CONDITION MONITORING OF ELECTRICAL CABLES USING LINE RESONANCE ANALYSIS (LIRA)

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ABSTRACT

This paper describes a method for cable system condition monitoring that is based on transmission line theory and resonance analysis. This method resulted in the development of a system called LIRA (LIne Resonance Analysis), which can be used on-line to detect local or global changes in the cable electrical parameters because of insulation faults or degradation. This paper presents the latest results achieved in field experiments on medium and high voltage cables.

KEYWORDS

Condition Monitoring; Transmission Lines; LIRA; Cable Ageing

INTRODUCTION

There is a continued interest worldwide in the safety aspects of electrical cable system degradation. Degradation of a cable system can result in loss of critical functions of the equipment energized by the system, or in loss of critical information relevant to the decision-making process and operator actions. In either situation, unanticipated or premature aging of a cable can lead to unavailability of equipment important to safety and compromise public health and safety.

Current techniques to evaluate aging properties of electric cables include electric properties tests.

While known to be difficult, advancements in detection systems and computerized data analysis techniques may allow ultimate use of electrical testing to predict future behavior and residual life of cables. The following describes the current results and development of a system (LIRA) and its progress in being able to determine the degree of cable degradation through electrical testing. LIRA has gone through extensive tests since 2005 with low, medium and high voltage cables, both in laboratory tests and in-situ experiments and it has been used in service assignments since 2007.

The LIRA (Line Resonance Analysis) Technology is a cable condition assessment, cable fault location and cable aging management system that works in frequency domain through advanced proprietary algorithms. LIRA is based on the transmission line theory, and calculates and analyse the complex line impedance as a function of the applied signal for a wide frequency band. It detects and locate changes in the cable impedance and makes it possible to perform fault location and cable condition monitoring on I&C, low, medium and high voltage cables even in inaccessible challenging environments. The applied frequency band is a 5V signal, and is harmless to the cable.

LIRA will detect and locate local degradations in the cable, which is specific to certain sections of the cable and caused by mechanical stress and damages, or by heat-induced oxidation and radiation. It will also detect global degradation in the cable, which is applicable for the entire cable, and is caused by general aging, influenced by external and internal environmental conditions.

This paper presents the current technology at the base of this system, together with some interesting results on installed cables.

THE LIRA METHOD

The Line Resonance Analysis (LIRA®) method has been developed by the Halden Reactor Project in the years 2003-2006 [4] and then further developed by Wirescan AS and it is based on transmission line theory [5-8]. A transmission line is the part of an electrical circuit providing a link between a generator and a load. The behavior of a transmission line depends on its length in relation to the wavelength of the electric signal traveling into it.

When the transmission line length is much lower than the wavelength (λ), as it happens when the cable is short and the signal frequency is low, the line has no influence on the circuit behavior and the circuit impedance, as seen from the generator side, is equal to the load impedance at any time.

However, if the line length and/or the signal frequency are high enough, so that *Length* $\geq \lambda$, the line characteristics take an important role and the circuit impedance seen from the generator does not match the load, except for some very particular cases.

LIRA includes a proprietary algorithm to evaluate an accurate line impedance spectrum from high frequency measurements. Figure 1 shows the estimated impedance for an instrument cable 100m long, in the 0-10 MHz range.

Line impedance estimation is the basis for local and global degradation assessment. Tests performed with LIRA show that thermal degradation of the cable insulation and mechanical damage on the jacket and/or the insulation do have an impact on C and at a lesser degree on L. Direct measurement of C (and L) would not be effective because the required sensitivity has the same magnitude of the achievable accuracy, due to the environment noise normally present in installed cables (especially for unshielded twisted pair cables, see Figure 2. Some results were achieved with coaxial cables [4]). LIRA monitors C variations through its impact on the complex line impedance, taking advantage of the strong amplification factor on some properties of the phase and amplitude of the impedance figure, as shown in Figure 3.

Hot spot damage due to localized high temperature conditions and local mechanical damage to the insulation are detectable by LIRA through use of a proprietary algorithm starting from the line impedance spectrum .