Wirescan Digital Sensor System
Condition Monitoring of Energized Cables

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The energy industry are constantly looking to cut costs and increase reliability. This is pushing the industry towards digitalization of asset integrity monitoring to better plan maintenance and increase reliability and predictability of power networks. Condition monitoring of power cables in operation has been limited to Partial Discharge (PD) and optics-based technologies. Wirescan together with SINTEF has developed a sensor system collecting condition related data from energized cables which feeds the Wirescan Digital cloud analysis and reporting engine. Such system will increase knowledge about the condition of a single cable, and on a larger scale, provide useful information and decision basis for a power cable network. This paper presents a brief overview of the data collection system together with results from the first field trial of the system.

1 Background

A constant push for cost cutting has driven the energy market toward digitalization of asset management. The asset owners seek new and optimized solutions to reduce their capital and operational expenditure. The infrastructure aging and ever-increasing investment requirements add to the severity of the matter. Thousands of kilometers of underground and subsea cables holds a critical position in the operation of these energy producers and network operators.

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 Time Domain Reflectometry (TDR) technique. Some testing methods may be destructive and further deteriorate the condition of the cable, and cause failures before the test is complete and ended. 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.

Other test methods can be performed offline and online; while the system is energized and monitor remotely at any desired moments. Competitive nature of the energy market demands preventive cable maintenance instead of breakdown-based cable maintenance. Research has shown that most measurement methods that are capable of online measurement have limitations, such as Partial Discharge (PD) and Distributed Temperature/Acoustic Sensing (DTS/DAS), and cannot detect all possible cable defects. Indeed, the mentioned optical based monitoring technique requires the cable to be collocated with optical fibers which is not the case for most underground cables today.

Condition assessment and monitoring of energized cables are an important online process which can bring a large impact on the security and quality of the power grids. The degradation of a cable is not often consistent and can occur instantly, without any significant warnings, and the ability to continuously evaluate cable condition enables early detection of potential anomalies. This ability allows for early detection and identification of a cable fault, improve repair and replacement strategies and, consequently, to anticipate and mitigate severe consequences that can be costly and catastrophic.

The Wirescan Digital Sensor System (WDSS) is developed for online condition assessment and monitoring of energized electrical cables using its own innovative technology, Line Impedance Resonance Analsyis (LIRA®). The LIRA technology is proven as a non-destructive method providing the most comprehensive set of results available in the market based on one single, easy, and fast measurement. Using the WDSS enables system operators to perform 24/7 online monitoring of their power cable network and early detect, locate and classify any minor degradations in real-time rather than some days later after breakdown, which means saving time and costs. Such an approach can help optimize operational (OPEX) and capital expenditures (CAPEX).

2 The Sensor Solution

Wirescan's LIRA technology is based on online Frequency Domain Reflectometry (FDR) technique, WDSS performs the measurements via the coupling with electromagnetic fields around the cable. A test signal is induced in real-time in the cable and the resulting current and voltage can be measured instantly at the measurement point by means of the WDSS; an inductive and capacitive sensor, which are associated to magnetic and electrical nearfields of the cable, respectively. The WDSS are designed to avoid any galvanic connection to the conductor of the power cable and perform online FDR on energized cables. Figure 1 shows the basic setup of the Wirescan Digital Sensor System.

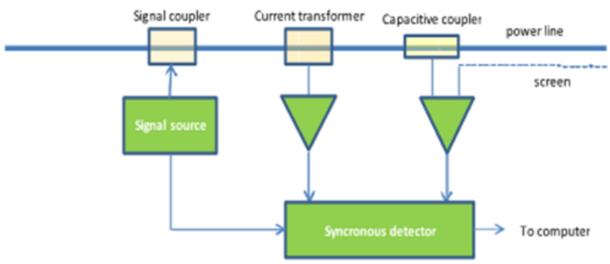

Figure 1: *Wirescan Digital Sensor System block diagram.*

The cable termination status, length, impedance, and other electrical characteristics of the cable give a unique signature of line impedance, which can be used to determine the condition of the cable. Based on the resulting current and voltage, the line impedance response $Z_{(in)}$ can be measured over a defined frequency range, then used to determine the overall condition of the cable and any degradations along the cable. The impedance spectrum, amplitude and phase, will be affected by any local and/or global physical and electrical cable property changes; such as physical damages, cable aging, splices, etc.

Wirescan Digital can measure the line impedance response from the WDSS, then collect data over time to continuously analysis via the Wirescan Digital cloud solution. Real-time measurements can be realized and analyzed instantly which enable the utilities to increase the availability for power supply, maximize efficiency, and optimize maintenance. Through a combination of Wirescan Digital hardware and software, and using various functionalities of the LIRA technology, system operators can improve the safety effectiveness and operating performance by:

- **Immediate detection and location of cable a fault** with ability to detect minor changes not causing failures;
- **Continuous monitoring of cable signature and early detection of impedance changes** to optimize maintenance based on the progression of impedance change and any degradations over time;
- **Detecting transient faults** which can occur instantly and which are not detectable while cable is de-energized;
- **Remotely gather measurement data for time series analysis to determine the global condition of the cable** such as aging indication, joint behavior and termination health status.

3 Test Results

3.1 Test Setup

The performance of the WDSS in terms of the accuracy and sensitivity to detect and locate the faults is tested by the controlled shield defect model. The measurements were performed on a 103 meter of a TSLF 240 mm^2 medium voltage power cable. The controlled shield damage is located at 27 meters from the testing point and realized by cutting of screen wires. (see Figure 2)

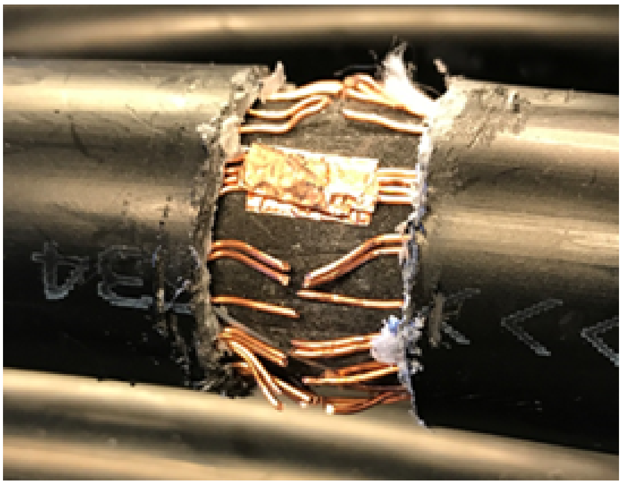

Figure 2: *Shield defect; 35 of 39 screen wires cut.*

The spot signature graph of the controlled shield defect is shown in Figure 3 as a function of the length and fault severity. As can be observed, the correct fault location is clearly identified after 24/39 cut and representing a higher magnitude against a higher level of shield damage severity.

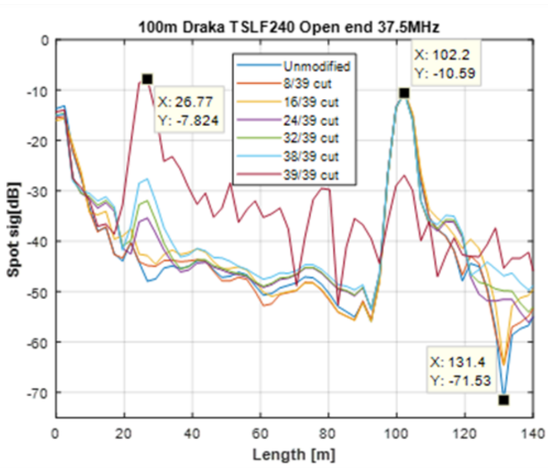

Figure 3: *Spot signature showing shield defects at 27 meters.*

3.2 11 kV Underground Cable

The WDSS were tested on 1850 kVA/11 kV operational underground distribution network of PILC cable with 830 m length. Figure 4 shows the underground 3-phase power cable route map in red linking two distribution kiosks. The WDSS was installed in the switchgear cabinet on one of the phases at one end of the cable, see Figure 5. The WDSS of this case study was configured for real-time measurements by means of an automated process through Wirescan on-line framework for data acquisition and analysis.

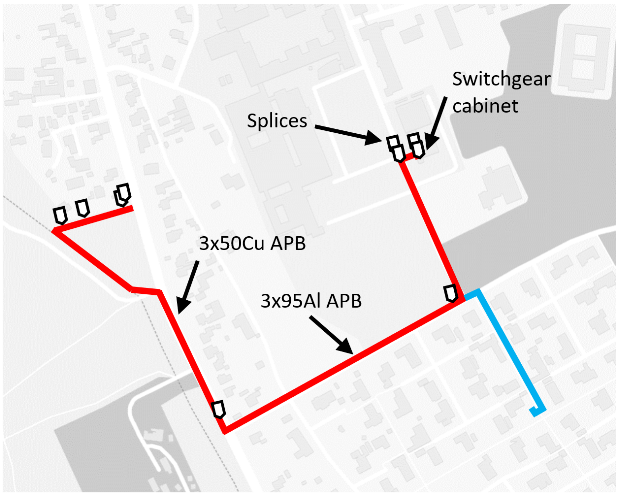

Figure 4: *Cable route.*

Figure 5: *Sensor system installed on a single phase in the switch gear cabinet.*

Figure 6 shows a snapshot of the normalized spot signature together with the step response normalized by the characteristic impedance. The spot signature, orange trace, clearly show all the splices along the length of the cable together with the termination at 855 meters. A very useful tool when monitoring for any changes in splices, joints or other local events. The step response, blue trace, is useful for identifying different cable sections. I.e. in this case the displayed graph show impedance information associated with each section which are all identified by the measurement.

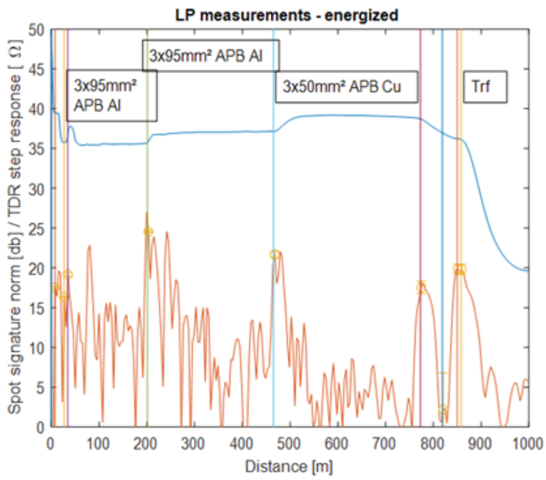

Figure 6: *Snapshot of spot signature and step response.*

Figure 7 is representing the results based on measurements made every 15 minutes over a 3 month period. This results is very useful for monitoring of already known events, and real-time identification and localization of any new events. E.g. if a fault occurs on the cable, the system is able to quickly identify and localize the fault and thus minimizing downtime related to any action needed to get the cable back online.

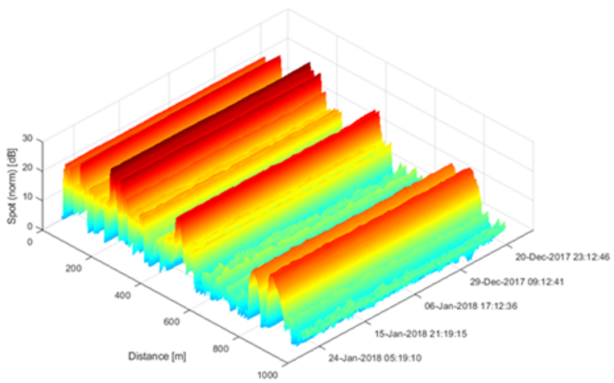

Figure 7: *Evolution of online spot signature measurements over the test period.*

4 Summary

The Wirescan Digital Sensor System enables 24/7 monitoring of power cables while they are in operation. A complete infrastructure handling measurement data from the sensor system, transportation to the Wirescan Digital cloud service, and advanced data analysis and machine learning algorithms, make the most comprehensive cable condition assessment and monitoring system available in the market.

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

Wirescan Digital 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. The system can also incorporate test results from other testing methods such as TDR, OTDR, CR, IR, etc.

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

Further reading

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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.
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