



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**PHOTOGRAPHIC OBSERVATION FOR TREEING AND
TRACKING FOR DETECTING LINE TO GROUND FAULT**

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

By

ABDUL MUHAIMIN BIN ABU BAKAR

B071510581

940630-01-7043

FACULTY OF ELECTRICAL AND ELECTRONIC ENGINEERING

TECHNOLOGY

2019

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **PHOTOGRAPHIC OBSERVATION FOR TREEING AND TRACKING
FOR DETECTING LINE TO GROUND FAULT**

Sesi Pengajian: 2019

Saya **ABDUL MUHAIMIN BIN ABU BAKAR** mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (X)

SULIT*

Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam


AKTA RAHSIA RASMI 1972.

TERHAD*

Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan.

TIDAK
TERHAD

Yang benar,



ABDUL MUHAIMIN BIN ABU
BAKAR

Alamat Tetap:

NO. 6493-01 KUARTERS JKR SKUDAI
BATU 10, 81300 SKUDAI
JOHOR

Tarikh: 7/1/2019

Disahkan oleh penyelia:



Ts. Dr. ZIKRI ABADI BIN
BAHARUDIN

Cop Rasmi Penyelia

Dr. Zikri Abadi Bin Baharudin
Pensyarah
Jabatan Teknologi, Kejuruteraan Elektrik
Fakulti Teknologi Kejuruteraan
Universiti Teknikal Malaysia Melaka

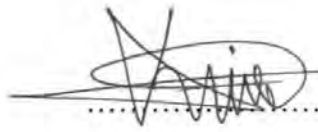
Tarikh: 7/1/2019

*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini

DECLARATION

I hereby, declared this report entitled PHOTOGRAPHIC OBSERVATION FOR TREEING AND TRACKING FOR DETECTING LINE TO GROUND FAULT is the results of my own research except as cited in references.

Signature:



Author :

ABDUL MUHAIMIN BIN ABU
BAKAR

Date:

7/11/2019

APPROVAL

This report is submitted to the Faculty of Mechanical and Manufacturing Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours. The member of the supervisory is as follow:

Signature:



Supervisor : Ts. Dr. ZIKRI ABADI BIN BAHARUDIN

ABSTRAK

Cadangan projek akhir tahun ini adalah mengenai pemerhatian fotografi untuk pokok elektrik dan penjejakan untuk mengesan talian ke kesalahan pbumian tanah melalui kamera berkelajuan tinggi. Oleh kerana pembentukan pemanasan elektrik dan pencemaran penjejakan boleh menyebabkan kerosakan dalam sistem voltan tinggi, pembentukan pemerhatian pemanasan elektrik boleh memberi gambaran tentang bagaimana untuk mengurangkan kebarangkalian kerosakan berlaku dalam sistem voltan tinggi garis ke kesalahan tanah sebagai langkah berjaga-jaga mengelakkan fenomena pecahan dalam sistem voltan tinggi terutamanya dalam operasi kereta api berkelajuan tinggi untuk mengawal voltan yang digunakan tidak melampaui batas sehingga ia boleh menyebabkan pembentukan pokok seperti belukar yang boleh menyebabkan kerosakan. Tujuan utama penyelidikan ini adalah untuk melihat pembentukan pokok elektrik selaras dengan kesilapan tanah menggunakan kamera berkelajuan tinggi yang boleh menyebabkan kerosakan disebabkan oleh permulaan dan penyebaran bentuk pokok. Projek ini akan dijalankan di makmal voltan tinggi di Fakulti Teknologi Kejuruteraan di Universiti Teknikal Malaysia, Melaka. Ujian akan dijalankan untuk penebat gelas dengan kadar bekalan voltan di bawah 33kV yang mempunyai kekuatan dielektrik yang tinggi kerana kekangan peralatan di makmal voltan tinggi menggunakan kit kecil voltan tinggi yang dimiliki oleh Univeristi Teknikal Malaysia. Penebat kaca ini juga digunakan untuk rangkaian pengedaran 33kV dengan persekitaran yang sesuai. Projek ini akan

menggunakan kamera kelajuan tinggi dan jalur elektrik elektrik Chronos 1.4 untuk mencetuskan saluran kerana penyebaran cahaya kerana ia lebih tinggi daripada radiowave menggunakan saluran luaran. Jarak pengamatan untuk kamera berkelajuan tinggi akan terhad pada jarak 2 hingga 5 meter di dalam sangkar keselamatan dengan resolusi kamera berkelajuan tinggi akan ditetapkan sehingga 5000 bingkai sesaat (fps) selama tempoh 2 saat. Parameter mengukur voltan kerosakan akan direkod dengan resolusi dari 40 hingga 100 ns (10 hingga 20 MS / s) selama tempoh 2 saat. Lain-lain, pecahan medan elektrik akan direkodkan melalui definisi tinggi perekam sementara (Lecroy HDO4024). Perubahan bentuk adalah berkaitan dengan peningkatan bekalan voltan sama ada ia menyebabkan pembentukan semak, cawangan, cawangan belukar dan sebagainya. akan menjalankan pemeriksaan pencemaran yang boleh menyebabkan pecahan sebagai pencemaran garam, kelembapan dan sebagainya. Di samping itu, ia akan menganalisa masa yang terpakai untuk kerosakan yang berlaku disebabkan peningkatan voltan tinggi yang terjejas oleh peningkatan kelajuan tinggi rel. Ini boleh menjejaskan peningkatan kerosakan medan elektrik kerana penyebaran cahaya lebih tinggi berbanding radiowave..

ABSTRACT

The proposal of this final year project is regarding on the photographic observation for electrical treeing and tracking for detecting line to ground fault via high speed camera. Since formation of electrical treeing and contamination of tracking may lead to breakdown in high voltage system, observation formation of electrical treeing may give an idea on how to reduce the probability of breakdown to occur in high voltage system of line to ground fault as the precaution to prevent the breakdown phenomena in high voltage system especially in high speed rail operation as to control the voltage applied not exceed its limit until it can cause formation bush-like tree that can lead to breakdown. The main purpose of this research is to observe the formation of electrical treeing in line to ground fault using high speed camera that can lead to breakdown due to its initiation and propagation of tree shape. This project will be conducted in high voltage lab in Faculty of Engineering Technology at Universiti Teknikal Malaysia, Melaka. Test will conduct for the glass insulator with rate of voltage supply under 33kV which is it have high dielectric strength due to the constrain of equipment in high voltage lab using high voltage small kit owned by Univeristi Teknikal Malaysia. This glass insulator also use for 33kV distribution network with the suitable environment. This project will use Choronos 1.4 High speed camera and broadband electric field measurement to trigger channel due to the propagation of light since it higher than radiowave using its external channel. The distance of observation for

high speed camera will be limited at the distance of 2 to 5 meters inside the safety cage with the resolution of high speed camera will be set up to 5000 frame per second (fps) for the duration of 2 seconds. Measuring parameter of breakdown voltage will be recorded with resolution from 40 to 100 ns (10 to 20 MS/s) for 2 seconds duration. Others, electric field breakdown will be recorded via high definition of transient recorder (Lecroy HDO4024. Changing of shape are related with the increasing of voltage supply whether it lead to formation of bush, branch, bush-branch and so on. Others, tracking test will conduct to observe the contamination of tracking that can lead to breakdown as the contamination of salt, humidities and so on. Besides, it will analyse time eleapsed for breakdown to occur due to the increasing of high voltage affected by the increasing motion of high speed rail . This can affect the increasing of electric field breakdown due propagation of light is higher compare to radiowave.

DEDICATION

Allah, Our Creator

Muhammad S.A.W, our Prophet

Abu Bakar bin Mahat, my Father

Ramah binti Salleh, my mom

Dr. Zikri Abadi bin Baharudin, my supervisor

Universiti Teknikal Malaysia, my colleague

All my lecturer

My fellow friends

Without all these support, this research cannot done until the end. Thank for being on my behalf give all the moral support, spirit, advice to complete this research. May god bless all of you.

ACKNOWLEDGEMENTS

I would like to thank to my beloved supervisor Dr. Zikri Abadi bin Baharudin because give the moral support, advice, idea as the guidelines to complete this research. I would to thank to my colleagues Universiti Teknikal Malaysia because giving a chance to use the facilities in the high voltage lab at Faculty of Engineering Technology. I also would like to thank to my first panel Mr. Mohd Firdaus bin Ab Halim because willing to appreciate this project and give idea for the new improvement same as my second panel Mrs. Intan Mastura binti Saadon for your new idea and improvement for this project

TABLE OF CONTENTS

	PAGE
TABLE OF CONTENTS	xi
LIST OF TABLES	xv
LIST OF FIGURES	xvi
LIST OF SYMBOLS	xxii
LIST OF ABBREVIATIONS	xxiii
CHAPTER 1 INTRODUCTION	1
1.1 Introduction	1
1.2 Project Background	1
1.3 Problem Statement	8
1.4 Objective Of The Project	9
1.5 Scope of the Project	10
1.6 Report Outline	11
CHAPTER 2 LITERATURE REVIEW	13
2.1 Introduction	13
2.2 Electrical Treeing	13
2.2.1 Electrical Treeing Initiation	15
2.2.2 Partial Discharge in Electrical Treeing.	17

2.2.3	Electrical Treeing of Mechanical Strain	21
2.2.4	Electrical stress in Electrical Treeing	23
2.2.5	Electrical Tree Propagation	25
2.3	Electrical Treeing Shape	28
2.3.1	Vented trees	32
	2.3.1.1 Mechanical Damage Theory in Vented Water Treeing	34
	2.3.1.2 Initiation and tree growth of Vented water tree	36
2.3.2	Bow-tie trees	37
	2.3.2.1 ION DIFFUSION IN BOW-TIE TREE	39
2.3.3	BUSH LIKE TREES	40
2.3.4	BRANCH-LIKE TREE	49
2.4	Solid Dielectric	59
2.4.1	Partial Breakdown in Solid Dielectric	61
2.4.2	Optical Detection	62
2.4.3	Partial Breakdown Degradation Solid Dielectric	62
2.5	Electrical Tracking Breakdown (Surface Discharge)	63
2.6	Fault Detection	67
2.6.1	Balance Three Phase Fault	67
2.6.2	Unbalance Fault	68
	2.6.2.1 Line to line fault	68

2.6.2.2	Double line to ground Fault	69
2.6.2.3	Single line to ground fault	70
2.7	Photographic Observations using High Speed Camera	71
2.7.1	CMOS Image Sensor	72
2.7.2	Pixel Electronic Shutter	73
2.8	High Speed Rail	73
2.8.1	Power System High Speed Rail	74
CHAPTER 3	METHODOLOGY	76
3.1	Introduction	76
3.2	Project Methodology for Overall System	76
3.3	Gantt Chart of Project	79
3.4	High Voltage Small Kit	80
3.5	X-Viewer Software	80
3.6	High Speed Camera Chronous 1.4	80
3.7	Overall Project Flow	84
3.8	Data Measurement and Testing	85
3.9	Data analysis and result	86
3.10	Data Verification	86
3.11	Expected Result	87
3.12	Preparation Report	88

CHAPTER 4	RESULT AND DISCUSSION	89
4.1	INTRODUCTION	89
4.2	Measured waveform	89
4.3	Data Determination	90
4.3.1	Applied Voltage	90
4.3.2	Withstand Test of 36kV Rated Voltage in One Minute	94
4.3.3	Withstand Test for 70kV of Withstand Voltage in One Minute	97
4.3.4	Puncture Voltage for Breakdown Test	106
CHAPTER 5	CONCLUSION AND RECOMMENDATION	111
5.1	Introduction	111
5.2	Summary of Project	111
5.3	Achievement of Project Objective	112
5.4	Constraint While Doing Project	113
5.5	Suggestion for Future Work	113
5.6	Conclusion	114
REFERENCES	115	

LIST OF TABLES

TABLE	TITLE	PAGE
Table 3.1	: Gantt chart project for FYP 1 and FYP 2	79
Table 4.1	: Corona Activity during Positive Half-Cycle for every 20ms/div	100
Table 4.2	: Corona activity at the negative half cycle for every 20ms/div	103
Table 4.3	: Measurement of spark voltage	108

LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 1.1 :	Formation of electrical treeing adapted from	3
Figure 1.2 :	Electrical Treeing with different structure adapted from (M. Bao et al. 2011)	4
Figure 1.3 :	XLPE cable construction adapted from	5
Figure 2.1 :	Initiation of electrical tree under transportation of polarity reversal voltage adapted from (Yunxiao Zhang et al. 2017)	16
Figure 2.2 :	Partial Discharge in copper conductor adapted from (https://electrominst.com/test-technology/partial-discharge-test/partial-discharge-bad/)	18
Figure 2.3 :	Effect of mechanical strain in AC breakdown strength adapted from (E. Ildstad 1992)	21
Figure 2.4 :	Mechanical stress using Rogowski type test adapted from E. Ildstad (1992)	22
Figure 2.5 :	Mechanical stress test of cable sample adapted from E. Ildstad (1992)	23
Figure 2.6 :	Probability tree initiation and shape distribution with different stress voltage adapted from (Yunxiao Zhang et al. 2017)	24
Figure 2.7 :	Equation Electric field at the tip of needle electrode adapted from (R. Sarathi et al. 2012)	25
Figure 2.8 :	Partial Discharge at propagation tree channel adapted from (R. Vogelsang et al. 2005).	27
Figure 2.9 :	Type of Vented Trees shaped adapted from (P. Mancinelli 2017)	30

Figure 2.10 : Equation Avalanche in Townsend-like discharge adapted from (Paolo Macinelli 2017)	31
Figure 2.11 : Example of vented trees in high voltage cable adapted from (Skoršepová Terézia 2013)	33
Figure 2.12 : Cracking and crazing breakdown process adapted from (https://www.flickr.com/photos/mitopencourseware/3350795749)	35
Figure 2.13: Mechanical model initiation and growth of vented tree adapted from E Ildstad (1990).	36
Figure 2.14 : Formation of bow-tie tree adapted from Skoršepová Terézia (2013)	37
Figure 2.15 : Differences between vented tree and bow-tie tree in High voltage cable adapted from Skoršepová Terézia (2013)	38
Figure 2.16 : Ion diffusion in bow-tie tree adapted from (Takao Kumazawa 2015)	40
Figure 2.17 : Bush-type discharge character adapted from (C. Laurent and C. Mayoux 1980).	41
Figure 2.18 : Equation Measured tree length growth adapted from N. H. Malik (2006)	42
Figure 2.19: Tree length propagation with time for bush-type adapted from N. H. Malik (2006)	43
Figure 2.20 : Electrical Tree Pattern under composite voltage adapted from R. Sarathi et al. (2003)	44
Figure 2.21 : Bush-type tree adapted from R. Sarathi et al. (2015)	45
Figure 2.22 : Bush-like tree in 66kV XLPE cable insulation adapted from A. Xie et al., (2009)	46
Figure 2.23 :Propagation characteristic for Bush-like tree in 110kV XLPE cable insulator adapted from A. Xie et al. (2009)	46

Figure 2.24 : Bubble grow when the frequencies greater than 100kHz adapted from Zhang et al., (2018)	48
Figure 2.25 : Branch like tree or tree-like tree adapted from R. Sarathi and A. Nandini (2012)	50
Figure 2.26 : Fabrillar tree type adapted from R. Sarathi and A. Nandini (2012)	50
Figure 2.27 : Intrinsic tree type adapted from R. Sarathi and A. Nandini (2012)	51
Figure 2.28 : Time dependence of number of discharges per second between bush type and branched type adapted from (L. A. Dissado 2001)	52
Figure 2.29 : Initiation process of branch like tree adapted from Yunxiao Zhang et al. (2018)	54
Figure 2.30 : Branch type tree in 66kV XLPE insulation cable adapted from (A. Xie et al. 2009)	55
Figure 2.31 : Branch-vine in 66kV XLPE insulation cable adapted from (A. Xie et al. 2009)	56
Figure 2.32 : : Branch-pine type in 66kV XLPE insulation cable adapted from (A. Xie et al. 2009)	56
Figure 2.33 : Branch-bush type in 66kV XLPE insulation cable adapted from (A. Xie et al. 2009)	57
Figure 2.34 : Growth rate of branch like tree to vine like tree adapted from M. Bao et al., (2011)	58
Figure 2.35 : Vine-like tree growth under a) 5 kV,10 kHz,1 mm, (b) 5 kV, 5 kHz,1 mm, and (c) 7 kV, 4 kHz, 2 mm respectively adapted from M. Bao et al. (2011)	58
Figure 2.36 : Vine like tree formation under lower frequency adapted from M. Bao et al. (2011)	59

Figure 2.37 : Variation of breakdown strength related with time elapsed due to applied voltage adapted from (Benha University 2014)	62
Figure 2.38 : a) Dry band discharge b) Tracking signal adapted from (V. Rajini et al 2004)	64
Figure 2.39 : Stable streamer of surface breakdown as well as leader corona adapted from Ravindra Arora and Wolfgang Mosch (2011)	65
Figure 2.40 : Equation Dissociation energy of all the bonds adapted from Ravindra Arora and Wolfgang Mosch (2011)	66
Figure 2.41 : Line to Line fault adapted from (https://circuitglobe.com/line-to-line-fault.html)	69
Figure 2.42 : Double Line to Ground Fault adapted from (https://www.chegg.com/homework-help/definitions/unsymmetrical-faults-and-symmetrical-components-4)	69
Figure 2.43 : Single line to ground Current waveform using Fuzzy-Neuro for transmission line protection adapted from H. Wang and W. W. L. Keerthipala (1998)	70
Figure 2.44 : Single line to ground fault model adapted from M.C. Rodríguez Paz et al. (2010)	71
Figure 3.1 : Flow process of the project methodology	78
Figure 3.2 : : Kron Technologies Chronous 1.4 High Speed Camera	81
Figure 3.3 : Chronous 1.4 specification	82
Figure 3.4 : Geometry Drawing for Chronous 1.4 a) Top view b) Front view c) Side view	83
Figure 3.5 : Overall Project Flow	85
Figure 3.6 : Pico Scope Oscilloscope	86

Figure 4.1 : Data taken using Lecroy HDO4024	90
Figure 4.2 : Initiation stage before ionization	91
Figure 4.3 : AC Hipot Test Equipment	91
Figure 4.4 : Initiation of treeing and tracking profile	92
Figure 4.5 : Initiation of corona activity for every 260ns/div	93
Figure 4.6 : Initiation of corona activity via High Speed Camera	94
Figure 4.7 : Lab Kit Software for Injection Voltage 36kV	95
Figure 4.8 : Measure output waveform during withstand voltage 36kV in one minute	96
Figure 4.9 : Photographic observation during 36kV	97
Figure 4.10 : Equation Withstand Voltage	98
Figure 4.11 : Puncture Voltage of 70kV using Lab Kit Software	98
Figure 4.12 : Output waveform of Withstand Voltage 70kV in one minute for every 20ms/div	99
Figure 4.13 :Equation RMS Voltage EQUation	100
Figure 4.14 : Graph of Phase versus Duration Corona Activity for every 20ms/div	102
Figure 4.15 : Graph of Relationship between phase and peak voltage of corona activity for every 20ms/div during Withstand Test within one minute	103
Figure 4.16: Relationship between phase and Duration of corona activity at negative half cycle for every 20ms/div during Withstand Test within one minute	105
Figure 4.17 : : Relationship between phase and highest peak value of Corona Activity at the negative half cycle for every 20ms/div during Withstand Test 70kV in One minute	105

Figure 4.18 : Photographic observation of branching treeing structure around the ball pin of disc insulator	106
Figure 4.19 : Contamination of dirt at the insulator	107
Figure 4.20 : Output waveform of corona activity between 73kV to 76kV before breakdown occur.	108
Figure 4.21 : Graph for relationship between duration of treeing formation for each puncture voltage with the highest peak voltage until breakdown	109
Figure 4.22 : Branch-bush tree structure at the insulator	110
Figure 4.23 : Bush tree structure	110

LIST OF SYMBOLS

E_{max}	-	Electric field
r	-	weighted mean average of tip radius of curvature of the needle electrode
d	-	insulation thickness from the needle tip to the center
U	-	Applied Voltage magnitude
N	-	Negative ions in the avalanche
x	-	Distance from avalanche starting point
α	-	Townsend ionization coefficient
$L(t)$	-	Tree length growth
L_m	-	Maximum or final tree branch length
$t - t_1$	-	Period followed the inception at t_1
τ_e	-	Time constant
T_c	-	breaking produce free carbon
T_m	-	Total bond energy of the molecules

LIST OF ABBREVIATIONS

PD	Partial Discharge
FTK	Fakulti Teknologi Kejuruteraan
UTeM	Universiti Teknikal Malaysia