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Graphical User Interface Capabilities of MATLAB in Centralized Failure Detection System (CFDS)

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Abstract - **This paper proposed a MATLAB-based graphical user interface (GUI) development named as Centralized Failure Detection System (CFDS) to increase the efficiency, survivability, and reliability of fiber-to-the-home (FTTH) customer access network. This program will be installed with optical line terminal (OLT) at central office (CO) to monitor the network system and identify any fiber fault that occurs in FTTH downwardly from CO towards residential customer locations. Conventionally, optical time domain reflectometer (OTDR) is used to localize any fiber fault in FTTH upwardly from customer residential location towards CO. However, OTDR can only display a result of a testing line in a time, which tends to time consuming. The usage of passive optical splitter in FTTH with point-to-multipoint (P2MP) configuration is blocking the reflected signal that need to be analyzed by OTDR. Therefore, it becomes a hindrance to detect any faulty fiber with a large number of subscribers and large coverage area downwardly in the fiber plant between the optical splitter and multiple optical network units (ONUs) at different customer residential locations by using OTDR. Thus the troubleshooting work become very complex and leads to increase the maintenance cost. CFDS is interfaced with OTDR to accumulate every network testing result to be displayed on a single computer screen for further analysis.**

Index Terms - **Survivability, reliability, FTTH, P2MP configuration, fiber fault.**

I. INTRODUCTION

FTTH is an end-to-end optical fiber connection for the deployment of high speed broadband services to homes. FTTH technology is specifically with its bandwidth capacity, reliability, security, and scalability as well as cost effective. The network service providers deliver triple-play (data, audio, and video) services from CO (or network operation center/local exchange) to multiple subscribers/customer premises at different customer residential locations over a sharing fiber (feeder fiber) in a passive optical network (PON) architecture with tree topology or P2MP configuration, where the distance between OLT and ONUs can be up to 20 km in this architecture. A passive optical splitter (branching device) is used to connect the feeder fiber (sharing fiber) to multiple drop fibers at remote node (RN) [1].

Due to the large transport capacity achieved by optical access network, failures caused huge losses of data and greatly influence upon a large number of users over a wide area. Besides, the laser light (optical source) used in optical communication systems may explore at the break point, it can cause burning in the retina that lead to damage temporarily or permanently (blind) in a few seconds or even less time depending to the energy absorbed by the retina. Therefore, the survivability of the whole network has to be examined more seriously [2].

OTDR is the most costly equipment among the optical fiber testing equipments, but it is most frequently used for characterizing a long haul communication link. According to Chomycz [3], OTDR testing is the best method for determining the exact location of broken optical fibers in an installed optical fiber cable when the cable jacket is not visibly damaged. A high intensity optical pulse is launched into an optical line and a high speed optical detector recorded and graphically displays the observed reflection in the screen. User can observe losses due to splice, break, connector, and other attenuation in the optical line from the visual representation on OTDR's screen.

II. OPERATIONAL PRINCIPLES OF CFDS

CFDS is a centralized control and surveillance system that provide the FTTH network service providers with a means of viewing traffic flow and detecting any breakdowns as well as other circumstances which may require some promptly actions. The developed program also provides the network service providers with a control function to intercom all subscribers with CO. The working principles of CFDS are structured into three main parts to support its operations: (i) Optical line measurement with OTDR, (ii) Interfacing personal computer (PC) with OTDR, and (iii) Advanced data analyzing with CFDS. The whole operating process can be simplified in the flow chart as depicted in Fig.1.

Our system architecture design is presented in Fig.2. The maximum distance between the OLT and ONUs is 20 km. A commercially available OTDR with a 1625 nm laser source is used for failure detection control and in-service troubleshooting without affecting the triple-play services transmission. The OTDR is connected to a PC or laptop to display the troubleshooting results via RS-232 (Serial port) connection.

The triple-play signals (operating wavelengths; 1310 nm, 1490 nm, and 1550 nm) are multiplexed with 1625 nm testing signal. When four kinds of signals are distributed, the 1625 nm testing signal will be split up by wavelength selective coupler (WSC), which is installed before the optical splitter. The WSC only allow the 1625 nm testing signal to enter into the tapper circuit and reject all unwanted signals (1310 nm, 1490 nm, and 1550 nm) that contaminate the OTDR measurement.

The downstream signal will go through the WSC, which in turn connected to optical splitter before it reaches the optical network units (ONUs) at different customer residential locations. On the other hand, the testing signal which is demultiplexed by WSC will be split up again in power ratio 99:1 by using directional coupler (DC) to activate the microprocessor system. The 99% 1625 nm signal will then be configured by using optical splitter, which each output is connected to single line of ONU.

CFDS is interfaced with OTDR at CO to accumulate all the troubleshooting results to be displayed on a computer screen for further analysis. Whenever a failure occurs on the primary entity, the traffic (service delivery) is switched from the working (primary) line to the

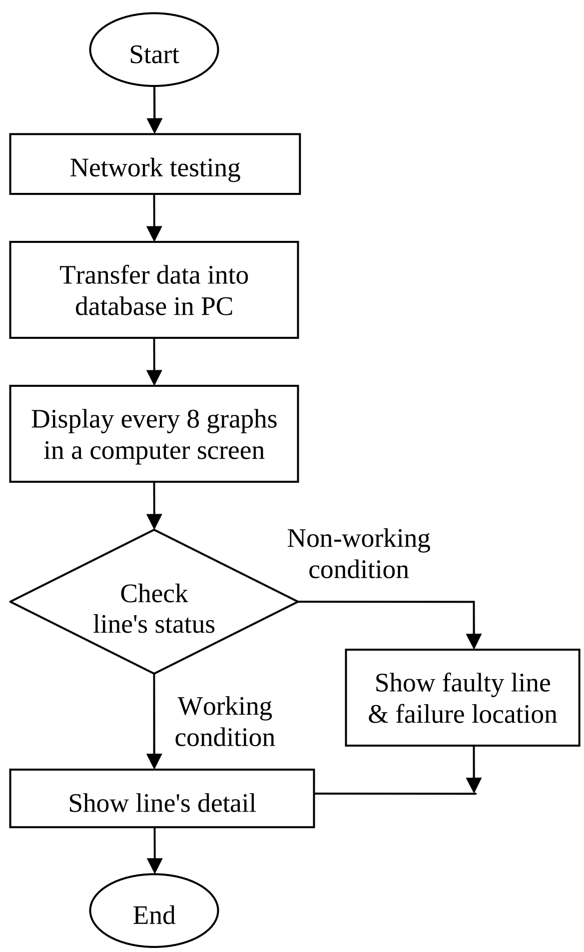

Fig.1. Flow chart for mechanism of CFDS detection

protection (backup) line to ensure the traffic flow continuously and the failure status will be automatically sent to the field engineers through the mobile phone or Wi-Fi/Internet computer using wireless technology for repairing and maintenance operation. After the restoration/maintenance process, the traffic will be switched back to the normal operation.

A. Optical Line Measurement with OTDR

In order to gauge the effectiveness and benefits of CFDS, we conducted two experiments through a point-to-point (P2P) network testbed composed by 30 km and 50 km fiber, mainly focusing on fiber fault localization in the network system. Two optical devices: fixed connection (FC) connector and optical attenuator are used as the performance study platform for characterizing optical signal in optical fiber lines in these experiments. The FC connector is used to connect between two fibers under test, meanwhile the optical attenuator is used to reduce (attenuate) the optical signal level and represent the break point in an optical line.

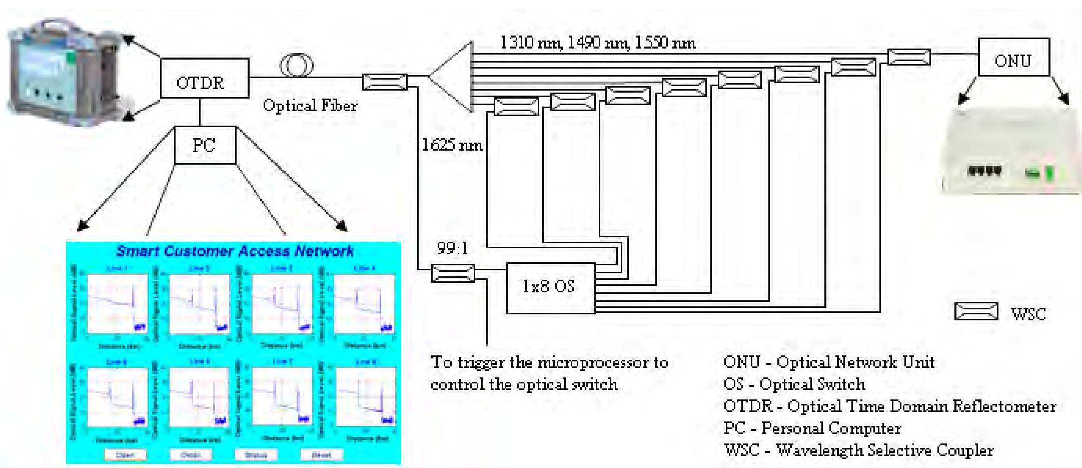

Fig.2. The proposed measurement system configuration for centralized monitoring and localizing fiber fault in FTTH downwardly from CO towards multiple residential customer locations (in downstream direction)

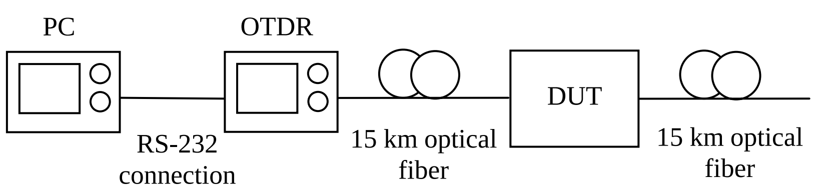

Fig.3. The block diagram of P2P network system configuration consists a single DUT

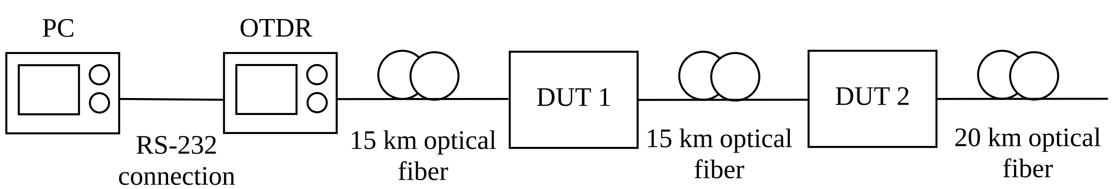

Fig.4. The block diagram of P2P network system configuration consists two DUTs

In the first experiment, there is only consists a single device under test (DUT) which is representing a single event occurs in the testing line as shown in Fig.3. The FC connector used as the DUT in the first test and then replaced by optical attenuator for the following tests. The attenuation at optical attenuator was set as 1 dB and increased 1 dB for every following test until the optical signal in the testing line is showed failure.

The optical network is modified as depicted in Fig.4 to represent two events occur in the testing line. FC connectors used as the DUTs in the first two tests. Then the optical attenuator used to replace the first FC connector as the first DUT (DUT 1). The attenuation at optical attenuator was set as 1 dB and increased 2 dB for every following test until the optical signal in the tested line is showed failure. Eventually exchanged the position of FC connector with optical attenuator and repeated the same experiment.

B. Interfacing between PC with OTDR

Each measurement results is saved (recorded) in OTDR as trace (TRC) file and then transferred into PC through RS-232 connection. RS-232 serial cable (null modem cable) is required to establish connection between both units for data archiving. After completing the transferring process, the OTDR traces need to be converted into American Standard Code for Information Interchange (ASCII) form and saved in database.

C. *Advanced Data Analyzing with CFDS*

All the measurement results are loaded into the developed program from database. Every eight network testing results will be displayed on a computer screen for further analysis (in *Line's Status* window). This program is focusing on providing survivability through event identification against optical signal level (input/output power), losses (connection losses, splice losses, optical device/component losses, fiber losses or attenuation), and failures. In this case, CFDS differentiated the mechanism of optical signal in working (good/ideal) and non-working (breakdown/failure) condition through analyzing the reflective fault event in the network system.

CFDS displays a "*Good condition*" message at the line's status panel in *Line's Detail* window if the testing line is in a good/ideal condition without any losses, or a "*Decreasing y dB at z km*" message to present the magnitude of decreasing together with the location. However in the non-working condition, a failure message "*Line x FAILURE at z km from CO!*" will be displayed when CFDS detects any fiber fault occurs in the network system.

III. CFDS DEVELOPEMNT

CFDS is built by using the Graphical User Interface Development Environment (GUIDE) Layout Editor in MATLAB software. Two main windows (*Line's Status* and *Line's Detail*) are reserving for system testing, monitoring, and failure detection. The four basic functionalities of CFDS are: (i) Tracking the optical signal level and losses, (ii) Monitoring and analyzing the line's status, (iii) Displaying the line's detail, and (iv) Visual representation. In combination of the distinctive functions, the network service providers and field engineers can centralize monitoring, testing, analyzing, and troubleshooting the FTTH network system more efficiency to provide the predefined quality of services (QoS) for customer premises/subscribers.

IV. TESTING RESULTS AND ANALYSIS

A. Execution Display for Single Event

When the *Open* button in *Line's Status* window is pressed, all the measurement results are loaded from database into MATLAB Current Directory. CFDS accumulated every eight network testing results to be displayed in *Line's Status* window for centralized monitoring at CO, where the distance (km) represented on the x-axis and optical signal level (dB) represented on the y-axis as depicted in Fig.5. CFDS analyzed each line's status by tracking every line’s optical signal level when pressing the *Status* button. A failure message “*Line 8 FAILURE at 15.1918 km from CO!*” displays to show the faulty line and failure location as depicted in Fig.6.

To obtain further details on the performance of specific line in the network system, every measurement results obtained from the network testing are analyzed in the *Line’s Detail* window. CFDS is able to identify and present all the parameters of each optical line such as the line's status, magnitude of decreasing, failure location and further details when pressing the *Detail* button in *Line’s Status* window or clicked at the individual line in *Line’s Detail* window (see Fig.7 to 10). All the information is mentioned in a specified unit.

B. Execution Display for Double Events

Every eight graphs that represented the characteristics of optical lines displayed in *Line’s Status* window as depicted in Fig.11. Two failure messages “*Line 5 FAILURE at15.1918 km from CO!*” and “*Line 8 FAILURE at 30.4601 km from CO!*” display to show the failure locations in the optical network as shown in Fig.12. The first two tests were featuring with FC connectors as DUTs. The optical power in line 2 is decreasing 0.263 dB at 15.1969 km and 1.227 dB at 30.4601 km (Fig.13).

Then the optical attenuator is replacing the FC connector as first DUT. A decreasing of optical power 3.148 dB at distance 15.1918 km and 1.259 dB at 30.4652 km are found in line 3 when the attenuation at optical attenuator set as 1 dB (Fig.14). The line 5 is failure while it attenuated at 5 dB. A failure message '*Line 5 FAILURE at 15.1918 km from CO!*' displays in the *Line’s Detail* window as shown in Fig.15. Fig.16 shows the optical signal breakdown at 30.4601 km when the position of optical attenuator exchanged with FC connector as the second DUT (DUT2).

C. Data Analyzing

During the experiment period, we were able to observe the behavior of an optical fiber. Theoretically, a signal is transmitted through a medium without any loss in a good condition and we will get a straight line in a power-distance graph. However, the OTDR doesn't show this characteristic in the real case due to it loses power over distance. The optical power is attenuated (reduction of the signal strength or loss of energy) through absorption and scattering mechanisms in fiber. The fiber is attenuated with 0.19 dB/km for operating wavelength 1550 nm (0.32 dB/km for operating wavelength 1310 nm). For guided media such as optical fiber, the signal strength normally decays exponentially. Normally the logarithmic power ratio measures the changes in the strength of a signal at two different points in unit of decibels (dB) [4].

Apart from the propagation loss in a fiber, bending of fiber, connector, splice, coupler, and optical device may also contribute significantly to the losses in an optical fiber communication link. The optical power in line 1 is decreasing 0.595 dB at distance 15.1969 km in the first test due to the alignment of the cores of two fibers is critical and the minutest misalignment or gap between the fibers cause significant connectors losses in experiment, as can be seen in Fig.7.

Then the FC connector replaced by optical attenuator. When the optical signal transmitted from the laser port to the end of fiber, the optical power in line 2 is decreasing 3.140 dB at distance 15.1969 km as shown in Fig.8. The decreasing power is the losses generated by optical attenuator. When the attenuation at optical attenuator is increasing 1 dB for every following test, we can observe that the optical signal level at distance 15 km will be decreasing. The change is clearly shown in Fig.9 when the line was attenuated 10 dB. The signal transmission was breakdown at distance 15.1918 km when the attenuation was increasing up to 13 dB. It visualized the actual break point of faulty fiber at that distance in the network system in a real condition. A failure message '*Line 8 FAILURE at 15.1918 km from CO!*' will display as shown in Fig.10.

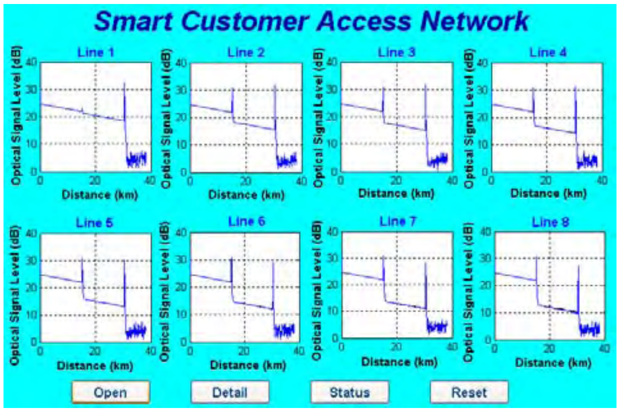

Fig.5. Every eight graphs displayed in *Line's Status* window for centralized monitoring (Single event)

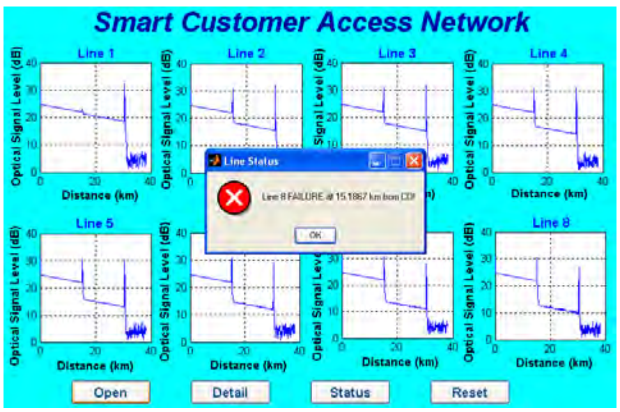

Fig.6. A failure message '*Line 8 FAILURE at 15.1918 km from CO!*' displays to show the faulty line and failure location in the optical network (Single event)

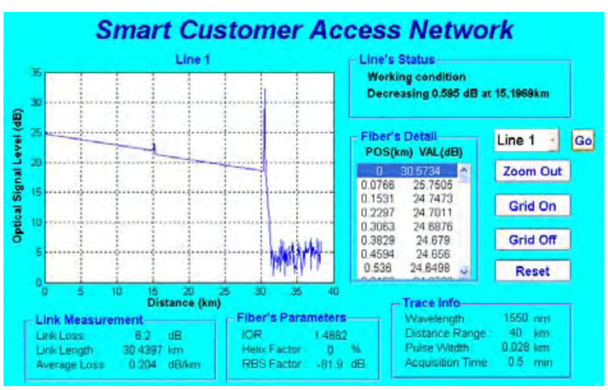

Fig.7. Optical power in line 1 decreased 0.595 dB at distance 15.1969 km

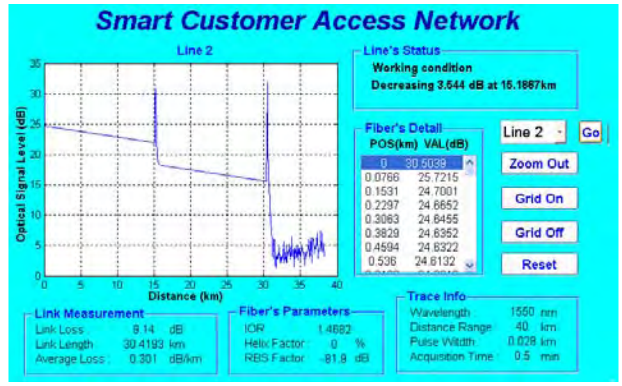

Fig.8. Optical power in line 2 decreased 3.544 dB at distance 15.1867 km

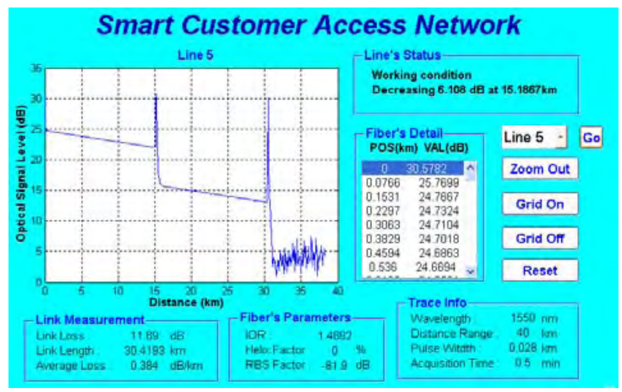

Fig.9. Optical power in line 5 decreased 6.108 dB at distance 15.1867 km

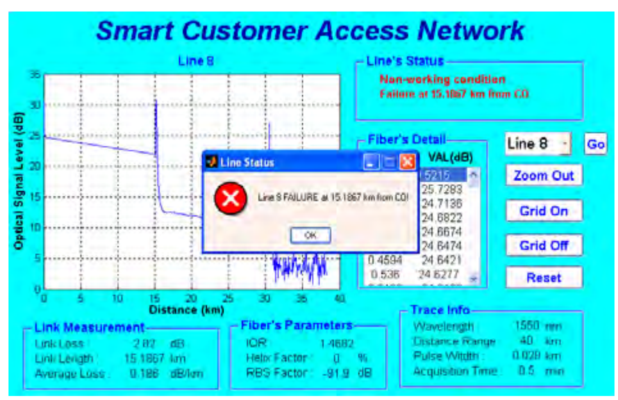

Fig.10. Line 8 is failure at distance 15.1867 km from the CO when the attenuation at optical attenuator is set as 13 dB

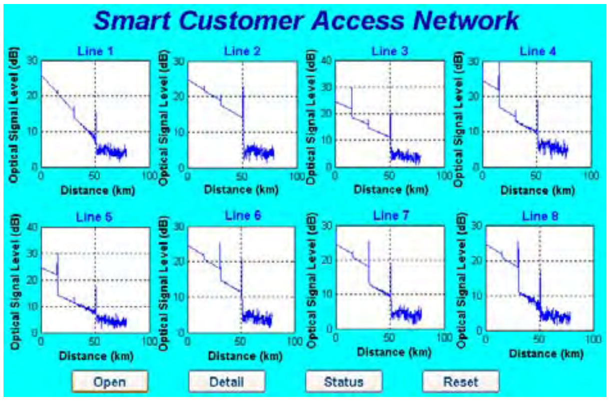

Fig.11. Every eight graphs displayed in *Line's Status* window for centralized monitoring (Two events)

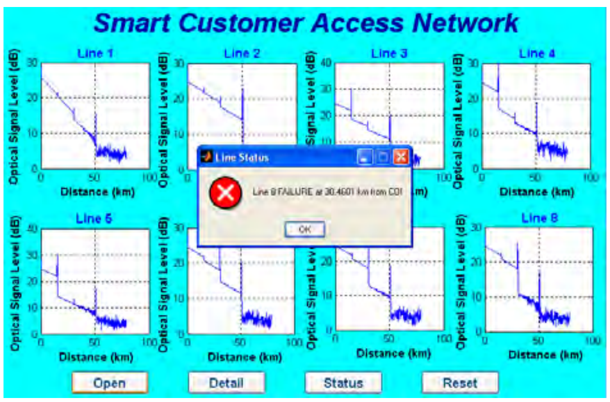

Fig.12. Two failure messages displayed to show the faulty lines and failure locations in the optical network (Two events)

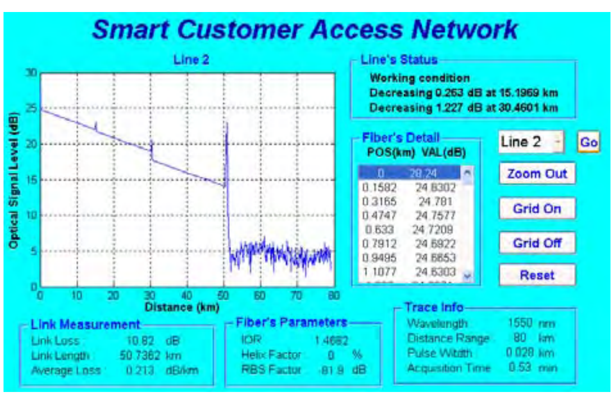

Fig.13. The optical power level in line 2 are decreased 0.263 dB at distance 15.1969 km and 1.277 dB at distance 30.4601 km

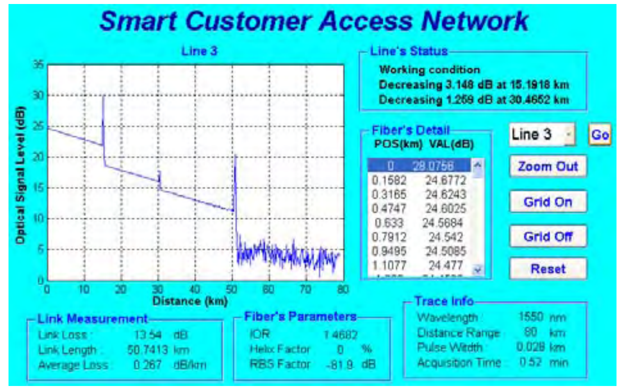

Fig.14. The optical power level in line 3 are decreased 3.148 dB at distance 15.1918 km and 1.259 dB at distance 30.4652 km

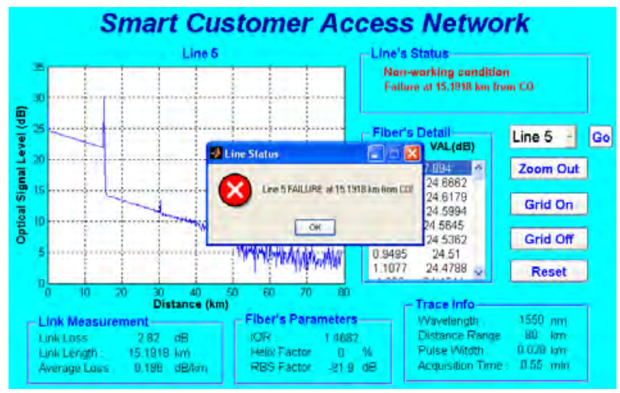

Fig.15. Line 5 is failure at distance 15.1918 km when the attenuation at optical attenuator is set as 5 dB

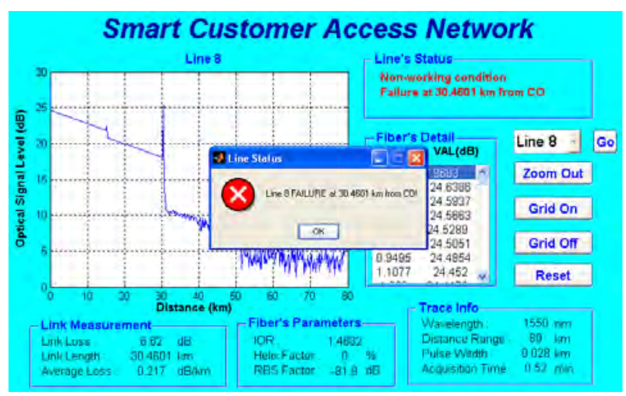

Fig.16. Line 8 is failure at distance 30.4601 km when the attenuation at optical attenuator is set as 5 dB

V. DISCUSSION

An OTDR trace is beginning with an initial input pulse. It can be having several common characteristics. Time period for the OTDR trace results from Rayleigh back scattering (RBS) as the laser source travels along the fiber section of optical line are interrupted by an abrupt shifts named as point defects. A point defect is a temporary or permanent local deviation of the OTDR signal either in upward or downward direction. Point defect caused by a connection, splice or failure along an optical line. The output pulse is indicated as end of an optical line from Fresnel reflection occurring at each fiber end.

There are four types of events getting from these experiments; they are launch level, fiber section, reflective fault and reflective end. A fiber break produces a reflective fault event in these experiments. Reflective fault are caused by an abrupt discontinuity in the index of refraction (IOR) and it caused a significant portion of the energy initially launched into the fiber to be reflected back towards the source. A loss and a reflective value are normally specified for reflective fault events [5].

CFDS is able to differentiate every line's status and detect the failure occurs in FTTH among a number of subscribers over a maximum distance of 99.9999 km It should be mentioned that CFDS is not limited to scenario with two events (two different conditions), but could be applied to more complicated network configuration. As a remark, we highlight that our strategy may also be modified to be applicable in the long haul optical communication link or fiber-to-the-x (FTTx) schemes. With CFDS no more cost and time misspending due to the troubleshooting mechanism is done downwardly.

However, it still has its own limitations. All the network testing results need to be transfer into the PC manually after been measured with the OTDR. Furthermore, the network testing results can only be saved in TRC form in OTDR, but the MATLAB software cannot directly extract the results. Thus the results need to be converted to another form such as ASCII form. Meanwhile, the program can only measure the parameters of optical lines in specific units.

VI. CONCLUSION

Even through CFDS can help any service providers and field engineers to monitor the status and detect the failure location of optical fiber line in FTTH network, but the program is still under the process of improvement. As discuss in the previous section, it is quite inconvenient to use MATLAB software for the analysis due to its own limitation. In future research activity, we aim to re-develop this program based on underlying software code (such as Visual C++ or C# language). The program will be focused on adding extra new features. When the program is successfully developed, it may help to improve the service reliability and reduce the restoration and maintenance time and cost.

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