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Optical Fiber Bending Detection on Long Distance OPGW using OTDR

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Abstract

In Malaysia, thousands of kilometers of Optical Ground Wire (OPGW) have been installed by a utility company.For long distance fiber cable, there is a possibility of optical fiber to bend with very small radius especially in joint closures which caused optical power to attenuate. This attenuation is known as 'bend losses. Bend lossincreases the total power attenuation of optical fiber. In addition, for long distance fiber cable, it is important to avoid any extra loss as the fiber itself attenuates 0.2 to 0.35 dB/km and splice loss about 0.1 dB each.Hence, in this study, the method of detecting bend loss as well as optical fiber bending is presented. The result of this study is expected to allow fiber industry players to determine the exact location and proper rectification can be done to solve bend loss problem.

Keywords: *optical ground wire, bend loss, power attenuation, optical fiber bend*

1. Introduction

Optical power attenuation increases as the length of fiber cable increases. Optical fiber itself causes the power to attenuate about 0.2 dB/km for 1550 nm wavelength to 0.35 dB/km for 1310 nm wavelength [1]. By taking into account other factors that can contribute to the attenuation of power for long distance such as dispersion loss, scattering loss etc., bending of optical fiber also can affect the power attenuation [2].

Bend loss is introduced by Mode Field Diameter (MFD) [3, 4]. MFD represents the area in which the light goes through and includes the core and a part of the cladding. A smaller mode field diameter indicates that light is more tightly confined to the fibre centre and, therefore is less prone to leakage when the fibre is looped [4]. Figure 1 shows the relationship of light power and MFD where the diameter of core and the wavelengths are the important parameters in determining the sensitivity of bend loss.

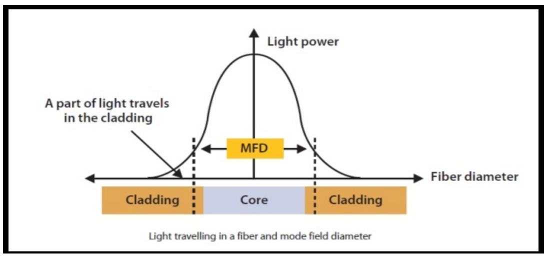

Figure 1. The relationship between light and MFD

The total number of modes supported in a curved, multimode fibre is therefore related to the index profile, the propagating wavelength, and the radius of curvature as shown in Equation (1).

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$$N_{eff} = N_{\infty}\left\{1 - \frac{\alpha+2}{2\alpha\Delta}\left[\frac{2\alpha}{R} + \left(\frac{3}{2n_2kR}\right)^{2/3}\right]\right\} \quad (1)$$

Where N∞ is the number of modes supported in a straight fibre, α defines the index profile, Δ is the core-cladding index difference, n_2 is the cladding index, k = 2π/λ and R is the radius of curvature of the bend [5].

However, single mode fibre has a larger mode field diameter at 1550 nm than at 1310 nm and at 1625 nm than at 1550 nm. Larger mode fields are sensitive to lateral offset during splicing, but they are more sensitive to losses incurred by bending during installation or in the cabling process [4]. 1550nm is more sensitive to bend in the fibre than 1310nm. This indicates that longer wavelength will encounter loss due to the bending at the same radius, R.

Bend loss is measured in dB and has direct relationship with radius of bending with the critical radius of curvature, R_c is defined by [6] and [7] as Equation (2).

$$R_c = \frac{3n_2.\lambda}{4\pi(NA)^3} \quad (2)$$

Where R_c is the critical radius of bending, n_2 is the refractive index of the clad and *NA* is the numerical aperture of the fibre and λ is the wavelength. Figure 2 shows the sensitivity of different wavelengths on bend radius.

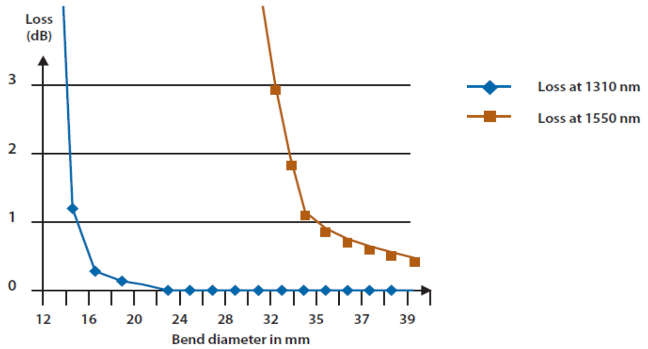

Figure 2. 1310 nm vs. 1550 nm on diameter of bend [5]

Optical Time-Domain Reflectometers are the ideal tools for detecting and locating bends in a fibre link. As bend is sensitive to longer wavelengths but not for shorter wavelengths, most of the operators use two wavelengths from OTDR to test the fibre links. The wavelengths that commonly used for detecting bend loss are 1310 nm and 1550 nm. These two wavelengths will be used in this paper for that purpose. For future analysis on bending loss should be taken between 1310 nm and 1625 nm, or between 1550 nm and 1625 nm, which are relevant wavelengths for DWDM testing.

2. Research Method

The scope of this study is to detect the bend loss as well as optical fiber bend. The activities are divided into two. The first activity is to detect any bend losses that occur along the link while the second activity involves the observation at site to verify the tests that have been done in the first activity.

2.1. Bend Loss Detection

This activity involves two different wavelengths from OTDR which are 1310 nm and 1550 nm wavelengths. As discussed in [5], the value of bend losses captured by 1550 nm will be higher than 1310 nm by at least 0.2dB. This will allow the process of detecting the presence of bend. As shown in Figure 3, the 1550 nm trace is attenuated more than 1310 nm at due to bend loss at the same location.

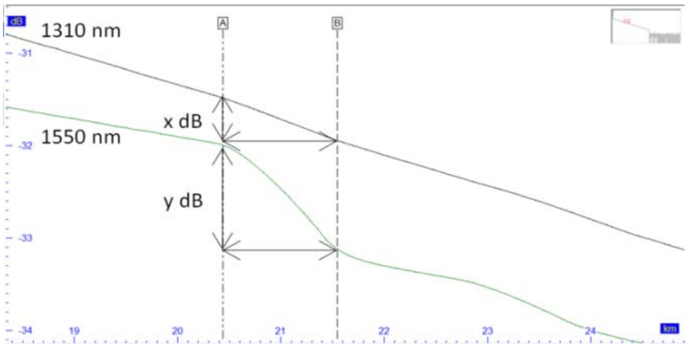

Figure 3. Trace comparison between 1550 nm and 1310 nm due to bend loss

Since there might be more than single locations of bending for long long distance fiber cable, the comparison of loss values has to be done at each location where there is high loss detected by 1550 nm.

Table 1. Method of detecting bend loss

1550 nm		1310 nm		Loss Different	Remark
Distance	Loss	Distance	Loss		
A	x	B	Y	x-y	If x-y > 0.2dB, there is optical fiber bending occur

Distance A and B will be slightly different. The value of A and B have to be compared with joint closure schedule provided by the project owner. To decide the exact location, the distance point tolerance will be calculated by measuring the average distance between each high voltage transmission towers.

$$Distance\ point\ tolerance = \frac{Total\ Fiber\ Cable\ length}{\text{Number of Towers}} \qquad (3)$$

In this study, the distance point tolerance is given by ±400 m where the location of bend fiber will be determined by accepting the nearest point to the location of joint closure as stated by joint closure schedule.

2.2. Optical Fiber Bend

After the location of related joint closures have been determined, the observation on the coiling optical fiber inside the joint closure have been done in order to see if there is any bending with small radius that probably causes the bend loss. The scope of observation is to verify if there is any defect on optical fiber in the joint closure.

Since bend loss can be solved by releasing the bending, this method will be used to verify that the bending of optical fiber is the cause of bend loss. Another test using OTDR will be done to see this activity and to prove that the location determination has been conducted correctly.

3. Results and Analysis

Results of the experiment wereanalyzed in order to determinewhether the method implemented in this study is able to detect bend loss as well as the location of bending optical fiber. The results of the experiments are then verified by the observation activity and rectification activity. Since the bending of optical fiber do not give any permanent effect on bend loss and attenuation, the results of this study can be proven as conducted with proper method and analysis by test conducted after the bending of optical fiber is released.

3.1. Bend Loss Detection

Losses that are captured by 1310 nm and 1550 nm wavelengths have been analyzed where the event table can be extracted from OTDR. The results of OTDR test have been arranged as in Table 2 with distance measured by 1310 nm and 1550 nm wavelength has been aligned accordingly by taking into account the distance point tolerance.

Table 2. Bend and splice loss differentiation.

Wavelength					
1550 nm		1310 nm		Loss Different	Remark
Distance	Loss	Distance	Loss		
6246.58	0.108	6226.03	0.142	-0.034	Splice
11044.52	-0.256	11136.99	-0.214	-0.042	Splice
14486.30	0.247	14496.58	0.274	-0.027	Splice
20404.11	1.634			1.634	Bend
23229.45	0.677	23183.22	0.047	0.630	Bend
27981.17	0.230	27991.44	0.221	0.009	Splice
30000.00	1.910	30092.47	0.184	1.726	Bend
35953.77	0.216	35902.40	0.193	0.023	Splice
38275.69	-0.147	38121.58	-0.153	0.006	Splice
41928.09	0.103			0.103	Splice
47799.66	0.316			0.316	Bend
54652.40	End	54929.8	End		

The results from OTDR test have shown that there were four bend losses found along the fiber link. These bend losses indicate that there were four possible locations of bending optical fiber. To clarify these results, the observation on site has been conducted to detect if there wasbending optical fiber that might probably introduce the bend losses captured in this experiment.

3.2. Bending Optical Fiber

The observations of bending optical fiber have been done on four locations as decided earlier. There were multiple bending optical fiber with very small radius observed occur in joint closures. These bendings are believed as the factor to the presence of bend loss. Figure 4, Figure 5, Figure 6 and Figure 7 show the multiple bending optical fibers found inside joint closures.

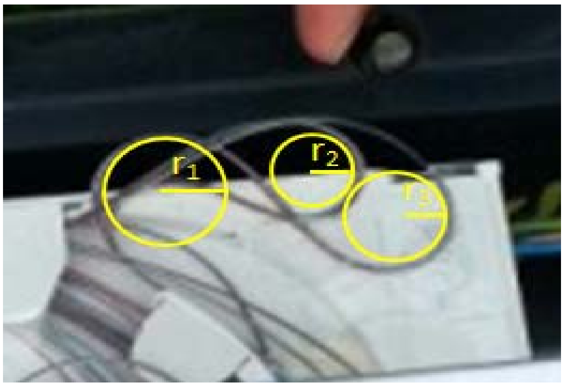

Figure 4. Three bending found at Location 1

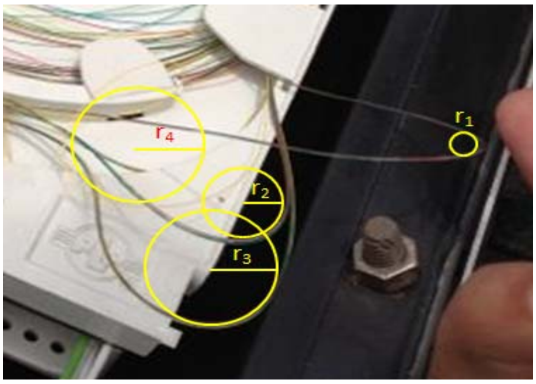

Figure 5. Three bending found at Location 2

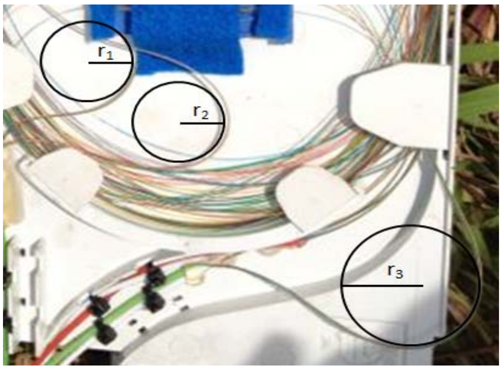

Figure 6. Three bending found at Location 3

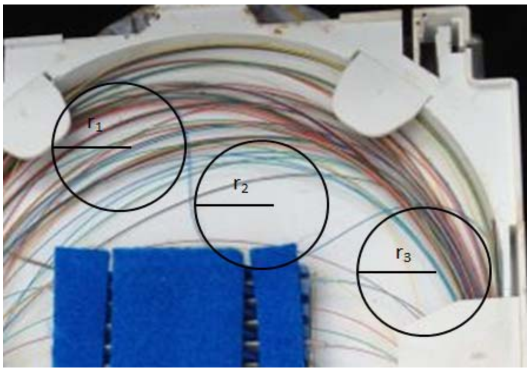

Figure 7. Three bending found at Location 5

All these bendings had been released and the results obtained from OTDR Test after the rectification at these four locations showed that there was no longer bend loss found. Figure 8 shows the traces of 1310 nm and 1550 nm wavelength with no more point of high loss detected by 1550 nm wavelength as before.

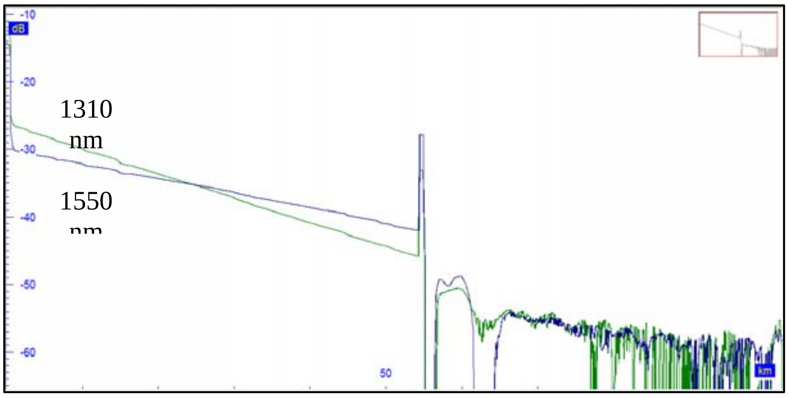

Figure 8. Traces of 1310 and 1550 nm wavelength without high loss points

4. Conclusion

The method of detecting bend loss on existing long distance OPGW has been implemented successfully. The results of OTDR test had been used to trace the location of bend loss as well as bending optical fiber and observation activities found that there were multiple bendings with small radius contribute to the bend loss. The findings had been verified as rectification on that locations successfully cleared the loss from OTDR traces.

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