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Identification of Cable Faults Onboard Ship using Power Line Communication

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Abstract: The integrity of an electrical cable is vital for the reliability and safety of a system. The change in operating conditions of the electrical cable often leads to unanticipated faults or premature ageing and any such defects has to be monitored so that corrective measures can be taken within the time limit. This is relevant particularly in the case of ships since they cannot afford discontinuity in power supply. In this paper, an experimental setup is developed to create and monitor the intermittent faults in ship electrical system using power line communication. The advantage of this technique is its non-intrusive nature in monitoring the faults.

Keywords: Error Detection, Intermittent Faults, Modulation, Power Line Communication

I. INTRODUCTION

To improve the safety and reliability of electrical cable system the importance of identification cable faults becomes increasingly apparent, especially in onboard ship applications. Many research has already been done in the area of cable fault detection, there so many serious concern worldwide because of its huge impact in several fields like power generation, transportation and defence [1][2].This paper develops an experimental setup to create and monitor the intermittent faults in onboard ship electrical system using power line communication.

The lifetime of a power cable is considered as 40 years; however any change in type of load or variation in branches may lead to unanticipated or premature breakdowns. Particularly, in a power distribution network of a ship where the continuity of power supply and reliability of electrical machines is of utmost priority, cable faults are unacceptable. It is nevertheless to mention that, the length of cables on board ship is in few kilometers and is continuously exposed to vibration, heat, salinity and other hazardous conditions.

Fig. 1. Insulation faults observed on ships [3]

Because of this, the cables used for power distribution, control and instrumentation onboard ship often experience issues like cracks, ricks and nags, as shown in Fig.1, which damage the insulation performance of the cable. Hence it is important to develop a efficient cable monitoring system to increase the reliability and maintain the safety of the ship and also at the same time reduce the operational costs.

The length of cabling would be in hundreds of kilometers in onboard ship or in submarine and thus it increases the difficulty in identifying the faults in an electrical cable. Keeping in view the long operational life span of these vessels, a perfect monitoring scheme has to be implemented. Out of many cable faults identified, intermittent faults are considered to be more serious than permanent faults [11]. These faults cannot reproduce at the time of routine testing and hence it becomes difficult to locate and rectify. Due to these intermittent faults, cable start to rub each other and create a small arc; also, insulation damaged due to the over-tightened clamp; connector creating occasional non-contacting with the pins due to corrosion [10].

Various test methods have been developed for cable monitoring such as insulation resistance, dielectric strength, dielectric loss, line resonance analysis, tanδ, partial discharge method etc [4]-[7]. Though these methods are sensitive to small changes in electric cable parameters, they are not very cost effective and the devices or sensors are to be placed in an intrusive manner.

The power line communication is a technology which uses the existing electrical network for data transmission. Because of the worldwide penetration of electrical network, it can play a vital role in telecommunication, automation services and network monitoring. Power line communication is a highly desirable technique to perform a non-intrusive power line monitoring at a low cost [7]-[13]. To identify the intermittent faults in the power cables, data is transmitted continuously over the distribution network. Any fault in the cable will result in error in the message received.

The paper is organized as follows. In section II, the merits of power line communication and its usage in transferring the data is explained. In section III, the feasibility of power line communication in monitoring the cable faults is explained through an experimental test setup. The data is transmitted over the power line using LABVIEW software. The evaluation of data and identification of different cable fault explained in section IV.

II. POWER LINE COMMUNICATION

PLC is a technology which uses the electrical infrastructure for transferring the data. This technology has found its applications at both medium voltage and low voltage levels serving the purpose of Industrial automation and network connectivity. PLC can be carried out in Narrowband frequency (1- 500 kHz) or in Broad band frequency (1-200 MHz) range. In the recent past, In-home power line communication has attracted the research community as a viable alternative to provide automation solutions and high speed internet connectivity for home appliances.

But the major concern with the PLC is that the power line is hostile to data communication. This is mainly due to the impairments like attenuation, impedance mismatch and noise present in the power line. However, advanced modulation techniques and filtering techniques are being proposed to overcome these challenges.

In this paper, the change in data transmission due to the physical variations of the cable is studied. It is noticed that with severe raise in temperature or any thermal attack on the conductor, the conductivity of the conductor decreases, the resistance increases.

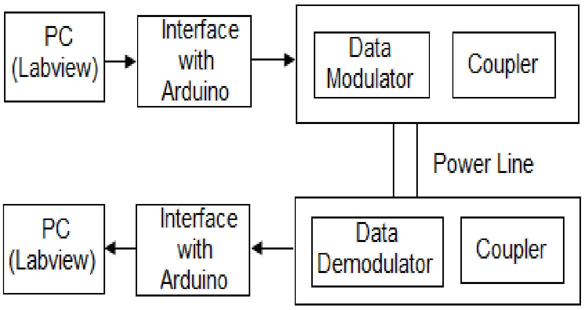

Fig. 2. Block diagram for power line setup

Due to the ageing of insulator material, or improper maintenance, it is found that the dielectric constant decreases, the capacitance and conductance G decreases.

Similarly, when cables are exposed to electromagnetic interference or magnetic ageing in the cable, the magnetic permeability decreases, resistance and inductance decreases.

This is primarily because, the attenuation of a power line channel depends on the basic parameters Impedance (Z) and propagation constant (γ) of the cable which in turn depends on the intrinsic parameters resistance (R), Inductance (L), Capacitance (c) as shown in (1) and (2).

$$Z_0 = \sqrt{\frac{(R + jwl)}{(G + jwc)}} \quad (1)$$

$$\gamma = \sqrt{(R + j\omega C)(G + j\omega C)} \quad (2)$$

III. EXPERIMENTAL TEST SETUP

The experimental test setup is as shown in Fig.2 and Fig. 3. The two PC with LABVIEW software are interfaced on the power line through a PLC Modem and arduino device.

Fig. 3. Experimental setup

Using the LABVIEW software continuous data is transmitted over the power line as shown in figure 1. These random bits stream are generated with an error detection code so as to avoid any loss of data over the power line.

A bit stream of 5000 messages with a baud rate of 9600 is transmitted over the power line with a time delay of 500 milliseconds as shown in Fig. 4. The pause of 500ms between the transmissions is necessary for the receiver to check packets for any errors. Arduino UNO R3 which is an open source, is used to interface the lab view with the modem. The modem transmits and receives serial data and has a carrier frequency of 150 Khz.

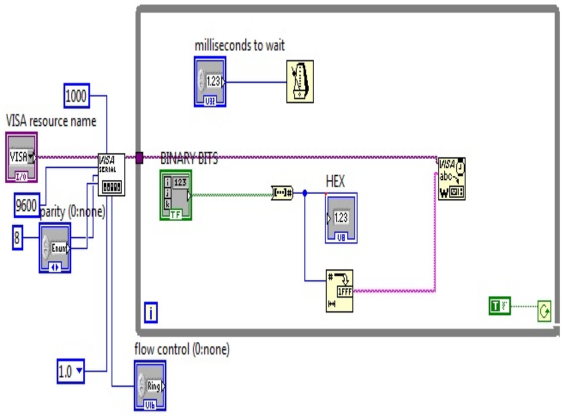

Fig. 4. Code for data transmission using LABVIEW

The received data from the power line is demodulated using the FSK demodulation technique and is fed into the Computer using the arduino device. The LabVIEW code for receiving data is as shown in Fig. 5.

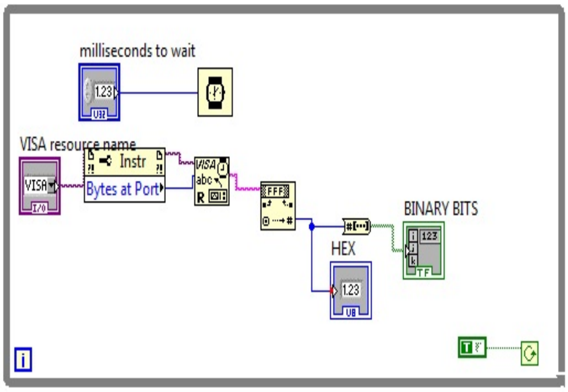

Fig. 5. Code for data receiving using LABVIEW

For the experimental setup, various fault scenarios are created as explained below

(a) The insulation of the cable is dented leading to mechanical stress and few strands are disconnected.

(b) The power cable is twisted and tightened against the clamp.

(c) High resistance is created in the cable.

(d) The connectors are loosely placed leading to occasional non-contact of the pins.

These fault scenarios both individually and in combination are created at different locations of the cable. Each test was repeated more than 10 times to confirm the results. The cable considered in this paper has parameters as shown in Table I

TABLE I. Cable Parameters

Parameters	***NYM 3x1.5mm^2***
Resistance R (mm)	1.22
Distance between conductor (mm)	4.04
Conductivity of conductor σ_c (S/m)	$5.8\text{x}10^7$
Relative dielectric strength ε_r	$-0.88\log f + 9.50$ ($1.6 \leq f < 5$MHz)
	$-3.3\text{x}10^{-9}f+3.61$ ($5 \leq f < 30$MHz)
Relative magnetic permeability µ	1
Dissipation factor tanδ	$-5.7\text{x}10^{-10}f + 0.085$ ($1.6 \leq f < 30$MHz)

IV. EXPERIMENTAL RESULTS

The feasibility of power line communication (PLC) in identifying the intermittent faults is analyzed using digital storage oscilloscope (DSO) by sending a known signal continuously over the power line. In normal conditions the transmitted data is received at the other end of the cable as shown in Fig. 6.

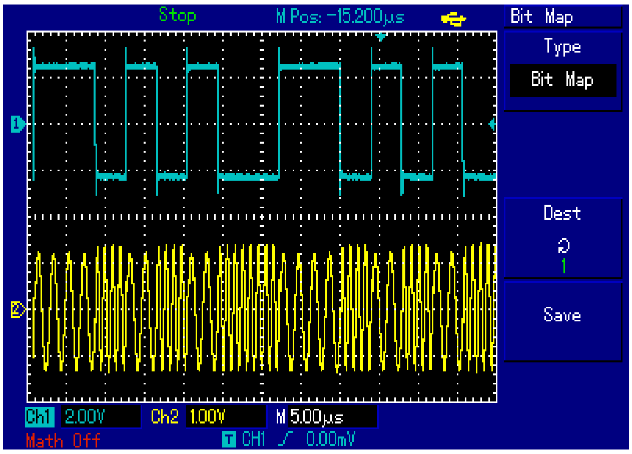

Fig. 6. Signal received in ideal condition

The insulation of the cable used is peeled off such that the strands of the conductor are visible. With this setup, the continuity of power supply exists but permeability of the cable changes. This leads to drop in the number of packets sent or drop in signal voltage as shown in Fig. 7.

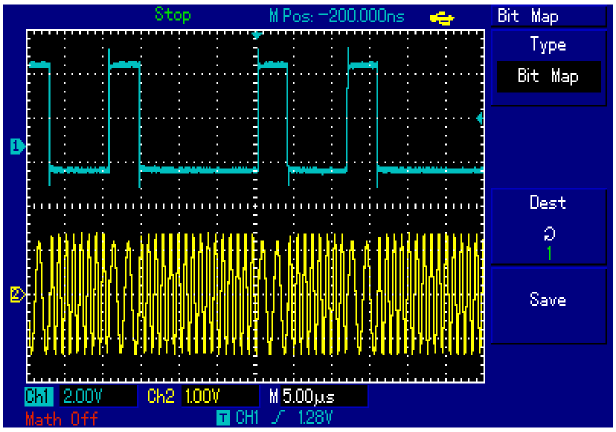

Fig. 7. Signal received due to insulation damage

The saline condition of a cable can be resembled with a high resistance fault in the cable. Fig. 8 shows the drop in voltage and the packets lost when a high resistance fault is created.

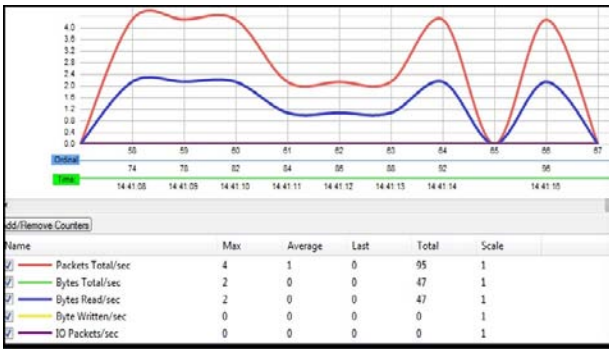

Fig. 8. Signal Response due to high resistance fault

Loose connections in a system explain the poor workmanship of a technician. These faults are very intermittent in nature and nearly impossible to detect. Fig. 9 show the drop in voltage and the packets lost due to lose connections.

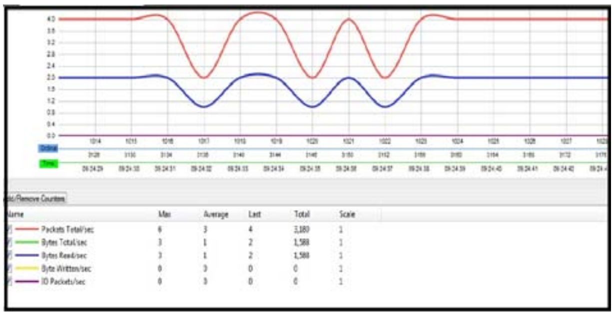

Fig. 9. Response due to Loose Connections

V. CONCLUSION

Faults in cables due to lose connections or insulation failures can be diagnosed in advance using the power line communication. The technique has the advantage of being non-intrusive in nature and also cost effective. Identifying a faulty condition not only saves the revenue but also increasing the sailing time of the ship.

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