Fault Localization Techniques of Submarine Power Cable

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***Abstract*: Fault detection is important aspect in maintaining submarine cables. Various techniques are present to provide protection to the cable such as, the electric time domain reflector, and the time-frequency domain reflectometry (TFDR). Both the techniques are compared in this proposed paper. TFDR is an upgraded fault localization method. TFDR technique can improve the fidelity of real world power systems.**

***Index Terms*: Fault localization, time domain analysis, time-frequency domain analysis**

I. Introduction

Short circuiting fault of the power feeding lines is the main reason of submarine cable failures. The fault location can be measured using several techniques. In this paper, two techniques are discussed:

– TDR

– TFDR

In TDR method, the round travel time (of an electric pulse) is measured. With the help of the computated result of the frequency response of the AC resistance measurement of the cable the frequency dependency of the pulse in the cable can be obtained. However as the propagation loss and the frequency dispersion are significant, it is difficult to measure fault point. Therefore, to improve accuracy AC resistance measurement method is used along with TDR.
Time domain reflectometry is well known offline fault localization method. But TDR has very limited accuracy. The rise time, frequency bandwidth and noise affect the performance of the method. Therefore, upgraded fault localization technique, time-frequency domain reflectometry (TFDR), is imposed to the submarine power cable system. TFDR determines a fault point by hunting the feature in the complete reflected signal. Because of the multiple reflections which make built-in problems that time-frequency domain reflectometry cannot avoid, users cannot strongly interpret results of TFDR. Therefore, in order to support the outcomes of TFDR a tangent distance is proposed.
In section II, TDR is introduced and then AC resistance measurement of cable is explained. In section III, TFDR is introduced.

II. Time Domain Analysis

Measurement system using TDR is shown in figure 1. Function generator, hybrid circuit and digital oscilloscope are present in the circuit. Digital oscilloscope records the reflected signal. Separation of transmission signal which is obtained by the reflected signal generated by the cable and function generator is done by the hybrid circuit.

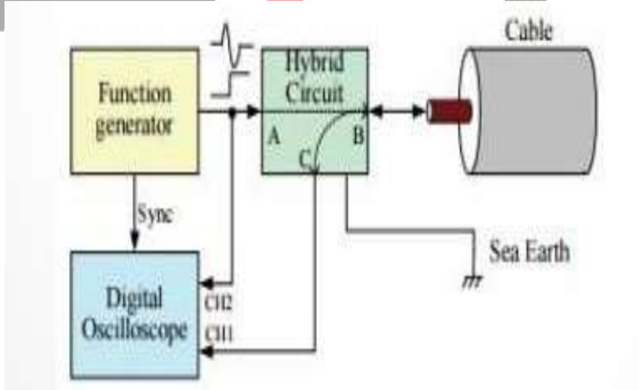

Fig 1. TDR measurement system

III. AC Resistance Measurement

With the help of two-phase lock-in amplifier, the measurement of frequency characteristics of the voltage passing into the cable and the electric current is done. Figure 2 shows the measurement method of input impedance of the cable.

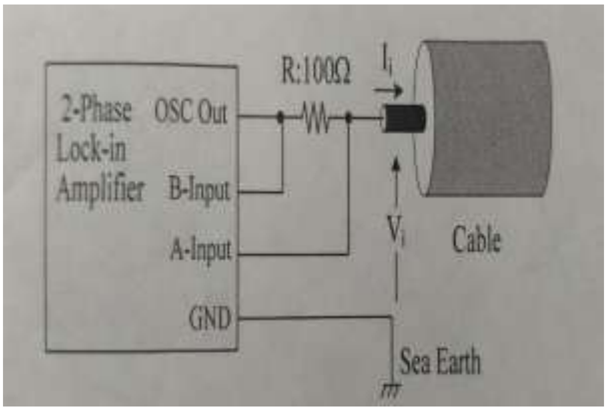

Fig 2. Impedance measurement

Calculation of input resistance is done by following expression:

$Z_{IN} = V_i / I_i = A_{IN}R / (A_{IN} - B_{IN})$

Where, measurement of A_{IN} and B_{IN} is done by the lock-in amplifier.

IV. TIME-FREQUENCY DOMAIN ANALYSIS

Based on reflectometry (such as TDR and FDR) various products are commercialized. Reference signal used for TDR such as step or impulse function can be used only in the time domain, therefore frequency localization is not present in TDR. Similarly, time localization is not present in FDR.

Hence, TFDR is developed to utilize a reference signal that has both frequency and time domain localizations. Gaussian enveloped chirp linear signal is used by TFDR in which as a reference frequency increases linearly. It is expressed by following expression:

$s(t) = Ae^{-\alpha(t-t0)\ 2/2+j\beta(t-t0)\ 2/2+j\omega 0(t-t0)}$

Inversely proportional relationship is present between time duration and α. Both α and β can be used for controlling frequency bandwidth. Center line is determined by t_0 and center frequency is determined by ω_0.

The advantage of TFDR is its versatility of selecting a reference signal. Reference signal is designed which suits with the cable under test. The signal which spreads along the cable will be reflected at impedance break points. Frequency non-selective feature is an advantage of TFDR over TDR.

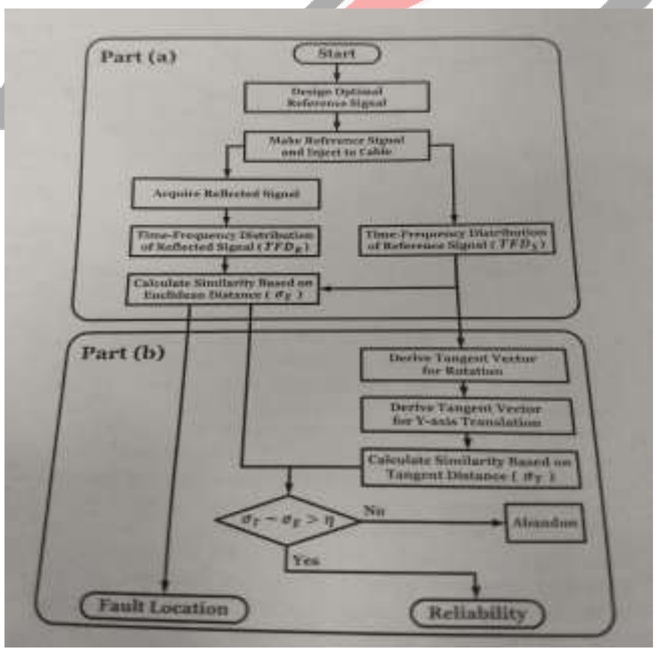

Fig 3. Flow chart of flaw localization; (a) TFDR and (b) tangent distance pattern recognition

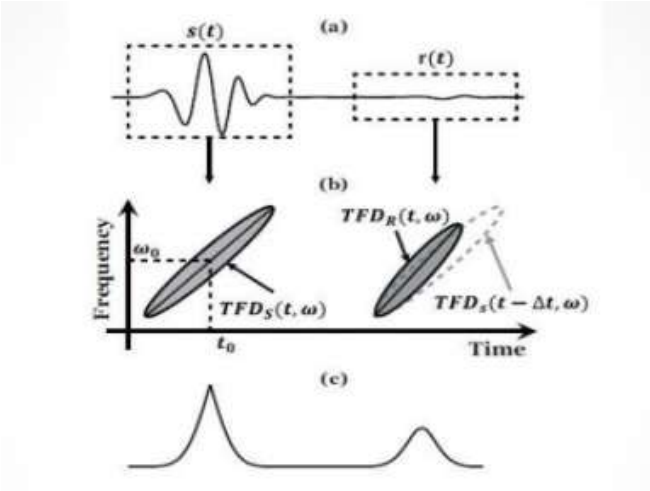

Fig 4. TFDR procedure; (a) time domain signal, (b) reference and reflected signal TFD, and (c) similarity builded on Euclidean distance

V. Conclusion

In this paper, comparison of two techniques, TDR and TFDR is done. The electric time-domain refelectometer with the AC resistance measurement is discussed. After that an upgraded fault localization technique, TFDR is proposed. To find a fault a similarity is applied based on Euclidean distance. TFDR have advantage over TDR like TFDR can localize fault for both time and frequency domain. However, since the technique is adaptable with the length of the cable, this technique can be used in the real world power systems.

References

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