	Multiple Run in PSCAD	58
3.8	Lightning Current in PSCAD	59
3.9	Distribution Line Configuration Component	61
3.10	Overhead Line Interface Component in PSCAD	61
3.11	Distribution Line Configuration Sub page	62
3.12	Description of Curve Fitting for Frequency Dependent Phase Model	62
3.13	Segment Cross Section of Pantai Remis - Trong Distribution Line	62
3.14	Distribution Line Configuration Component (Tower)	64
3.15	Developed Model of Distribution Tower	64
3.16	Distribution Line Configuration Sub page (Tower)	65
3.17	Description of Bergeron Model	65
3.18	Created Module of Tower Footing Resistance	66

3.19	Created Module of Insulator Gap	67
3.20	Circuit of Leader Propagation Time	67
3.21	a) Module Created of a Line Arrester b) Metal Oxide Arrester Nonlinear Arrester	69
3.22	Circuit of a Line Arrester Model	69
3.23	Placement of a Line Arrester on Modelling in PSCAD	71
3.24	Crossarm Model in PSCAD	72
3.25	Ground Stroke Density Map of the Pantai Remis Trong Line	73
3.26	Pantai Remis - Trong Tower Configuration and Dimensions	74
3.27	Simplified Design of the Developed Model System for Backflashover Analysis	76
3.28	Part of Developed Model System for Backflashover Analysis of Pantai Remis – Trong Line using PSCAD	78
3.29	Simplified Design of System Model for Backflashover Simulation	80
3.30	Placement of Line Arresters at a Tower for All Phases	82
4.1	Backflashover Rate to Strike Tower	86
4.2	Backflashover Rate with Increasing Soil Resistivity (ρ) when Ground Resistance (R_g) is Fixed to 8.5 Ω, 20 Ω, 50 Ω, 100 Ω, 300 Ω and 500 Ω	88
4.3	Effect of Tower Height Increase at 20%, 40% and 60%	91
4.4	BFR Recorded for Towers 96, 100 and 105 for Different Number of Insulator Pins	94
4.5	BFR With Different Shield Wire Placement and Striking Point	96
4.6	Backflashover Rate for Case 2	98
4.7	BFR versus Line Arrester Placement on Phase Conductors at Different Striking Point	101

LIST OF ABBREVIATIONS

BFO	Backflashover
BFR	Backflashover Rate
BIL	Basic Impulse Insulation Level
BSL	Basic Switching Impulse
CFO	Critical Flashover Voltage
CIGRE	International Council on Large Electric System
CMSF	Continuous Modelling System Function
GFD	Ground Flash Density
LDS	Lightning Detection System
MO	Metal Oxide
MOSA	Metal Oxide Surge Arrester
MV	Medium Voltage
MVOH	Medium Voltage Overhead Line
PSCAD	Power System CAD
SFFOR	Shielding Failure Flashover Rate
SiC	Silicon Carbide
TNBR	Tenaga Nasional Berhad (Research)

CHAPTER 1

INTRODUCTION

1.1 Research Background

Power system protection is a system that is required to protect equipment or a line system. In a power system there are lines and stations that are needed to control the system. The performance of the line or station is dependent on their insulation strength which can be described by the electrical dielectric strength due to lightning impulses, switching impulses, temporary overvoltage and power frequency voltages.

According to IEC 60071-1, [1] insulation coordination is "*The selection of the dielectric strength of equipment in relation to the voltages which can appear on the system for which the equipment is intended and taking into account the service environment and the characteristics of the available protective devices*". In some cases, the insulation coordination can be described as "*The process of bringing the insulation strengths of electrical equipment into the proper relationship with expected overvoltages and with the characteristics of surge protective devices*" [2].

Likewise for the distribution system, the insulation system should withstand various forms of overvoltage [3]. The basic impulse insulation level (BIL) is the electrical strength of insulation for the crest value of a standard lightning impulse [4]. In overhead distribution lines, the focus will be on the lightning impulse. Normally, the critical flashover (CFO) voltage is used to describe the insulation strength of the lines. CFO voltages refer to a 50 % probability of insulation failure when an impulse wave shape with the CFO peak voltage is applied to the insulation. CFO is normally used for self-restoring insulation as compared to the BIL which is used for evaluating non self-restoring insulation.

The definitions of the CFO and BIL can be best summarized as in Figure 1.1 where from that figure the CFO and BIL can be related to the insulation results at 50 % and 10 % probability of flashover respectively [4].

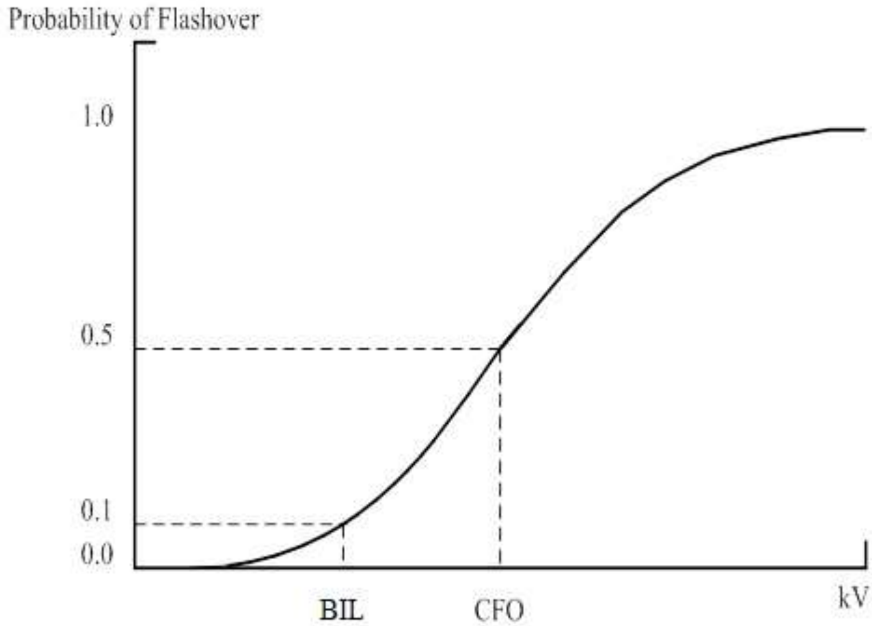

Figure 1.1. Definitions of CFO and BIL [4]

Lightning striking distribution lines is very important as it causes significant overhead line flashovers. The use of shield wires for lightning protection on overhead lines prevents most phase strikes but still results in the possibility of back flashovers.

Analysis of lightning performance is carried out on a 33 kV overhead distribution line underbuilt on a transmission structure which is connected from Pantai Remis to Trong through a palm oil estate and the coastal area of Perak state. This line was chosen as a case study as it has the worst line performance with a high tripping record because of the environmental area [6]. Data from TNB Research has recorded that this line has a Ground Flash Density (GFD) of around 10 to 23.3 flashes/km^2/year with an average GFD of 16.6 flashes/km^2/year [6].

A few computer programs are available that can be used to perform transient analysis studies for power system analysis. Examples are TFLASH, ATP/EMTP and PSCAD/EMTDC, which are examples of digital analysis tools that can be used as a policy for this task. Power System CAD (PSCAD) Software is used in this study due to its capability of modelling a continuous modelling system function (CMSF). It also provides the flexibility of building custom models, either by assembling such structures graphically using existing models, or by utilizing an intuitively designed Design Editor.

1.2 Problem Statement

A lightning strike on an overhead distribution line will cause an induced voltage or backflashover. The Pantai Remis – Trong line is a line built with an underbuilt on transmission structure. Reference [45] states that lightning has a high potential to strike at a high tower on an overhead line. The 33 kV Pantai - Remis to Trong line is 24.98 m in height with a record of tripping that increased from 2007 to 2008. Table

1.1 shows the tripping record for this 33 kV overhead line between the years 2007 to 2008.

Table 1.1. Tripping Record for 33 kV Overhead Line between Pantai Remis and Trong Line [6]

Year\Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
2008	1	5	4	1	2	1	1	0	0	0	0	0	15
2007	1	3	0	1	2	1	0	0	0	4	0	1	13

There is no strong reason for this data to show an increasing tripping rate as the line has a good tower footing resistance at 10 Ohms. This underbuilt overhead distribution line runs through a palm oil estate along the coastal area of Perak. Many reasons could be the cause of the tripping on the line, such as the structure of tower or contamination that causes this line to suffer from backflashovers. So, from the data, it is important to investigate why this line has an increasing record of tripping.

The structure of the towers is somewhat the same as the one used for transmission line but in this case, it is used to energize the 33 kV system . So, this underbuilt tower with a greater structure height than normal will draw more direct flashes [9]. Figure 1.2 shows a map of the Pantai Remis to Trong line for all towers.

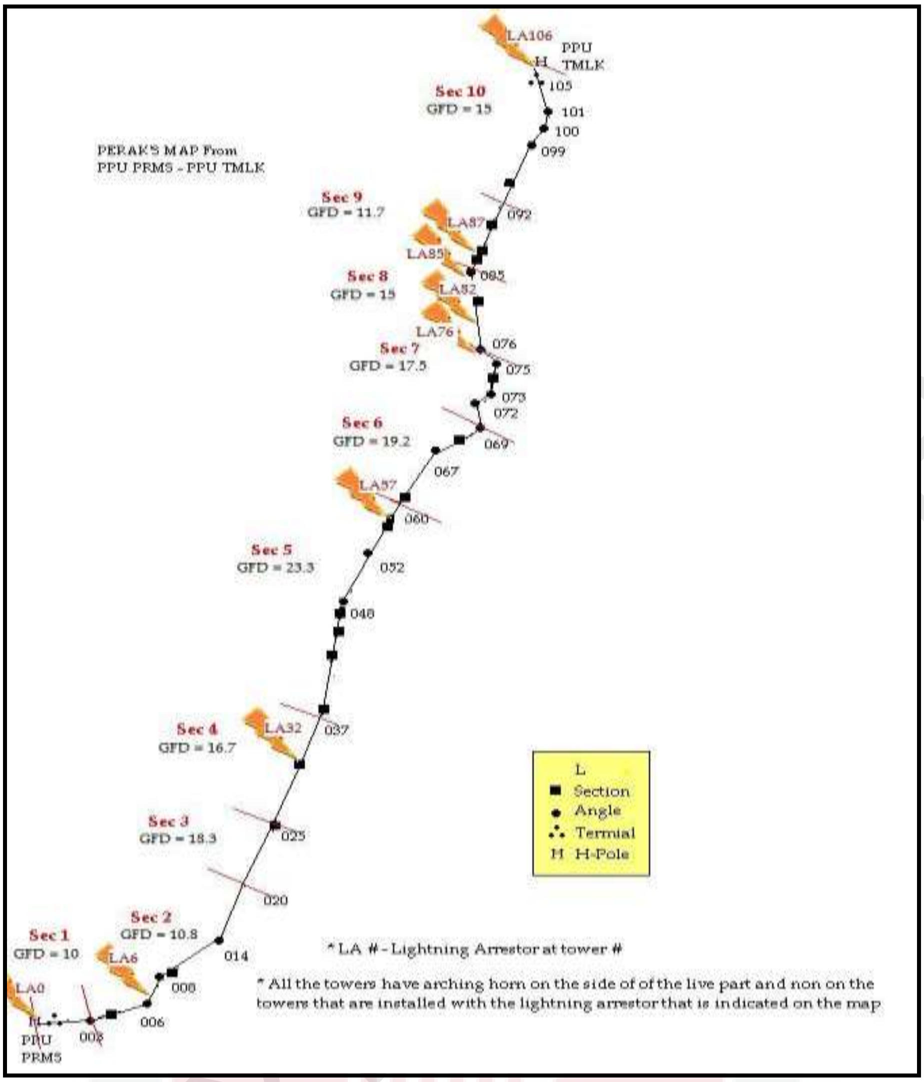

Figure 1.2. Map of Pantai Remis – Trong Line [6]

1.3 Research Aim and Objectives

The primary aim of this research is to provide findings for the development of a guideline pertaining to insulation coordination studies for a medium voltage (MV) overhead distribution line which would be used for engineers involved in the design, planning, construction and operation of such a line. Evaluation of backflashover analysis of the distribution line underbuilt on a transmission structure in terms of insulation coordination studies is also conducted.

Together with the results of simulation backflashover analysis on the tower, the results can be used by the proper authorities to reduce the backflashover value and demonstrate good performance analysis. The objectives of this study are:

- To model the underbuilt Malaysian 33 kV distribution line using PSCAD software.
- To estimate the backflashover current and backflashover rate (BFR).
- To provide the optimum placement of line arresters on phases at the tower of a distribution line.
- To investigate the effect of line parameters on the lightning performance of a distribution line.

1.4 Scope of Work

The scope and limitations of the research work are:

a) This research only considers the first return stroke of the lightning strike on the tower. The lightning current varies from 0 to 200 kA.

b) This research only focuses on a 33 kV underbuilt overhead distribution line where all the towers of this line have the same line parameter values.

c) This investigation is only focused on an underbuilt section on a transmission structure where the tower is used as a distribution system and the system voltage, characteristics and insulation strength are based on a distribution system.

1.5 The Significance of the Research

The major problem faced by this line as highlighted by Tenaga Nasional Berhad Research (TNBR) is due to the amount of lightning strikes [8]. Figure 1.3 shows the observation of thunderstorm days per year at selected cities throughout Malaysia. Data from the Meteorological Department indicates that Subang has 200 lightning days per year which is the highest figure compared to the other cities.

Figure 1.3. Observation of Thunderstorm Day per Year at Selected Cities Throughout Malaysia [7]

On the other hand, it is important to understand that the lightning phenomena cannot be eliminated but the effects can be minimized or reduced with a proper solution and technique. It is known that lightning strikes can cause death and also damage to utilities and the failure of line operations.

Lightning transient activity is so fast that air ionization time constants lead to a particular time and waveshape, and whether the system can withstand such a strike is dependent on the insulation strength. On distribution lines, lightning is a major cause of faults. Estimates of the lightning performance of distribution lines contain many uncertainties such as the lightning intensity measured by GFD [9]. Figure 1.4 shows the ground flash density for PPU Pantai Remis to PPU Trong.

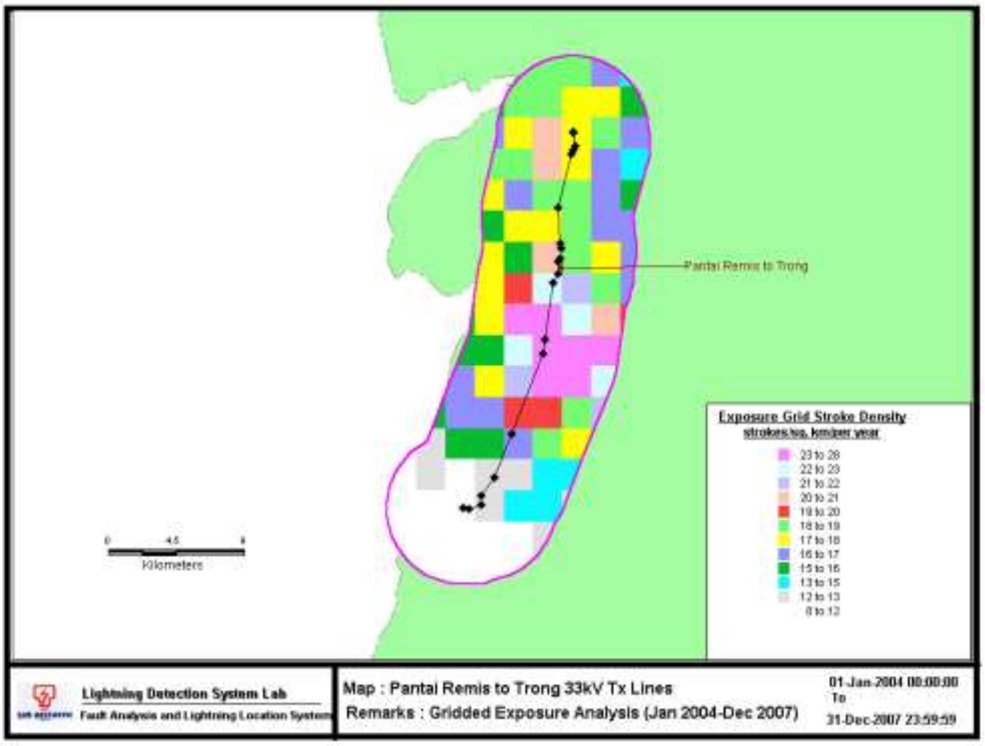

Figure 1.4. Ground Flash Density for PPU Pantai Remis to PPU Trong [6]

Figure 1.5 shows Peninsular Malaysia at the keraunic level of GFD from 2004 to 2007. Over that period, nearly 9 million lightning strikes were detected in Peninsular Malaysia using the TNBR Lightning Detection System (LDS) [10].

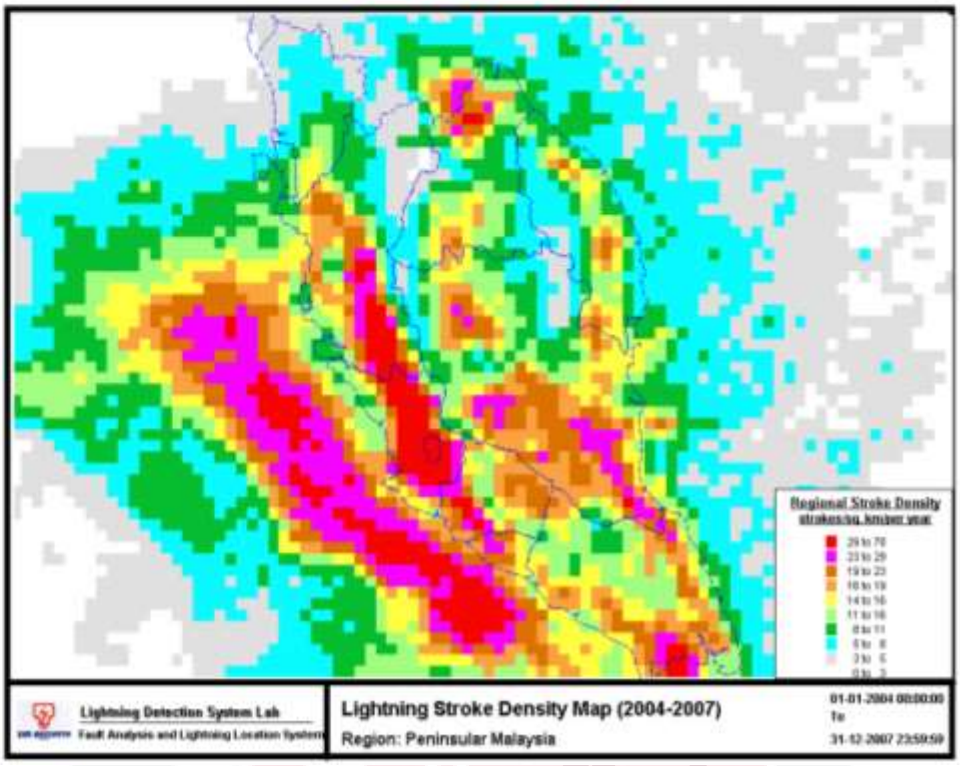

Figure 1.5. GSD Map for Years 2004 - 2007 [6]

Lightning is difficult to model and study but there are methods that can be used to estimate the expected lightning performance of the line. Backflashover analysis and simulation methods can be used by accurate models to help suggest how to obtain a good performance from a distribution line. This research is important to give guidelines in designing and improving distribution line performance. It focuses on searching methods or parameter instalments that can reduce BFR and transformer damage at the substation.

1.6 Thesis Layout

This thesis consists of five chapters which are the Introduction, Literature Review, Methodology, Results and Discussion and the last chapter is the Conclusions and Recommendations for future work.

Chapter one describes the Introduction to this research, the Problem Statement, Objective and the lightning utilities in Malaysia especially the 33 kV Pantai Remis to Trong line.

Chapter two discusses the Literature Review of this project which comprises of prior research into insulation strength, over voltage, lightning, mechanisms of lightning, backflashover, line arresters for protection and lastly the modelling of a distribution line.

Chapter three elaborates the Methodology used to model and to simulate the model by using PSCAD Software. It starts by developing a model of a steel tower to measure the backflashover and to research a better model by simulating different parameters to choose the most suitable arrangement. The optimum placement of line arresters is also considered.

Chapter four presents the Results and Discussion of this research. The results obtained from the analysis will be in terms of backflashover rate and time. Results for comparative study are also included in this chapter.

Finally, chapter five provides a Conclusion of the findings and objectives of the project related to lightning performance of a 33 kV distribution line underbuilt on a transmission structure. At the end of this chapter a recommendation is put forward for future research work in continuing to improve the system.

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