IJCSE International Journal of Computer Sciences and Engineering Open Access
Review Paper Volume-4, Special Issue-2, April 2016 E-ISSN: 2347-2693

Analysis of Spread Spectrum Time Domain Reflectometry for Cable Fault Detection

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Available online at: www.ijcseonline.org

Abstract— Cable fault detection is crucial and helps to avoid severe damage and maintain continuous functioning of an electrical system. Spread Spectrum Time Domain Reflectometry is considered to be an effective method to detect intermittent faults such as open circuits and short circuits. This paper shows the working and advantages of Spread Spectrum Time Domain Reflectometry (SSTDR). It also includes experimental data analysis performed on low voltage cable using ARC CHASER SSTDR kit manufactured by LIVE WIRE INNOVATIONS.

Keywords— Spread spectrum time domain reflectometry (SSTDR), pseudo noise (PN), time domain reflectometry (TDR), cable fault detection, correlation.

I. INTRODUCTION

Electric cables are used to supply electric power to electrical systems and to interconnect the systems with their instruments and controls, which makes them an important component of an electrical system. The polymer materials used for the insulation and jacket materials for electric cables, cable splices, and terminations are susceptible to aging and degradation mechanisms caused by exposure to many of the stressors encountered in the location installed. The aging and degradation of a cable is caused by exposure to these stressors and can result in degradation of the dielectric properties of a cable's polymer insulation material.

Over time, the aging and degradation mechanisms caused by these stressors can eventually lead to early failure of the cable. It is therefore important that periodic inspection and testing of electric cables be considered. Severely damaged or degraded cable insulation can then be identified and repaired or replaced to prevent unexpected early failures while in service.

The most difficult wiring problems involve intermittent faults. Intermittent faults are malfunctions of a device or system that occur at intervals, usually irregular, in a device or system that functions normally at other times. One such method based upon spread spectrum technique that can detect such faults is described in this paper [1].

II. CONVENTIONAL FAULT DETECTION TECHNIQUES

There are several fault detection techniques used which include high potential test (AC/DC/step DC), time domain reflectometry (TDR), frequency domain reflectometry (FDR), resistance measurements and capacitance measurements[7] [8]. These methods are not able to detect intermittent faults. Also, some of these methods are destructive and intrusive which are not desirable characteristics.

Therefore, there is a requirement of another test method which can detect intermittent faults as well as faults in noisy environment.

III. PRINCIPLE OF REFLECTOMETRY

The principle of reflectometry is similar to that of RADAR. In this method, a high frequency signal is injected into a cable which is to be tested. The presence of impedance mismatches in the cable result in the reflection of the injected signal. The combination of incident and reflected signal is observed and the time of flight of this reflected signal is observed or determined.

$$D = V*(T/2) \quad (1)$$

Where,
D = distance of the fault
T = round trip propagation time to the fault and back
V = velocity of propagation of signal in the cable

The fault location is calculated by using the time of flight and pre-determined velocity of propagation of injected signal varying according to the type of cable, as shown in (1).

IV. SPREAD SPECTRUM TIME DOMAIN REFLECTOMETRY

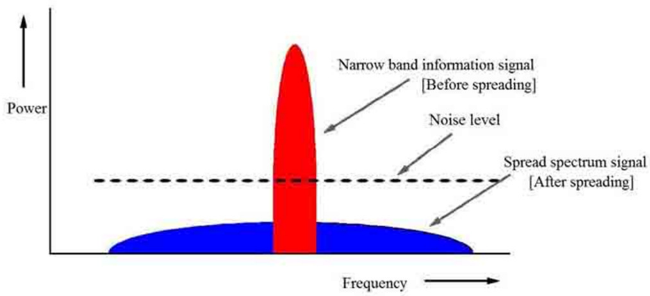

Fig.1 Spread of signal in frequency domain [2]

Spread spectrum uses broadband noise like signals that are difficult to detect, jam or intercept. Since, spread spectrum signals are so wide, they transmit at much lower power spectral density which makes spread spectrum signals difficult to interfere with narrow band signals [2].

Frequency hopping and direct sequence spread spectrum (DSSS) techniques are used to spread the signal over a wide range of frequency band. In SSTDR, DSSS technique is employed. DSSS technique uses pseudo noise (PN) sequence to make the signal broad band and noise like.

The block diagram of SSTDR is shown in Fig.2. SSTDR uses a sine wave generator. This sine wave is fed to a shaper to generate square wave signal which in turn drives a PN code to produce PN sequence at the output of PN generator. This PN sequence is modulated using BPSK and injected into the cable to be tested. Due to certain impedance mismatch (short circuit, open circuit or insulation damages) in the cable, the incident/injected signal is reflected back. On the other hand, the incident signal is given a variable phase shift. This signal along with the combination of incident and reflected signal is fed to correlator block. SSTDR uses cross-correlation which is a measure of similarity of two signals as a function of the lag of one relative to the other. The time of flight of reflected signal is determined using correlation.

$$X_{corr} = \int_{-\infty}^{\infty} x(t) \times x(t-\tau)dt \qquad (2)$$

Where,
$\tau = 0$ to ∞

Also, correlation of signals results in elimination of the effect of noise. Outputs obtained at the correlator are fed to analog to digital converter and stored in PC interface. The graph of correlation v/s distance is plotted and the fault location is determined using (1).

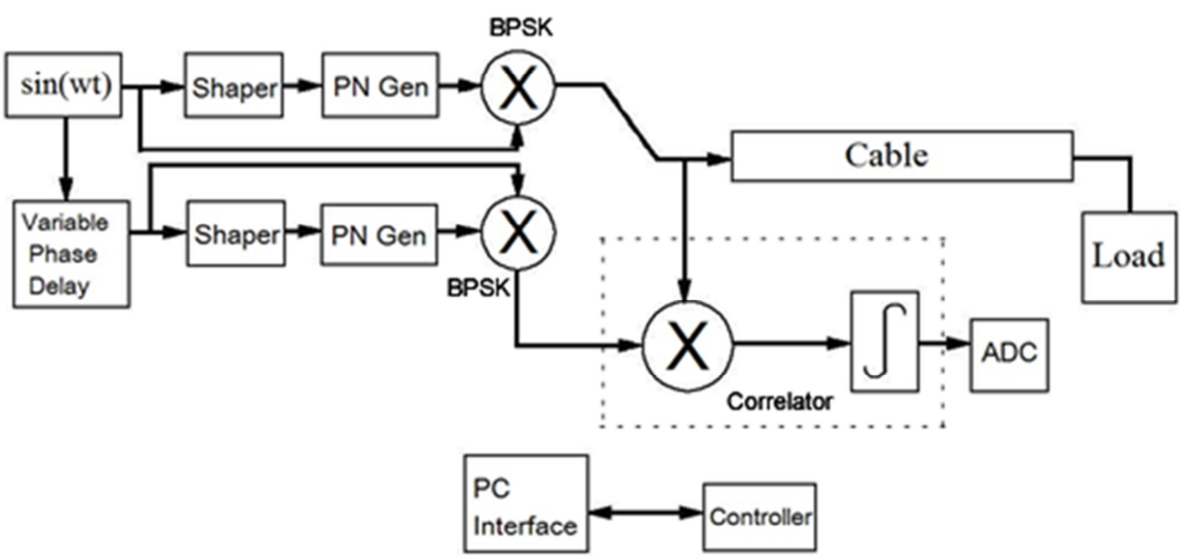

Fig.2 Block diagram of SSTDR [1]

V. EXPERIMENTAL RESULTS

The experiment was conducted using the *ARC CHASER* SSTDR kit manufactured by *LIVE WIRE INNOVATIONS*.

The types of cables tested were two twisted multi stranded cables:

- Cable A : 10m long healthy cable
- Cable B : 20m long cable containing insulation damages at 5m and 10m.

The velocity of propogation (V) of the signal through the cable was determined using the *ARC CHASER*, which was measured to be 57.9m/s.

The graphical output of the *ARC CHASER* is a graph of Correlation vs. Distance.

TABLE I
OBSERVATIONS

Type of Fault	Fault location measured (meters)	Fault location observed (meters)	Graphical Output
Cable A			
Termination Open	10	10	Fig.3
Termination Short	10	10.1	Fig.4
Cable B			
Termination Open	20	20	Fig.5
Termination Short	20	20	Fig.6

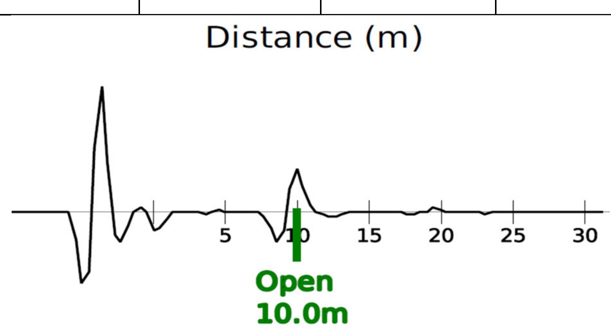

Fig.3 Cable A- Termination open

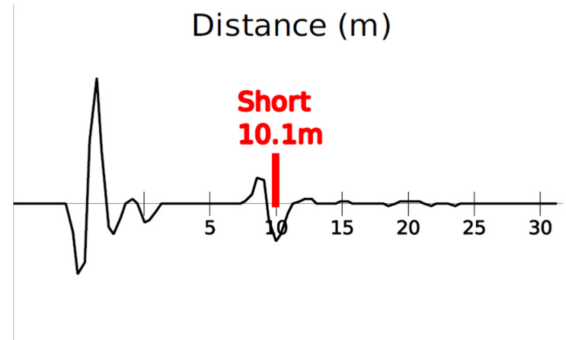

Fig.4 Cable A- Termination short

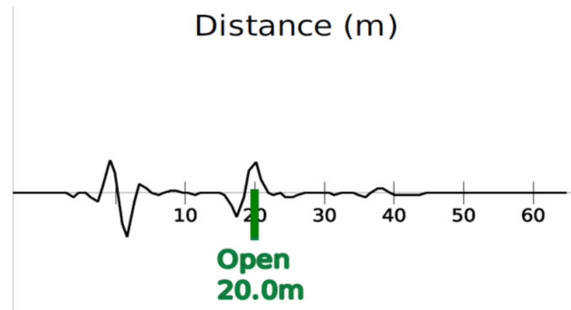

Fig.5 Cable B- Termination open

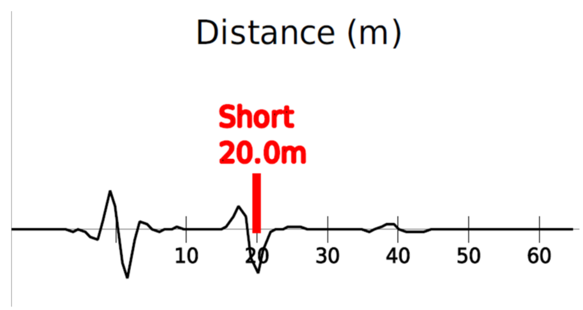

Fig.6 Cable B- Termination short

VI. CONCLUSIONS

The paper emphasizes on SSTDR technique which is desirable to locate intermittent faults and insulation damages on the cable. SSTDR is capable of providing accurate results in noisy environment. This technique is non-intrusive and a non-destructive technique. *ARC CHASER* provides accurate results for fault detection (accuracy= ±0.1m). In some embodiments, SSTDR can be used to detect arc faults, ground faults, winding faults and insulation degradation in motors and transformers, and it is widely used in aviation industries and aircrafts.

ACKNOWLEDGMENT

We would like to thank Dr. A. P. Tiwari, SO-H, BARC and Ch. Santosh Subudhi, SO-D, BARC for supporting us in conducting the experiments. We would also like to acknowledge Dr. S. R. Deore, HOD, Electrical department, ACPCE and Mrs. Jisha Sathish, Professor, Electrical department, ACPCE for helping us to present this paper.

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