

STUDY ON THE PERFORMANCE OF UNDERGROUND XLPE CABLES IN
SERVICE BASED ON TAN DELTA AND CAPACITANCE PARAMETERS

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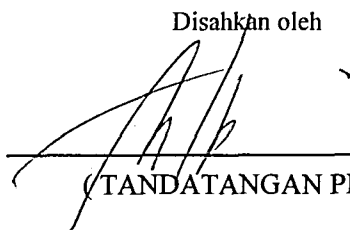
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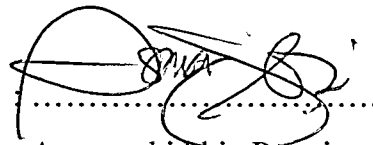
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Faculty of Electrical Engineering
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MARCH 2005

I declare that this thesis entitled “Study on The Performance of Underground XLPE Cables in Service Based on Tan Delta and Capacitance Parameters” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature

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Date

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To my Beloved

Wife

Siti Noraidah binti Mohamed

Parents

Ponniran bin Semat and Ruhinah binti Surif

Brothers

Asmarizal

Mohd. Saiful

Mohd. Ridzuan

Hairul Amin

For Their

Love, Encouragement, Sacrifice, and Best Wishes

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ABSTRACT

By the rapid of urban growth, it is impossible to accommodate the number and size of feeder required for distribution using the overhead line system approach. As an alternative the underground cables becomes more increasingly necessary to replace some of the overhead line for power transmission and distribution. Because of that reason, underground XLPE cables are the most popular for the underground systems. Performance of underground cables in service is being critical because of ageing mechanisms influences. There are many suitable techniques can be used to evaluate performance of aged and unaged underground cables. One of the techniques is based on tan delta and capacitance parameters of underground cables. This study only focuses on underground XLPE cables, which are voltage rated at 11kV and 22kV for 1-core and 3-cores types. By using Tettex Instruments – Schering Bridge Model 2816, tan delta and capacitance data of XLPE underground cables are obtained. Tan delta and capacitance measurements were performed at ambient temperature (26.6°C) and at power frequency (50 Hz). From these analyses, show that tan delta values will be increased proportional with aging time of cables in service. Aging mechanisms are contributes these deteriorations of cables in service and consequently values of tan delta are increased with aging time of cable. Meanwhile, form capacitance analysis, the values of capacitance will be increased when contaminants, protrusions and voids are affected cables insulation and when moisture enters inside underground cable systems.

ABSTRAK

Pembangunan yang pesat terutamanya di kawasan bandar menyebabkan penghantaran bekalan elektrik menggunakan sistem talian atas adalah mustahil dan kurang sesuai. Sebagai gantinya, sistem bawah tanah sangat diperlukan bagi menggantikan sistem talian atas untuk penghantaran dan pengedaran bekalan elektrik. Atas sebab tersebut, kabel XLPE bawah tanah telah meluas digunakan didalam sistem bawah tanah. Prestasi kabel bawah tanah dalam perkhidmatan menjadi kritikal disebabkan pengaruh mekanisma-mekanisma penuaan. Terdapat beberapa teknik yang sesuai dan boleh digunakan bagi menilai prestasi kabel bawah tanah. Salah satu daripadanya adalah berdasarkan parameter tan delta dan kemuatan kabel tersebut. Kajian ini hanya memfokuskan kabel XLPE bawah tanah bagi kadar voltan 11 kV dan 22 kV serta jenis 1 teras dan 3 teras. Dengan menggunakan peralatan Tettex Instruments – Schering Bridge Model 2816, data tan delta dan kemuatan kabel XLPE bawah tanah telah diperolehi. Daripada analisis ini, menunjukkan bahawa nilai tan delta akan meningkat berkadar dengan tempoh masa kabel dalam perkhidmatan. Mekanisma-mekanisma penuaan telah menyumbang dengan tinggi ke arah penurunan prestasi kabel dalam perkhidmatan dan sebagai akibatnya nilai tan delta meningkat mengikut tempoh kabel dalam perkhidmatan. Manakala daripada analisis kemuatan, nilai kemuatan kabel akan meningkat apabila *contaminants*, *protrusions* dan *voids* menjejaskan penebatan kabel dan apabila kelembahan memasuki sistem kabel bawah tanah.

CONTENTS

CHAPTER	TITLE	PAGE
	TITLE	i
	DECLARATION	ii
	DEDICATIONS	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	CONTENTS	vii
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
	LIST OF GRAPH	xiv
	LIST OF SYMBOLS	xvi
	LIST OF APPENDICES	xviii
I	INTRODUCTION	
	1.0 Introduction	1
	1.1 Background Study	2
	1.2 Objectives	3
	1.3 Scopes	4
	1.5 Expected Results	4

II LITERATURE REVIEW

2.0	Introduction	5
2.1	Aging Process of Underground Cable	6
2.2	Studies of $\tan \delta$ and Others Parameters to Investigate Cable Behaviors	9
2.3	XLPE Cable Joints and Termination	12
2.4	Other Effects is deteriorated XLPE Cable Performance	13
2.5	Conclusion	14

III DIAGNOSTICS IN EXTRUDED INSULATIONS FOR POWER CABLES

3.0	Introduction	16
3.1	Ageing Mechanisms	18
	3.1.1 Wet Aging Mechanisms	19
	3.1.2 Dry Ageing Mechanisms	22
3.2	Diagnostic Techniques	27
	3.2.1 Diagnostic Techniques for Medium-Voltage Cables	30
	3.2.2 DC Depolarization Current	32
	3.2.3 Tan Delta	33
	3.2.4 AC Conduction Current	36
	3.2.5 Low Frequency Measurements	36
3.3	Conclusion	39

IV PRINCIPLES OF TAN DELTA AND CAPACITANCE OF CABLES

4.0	Introduction	40
4.1	General Concept of Dissipation Factor ($\tan \delta$)	41
4.1.1	Parallel Model	42
4.1.2	Series Model	43
4.2	Principle Measurement of $\tan \delta$	45
4.2.1	General Principle of Schering Bridge	47
4.3	Dissipation Factor ($\tan \delta$) of a Cable	49
4.4	Bridge Techniques for the Measurement of $\tan \delta$ of Cable	54
4.5	Capacitance of Underground Cables Insulation	58
4.6	Conclusion	61

V METHODOLOGY

5.0	Introduction	62
5.1	Measurement Setup	64
5.2	Data from Measurement	67
5.3	Conclusion	67

VI RESULTS, ANALYSIS AND DISCUSSIONS

6.0	Introduction	68
6.1	Tan δ Analysis and Discussion	68
6.2	Capacitance Analysis and Discussion	81
6.3	Power Loss in XLPE Insulator Cables for Medium Voltage	91
6.4	Conclusion	93

V CONCLUSION AND SUGGESTION

7.0	Conclusions	94
7.1	Suggestions for Future Work	97

LIST OF REFERENCES	98
---------------------------	-----------

APPENDICES	102 - 112
-------------------	------------------

LIST OF TABLES

TABLE NO.	TITLE	PAGE
3.1	Ageing Factors which affect Extruded Insulation Systems for Cables	20
3.2	Mean Time between Electrons for Spherical Cavities of Different Diameters	27
3.3	Diagnostic Test for Medium Voltage Cable	33
3.3	Harmonic Distortion at 0.1 and 1.0 Hz for Water Treed Cable	39

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
3.1	Wet Aging	23
3.2	Dry Aging	23
3.3	Discharge Inception Stress vs. Cavity Size	24
3.4	Discharge Magnitude vs. Cavity Diameter for 230 kV	25
3.5	DC Depolarization Currents for Wet and Dry 5 kV XLPE Cables	36
3.6	Tan Delta Vs Time for Wet and Dry 5 kV XLPE Cables	37
3.7	Capacitance and Tan Delta Vs Voltage Characteristics for Wet and Dry 5 kV Cables	37
3.8	Harmonic Component of loss current of Degraded Cable vs. Applied Voltage	40
4.10	Capacitor and phasor diagram, I (current) lead V (voltage) at θ^0 and δ is loss angle	43
4.11	Parallel $R_p C_p$ model equivalent circuit and phasor diagram	44
4.12	Series $R_s C_s$ model equivalent circuit and phasor diagram	45
4.20	General A.C. bridge circuit	48
4.21	Schering Bridge	50

4.30	Equivalent lumped-circuit of a cable	53
4.31	Phasor relationship of charging and leakage currents in cable dielectric	53
4.40	Basic Schering bridge circuit	58
4.50	Disc Capacitor	60
4.51	Capacitance arrangement of underground cable	62
4.52	Capacitor phasor diagrams	63
5.10	Measurement Setup for single core XLPE cables	68
5.11	Measurement Setup for three cores XLPE cables	68
6.10	Capacitor phasor diagrams	71
6.30	Equivalent circuit of a cable and phasor for apparent power (S), real power (P) and reactive power (Q) relations	93

LIST OF GRAPHS

GRAPH NO.	TITLE	PAGE
6.10	Tan δ against U test voltage for twelve samples of XLPE cables	73
6.11	Tan δ against U test voltage for cable 3	76
6.12	Tan δ against U test voltage for cable 4	77
6.13	Tan δ against U test voltage for cable 6	77
6.14	Tan δ against U test voltage for cable 7	78
6.15	Tan δ against U test voltage for cables 11	78
6.16	Tan δ against U test voltage for cables 10	79
6.17	Tan δ against U test voltage for cables 1, 2 and 5	79
6.18	Tan δ against U test voltage for cables 8	80
6.19	Tan δ against U test voltage for cables 12	81
6.20	Capacitance against U test voltage for twelve samples of XLPE cables	85
6.21	Capacitance against U test voltage for cables 1,2 and 5	87
6.22	Capacitance against U test voltage for cable 7	87
6.23	Capacitance against U test voltage for cable 12	88

6.24	Capacitance against U test voltage for cable 9	90
6.25	Capacitance against U test voltage for cable 3	91
6.26	Capacitance against U test voltage for cable 4	91
6.27	Capacitance against U test voltage for cable 6	92

LIST OF SYMBOLS AND ABBREVIATIONS

XLPE	-	Cross-linked Polyethylene
LDPE	-	Density Polyethylene
TRXLPE	-	Tree-retardant Cross-linked Polyethylene
EPR	-	Ethylene Propylene Rubber
WTR	-	Water Tree Retardant
IEC	-	International Electrotechnical Commission
TNB	-	Tenaga Nasional Berhad
TNBD	-	Tenaga Nasional Berhad – Distribution
VLF	-	Very Low Frequency
U_0	-	Rated power frequency voltage between conductor and earth or metallic screen for which the cable is designed
AC	-	Alternating Current
DC	-	Direct Current
rms	-	root-mean-square
R	-	Resistor
C	-	Capacitor
Z	-	Impedance
Y	-	Admittance
$\tan \delta$	-	Dissipation factor of cable insulator
δ	-	Loss angle
θ	-	Phase angle
PD	-	Partial discharge

DR	-	Dielectric response
ϵ	-	Real permittivity
ϵ''	-	Imaginary permittivity
ϵ_0	-	Permittivity in vacuum
ϵ_r	-	Relative permittivity or Dielectric constant
SIC	-	Maximum permittivity
σ	-	Conductivity
CPV	-	Contaminants, Protrusions or Voids

LIST OF APPENDICES

APPENDICES	TITLE	PAGE
A	Tettex Instruments – Schering Bridge Model 2816 with automatic guard potential regulator	102
B	Data of cable samples from measurements	103
C	Comparison of Capacitance values from Measurement and Calculation	108

CHAPTER 1

INTRODUCTION

1.0 Introduction

By the rapid of urban growth, it is impossible to accommodate the number and size of feeder required for distribution using the overhead line system approach. As an alternative the underground cables becomes more increasingly necessary to replace some of the overhead line for power transmission and distribution. Many cities in the world are practicing to apply this trend.

Power cable technology had its beginnings in the 1880s when the need for power distribution cables became important [1]. Some of the earliest power cables consisted merely of duct with the copper conductors insulated from ground by glass or porcelain insulators. Some of the more common early solid and liquid insulating materials employed in various underground cable installations were natural rubber, gutta-percha, oil and wax, rosin and asphalt, jute, hemp and cotton. First oil-impregnated-paper power cable was introduced in 1890 and that cables was installed in

London in 1891 for 10kV operation. After that, many researches had been done to find alternative insulations which are provided more good characteristics of dielectric.

In the late 1960s power distribution cables insulated with cross-linked polyethylene (XLPE) began making their appearance in Canada and United State in 1965 [1]. Cables insulated with XLPE presently dominate the distribution cable field in North America, Japan and Northern Europe. After that, Cross linked Polyethylene (XLPE) has been used over the world as electrical insulating material in underground distribution and transmission class cables because of their excellent dielectric strength, low dielectric permittivity and loss factor, good dimensional stability, solvent resistance and good thermo-mechanical behavior.

1.1 Background Study

Underground power distribution system is become more important in Malaysia environment especially in urban area. Because of that, more electricity power is needed to supply those facilities in compact urban area. Therefore, that underground electrical supply system is most important to apply. Underground XLPE insulators cables are widely used for underground cables system especially in urban or compact area with many of facilities are provided. Even though underground XLPE cables provided excellent dielectric strength, low dielectric permittivity and loss factor, good dimensional stability, solvent resistance and good thermo-mechanical behavior,