SOFTWARE DEVELOPMENT FOR THE EVALUATION OF THE LIGHTNING PROTECTION SYSTEM DESIGN

RAVEEN KUMAR RAMALINGAM

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical - Power).

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JUNE 2014

To my beloved
Family and Friends,

To my supervisor,
Assoc. Prof. Dr. Zulkurnain Abdul-Malek

To all my supportive members,

Thank for your support and sacrifices

ACKNOWLEDGEMENT

I would like to express my many thanks to my supervisor of this project, Dr. Zulkurnain Abdul-Malek for the inspiration and guidance in this project. He has constantly provided valuable guidance and advice which has motivated me to contribute my fullest to this project.

In addition, gratitude is dedicated to my family and close friends who has been all the way tolerating and helping me in providing moral and technical support during the course of this project. Their constant support has greatly motivated me to continuously put in effort towards the completion of this project.

Finally, I would like to thank all my friends for their friendship and their support, which made this journey a joyful and unforgettable. Thanks.

ABSTRACT

Due to the high lightning activity in Malaysia, a good and robust lightning protection system (LPS) is required and this system has to be evaluated based on actual influencing parameters. This work describes the development and results of a computer based software for the evaluation of lightning occurrences on a structure. Lightning Protection System Design is a software that allows designers to design a lightning protection system for a particular building or structure. The work discusses on the relevant algorithms to compute the lightning strike probability on a given structure. The program was written in Python and a very simple guided user interface using Visual Basic.NET. It also provides the flow chart in designing and computing the protection system. The software is based on 3 dimensional modeling implementing the electro geometrical model of lightning stroke on the structures that requires protection. The work also evaluates different building structure with different protection levels to calculate the probability of lightning strike.

ABSTRAK

Kertas ini menerangkan pembangunan dan keputusan perisian berasaskan komputer untuk penilaian kejadian kilat untuk struktur. Sistem Perlindungan Kilat Design adalah perisian berasaskan program yang membolehkan pereka untuk mereka bentuk sistem perlindungan kilat untuk bangunan atau struktur tertentu. Kertas ini akan membincangkan algoritma berkenaan untuk kilat mogok kebarangkalian pada struktur. Program ini ditulis dalam Python dan antara muka pengguna yang amat mudah dipandu menggunakan Basic.NET Visual. Ia juga akan menyediakan carta alir dalam mereka bentuk dan pengiraan sistem perlindungan. Perisian ini adalah berdasarkan kepada 3 model dimensi melaksanakan model elektro geometri sambar kilat ke atas struktur yang memerlukan perlindungan. Oleh kerana aktiviti kilat yang tinggi di Malaysia, sistem perlindungan kilat yang baik dan teguh (LPS) diperlukan dan sistem ini perlu dinilai berdasarkan parameter mempengaruhi sebenar. Kertas ini juga menilai struktur bangunan yang berbeza dengan tahap perlindungan yang berbeza untuk mengira kebarangkalian kilat.

TABLE OF CONTENT

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENT	vii
	LIST OF TABLES	ix
	LIST OF FIGURES	xii
	LIST OF ABBREVIATION	xv
1	**INTRODUCTION**	
	1.1 Background	1
	1.2 Problem Statement	2
	1.3 Objectives	2
	1.4 Scope of Study	3
2	**THEORY AND LITERATURE REVIEW**	
	2.1 The Thundercloud	4
	2.2 Ground Flash Density (GFD)	7
	2.3 Electro-Geometrical Modelling	9
	2.3.1 Striking Distance	9
	2.3.2 The Monte Carlo Method	10
	2.3.3 3-Dimensional Modelling of Lightning Strike	11
	2.4 Lightning Current Analysis	12
	2.5 Lightning Protection System Design	14

2.5.1 Mesh Method 15
2.5.2 Protective Angle Method 16
2.5.3 Rolling Sphere Method 18

3 METHODOLOGY
3.1 Initialization 21
3.2 Lightning Simulation 22
3.3 LPSD Visualization 24

4 RESULTS AND DISCUSSION
4.1 GFD Checking on LSPD 25
4.2 Effect of Lightning Striking on Different Structure Area 27
4.3 Effect of Building Height on Lightning Strike 33
4.4 Effect of Protection Class on Probability of Lightning Strike 36

5 CONCLUSION AND RECOMMENDATION
5.1 Recommendation 40

REFERENCES 42

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Maximum current levels for lightning protection levels I to IV	7
2.2	Values of probability P as function of the lightning current I	13
2.3	Mesh size for mesh method	15
2.4	Rolling sphere based on class of protection	18
2.5	Examples of rolling sphere protection distance	20
4.1	Summary result of probability of lightning using LPSD	28
4.2	Probability of lightning strike vs Area of structure	32
4.3	Results of simulation on area varying effect on probability of lightning strike	34
4.4	Distance between rods with respect to class of protection	37

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Typical charge distribution	5
2.2	Stepped leader progressing towards ground	5
2.3	Current Waveform	6
2.4	Average number of thunderstorm days (annual)	8
2.5	World lightning flash rate data	8
2.6	Striking distance model	10
2.7	Lightning direction and angle	11
2.8	Mesh method protection	16
2.9	Protection angle method	17
2.10	Protection angle graph	17
2.11	Rolling sphere protection method	19
3.1	Graphical representation of parameters required	21
3.2	Lightning strike point computation flow chart	23
3.3	Overall flow chart of LPSD	24
4.1	Input parameter menu for GFD checking	26
4.2	Output result of lightning simulations of LPSD	26
4.3	Coordinates of ground collision	27
4.4	Graph of number of strike on structure with different GFD for area 20m x 20m	29
4.5	Graph of number of strike on structure with different GFD for area 40m x 40m	30
4.6	Graph of number of strike on structure with different GFD for area 80m x 80m	30
4.7	Graph of number of strike on structure with different GFD for area 160m x 160m	31

4.8	Graph of number of strike on structure with different GFD for area 320m x 320m	31
4.9	Linear graph of probability of lightning strike versus area of structure	33
4.10	Graph of area varying effect on probability of lightning strike	35
4.11	Probability of lightning strike on height varying	36
4.12	Building modelling with respect of protection class in Blender	38
4.13	Probability of lightning strike with accordance of protection class	39

LIST OF ABRREVIATION

GFD	-	Ground Flash Density
LPS	-	Lightning Protection System
LPSD	-	Lightning Protection System Design
PDF	-	Probability Density Function
IEEE	-	Institute of Electrical and Electronics Engineers
LPL	-	Lightning Protection Level

CHAPTER 1

INTRODUCTION

Lightning is a natural phenomenon which is unavoidable and as of great concern for mankind. The effects of lightning including impacting human safety, electronics devices and AC power system equipment failure. [1].

Due to the high thunderstorm days recorded in Malaysia, probability of lightning striking in Malaysia is relatively high. [3]Therefore, since it is unavoidable, a proper lightning protection system is required for structures, buildings and AC power system related equipment. This is to prevent any hazard or electrical nuisance tripping due to lightning impulse current

1.1 Background

For this project, literature review on the ground flash density (GFD) and the thunderstorm days in Malaysia is to be done. These values are vital for lightning protection system design and determine the amount of lightning strike on a structure.

Furthermore, statistical methods such as probability density function are being utilized to perform the random calculation along with other algorithms. A few case studies were done to evaluate the software and the effectiveness of lightning protection system (LPS). Any assumptions or conclusions upon evaluating are discussed further in the report.

1.2 Problem Statement

Malaysia has generally high thunderstorm days due to its location at the equator. This resultant in having more lightning activity across Malaysia and higher probability of lightning striking on buildings compared to other countries.

Hence, a good and robust lightning protection system (LPS) is required to arrest the lightning and providing the best path to be grounded. Currently, consultants prefer to use rule of thumb and 2D drawings to design the placement of lightning arrestors.

Design is basically done on placing at the edges of building and according to cost or budget given. Some consultants only use rolling sphere method which only gives results of possible point of strikes and no information on probability of strikes at the individual points. Neither proper risk evaluation nor lightning simulation are done to structures before designing the LPS.

This has been the motivation for the project in order to provide a better protection system against lightning for mankind. Besides that, most of the software available is more suitable for overhead transmission lines.

1.3 Objectives

The objectives of this project are;

- To develop a software which able to design a lightning protection system for a building based on actual lightning characteristics.
- To develop algorithm of lightning simulation
- To study on the inclusion of lightning protection and the effectiveness level based on protection levels or locations.

1.4 Scope of study

The scope of study of this project covers the following;

- To understand the algorithm of lightning striking and implementation
- To evaluate the LPSD with various structure with different levels of protections and provide advice on protection level
- To determine probability of lightning striking with varying building height and area

REFERENCES

[1] W.I Ibrahim and M.R Ghazali, "An Overview of Pekan Lightning Detection System (PLDS)," in 2012 IEEE International Conference on Power and Energy (PECon), 2-5 December 2012, Kota Kinabalu Sabah, Malaysia

[2] A.C. Liew, Sr.M.I.E.E.E and C.M.Gui, "Performance assessment of lightning shielding systems,"

[3] Hartono Zainal Abidin, and Robiah Ibrahim, "Thunderstorm Day and Ground Flash Density in Malaysia," in National Power and Energy Conference (PECon) 2003 Proceedings, Bangi, Malaysia

[4] M.Z.A. Ab Kadir, N.R. Misbah, C.Gomes, J,Jasni, W.F. Wan Ahmad, M.K. Hassan, "Recent Statistics on Lightning Fatalities in Malaysia," in 2012 International Conference on Lightning Protection (ICLP), Vienna, Austria

[5] H.R. Armstrong, E.R. Whitehead, "Field and analytical studies of transmission line shielding", IEEE Transaction on Power Apparatus and systems, Vol PAS-87, pp 270-281, 1968

[6] G. W. Brown, E. R. Whitehead, Field and Analytical Studies of Transmission Line Shielding, Pt. I, Ibid. Vol. 88, pp. 617-26, May 1969.

[7] J.R.Curie, Liew Ah Choy, and M.Darveniza, "Monte Carlo determination of the frequency of lightning strokes and shielding failures on transmission lines", ibid, Vol. PAS-90, 1971, pp. 2305-2312

[8] Alexender Kern, Christof Schelthoff, and Moritz Mathieu, “Probability of lightning strikes to air terminations of structures using the electro-geometrical model theory and the statistics of lightning current parameters”, IEEE Paper 750

[9] IEC 62305-1: 2006-01: Protection against lightning- Part 1: General Principles

[10] IEC 62305-3: 2006-01: Protection against lightning- Part 3: Physical damage to structures and life hazard

[11] Erikssion, A. J. (1993). “IEE Working Group report estimating lightning performance of transmission lines II-Updates to Analytical Models.” IEEE Trans. on Power Delivery, 8 (3)

[12] M.M. Rezinkina, V.V. Knyazyev, and V.I. Kravchencko, “Computation of the Probability of Lightning Damage to Ground Objects,” Technical Papers, 2007, Vol 52.

[13] E.Mansell, D. MacGorman, C.Ziegler, and J.Straka, J. Geophys. Res. 107 (D9) (2002)

[14] National Weather Services of USA 2012

[15] Lightning- Eritech (www.eritech.com).

[16] IEEE Working Group on Lightning Performance of Transmission Lines, "A simplified method for calculating lightning performance of transmission lines", IEEE Transactions on Power Apparatus and Systems, Vol. PAS-85, pp.919-932, 1985.