



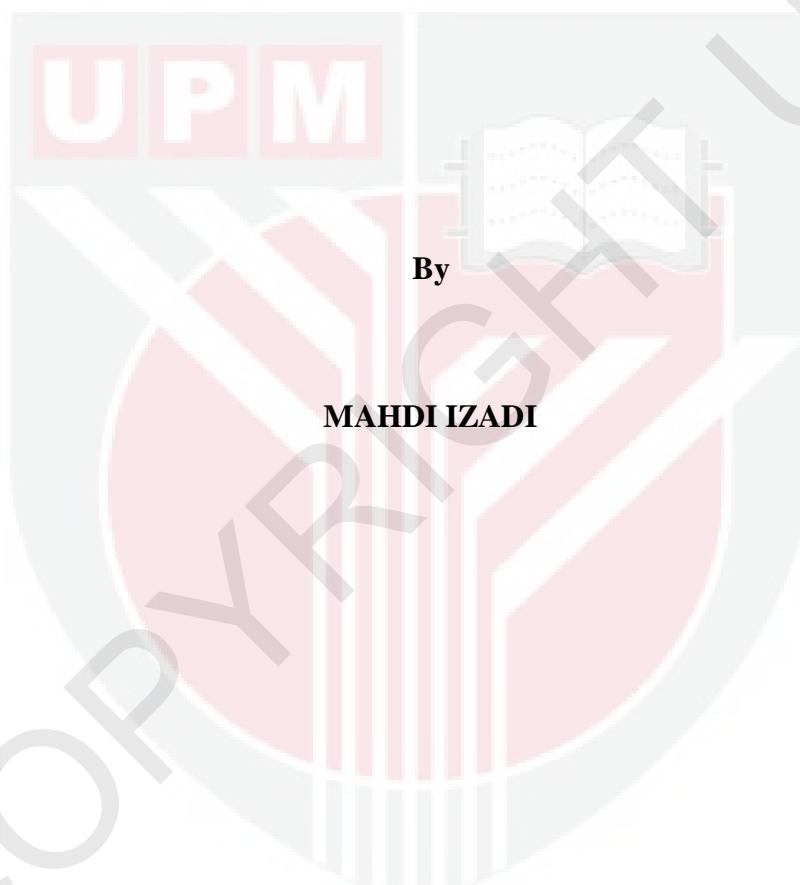
UNIVERSITI PUTRA MALAYSIA

***IMPROVED ALGORITHM FOR EVALUATION OF LIGHTNING INDUCED
OVERVOLTAGE ON DISTRIBUTION LINES***

MAHDI IZADI

FK 2010 23

**IMPROVED ALGORITHM FOR EVALUATION OF LIGHTNING INDUCED
OVERVOLTAGE ON DISTRIBUTION LINES**



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

February 2010

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

**IMPROVED ALGORITHM FOR EVALUATION OF LIGHTNING INDUCED
OVERVOLTAGE ON DISTRIBUTION LINES**

By

MAHDI IZADI

February 2010

Chairman : Mohd. Zainal Abidin Ab Kadir, PhD

Faculty : Engineering

Lightning is a natural phenomenon and can affect the performance of the power lines in two different ways, i.e. direct and indirect strikes. In case of direct strike, it occurs when the tower or shield wire is struck by the lightning and creates an induced overvoltage on phase conductors or shielding wire. Whilst for indirect strikes, it could happen if a lightning strike near the power lines and it produces electric and magnetic fields which depend on a number of factors such as lightning return stroke current and lightning parameters, the distance from power lines and conductivity of the ground. Induced overvoltage is a major cause of interruption on distribution networks and specific research is needed in evaluating the amount of overvoltage induced on such network accurately without many assumptions involved.

This thesis presents the work in estimating the lightning induced overvoltage on distribution lines. Overall, many improvements have been made especially in calculating the electric and magnetic field by revising the integral limits in dipole equations and by considering the different effect of ground conductivities. Additionally, various coupling methods to evaluate the lightning induced voltage have been proposed before reaching the final step of the algorithm which is the estimation of lightning induced overvoltage on the multi-conductors distribution line. The results obtained were then compared with the measurement values recorded during rocket-triggered lightning and other published data.

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

**ALGORITMA DIPERBAIKI UNTUK PENILAIAN VOLTAN LEBIHAN
TERARUH KILAT KE ATAS TALIAN PEMBAHAGIAN**

By

MAHDI IZADI

February 2010

Pengerusi : Mohd. Zainal Abidin Ab Kadir, PhD

Fakulti : Kejuruteraan

Kilat adalah satu fenomena semulajadi dan boleh mengganggu prestasi talian kuasa dalam dua cara, iaitu langsung dan tak langsung. Bagi kes panahan langsung, ia terjadi bila menara atau kabel pelindung di panah kilat dan menyebabkan voltan lebihan pada konduktor fasa atau kabel pelindung. Sementara bagi panahan tak langsung, ia boleh terjadi sekiranya kilat memanah berdekatan dengan talian kuasa dan menghasilkan medan elektrik dan magnet yang mana bergantung kepada beberapa faktor seperti arus panahan balik kilat dan parameter kilat yang lain, jarak dari talian kuasa dan kekonduksian bumi. Voltan lebihan teraruh merupakan penyebab besar bagi gangguan ke atas rangkaian pembahagian dan banyak penyelidikan diperlukan dalam menilai

jumlah voltan lebihan teraruh pada rangkaian tersebut dengan tepat tanpa banyak melibatkan andaian-andaian.

Tesis ini mempersempahkan kerja-kerja yang telah dijalankan di dalam menganggarkan voltan lebihan teraruh kilat pada talian pembahagian. Keseluruhannya, banyak penambahbaikan telah dilakukan ke atas algortma terutamanya di dalam pemgiraan medan elektrik dan magnet dengan menyemak semula had-had kamiran bagi persamaan dwi-kutub dan dengan mengambil kira kesan yang berbeza bagi kekonduksian bumi. Sebagai tambahan, pelbagai kaedah gandingan untuk menilai voltan teraruh kilat telah dicadangkan sebelum menghampiri kepada langkah terakhir bagi algoritma tersebut iaitu penganggaran voltan lebihan teraruh kilat ke atas konduktor-berbilang (*multi-conductors*) talian pembahagian. Keputusan-keputusan yang dihasilkan kemudiannya dibandingkan dengan nilai-nilai pengukuran yang direkodkan semasa experiment kilat terpicu-roket (*rocket-triggered*) dan data-data lain yang telah diterbitkan.

ACKNOWLEDGEMENTS

At first, I would like to thank from ALLAH

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-supervisor Dr. Wan Fatinhamamah Wan Ahmad for her comments and advices in this project.

My wife, Maryam and my son, Siavash for sharing the difficulties and for being patient and understanding throughout the course of this study. Last but not least, my parents for their support and love.

APPROVAL

I certify that an examination committee met on month/date/year to conduct the final examination of Mahdi Izadi on his Master of Science thesis entitled "Improved Algorithm for Evaluation of Lightning Induced Overvoltage on Distribution Lines" 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:

Assoc. Prof. Dr. Roslina bt. Mohd. Sidek

Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Professor Ir. Dr. Norman b. Mariun

Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Dr. Hashim B. Hizam

Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Prof. Dr. Titik Khawa Abdul Rahman

Faculty of Electrical Engineering
Universiti Teknologi MARA
(External Examiner)

BUJANG KIM HUAT, PhD

Professor/ 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

Faculty of Engineering
University Putra Malaysia
(Chairman)

Wan Fatinhamamah Wan Ahmad, PhD

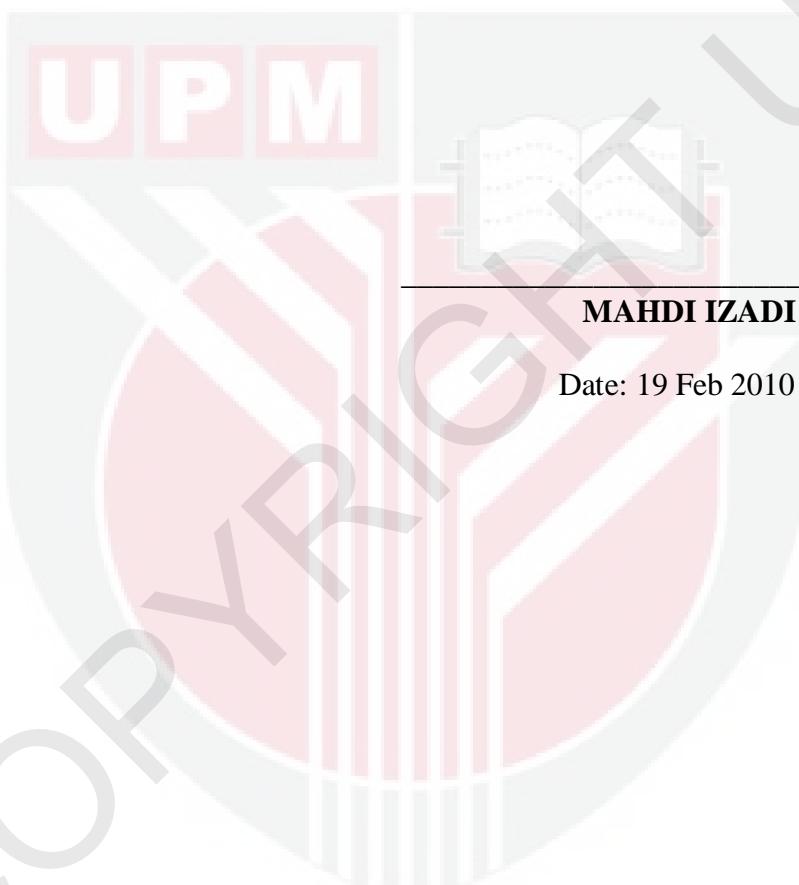
Faculty of Engineering
University Putra Malaysia
(Member)

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

Date: 13 May 2010

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.



MAHDI IZADI

Date: 19 Feb 2010



TABLE OF CONTENTS

	Page
DEDICATION	i
ABSTRACT	ii
ABSTRAK	iv
ACKNOWLEDGEMENTS	vi
APPROVAL	vii
DECLARATION	ix
LIST OF TABLES	xii
LIST OF FIGURES	xiv
LIST OF ABBREVIATION	xix
 CHAPTER	
1 INTRODUCTION	
1.1 Historical Overview	1
1.2 Problem Statement	1
1.3 Aim and Objectives	4
1.4 Scope of Work	4
1.5 Thesis Layout	5
1.6 Summary	6
2 LITERATURE REVIEW	
2.1 Determination of Special Areas for Direct and Indirect effect of lightning	7
2.1.1 IEEE Working Group method	8
2.1.2 Armstrong and Whitehead method	10
2.1.3 Eriksson method	10
2.1.4 Rizk method	11
2.1.5 Anderson method	11
2.1.6 Dellera and Garbagnati method	12
2.1.7 Golde method	12
2.2 Engineering return-stroke current models	14
2.2.1 Calculating the channel base current	20
2.2.2 Return stroke velocity	26
2.2.3 Return stroke current models	27
2.3 Calculation of lightning returns stroke Fields	32
2.3.2 Ground conductivity effect	38
2.4 Coupling Models	42
2.4.1 Rusck model	43
2.4.2 Taylor model	51
2.4.3 Chowdhuri model	52
2.4.4 Rachidi model	60
2.4.5 Agrawal model	61

2.5 Summary	63
3 METHODOLOGY	
3.1 Overview	70
3.2 The Iranian 20kv Distribution Line Parameters	71
3.3 Direct and Indirect Strike Area Calculations on the lines	72
3.4 Calculation of return stroke current	73
3.5 Calculation of electric and magnetic fields	74
3.6 Estimation of induced overvoltage (coupling method)	84
3.7 The modified FDTD method for solving coupling equations	85
3.8 Introducing simulator software	94
3.9 Introduction to initial parameters	97
3.10 Summary	100
4 RESULTS AND DISCUSSION	
4.1 Overview	102
4.2 Direct and indirect strike area values on the lines	102
4.3 Electric and magnetic fields behavior considering return stroke velocity changes	103
4.4 Electric and magnetic fields behavior considering lateral distance changes	105
4.5 Electric and magnetic fields behavior considering observation points height changes	107
4.6 Magnetic fields behavior considering integral limits change	109
4.7 Induced Voltage on the Line	110
4.8 Summary	126
5 CONCLUSION AND FUTURE WORK	
5.1 Conclusion	127
5.2 Suggestion for Future Work	129
REFERENCES	130
APPENDICES	
A Initial parameters for evaluation of induced voltage in Chowdhuri model	136
B Modified FDTD method for solving Agrawal coupling equations	138
BIODATA OF STUDENT	147