



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

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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 melibatkan 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 diperolehi dari OPGW sediada sepanjang 55.554km yang menyambungkan Pencawang Masuk Utama 275kV Batu Pahat Timur (BPHE) dan Pencawang Masuk Utama 275kV Yong Peng Utara (YGPNU). Dua set maklumat yang berbeza diperolehi 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 dirancang 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 kualiti 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.*

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## TABLE OF CONTENTS

	PAGE
<b>DECLARATION</b>	
<b>APPROVAL</b>	
<b>ABSTRACT</b>	<b>i</b>
<b>ABSTRAK</b>	<b>ii</b>
<b>ACKNOWLEDGMENT</b>	<b>iii</b>
<b>TABLE OF CONTENTS</b>	<b>iv</b>
<b>LIST OF TABLES</b>	<b>vii</b>
<b>LIST OF FIGURES</b>	<b>x</b>
<b>LIST OF ABBREVIATION</b>	<b>xiv</b>
<b>LIST OF SYMBOLS</b>	<b>xv</b>
<b>LIST OF PUBLICATIONS</b>	<b>xvii</b>
 <b>CHAPTER</b>	
<b>1. INTRODUCTION</b>	<b>1</b>
1.0 Background	1
1.1 Problem Statement	6
1.2 Objectives	8
1.3 Scope of Work	9
1.4 Contribution of the Thesis	9
1.5 Thesis Organization	11
 <b>2. LITERATURE REVIEW</b>	<b>13</b>
2.0 Introduction	13
2.1 Optical Ground Wire (OPGW) Cable	13
2.1.1 Basic Concept of OPGW	14
2.1.1.1 Data Transportation	15
2.1.1.2 Protection of Conductor	15
2.1.2 Advantages	16
2.1.3 Excess Fiber Length (EFL)	18
2.1.3.1 Mechanism of EFL	18
2.1.3.2 Effects of EFL	20
2.2 Optical Fibre Loss and Attenuation	20
2.2.1 Scattering Loss	22
2.2.2 Bending Loss	25
2.2.2.1 Macrobend loss	25
2.2.2.2 Microbend loss	26
2.2.3 Core and Cladding Loss	27
2.3 Loss and Attenuation Measurement	28
2.3.1 Maximum Allowable Loss Margin	28
2.3.2 Concept of Measuring Loss	29
2.3.2.1 Rayleigh Scattering Concept	30
2.3.2.2 Fresnel Reflection Concept	32
2.3.3 Measuring Attenuation	33
2.4 Light Wavelengths	34
2.4.1 Band of Wavelengths	36
2.4.2 Power	38
2.4.3 Low Water Peak of Fiber	40



2.4.4	Mode Field Diameter	41
2.5	Loss Factors for Bending Fiber	44
2.5.1	Effect of Radius	44
2.5.2	Effect of Wavelength	47
2.5.3	Effect of Temperature	49
2.6	Summary	50
<b>3</b>	<b>METHODOLOGY</b>	<b>53</b>
3.0	Introduction	53
3.1	Flow Chart of the Project	53
3.2	Experiment Background	56
3.2.1	Tower and Joint Closure Schedule	57
3.2.2	Test Apparatus	59
3.2.3	Experiment Procedure	59
3.3	Optical Fiber Performance Monitoring	60
3.3.1	Maximum Allowable Loss	60
3.3.2	Total Attenuation Margin	61
3.3.3	Loss (dB) Difference	62
3.3.4	OTDR Distance Tolerance	63
3.4	Optical Power Attenuation Measurement	64
3.4.1	Power Meter Calibration	65
3.4.2	Power Meter Test setup	66
3.5	Bend Loss Measurement and Detection	68
3.5.1	OTDR Setting	68
3.5.2	OTDR Testing Setup	69
3.5.3	Graph Observation	70
3.5.4	Event Table Analysis	71
3.5.5	Macro Bend Loss and Location	72
3.6	Verification Test	73
3.6.1	Attenuation Improvement	73
3.6.2	Bend Loss Presence	74
3.7	Summary	75
<b>4.</b>	<b>ATTENUATION MONITORING USING POWER METER</b>	<b>76</b>
4.0	Introduction	76
4.1	Results of 1310 nm Wavelength	77
4.1.1	Calibration Test of 1310 nm Wavelength Experiment	77
4.1.2	Attenuation of 1310 nm Wavelength Experiment	78
4.1.3	Loss Margin of 1310 nm Wavelength Experiment	80
4.1.4	Analysis of 1310 nm Wavelength Experiment	81
4.2	Results of 1550 nm Wavelength	83
4.2.1	Calibration Test of 1550 nm Wavelength Experiment	83
4.2.2	Attenuation of 1550 nm Wavelength Experiment	85
4.2.3	Loss Margin of 1550 nm Wavelength Experiment	87
4.2.4	Analysis of 1500 nm Wavelength Experiment	88
4.3	Discussion of Result	89
4.3.1	Attenuation: 1310 nm vs 1550 nm	90
4.3.2	Loss Margin: 1310 nm vs 1550 nm	91
4.4	Results of Verification Test	93

4.4.1	Calibration Test of Verification Experiment	93
4.4.2	Attenuation of Verification Experiment	94
4.4.3	Loss Margin of Verification Experiment	95
4.4.4	Analysis of Verification Experiment	96
4.5	Summary	97
<b>5.</b>	<b>BEND LOSS MONITORING USING OTDR</b>	<b>99</b>
5.0	Introduction	99
5.1	Results of 1310 nm Wavelength	100
5.1.1	Graph Observation of 1310 nm Wavelength	100
5.1.2	Event Table of 1310 nm Wavelength	102
5.1.3	Analysis of 1310 nm Wavelength	105
5.2	Results of 1550 nm Wavelength	106
5.2.1	Graph Observation of 1550 nm Wavelength	106
5.2.2	Event Table of 1550 nm Wavelength	108
5.2.3	Analysis of 1550 nm Wavelength	111
5.3	Bend Loss Detection	112
5.3.1	Graph Comparison	112
5.3.2	Point Loss Margin	113
5.4	Bend Loss Location	117
5.5	Results of Observation	118
5.5.1	Bending Optical Fiber	119
5.5.2	Bend Radius Measurement	121
5.5.3	Rectification	123
5.6	Results of Verification Test	124
5.6.1	Graph Observation of Verification Experiment	125
5.6.2	Event Table of Verification Experiment	126
5.6.3	Analysis of Verification Experiment	127
5.7	Discussion of Result	129
5.7.1	Attenuation Performance	129
5.7.2	Bend Loss Performance	130
5.7.3	Permanency of Bend Optical Fiber	131
5.8	Summary	133
<b>6.</b>	<b>CONCLUSION AND FUTURE WORK</b>	<b>134</b>
6.0	Conclusion	134
6.1	Future Work	137
	<b>REFERENCES</b>	<b>140</b>

## LIST OF TABLES

TABLE	TITLE	PAGE
2.1	DWDM Band Wavelength Range (FOA, 2010)	37
2.2	Summary of Critical Literature Review	50
3.1	Information of OPGW	57
3.2	Joint closure schedule	58
3.3	Tool sets	59
3.4	Date of each Experiment	59
3.5	Test Setup	61
3.6	Margin tolerance calculation	64
3.7	Optical Power Parameters	65
3.8	Result of calibration using 1310 nm	66
3.9	Bend Loss Parameters	68
3.10	Parameters of Experiment	68
4.1	Date of Power Meter Test	76
4.2	Result of calibration of Test 1	77
4.3	Result of calibration of Test 2	78
4.4	Result of calibration of Test 3	78
4.5	Attenuation result of Test 1 using 1310 nm	79
4.6	Attenuation result of Test 2 using 1310 nm	79
4.7	Attenuation result of Test 3 using 1310 nm	79
4.8	Loss margin of Test 1 for 1310 nm	80

4.9	Loss margin of Test 2 for 1310 nm	80
4.10	Loss margin of Test 3 for 1310 nm	81
4.11	Trend of attenuation using 1310 nm	81
4.12	Result of calibration using 1550 nm Test 1	84
4.13	Result of calibration using 1550 nm Test 2	84
4.14	Result of calibration using 1550 nm Test 3	85
4.15	Result of Test 1 using 1550 nm	86
4.16	Result of Test 2 using 1550 nm	86
4.17	Result of Test 3 using 1550 nm	86
4.18	Loss margin of Test 1 for 1550 nm	87
4.19	Loss margin of Test 2 for 1550 nm	87
4.20	Loss margin of Test 3 for 1550 nm	88
4.21	Trend of attenuation using 1550 nm	88
4.22	Loss margin for all samples	91
4.23	Result of calibration of 1310 nm wavelength	93
4.24	Result of calibration of 1550 nm wavelength	94
4.25	Attenuation result of Verification Test using 1310 nm	94
4.26	Attenuation result of Verification Test using 1550 nm	95
4.27	Result of loss margin for 1310 nm	95
4.28	Result of loss margin for 1550 nm	96
4.29	Attenuation comparison of 1310 nm	96
4.30	Attenuation comparison of 1550 nm	97
5.1	Date of OTDR Test	99
5.2	Event Table of 1310 nm for Test 1	103
5.3	Event Table of 1310 nm for Test 2	104

5.4	Event Table of 1310 nm for Test 3	104
5.5	1310 nm attenuation and loss relationship	105
5.6	Event Table of 1550 nm for Test 1	109
5.7	Event Table of 1550 nm for Test 2	110
5.8	Event Table of 1550 nm for Test 3	110
5.9	1550 nm attenuation and loss relationship	111
5.10	1310 nm and 1550 nm for Sample 1	114
5.11	Point of bend loss for Test 1	115
5.12	Point of bend loss for Test 2	116
5.13	Point of bend loss for Test 3	116
5.14	Tower schedule analysis	117
5.15	Point 2 and Point 3 distance analysis	118
5.16	Location of observation	119
5.17	Measurements of bending radius	123
5.18	Point of bend loss for verification test	127
5.19	Attenuation and bend loss relationship	130

## LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Position of OPGW and ADSS cable respectively on HV Transmission tower	2
1.2	Bending of cable on transmission tower	3
1.3	Cable inside trench	3
1.4	Extra cable turned in circle	4
1.5	Bending of optical fiber inside joint closure	4
1.6	Macro bend loss and location detection.	5
1.7	New route with longer distance, $D_2 > D_1$ by patching the fibers at PMU C	7
2.1	Construction of Optical Ground Wire (FOA, 2014)	14
2.2	Helix design of fiber inside the tube	19
2.3	Illustration of light scattering (Kumar, 2009)	23
2.4	Illustration of Rayleigh Scattering.	24
2.5	Sketch of the fundamental mode filed in a curved optical waveguide	26
2.6	Microbending losses arising from small-scale fluctuations in the radius of curvature of the fiber axis.	27
2.7	Determination of ORL value of a reflection feature using an OTDR measurement trace.	31

2.8	Illustration of Fresnel Reflection	32
2.9	Different wavelengths on bending fibre	35
2.10	Relationship of photon energy and wavelength using Planck's equation (Ryer, 1998).	39
2.11	Power attenuated due to bending. (a) without bending (b) with bending (Yu Zhi and Wang Hong, 2012)	39
2.12	Graph of Water Peak (Lietaert, 2009)	40
2.13	The relationship between light and MFD (JDSU, 2007)	41
2.14	1310 nm vs. 1550 nm on diameter of bend (JDSU, 2007)	43
2.15	The different of loss according to bending radius (a) 5 mm (b) 8 mm. (Yu Zhi and Wang Hong, 2012)	45
2.16	Variation of loss against radius of curvature, R. (Zendehnam, et. al., 2010)	46
2.17	Bend loss and exponential interpolation. The vertical bars are defined by the interpolated value, $\pm 50\%$ (Cattelan, et. al., 2009)	47
2.18	Loss sensitivity on wavelength (Wang, et. al., 2006)	48
3.1	Flow Chart of Project	54
3.2	Loss different between 1310 nm and 1550 nm wavelength on bend diameter (JDSU, 2007)	63
3.3	Calibration setup of Power Meter	65
3.4	Power Meter setup for experiment	67
3.5	OTDR testing setup for experiment	69
3.6	Display of OTDR for Two Wavelengths	70
3.7	Macro bend captured by 1550 nm	71
3.8	Event Table of 1310 nm	71

3.9	Event Table of 1550 nm	72
4.1	Trend of samples mean attenuation (1310 nm) in ten months	82
4.2	Trend of samples mean attenuation (1550 nm) in ten months	89
4.3	The comparison of pattern of attenuation 1310 nm and 1550 nm	90
4.4	The total loss margin for 1310 nm and 1550 nm wavelength	92
5.1	1310 nm wavelength traces of Test 1	101
5.2	1310 nm wavelength traces of Test 2	101
5.3	1310 nm wavelength traces of Test 3	102
5.4	1550 nm wavelength traces of Test 1	106
5.5	1550 nm wavelength traces of Test 2	107
5.6	1550 nm wavelength traces of Test 3	107
5.7	Comparison of trace of 1310 nm and 1550 nm for sample 1	112
5.8	Bend inside JC8 at T53 of Location 1	119
5.9	Bend inside JC10 at T61 of Location 2	120
5.10	Bend inside JC12 at T81 of Location 3	120
5.11	Bend inside J21 at T144 of Location 5	121
5.12	Three bending found at Location 1	122
5.13	Three bending found at Location 2	122
5.14	Three bending found at Location 3	122
5.15	Three bending found at Location 5	123
5.16	Re-arrangement of fiber with appropriate bending	124
5.17	1310 nm wavelength traces of Verification Test	125
5.18	1550 nm wavelength traces of Verification Test	126
5.19	Comparison sample 1 of Test 3 and Verification Test 1310 nm	128
5.20	Comparison sample 1 of Test 3 and Verification Test 1550 nm	128



5.21	Comparison of 1310 nm and 1550 nm wavelength of verification test	129
5.22	Observation on 1310 nm traces of Test 3 and Verification Test at Location 1	132
5.23	Observation on 1550 nm traces of Test 3 and Verification Test at Location 1	132
6.1	Illustration of relationship between two different tools	137
6.2	Illustration of effect of bend loss to next bend loss	138
6.3	Illustration of the permanency effect test	139

## 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	-	Coarse 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 <sup>2</sup> 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
$\alpha_{\text{total}}$	-	total attenuation coefficient including all contributions to attenuation
%T	-	percentage optical power transmission
$n^*$	-	complex refractive index
$n(\omega)$	-	real portion of the refractive index
$\kappa(\omega)$	-	extinction coefficient
$\alpha(\omega)$	-	absorption coefficient
$c$	-	speed of light
dB	-	decibel
$\lambda$	-	wavelength
$n_l$	-	refractive index of the scattering center
$n_o$	-	refractive index of the scattering medium
$\beta$	-	isothermal compressibility of the medium
$k$	-	Boltzman's constant
$T_f$	-	fictive temperature of glass
$P_{\text{core}}$	-	fractional power carried in the core

$P_{\text{clad}}/P$	-	fractional power carried in the cladding
$P$	-	total power transmitted.
$\alpha_1$	-	attenuation coefficients for the core
$\alpha_2$	-	attenuation coefficients for the cladding
$\alpha$	-	Cable Loss (dB/km)
$d$	-	Cable Distance (km)
$\beta$	-	Splice Loss (dB)
$\eta_1$	-	No. Of splices/Joints
$c$	-	Connector loss (dB)
$\eta_2$	-	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
$N_\infty$	-	number of modes supported in a straight fiber
$\Delta$	-	core-cladding index difference
$R$	-	radius of curvature of the bend
$R_c$	-	critical radius of bending
$J_1$	-	Bessel function of first order
$R_{\text{eff}}$	-	effective bending radius
$\alpha_T$	-	thermal expansion coefficient
$\beta_T$	-	thermo-optic coefficient
$l$	-	length
$\partial\phi/\partial T$	-	temperature coefficient of optical phase

## LIST OF PUBLICATIONS

### Journal :

### 2015

1. Salleh, M. F. M., and Zakaria, Z., 2015. Optical Power Attenuation of Long Distance OPGW in Malaysia. *Journal of Theoretical and Applied Information Technology*, vol. 75 (3), pp. 331-335. (Scopus)
2. Salleh, M. F. M., and Zakaria, Z., 2015. Evaluation of Macrobend Loss on Long Distance Optical Ground Wire. *International Journal of Engineering and Technology*, vol. 7 (3), pp. 1085-1090. (Scopus)
3. Salleh, M. F. M., and Zakaria, Z., 2015. Optical Fiber Bending Detection on Long Distance OPGW using OTDR. *Telecommunication Computing Electronics and Control*, vol. 13 (3), pp. 889-893. (Scopus)
4. Salleh, M. F. M., and Zakaria, Z., 2015. Effect of Bending Optical Fibre on Bend Loss Over a Long Period of Time, *Asian Research Publishing Network (ARP) Journal of Engineering and Applied Sciences*, vol. 10 (9), pp. 6732-6736. (Scopus)

## **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.

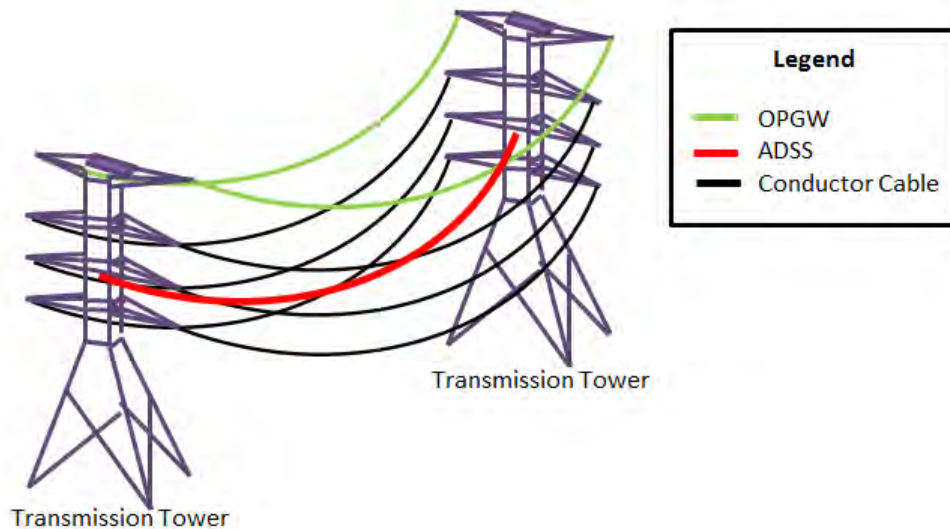


Figure 1.1 : Position of OPGW and ADSS cable respectively on HV Transmission tower

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.

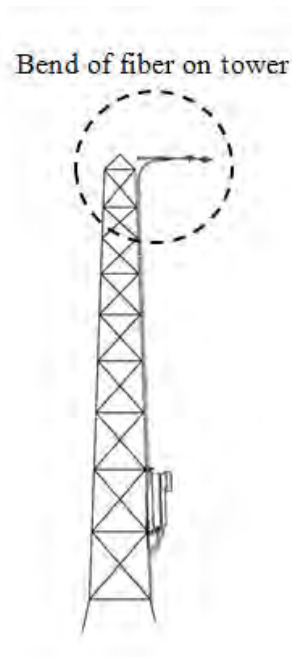


Figure 1.2 : Bending of cable on transmission tower

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)