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

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

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Date : 24 March 2005

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

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

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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.

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Date : 24 March 2005

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 at11kV 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 menggunkan 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 berkadaran 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 analysis kemuatan, nilai kemuatan kabel akan meningkat apabila *contaminants, protrusions* dan *voids* menjejaskan penebatan kabel dan apabila kelembahan memasuki sistem kabel bawah tanah.

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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_o	-	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

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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,