# Subsea Fiber optic cable maintenance using ROV based flux leakage expert system

Md. Reza Hedayati

*Scientific-Applied Faculty of Post and Telecommunications*
*Danesh Blvd., Janah Expressway Azadi Sq., Tehran- Iran*
*(Tel: +98 21- 446594900, 44654555, Fax: 44659665 )*
*(Email: hedayati@ictfaculty.ir)*

***Abstract:*** Word events have increased the demand for secure high band width under water fiber optic communications and at the same time the telecommunications service providers are struggling with maintenance and protection expense containment. As a result of extended usage of the sub sea industries, the number of installed subsea optic services continues to increase and the potential for external aggression resulting to these cables increased.
This paper addresses the evolving subsea especially designed Remotely Operated Vehicle (ROV) with dedicated electromagnetic flux leakage searching arm as a part of associated maintenance arrangement. Current research achievements apply the expert system techniques in the diagnostic system of sub sea fiber optic cables base on the concept of Ampere's law and method of measuring circulating currents without any physical destruction by testing the suspected section which is already subjected to alternating current flow with selected frequencies.

***Keywords***: Diagnostic, Undersea fiber optic cable, Electromagnetic flux leakage, Expert system

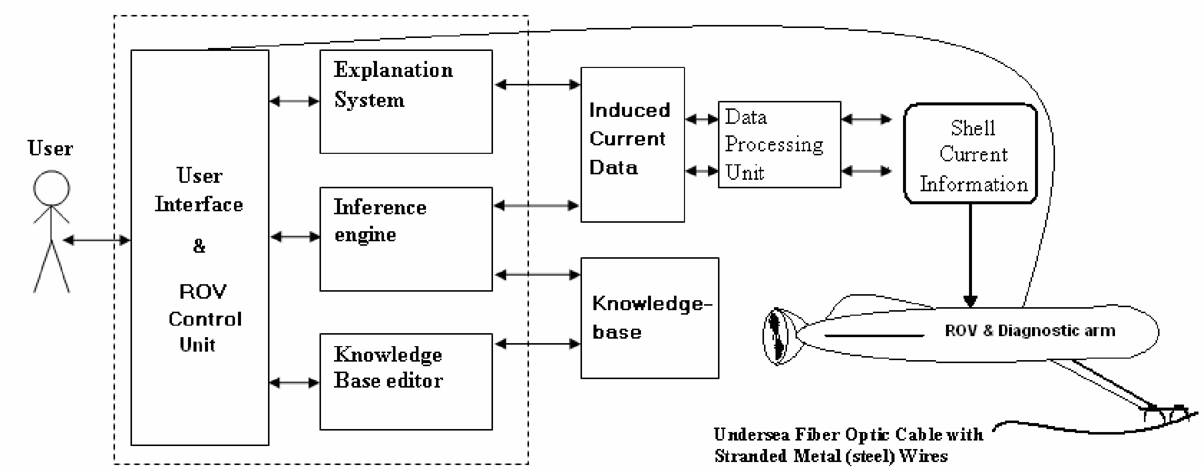


Fig.1. The most important modules of proposed rule-based diagnostic expert system

## I. INTRODUCTION

Reduction of the human experts' involvement in the diagnosis process has gradually taken place upon the recent developments in the modern artificial intelligence (AI) tools. Artificial neural networks (ANNs), fuzzy and adaptive fuzzy systems, and expert systems are good candidates for the automation of the diagnostic procedures and e-maintenance application [6, 9]. The present work surveys the principles and criteria of the diagnosis process and introduces these achievements to an expert system technique. In this paper a new sensor design is discussed and experimental results are presented for an expert system application, based on the concept of Ampere's law and method of measuring alternating circulating currents without disturbing their paths for suspected part of undersea fiber optic cable. A transducer using the principle of a toroidal search coil has been tried and considered to be suitable for measuring any probable damage due to irregular phenomenal impact on the suspected superficial portion of the cable. Such transducers are proposed to be the basis for condition monitoring of armored steel structure in the cable by means analyzing the change of e.m.f induced by primary winding of the testing probe.

The telecommunications service providers have worked out several diagnostic techniques including optical time-domain reflectometer method (OTDR) suiting to individual requirements [1]. Some of these are listed as below:

- Condition monitoring based on video observations
- Leaser detection and monitoring
- Ultrasonic fault and health monitoring device
- Electromagnetic flux leakage (EMFL)diagnostic
- Radiography (X-Ray)

The information already gathered for a healthy cable stored in a data base which can be used by expert system shell. The test personnel interact with the system through a user interface which uses menus and style of interaction. An inference engine is used to reason with both the expert knowledge (extracted from our experienced expert) and data specific to the problem solving. The expert knowledge is in the form of a set of IF-THEN rules. The case specific data includes both data provided by ROV's test personnel (user) and partial conclusions (along with certainty measures) based on this data [4, 6, and 9]. The explanation subsystem, which allows the program to explain its reasoning to the test personnel beside knowledge base editor help the expert or knowledge engineer to easily update and cheek the knowledge base as shown in the Fig (1).

## II. Study of Problem

According to the statistics the most important causes of mechanical faults of fiber optic cables in Persian Gulf are included the following:

- Fishing activities
- Aggression due to installation and maintenance of offshore utility installation
- Anchor drop

The effects of the above mentioned activities are in the form of mechanical impact load or stress on the submarine cable which usually it is not possible to diagnosis them through video inspection. The irregular mechanical impact changes the structure of wired steel armor and therefore causes unusual pressure on the fiber housing situated in the middle of the cable. The undersea fiber optic cable which is subjected to these types of unusual mechanical stress is subjected to the disruption of interior fibers in the near future.

The alternating flux generated by semicircular active part of designed sensor is affecting the suspected portion of the cable. In the proposed method asymmetries in the magnetic circuit of damaged section of cable are due to uneven air gap-caused by displacement and misalignment of standard steel wires (armored Surrounding section of the cable). Such asymmetry are inevitable after a high mechanical impact load or stress on the surface of undersea fiber optic cables and changes the permeability of the tested section. Saturation of the steel wire also introduces high order harmonics in the search coil. The important components of induced currents are fundamental, the third and the fifth harmonic, corresponding to the most dominant components in the magnetic field.

The predominance of one component or the other will depend on both the type of the asymmetry and misalignment of the selected wires, which is related to the type of engineering information to be generated with respect to the structure of the armor wires, for the knowledge base which contributes data with the proposed expert system shell through interface engine and knowledge base editor. The half circle transducer clamped around the suspected part of the under surveillance and induced current variation is recorded with respect to healthy portion of the cable.

## III. The Principle of EMFL Contact less health monitoring of undersea fiber optic cable

The current value depends on the way the measuring instrument is connected, i.e. the way the connecting leads are laid out. Since it has been seen that in circulating current circuits, the current is the only uniquely defined quantity, its measurement needs grater care than similar measurements in an externally forced current circuit [3, 9]. Whilst the induced emf in the closed contour of the circulating current circuit is a unique value.

$$e = -N\, d\Theta/dt,$$

If the current starts flowing in it, the potential drop between any two points on it is no longer a single-value function. A split type, uniformly wound, flat induction coil with equal cross-section all along the turns, is used for contact less induced cable current measurement, Fig.(4). Such an arrangement facilitates the determination of the enclosed current. If the coil is arranged as a closed loop around a conductor, then the line integral corresponds to the induced cable current in the enclosed conductor. Such a coil must have an inner diameter just more than the diameter at the mounting location. Depending on the type of the coil, it can cover a wide range of induced currents from a few milliamperes to a few tens of miliampers over a wide frequency range, with the help of FFT analyzer. It is well known that the current flowing in a conductor gives rise to the flux around, Fig. (4), illustrating the principle of ampere's law. Mathematically, Ampere's law is expressed as:

$$\oint H.ds \quad = \; I \;\; \text{enclosed}$$

For a circular path C, around suspected part of the cable carrying an induced current. Integrating over the circular contour ,C,

$$B = \mu\, I / 2\pi\, r$$

Flux linkage for a toroid of axial length L meter and N turns, of the dimensions as shown in Fig. (4), we have

$$N\Phi = (\mu\, I\, L\, N / 2\,\pi)\, [\ln (r_2/r_1)]$$

Voltage induced across the toroidal coil of axial len gth L meters and N turns, and then induced current,

$$i = I_{max} \sin \omega\, t,$$

$$e_{\,rms} = \mu\, L\, N\, f\, [\ln(r_2/r_1)]\; T_{\,rms}$$

The above expression is used for designing toroidal search coil used for measurement of current in the suspected part of the cable.

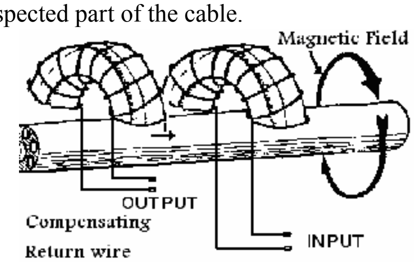


Fig. 4. Current Measurement Principle in the suspected part of subsea fiber optic cable

## IV. Typical Test Results

For construction of knowledge base and serving expert system shell, measurement of current in the suspected part of cable, incorporated through data processing unit and induced current data modules. Fabrication, calibration of split toroidal search coil and mounting on the suspected part, resulted to obtain the following induced values on a test cable.

Test results in suspected portion (Which already subjected to mechanical impact load and damaged) indicate that the third harmonic component is predominant. Variation in the behavior and operating condition of the cable will be reflected in the data processing unit and knowledge base module of expert system for proper decision making. Typical induced cable current values are recorded as shown in Fig. (5). for an undersea fiber optic cable.

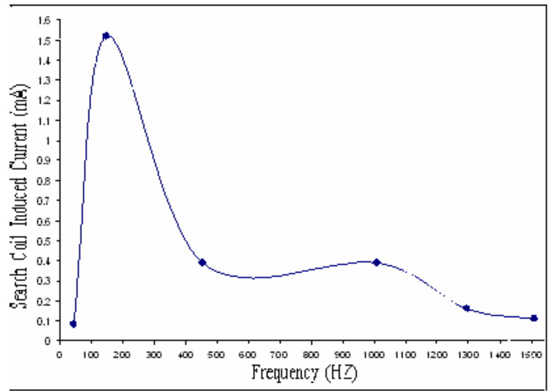


Fig.5. A typical variation of transducer signal for shaft current measurement

Fig. (6) Shows several typical discontinuities and how their corresponding signals may appear on a test screen monitor. Fig.(7) shows the nature of the change can be analyzed and diagnosis made according to the fault and used for construction of knowledge base module.

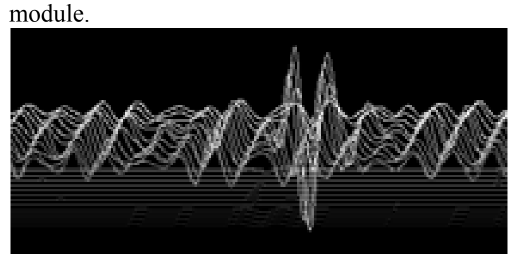

Fig.6: Signal From search coil to data processing unit

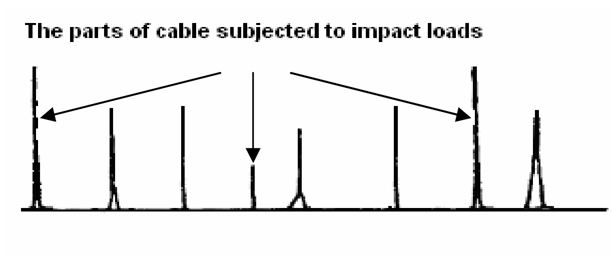


Fig. (7): Samples Data for Knowledge Base Module

## V. Conclusions

It is apparent that in the proposed method the perfect undersea fiber optic cable should produce induced voltage more or less than abnormal value. This is never the case, for it is impossible to eliminate all asymmetries in the materials and geometry of the steel wires in the cable. To extract knowledge from the expert the knowledge engineer must become familiar with problem of electromagnetic flux leakage and induced current. The rule base system is goal driven using back ward chaining strategy to test the collected induced current information is true. The case specific data plus the above information with the help of explanation subsystem, allows the program to explain its reasoning to the user and will provide the expert system shell requirements.

Significant difference can exist between the signals created by cable defects. Alternating induced current in undersea fiber optic cable can be measured conveniently and with reasonable accuracy using toroidal coil located by an ROV and proposed diagnostic arm. This device serves as a base for development of expert system monitoring module. The change of reference signal with proposed expert system implies that something within the fiber optic cable structure has altered and diagnosis is made.

**References:**

[1] Siddique A, Yadava G S, Singh B, (2003) Applications of artificial intelligence techniques for induction machine stator fault diagnostics: review SDEMPED 2003. 4th IEEE International Symposium on Diagnostics for Electric Machines, Power Electronics and Drives 1:29-34

[2] Whitcomb LL (2000) Underwater Robotics: Out of the research laboratory and into the field.IEEE International Conference on Robotics and Automation 1:1-14

[3] Roman H T, Pellegrino B A, Sigrist W R (1993) Pipe crawling inspection robots: an overview IEEE Transaction on Energy Conversion 8 :3:576-583

[4] Han Y, Song Y H, (2003) Condition monitoring techniques for electrical equipment-a literature survey IEEE Transactions on Power Delivery, 1:4-13

[5] Bannon R T (2000) Remotely operated vehicles evolution for maintenance and repair of fiber optic system. OCEANS 2000 MTS/IEEE conference and exhibition 1:489-496

[6] Filippetti, F. Martelli, M. Franceschini, G. Tassoni, C. (1992) Development of expert system knowledge base to on-line diagnosis of rotor electrical faults of induction motors, IEEE Industry Applications Society Annual Meeting, 1:92 - 99

[7] Nandi, S. Toliyat, H.A. (1999) Condition monitoring and fault diagnosis of electrical machines-a review, Industry Applications Conference, IEEE Annual Meeting, 1:115-118

[8] Greska, M (2002) Requirement standards for qualified submarine cable technicians. OCEANS, 2001. MTS/IEEE Conference and Exhibition 1.1: 586-590

[9] Hedayati MR (2004) On-line condition monitoring of locomotives, the 7th Railway conference, Sharif University, (in Persian), Tehran- Iran 1: 60-65