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Comparative Analysis on Fault Detection Techniques in Fiber Optics Communication Links

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ABSTRACT

One of the major challenges in fiber optics communication links is the maintenance of steady or uninterrupted network which include localization and identification of cable fault or break. Optical Time Domain Reflectometer, OTDR, is one of the methods or techniques used in fault detection on fiber links. However, this technique presents some challenges among which is fading of precision and accuracy due to increased variations of the distances measured which leads to more uncertainty in fault localization. In order to solve this problem, an algorithm was proposed and implemented which gives the actual locations of fault/break on earth. Results obtained from both the OTDR and the algorithm was compared and analyzed using a statistics and data analyzing software (STATA). A perfect correlation (r =1) of the measured distance by OTDR and the actual location of fault from the algorithm was obtained. Also, a probability value, "P value", of 0.9992 with 95% Confidence Interval obtained using STATA in the analysis of the measured distance from OTDR and the actual location of fault implies no significant difference. This authenticates the accuracy of the algorithm in locating the actual location of faults in fibers on earth which will be of great benefit to fiber optics engineers.

Keywords: Fiber Optics, Fault Detection, OTDR, Algorithm, STATA

1.0 INTRODUCTION

Fiber optics is a thin long strand of ultra-pure glass or plastic that can transmit light from one end to another without much attenuation or loss (Agrawal, 2002). Fibers that support many propagation paths or transverse modes are called Multi-Mode Fibers (MMF), while those that support only one mode are called Single-Mode Fibers, SMF (Ilyas and Moftah, 2003). Fiber optics is mostly deployed in communication to transmit telephone signals. It offers ample advantages over existing copper wire in long-distance and high-demand applications due to much lower attenuation and interference (Akiba, 2003). As signals move along these links losses are recorded as faults. These losses are attributed to high signal latency, poor cable handling and installation procedures, substandard cables, harsh environmental conditions and high rate of cable vandalism. It is one thing to identify these faults and another to locate the actual points on earth since the cables are buried under the ground. Some of the known effects of these faults include: Signal outage or failure when on call or on the Internet with a mobile or personal computer, undelivered messages, freezing of signal pictures or video when surfing the internet, unavailability of service etc. (Dharamvir, 2012).

Baskaran and Seethalaskshmi (2012) designed a module that monitors faults in fiber by monitoring the received power. In 2015, Kalprasanna, Jagannath, Prasad, and Gopinth did similar work on 'Fault detection system in optical fiber using Arduino'. Both however, do not give actual location of fiber fault on earth. Conventional method employs Optical Time Domain Reflectometer (OTDR) to detect

faults/breaks. OTDR uses the effects of Rayleigh scattering and Fresnel reflection to measure the characteristics of an optical fiber. Rayleigh scattering occurs when a pulse travels down the fiber and small variations in the material, such as variations and discontinuities in the index of refraction, cause light to be scattered in all directions. However, the phenomenon of small amounts of light being reflected directly back toward the transmitter is called backscattering. Fresnel reflections occur when the light traveling down the fiber encounters abrupt changes in material density that may occur at connections or breaks where an air gap exists.
OTDR can provide the following information: total fiber loss, loss per unit length, connector insertion, loss connector return loss (reflection), splice loss, inter-splice loss, absolute fiber length, evidence of macro/micro bending, and position of cable defects or breaks. However, this method has its own challenges among which is fading of precision and accuracy due to increased variations of the distances measured which leads to more uncertainty in fault localization. This paper proposed an algorithm that can locate the actual location of fiber break on earth. The result obtained from OTDR and the algorithm are analyzed and compared.

2.0 MATERIALS & METHODS

Materials:

1. Single-Mode Patch cords
2. Power meter
3. Optical Time Domain Reflectometer (OTDR)
4. Media Converter/Transmission Equipment
5. Flash drive

Method 1:
<u>OTDR test procedures</u>

Location: Abubakar Tafawa Balewa University Teaching Hospital (ATBUTH), Bauchi State, Nigeria to Abubakar Tafawa Balewa University (ATBU), Bauchi State, Nigeria
Fiber Type: SM 36CORE
Device: MTS 6026VSR
Module: 7508 Num.8126 VSRE
The OTDR parameters were set as:
Wavelength: 1550 nm
Range (Km): 88.6673
Acq. Time: 10s
Resolution: 1.25m
Index: 1.466480

A power meter was used in testing for continuity along the cable before the measurements were taken. A single-mode patch cord was attached to the OTDR and to cable plant under test via the patch panel. The OTDR was preset as stated above and it emitted light power pulses along the cable in a forward direction by the injection laser. The light pulses then bounced back and were measured by the factoring out of time and distances. The backscattered light was detected by the Avalanche photodiode receiver. The output of the photodiode receiver was driven by an integrator which improved the Signal to Noise Ratio (SNR) by giving an arithmetic average over a number of measurements at one point. This signal was fed into a logarithmic amplifier and the average measurements for successive points within the fiber were plotted and recorded with the chart recorder. The media converter was then used in converting the trace to another format which was retrieved with an external drive. The same procedure was repeated for all the fiber cores and data analyzed and various distances tabulated as seen in Table 2.

Method 2:

SYSTEM DESIGN OF PROPOSED ALGORITHM

System Flowchart

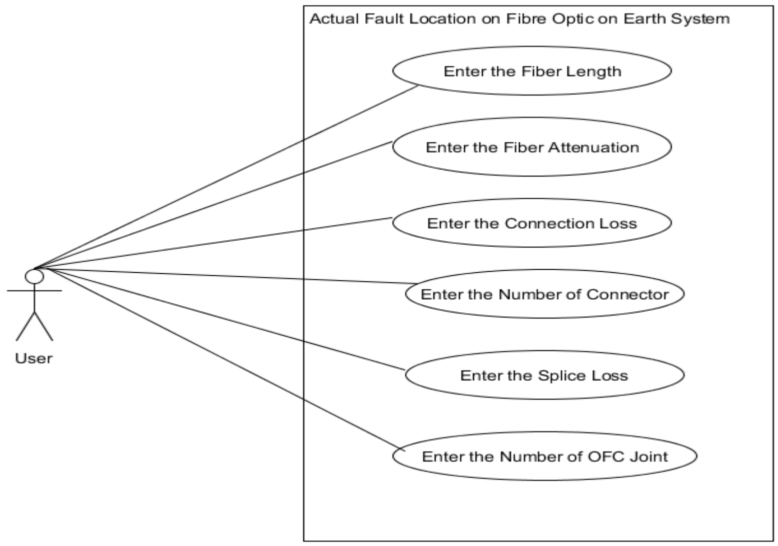

Figure 1: The use cases for the system user (Input)

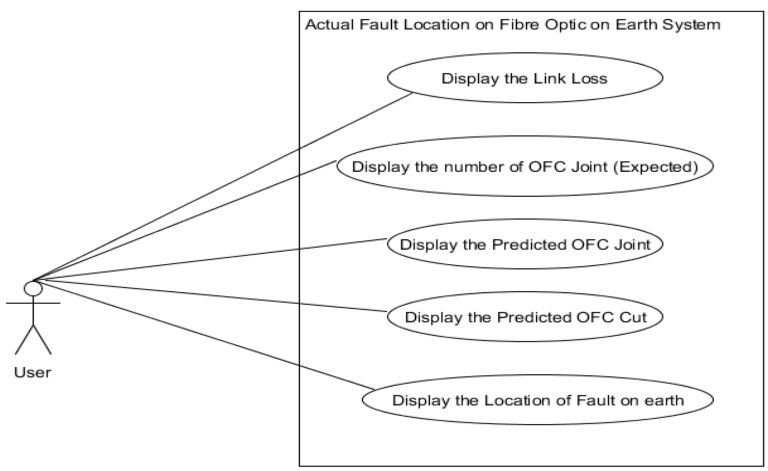

Figure 2: The Use cases for the System user (Output)

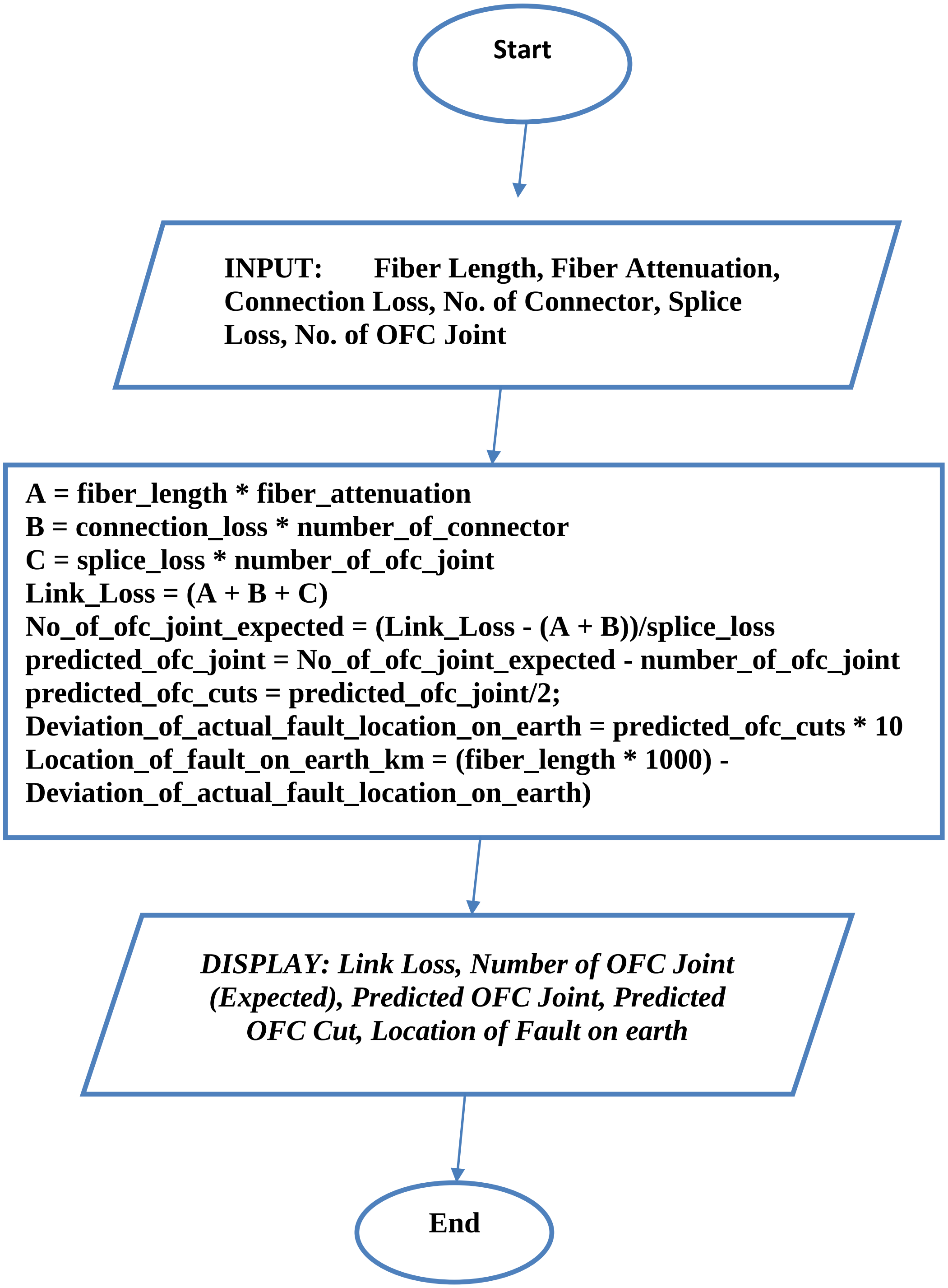

Figure 3: The Flowchart for the Actual Fault Location on Fiber Optic on Earth System

Choice of language

The programming language chosen for this research work is Personal Home Page (PHP) amongst C+, Java script, JAVA, Python, C++, C, Pear, etc . Its development started in 1994, by Rasmus Lerdorf. Its syntax resembles C and Perl and is easy to learn for any programmer with C or Perl background. It runs on a web server and it supports many databases, command line scripting, and client side Graphical User Interface (GUI) applications.

Advantages of PHP

I. Speed: It is relatively fast when compared with other programming languages.
II. Easy to use: It is very easy to create dynamic scripts.
III. Stable: It is maintained by many developers, so when bugs are found, it can be quickly fixed.
IV. Powerful library support: You can easily find functional modules you need such as mail functions, headers etc.
V. Functionality**:** It gives life to a web page. PHP script can make a static web page dynamic. This is one of the most effective uses of PHP in web design.
VI. Platform independence: PHP can run on different platforms, including Windows, Linux, and Mac.
VII. PHP is powerful, robust, and scalable.
VIII. PHP supports all web browsers, web servers, and it is also easy to learn and program within a short period of time.

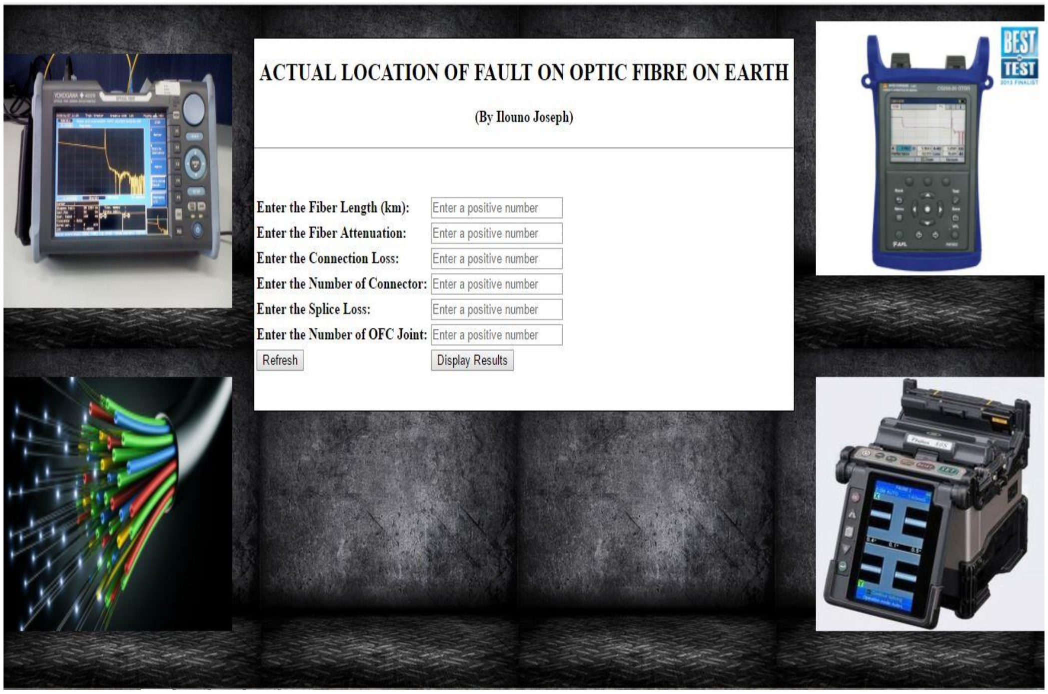

Figure 4: Screenshot of the System before inputting values of parameters

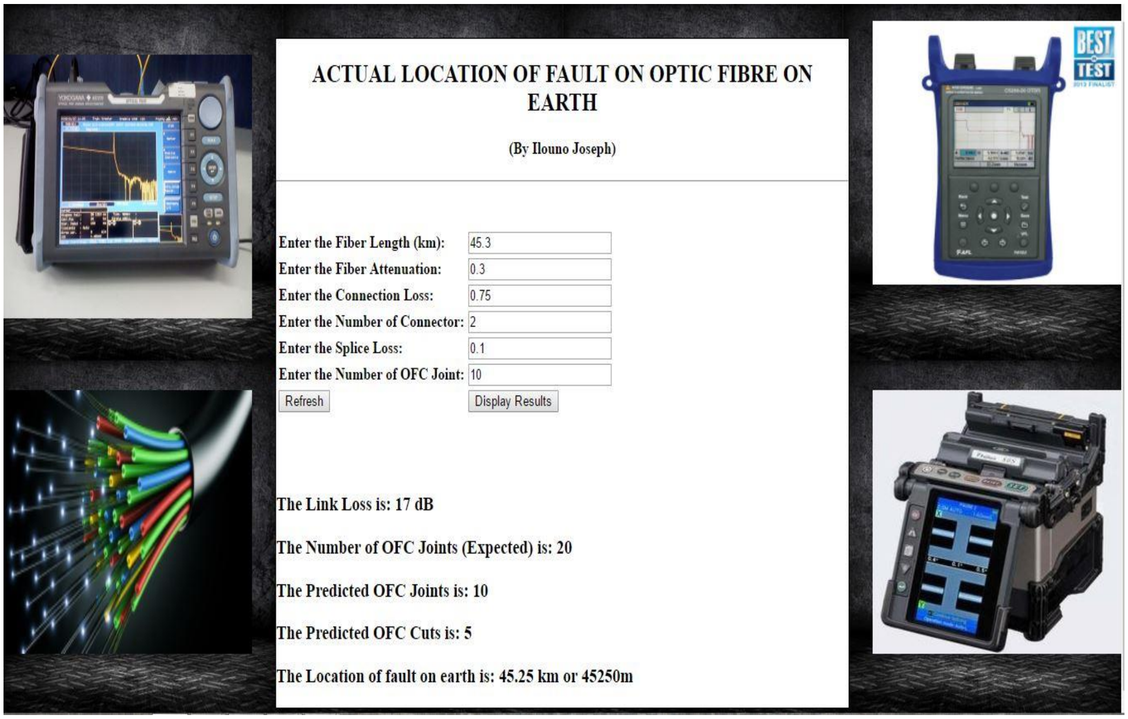

Figure 5: Screenshot of the System showing results

3.0 RESULTS

Table 1: Manufacturer's specifications for single-mode 1550nm fiber

Fiber attenuation (dB/km)	Connection loss (dB)	No of connector	Splice loss (dB)	Fiber length/drum (km)
0.30	0.75	1	0.10	2

Table 2: Results from OTDR & Algorithm compared

distance measured by otdr (km)	no. of OFC joint	actual location of break (km)	fiber loss (dB)	Predicted OFC cut	predicted OFC joint
10.221	10	10.211	5	1.0	2
12.620	12	12.605	6	1.5	3
14.222	14	14.192	7	3.0	6
15.000	14	14.985	7	1.5	3
17.124	17	17.099	8	2.5	5
18.432	18	18.382	9	5.0	10
20.242	20	20.232	9	1.0	2
22.122	22	22.097	10	2.5	5
24.466	24	24.436	11	3.0	6
25.656	25	25.651	11	0.5	1
27.700	27	27.685	12	1.5	3
29.420	29	29.390	13	3.0	6
30.422	30	30.412	13	1.0	2
32.262	32	32.242	14	2.0	4
34.671	34	34.646	15	2.5	5
37.411	37	37.391	16	2.0	4
40.211	40	40.201	17	1.0	2
43.333	43	43.283	19	5.0	10
45.621	45	45.616	19	0.5	1
50.242	50	50.232	21	1.0	2
52.212	52	52.192	22	2.0	4
53.444	53	53.394	23	5.0	10
56.667	56	56.632	24	3.5	7
58.212	58	58.162	25	5.0	10
60.112	60	60.097	25	1.5	3

Table 3: Variance ratio and t- tests of measured distance by OTDR and actual distance from Algorithm

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.Interval]	
distan~m	25	33.2818	3.131712	15.65856	26.81826	39.74534
actual~m	25	33.2586	3.131032	+15.65516	26.79647	39.72073
combined	50	33.2702	2.191504	15.49628	28.86621	37.67419
diff		0.0232001	4.428429		-8.880752	8.927153

Footnote:
ratio = sd(distancemeasur~m) / sd(actuallocation~m) f = 1.0004
Ho: ratio = 1 degrees of freedom = 24, 24
Pr(F < f) = 0.5004 2*Pr(F > f) = 0.9992 Pr(F > f) = 0.4996
Pr ($|T| > |t|$) = 0.9958
Correlation coefficient = 1

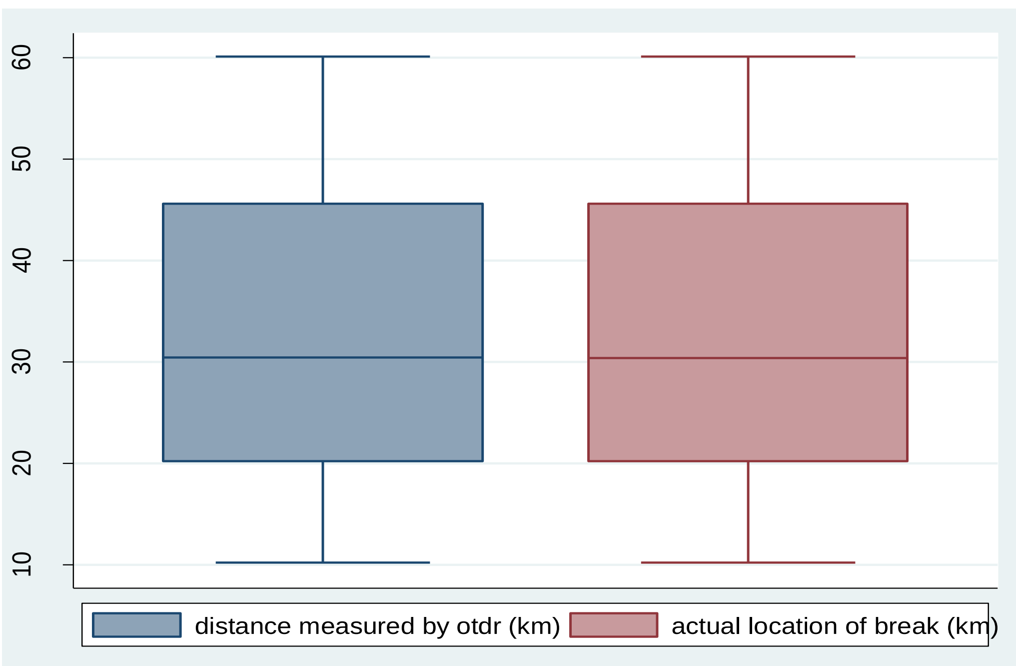

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Figure 6: Box plot of distance measured by OTDR and actual location of break from the algorithm

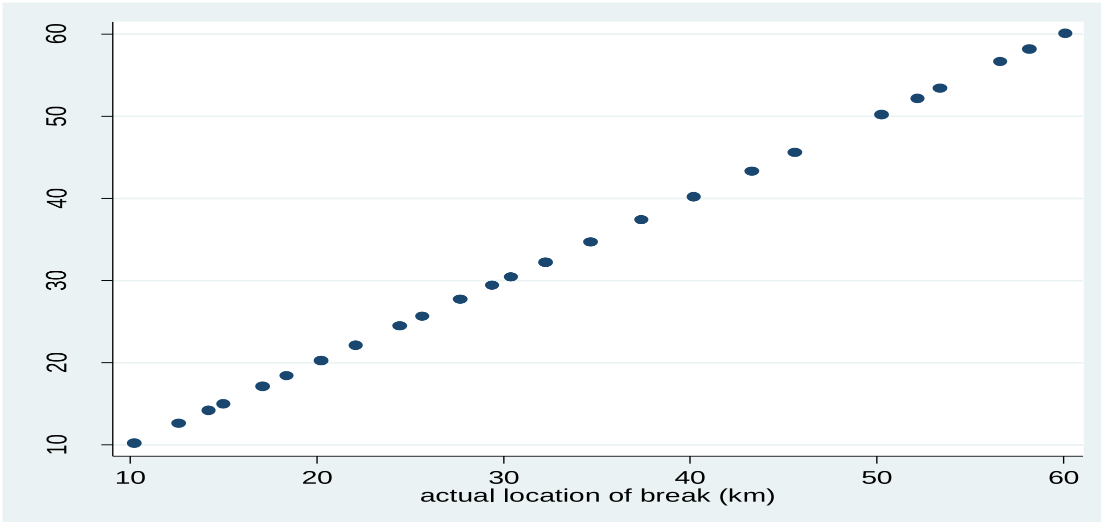

Figure 7: Distance measured by OTDR against actual location of break from the algorithm

4.0 DISCUSSION

With the implementation of this proposed algorithm as shown in Figures 4 and 5, the actual locations of faults/breaks were traced which save time and cost. From Table 2, considering for example 10.221km measured by OTDR, the actual location of the break is 10.211km which is 10 meters before 10.221km. The statistical analysis of the dataset using STATA gave a perfect correlation (r =1) of the measured distance by OTDR and the actual location of fault as seen in Table 3 and Figures 6 and 7. A “P value” of 0.9992 obtained using STATA in the analysis of the measured distance from OTDR and the actual location of fault implies no significant difference. This authenticates the accuracy of the algorithm in locating the actual location of faults or breaks on fibers on earth. The box and scatter plots (Figures 6 and 7) of the distance measured by OTDR and the actual location of fault gave a perfect correlation of both variables.

5.0 CONCLUSION

Optical Time Domain Reflectometer (OTDR) a commonly used technique was used for the characterization and fault location in optical fiber transmission systems. The practically observed values of the OTDR showed the gradual decrement of accuracy in locating the actual place of fault. An algorithm was proposed in this paper which gives a more precise, economic and time-saving fault detection and rectification technique. The statistical analysis using STATA shows a perfect correlation of the distance measured by OTDR and the actual location of fault or break from the algorithm. Hence, with the use of the algorithm, the actual place of fault or break in a fiber optic link can be traced more precisely.

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