LIRA Technology
Cable Condition Assessment and Monitoring

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Wirescan AS provides products and services for condition assessment and monitoring of electrical cables, using the innovative technology, LIRA (Line Impedance Resonance Analysis). The LIRA technology is a solution which enables system operators, cable manufacturers, and cable owners to evaluate the condition of their electrical cables. This paper presents the performance and various functionalities of the LIRA technology, related to reliable operation of electrical cable systems, and its accuracy to detect and localize local and global degradations.

1 Background

Condition assessment and monitoring of electrical cables are certainly important processes required in electrical power systems operation. The ability to systematically evaluate cable condition enables early detection and accurate location of potential faults. This ability allow to anticipate and mitigate severe consequences that can be costly and catastrophic.

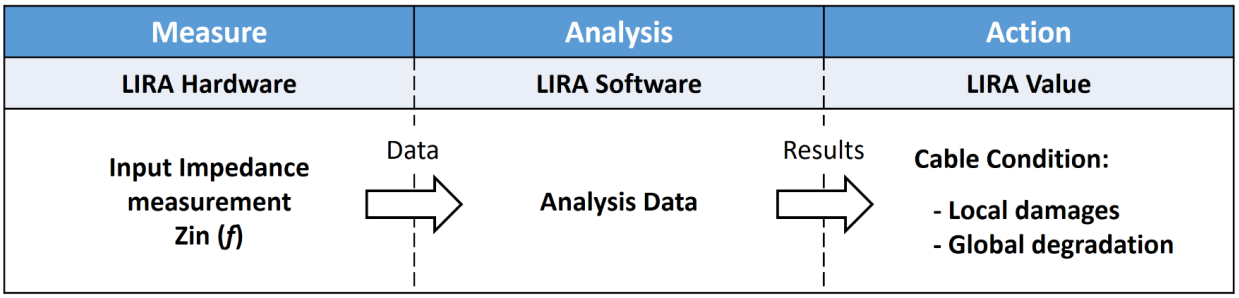
Various testing techniques and procedures are available to evaluate cable performance under installation, normal operating conditions, maintenance and repairs. Some techniques are only used for fault-location such as the traditional TDR techniques. Some testing methods may be destructive and further deteriorate the condition of the cable, and cause failures before the test is terminated. Other test methods provide an indication of the overall performance of the cable such as Tan Delta, Insulation and conductor resistance tests, but cannot be used for fault-location.

Wirescan AS has developed the LIRA technology for condition assessment and monitoring of electrical cables. LIRA is a non-destructive test providing the most comprehensive set of results available in the market based on one single, and fast measurement.

LIRA provides information regarding the local and global condition of electrical cables. E.g. progressive degradation of the cable insulation, as well as local defects, due to several factors including physical stress, inadequate maintenance, cable aging, hostile environments, etc.

Wirescan's LIRA technology presents a number of advantages over other fault-location and condition monitoring techniques:

- Non-destructive, low amplitude sine waves ($V_pp = 4v$)
- Assessment of both global and local degradation



Wirescan's LIRA technology provides high performance power cable condition monitoring and enables system operators to investigate and reduce the risk of damages.

- Sensitive to minor changes of electrical properties of the cable
- Better than 0.3% average fault location accuracy error
- Suitable for most types of electrical cables with length of less than 10 meters up to several hundred kilometers, depending on its design and attenuation
- Simple to connect and quick test setup
- Results displayed graphically with built-in report generation
- Easy transfer of measurement data to Wirescan for further evaluation and deeper analysis
- Playback of post analysis results
- Detecting and localizing single or multiple faults and evaluating their severity
- Pre-studying of the cable under test response by means of a cable simulation tool

2 LIRA Principle

Wirescan's core LIRA technology is based on the input impedance response analysis of the cable under test. The technique is based on Frequency Domain Reflectometry (FDR), which injects a set of non-destructive, low amplitude, sine waves into the cable by means of LIRA Acquire. These waves propagate to the far end of the cable and are reflected back to the injection port.

The input impedance response is related to the wave reflections along the cable and can be measured by the LIRA Acquire over the required frequency range. The cable termination, length, impedance, and other electrical characteristics give a unique signature of input impedance amplitude and phase, which can be used to determine the condition of the cable. Input impedance spectrum, amplitude/phase, can be affected by any local and/or global physical and electrical cable property changes such as insulation damages, splices, or shield defects.

3 LIRA Results

The LIRA software includes an advanced proprietary algorithm to evaluate the input impedance spectrum. It produces several results that provide a comprehensive estimation of the cable condition.

3.1 Cable Characteristics

The proper measurement of the electrical parameters in power cables has a major interest for electrical engineers, cable manufactures, owners and operators. For this purpose, LIRA technology includes an algorithm to extract the high frequency parameters of a cable such as the distributed parameters per unit length, resistance (R), inductance (L), capacitance (C) and characteristic impedance (Z0). The electrical parameters data can be calculated by means of one quick measurement analyzed at resonance frequencies. In order to fully characterize the cable, LIRA also provides the wave propagation characteristics such as the phase constant, attenuation and velocity ratio. Such knowledge enables LIRA to monitor cable parameters and detect their variations that might be initiated by local or global degradations.

3.2 Spot Signature

Any impedance changes along cable can be initiated by discontinuities such as joints, splices or defects. Through frequency domain analysis, these changes can create a deviation in the input impedance spectrum. The resonance frequencies are used to determine the cable length while deviations in the phase spectrum is used to determine the overall condition of the cable and identify joints and degradations along the cable. LIRA provides an accurate and clear trace indication of impedance changes, called Spot Signature. The Spot Signature trace is a function of distance and any degradation detected as difference in spot amplitude depend on the intensity of the impedance change. The Spot Signature is especially useful for fingerprinting and fault detection.

Comparing to other existing techniques, the Spot Signature trace is based on the Fast Fourier Transform (FFT) analysis on the input impedance phase spectrum, which can be more sensitive to detect soft defects with a low impedance variation. A further advantage of the Spot Signature, is the possibility of cable attenuation compensation. This feature is useful when analyzing e.g. very long cables reducing the risk of spot masking due to attenuation.

3.3 DNORM

A further advantage of LIRA technology is its capability to predict the nature of a local degradation and also to characterize and quantify its severity. LIRA presents the DNORM, which can be applied to determine the degree of severity of any local impedance changes along the cable. The DNORM is a useful indicator which is to be used as a decision support tool to examine and evaluate the severity of local impedance changes. Furthermore, the sign of the DNORM signature contains information that is useful in determining the type of impedance change. This allows to infer the nature of the impedance variation if it corresponds to e.g., shield degradation or water ingression, with positive and negative impedance changes, respectively.

3.4 Delta-G

As part of preventive maintenance, Wirescan performs tests and diagnostics to evaluate the condition of cable insulation material to identify the possible global degradation due to ageing effects. The diagnostic test provides an indication which is represented by a single number, the Delta-G number. Delta-G ageing indicator is based on the measured cable attenuation which is sensitive to changes in the electrical properties of the cable dielectric. Comparing to other ageing test methods, the Delta-G technique holds two significant advantages, namely: i) applicability to all cable types (Low-, medium-, and high-voltage) and ii) completely non-destructive test.

3.5 BTS

A significant portion of failures in high voltage power cables can be attributed to the terminations connecting the cable to another element of the power network. A proper cable termination is an essential element during installation and operation and secures reliable delivery of electricity. LIRA provides a diagnostics technique, BTS (Balanced Termination Signature) analysis, to test the condition of cable terminations, and predict any deviation from its normal and undamaged condition. A major advantage of BTS analysis is that its performance to measure and monitor of cable terminators for situations in which the far end of the cable is not accessible, such as in nuclear power plants or subsea infrastructure.

3.6 Impulse Response (TDR Trace)

It is often need to obtain the impulse response as a function of time that is similar to traditional Time Domain Reflectometry (TDR) measurements. It displays signal reflections versus time (or position) which allows to infer the location of impedance changes and to observe the waveform shape.

LIRA can measure the input reflection coefficient as a function of frequency. The reflection coefficient can be considered as a function relating the incident and reflected waves. An inverse transform converts the reflection coefficient directly to a function in time domain; the low-pass impulse response. This result is highly comparable to TDR trace.

4 Summary

Wirescan AS is an expert in cable condition monitoring and assessment since 2007, operating worldwide. The company offers an advanced system comprising effective data collection and analysis produced by a combination of hardware, software and application expertise to provide high performance cable condition assessment and monitoring.

Wirescan AS and the LIRA technology offer a comprehensive testing and condition monitoring services of electrical cables under manufacturing, installation, operation and maintenance, to ensure efficient and reliable operation and extend the lifetime of cables.

LIRA is well-adapted to most types of electrical cables, for low-, medium-, and high-voltage. LIRA is successfully used to monitor power cables in Offshore Wind Farms, Oil and Gas industries, Nuclear Power Plants, etc., and is proven to be a reliable and accurate solution with high sensitivity against changes along the cable.

Wirescan AS is a leader in assessing long distance cables. The LIRA technology has successfully tested and monitored cables longer than 300 km.

Further reading

1. P. F. Fantoni, “Advancements in Wire Condition Monitoring Using Line Impedance Resonance Analysis (LIRA),” CIGRE CMDM, Bucharest, 2015.
2. P. F. Fantoni, “Condition Monitoring of Electrical Cables Using Line Resonance Analysis (LIRA),” CIGRE Jicable, Paris, 2015.
3. P. F. Fantoni, A. Nordlund, “Wire System Aging Assessment and Condition Monitoring: The Line Resonance Analysis Method (LIRA),” Halden Reactor Project (HWR-788) , 2005.
4. P. F. Fantoni, “Wire System Aging Assessment and Condition Monitoring (WASCO)”, Technical report, Nordic Nuclear Safety Research, 2006.