UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electronic and Computer Engineering

STUDY AND ANALYSIS OF POWER ATTENUATION DUE TO OPTICAL BEND LOSS IN OPGW OVERHEAD TRANSMISSION IN MALAYSIA

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MSc. in Electronic Engineering

2016

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A thesis submitted
in fulfillment of requirements for the degree of Master of Science
in Electronic Engineering

Faculty of Electronic and Computer Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this thesis entitled "Study and Analysis of Power Attenuation Due to Optical Bend Loss in OPGW Overhead Transmission in Malaysia" 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 : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering.

Signature :..

Supervisor Name :..

Date :..

ABSTRACT

This thesis presents a study in detecting the optical fiber bending on long distance Optical Ground Wire (OPGW) using Optical Time-Domain Reflectometer (OTDR) in order to eliminate the bend loss and improve the optical power attenuation. This thesis also present the investigation and analysis of the performance and characteristic of bend loss and optical power attenuation for OPGW over a long period of time as well as to validate the impact of bend loss on optical fiber attenuation through experimental works on site. Bending fiber optic is important to be detected because a fiber optic that has a bending radius smaller than its critical radius will attenuate optical power and cause the data sent through the fiber optic to be partially lost or totally lost. The study involved the process of collecting optical fiber data that provided by Tenaga Nasional Berhad (TNB) for a period of 10 months. This research is the first effort of its kind where data from actual OPGW are collected and presented to the public. All data were obtained from the existing 54.554 km OPGW laid from Main Substation 275kV Batu Pahat Timur (BPHE) to Main Substation 275kV Yong Peng Utara (YGPN). Two different data sets were obtained from this optical fiber, which are optical power attenuation and point of optical power loss, using the Power Meter test and OTDR test respectively. The analysis study is presented in this thesis and the study to detect the presence of bending optical fiber involves several processes, such as measuring the optical power attenuation, detecting the point of optical power loss and comparing the loss value of different wavelengths, 1310 nm and 1550 nm. In this thesis, the study on bend losses and power attenuation of optical fiber led to the discovery of the relationship between bend losses due to the bending of optical fiber, with the attenuation of fiber. From the experiment designed in this study, the effects of permanent bending on loss and attenuation is discovered as well as the discovery that the bending of optical fiber can occur naturally over time and the value of losses are varied with significant effects when the level of wavelength increased. From the analysis, the location of the bending fiber optic is identified and it is found that the actual location of bending optical fiber is in agreement with the analysis result. Once the location of the bending fiber optic have been found, the bending optical fiber is then released to observe the effect of that bending on optical power loss. The main benefit of this study is that the location of the bending fiber optic can be detected using OTDR and the ability to compare wavelengths at a particular point. The results also found that the quality of optical fiber decreases at 0.19 dB for 1310 nm and 4.85 dB for 1550 nm after a period of monitoring due to bending that occurs naturally but fortunately, it does not give a permanent effect at the point bending where after rectification, the quality has improved at 0.49 dB for 1310 nm and 7.17 dB for 1550 nm. It is also found that bend loss kept occurring and scattered at several points. This study of detecting bending fiber optic is suitable and an alternative solution to overcome the problem of reduced fiber optic performance for long distance fiber optic cable in a long period of time.

ABSTRAK

Tesis ini mencadangkan kajian bagi mengesan gentian kaca yang bengkok pada Wayar Bumi Bercahaya (OPGW) dengan menggunakan Pengukur Bayang Cahaya Masa Terkawal (OTDR) bagi menghapuskan kehilangan bengkok dan pelemahan kuasa cahaya bagi OPGW bagi satu jangka masa yang panjang dan juga untuk mengesahkan kesan kehilangan bengkok pada pelemahan kuasa cahaya melalui ujikaji di lapangan. Gentian kaca yang bengkok penting untuk dikesan kerana gentian kaca yang memiliki jejari bengkok lebih kecil dari jejari kritikal akan melemahkan kuasa cahaya dan menyebabkan maklumat yang dihantar melalui gentian kaca akan separa hilang atau hilang keseluruhannya. Kajian melibatka proses mengumpul maklumat gentian kaca yang disediakan oleh Tenaga Nasional Berhad (TNB) bagi tempoh 10 bulan. Kajian ini merupakan usaha yang pertama di mana maklumat sebenar OPGW dikumpul dan dipersembahkan kepada umum. Semua maklumat diperoleh dari OPGW sediada sepanjang 55.554km yang menyambungkan Pencawang Masuk Utama 275kV Batu Pahat Timur (BPHE) dan Pencawang Masuk Utama 275kV Yong Peng Utara (YGPN). Dua set maklumat yang berbeza diperoleh dari gentian kaca ini iaitu pelemahan kuasa cahaya dan titik kehilangan kuasa cahaya masing-masing dari ujian pengukur kuasa dan ujian OTDR. Kajian analisis dipersembahkan dalam tesis ini dan kajian untuk mengesan kewujudan gentian kaca yang bengkok yang melibatkan beberapa proses seperti mengukur pelemahan kuasa cahaya kaca, mengesan titik kehilangan kuasa cahaya dan membandingkan nilai kehilangan bagi panjang gelombang yang berbeza, 1310 nm dan 1550 nm. Dalam tesis ini, kajian pada kehilangan bengkok dan pelemahan kuasa bagi gentian kaca membawa kepada penemuan tentang hubungan antara kehilangan kuasa akibat gentian kaca yang bengkok dengan pelemahan bagi gentian. Dari ujian yang dirangka dalam kajian ini, kesan kekal bagi pembengkokan pada kehilangan dan pelemahan telah ditemui, begitu juga penemuan bahawa bengkokan gentian kaca boleh berlaku secara alami sepanjang masa dan nilai kehilangan berubah-ubah dengan kesan yang ketara apabila panjang gelombang meningkat. Setelah lokasi gentian kaca yang bengkok ditemui, bengkokan akan dilepaskan bagi melihat kesan bengkokan pada kehilangan kuasa cahaya. Faedah utama kajian ini ialah lokasi gentian kaca bengkok boleh dikesan menggunakan OTDR dan kebolehan untuk membandingkan panjang gelombang di titik tertentu. Keputusan juga mendapati bahawa kualit gentian kaca menurun sebanyak 0.19 dB bagi 1310 nm dan 4.85 dB bagi 1550 nm sepanjang tempoh pemerhatian akibat bengkokan yang terjadi secara alami, namun ianya tidak memberikan kesan kekal pada tempat bengkokan di mana selepas pembaikan, kualiti meningkat pada 0.49 dB bagi 1310 nm dan 7.17 dB bagi 1550 nm. Juga ditemui bahawa kehilangan bengkok sentiasa terjadi dan bersepah di mana-mana tempat. Kajian mengesan bengkokan gentian kaca ini sesuai dan merupakan penyelesaian pilihan bagi mengatasi masalah penurunan prestasi gentian kaca yang panjang bagi tempoh masa yang lama.

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Associate Professor Dr. Zahriladha Bin Zakaria from the Faculty of Electronic and Computer Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this thesis.

Special thanks to all my peers, my beloved mother, beloved father and siblings for their moral support in completing this degree. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

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LIST OF ABBREVIATION

PMU	-	Pencawang Masuk Utama
ADSS	-	All-Dielectric Self-Supporting
OPGW	-	Optical Ground Wire
DWDM	-	Dense Wavelength-Division Multiplexing
OTDR	-	Optical Time-Domain Reflectometer
MFD	-	Mode Field Diameter
EFL	-	Excess Fibre Length
ACSR	-	Aluminium-Conductor Steel-Reinforced
CLE	-	Coefficient of Linear Expansion
IOR	-	Index of Refraction
PMD	-	Polarization Mode Dispersion
CWDM	-	Corse Wavelength Division Multiplexing
LAN	-	Local Area Network
ORL	-	Optical Return Loss
WDM	-	Wavelength-Division Multiplexing
SMF	-	Single Mode Fiber
FOA	-	Optical Fiber Association
WG	-	Whispering Gallery
TNB	-	Tenaga Nasional Berhad
MAL	-	Maximum Allowable Loss
NM	-	Nanometer
DB	-	Decibel

LIST OF SYMBOLS

N	-	number of flashes/100 km/year
N_g	-	ground flash density (flashes per km^2 per year)
H_t	-	the height of the OPGW at the tower
B	-	the OPGW separation in m
$P_{(0)}$	-	optical power
$P_{(z)}$	-	output power
z	-	distance of light propagates
α_{total}	-	total attenuation coefficient including all contributions to attenuation
%T	-	percentage optical power transmission
n*	-	complex refractive index
n(ω)	-	real portion of the refractive index
κ(ω)	-	extinction coefficient
α(ω)	-	absorption coefficient
c	-	speed of light
dB	-	decibel
λ	-	wavelength
n_1	-	refractive index of the scattering center
n_o	-	refractive index of the scattering medium
β	-	isothermal compressibility of the medium
k	-	Boltzman's constant
T_f	-	fictive temperature of glass
P_{core}	-	fractional power carried in the core

P_{clad}/P	-	fractional power carried in the cladding
P	-	total power transmitted.
α_1	-	attenuation coefficients for the core
α_2	-	attenuation coefficients for the cladding
α	-	Cable Loss (dB/km)
d	-	Cable Distance (km)
β	-	Splice Loss (dB)
η_1	-	No. Of splices/Joints
c	-	Connector loss (dB)
η_2	-	No. Of Connector
w	-	pulse width in units of time
n	-	group index of refraction of the fibre
h	-	Planck's constant
f	-	frequency of the wave
N_∞	-	number of modes supported in a straight fiber
Δ	-	core-cladding index difference
R	-	radius of curvature of the bend
R_c	-	critical radius of bending
J_1	-	Bessel function of first order
R_{eff}	-	effective bending radius
α_T	-	thermal expansion coefficient
β_T	-	thermo-optic coefficient
l	-	length
$\partial\emptyset/\partial T$	-	temperature coefficient of optical phase

LIST OF PUBLICATIONS

Journal :

2015

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CHAPTER 1

INTRODUCTION

1.0 Background

Electric utility companies currently use fiber optics as their medium of communication for protection system of their high voltage transmission lines between two substations. In Malaysia, these substations are known as Pencawang Masuk Utama (PMU) and are widely spread all over Peninsular Malaysia and are connected in a grid. There are two types of fiber cable widely used and installed on high voltage transmission line towers: All-Dielectric Self-Supporting (ADSS) and Optical Ground Wire (OPGW). Even though the main function of these two cables is the same, which is to provide fiber optic for communication purpose, OPGW is always considered as the most preferred cable because it also functions as a grounding wire, a protection of conductor from lightning and is short-circuited. OPGW cables have been tested several times for its reliability and strength. OPGW cables will only be installed at the top of the transmission tower once it has satisfied and passed the entire compulsory tests required by IEEE Standards. Figure 1.1 shows the illustration of fiber optic cable installed on high voltage transmission towers.

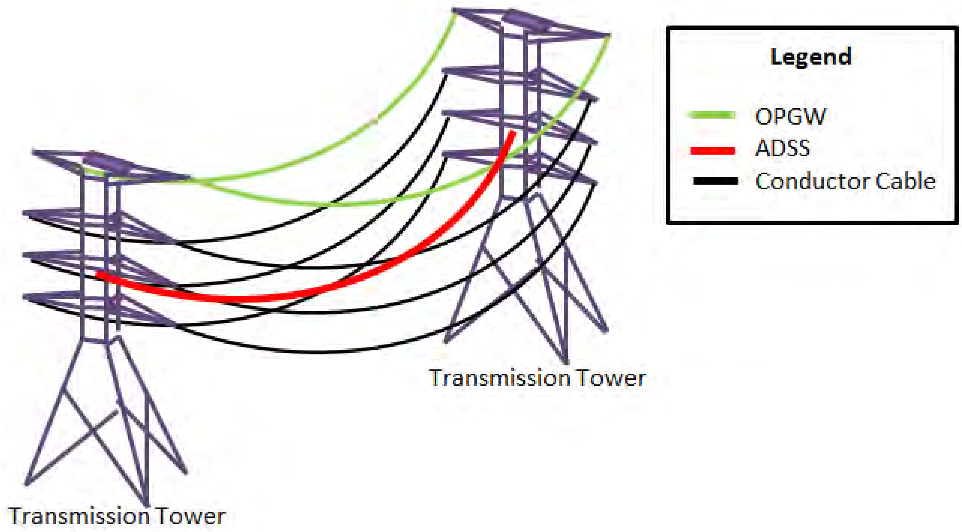

Figure 1.1 : Position of OPGW and ADSS cable respectively on HV Transmission tower

In current practice, the focus of telecommunication companies is to obtain the most perfect fiber optic with the lowest attenuation and the utility company will give any core without taking into account the degrading factor since they have a lot of dark fibers. As the demand for dark fibers belonging to the utility company increases rapidly, every single fiber optic is now becoming valuable. This research has discovered the factors that contribute to the high attenuation of fiber optic and this will help the utility company to address the attenuation problem.

Fiber optic cable will be bent along the link either for being pulled down for termination, bending inside trenches or bending at the splicing point. All these bending of cables have the potential to introduce loss. For example, in Figure 1.3, the cable is bent at the top of tower.

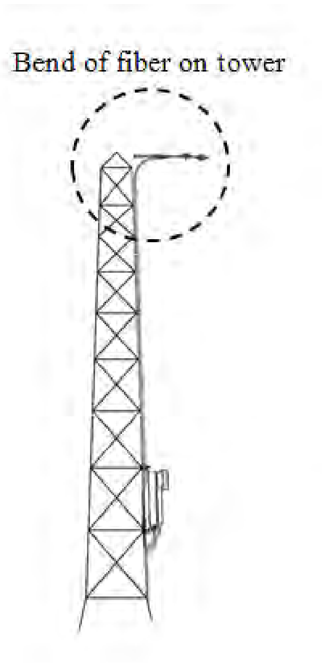

Figure 1.2 : Bending of cable on transmission tower

In Figure 1.3, the bending of cable is purposely done to land the cable either for jointing or termination point. Usually, this bending will not give so much effect on the attenuation as the radius of bending will be large enough. This is similar to the bending of cable inside the trench as shown in Figure 1.4, where this position of bending will not allow the optical fiber to have too small radius as the outer layer of the cable will prevent that from happening.

Figure 1.3 : Cable inside trench (FOA, 2014)