COMMISSIONING & CONDITION ASSESSMENT

1. COMMISSIONING & CONDITION ASSESSMENT WITH DAMPED AC 20-500 Hz
2. ON-LINE CONDITION ASSESSMENT ON ELECTRICAL ASSETS
3. PD SURVEILLANCE ON CABLE INSTALLATIONS WHILE SOAK TEST
4. CONDITION ASSESSMENT AND FAULT LOCATIONLINE RESONACE ANALYSIS (LIRA)
5. COMMISSIONING & CONDITION ASSESSMENT WITH VLF TD & PD

COMMISSIONING & CONDITION ASSESSMENT WITH DAMPED AC 20-500 Hz

Damped AC is a proven and recognized technology for high voltage diagnostic testing with application of IEEE, IEC, CENELEC and Cigrè.

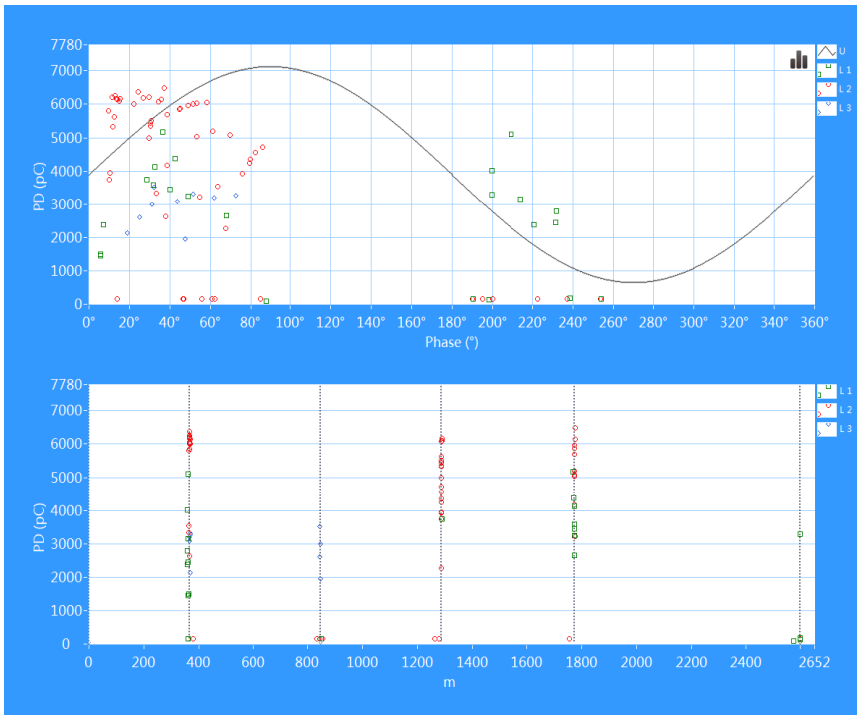
The test includes:

- Monitored Withstand test
- Partial Discharge measurement (PD)
- Dissipation factor estimation (tan d)

PD testing is regarded as the best diagnosis tool, and are often required, both in FAT and SAT. During a PD test it is important that the test conditions are as close to 50 Hz as possible. The test frequency during a DAC test is between 20-500 Hz which gives the same conditions as under normal operation (50 Hz)

This means that the weaknesses detect while testing are the same as during normal operation.

The diagnosis can be performed on all types of cables from 6.3 to 66 kV. With single-sided PD measurement, up to 15 km of cable can be PD-tested. For cables > 15 km, two-sided PD measurement is recommended



The PD diagnosis reveal typical Installation faults as;

- Bad XLPE insulation preparation
- Poor removal of the semicon
- Wrong stress control assembly
- Poor heat shrinking technique

And other defects as:

- Manufacturing defects
- Transportation damage
- Mechanical damage
- Aging

In most cases this type of faults ***do not cause a breakdown*** *under a regular pressure-test. However it is very likely that these abnormalities will lead to a breakdown at a later time.*

A DAC PD test collects all necessary information in order to do a correct analysis on the PD phenomena

- PD mapping (Localization < 1 meter)
- PDIV (PD inception voltage)
- PDEV (PD extinction voltage)
- PRPD (Type of PD phenomena)
- PD level (Amplitude/Repetitionrate)

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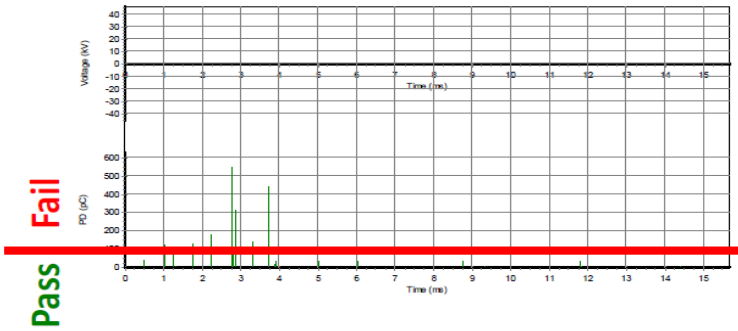
Inter-array Cable String Testing and Diagnosis

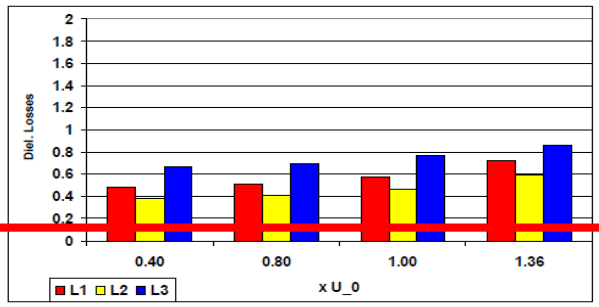
Criteria for the risk management for de contractor (e.g. 5 year warranty) system operators, insurers have to be related to the quality control e.g.:

- **Soak Test** = due to lack of information about operational reliability = **No warranty**
- **Voltage test only** = due to showing extreme defects only = **Limited warranty**
- **DAC or AC Voltage test** = including sensitive (PD- and Tan δ) finger printing = **Full warranty**

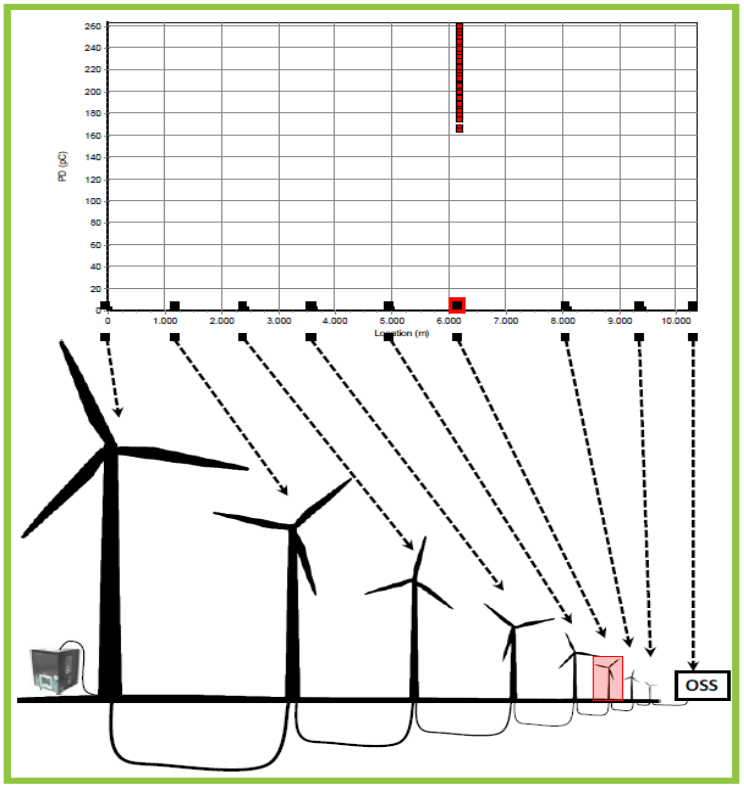
Partial Discharge pattern



Dissipation factor



PD- and Tan δ - monitored damped AC voltage withstand testing of ODWF power cables



DAC PD mapping of a complete string, indicating the location of the PD defect in the string (cable termination) at WTG6 (6190 meter from measurement location).

"Commissioning with Damped AC diagnostics assures the quality of new installations"

"Condition assessment with Damped AC diagnostics reveals the real health in old installations"

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Relevant International Standards & Guidelines

General

- **IEC 60060-3:** High Voltage Test Techniques Part 3: Definitions and Requirements for On-site Testing

On-site Testing

- **IEEE 400:** Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems Rated 5 kV and Above
- **IEEE 400.4:** Guide for Field-Testing of Shielded Power Cable Systems Rated 5 kV and Above with Damped Alternating Current Voltage (DAC)
- **IEC 60502:** Power Cables with Extruded Insulation and Their Accessories for Rated Voltages from 1 kV up to 30 kV - Part 2: Cables for Rated Voltages from 6 kV up to 30 kV
- **HD 620 S2 (CENELEC):** Distribution Cables with Extruded Insulation for Rated Voltages from 6 kV up to 36 kV
- **IEC 60840:** Power Cables with Extruded Insulation and Their Accessories for Rated Voltages Above 30kV up to 150kV – Test Methods and Requirements
- **IEC 62067:** Power Cables with Extruded Insulation and Their Accessories for Rated Voltages Above 150 kV up to 500 kV – Test Methods and Requirements
- **HD 632 S2 (CENELEC):** Power Cables with Extruded Insulation and Their Accessories for Rated Voltages Above 36kV up to 150kV
- **Cigré TB 496:** Recommendations for Testing DC Extruded Cable Systems for Power Transmission at a Rated Voltage up to 500 kV

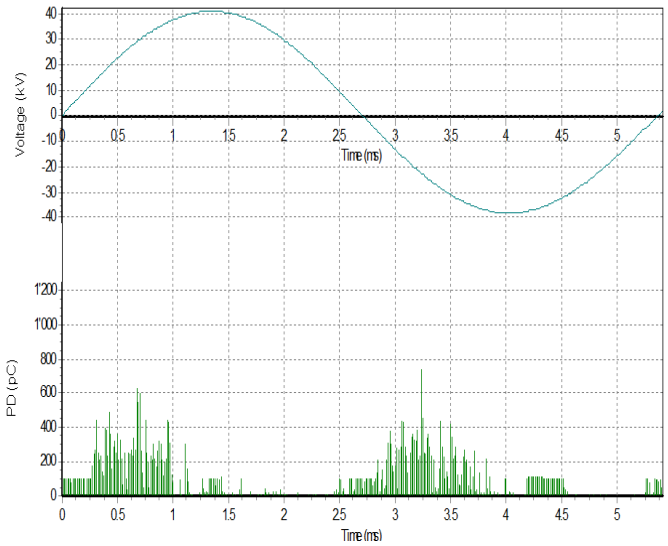
Standardized PD Detection

- **IEEE 400.3:** Guide for PD Testing of Shielded Power Cable Systems in a Field Environment
- **IEC 60270:** Partial discharges measurements
- **IEC 60885-3:** Test Methods for Partial Discharges Measurements on Lengths of Extruded Power Cable
- **Cigré TB 502:** High-Voltage On-Site Testing with Partial Discharge Measurement
- **IEC 62478:** High voltage Test Techniques - Measurement of Partial Discharges by Electromagnetic and Acoustic Methods
- **Cigré TB 444:** Guidelines for Unconventional Partial Discharge Measurements
- **Cigré TB 662:** Guidelines for Partial Discharge Detection Using Conventional (IEC 60270) and Unconventional Methods

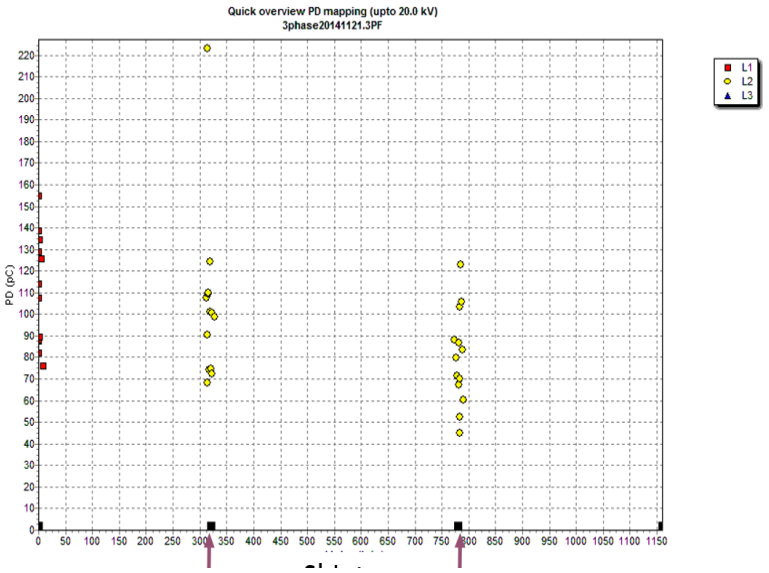
Dissipation Factor Measurement

- **IEC 60141:** Tests on Oil-Filled and Gas-Pressure Cables and Their Accessories
- **IEEE 1425:** Guide for the Evaluating of the Remaining Life of Impregnated Paper-insulated Transmission Cables Systems
- **IEC 60141:** Tests on Oil-Filled and Gas-Pressure Cables and Their Accessories;
- **Cigré TB 627:** Condition Assessment for Fluid-Filled Insulation in AC Cables

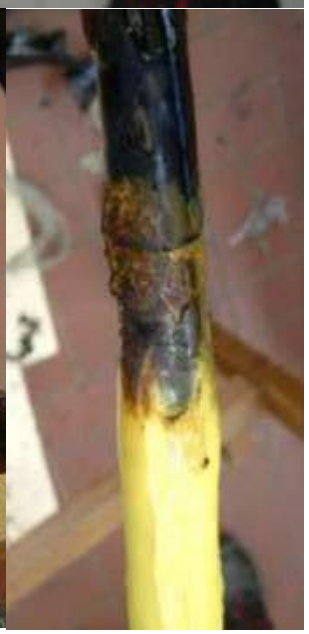
PRPD (Type of PD phenomena)



Bad joints or terminations are localization < 1 meter



Typical installation faults that passes a pressure-test but gets exposed by a DAC PD diagnosis



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ON-LINE CONDITION ASSESSMENT ON ELECTRICAL ASSETS

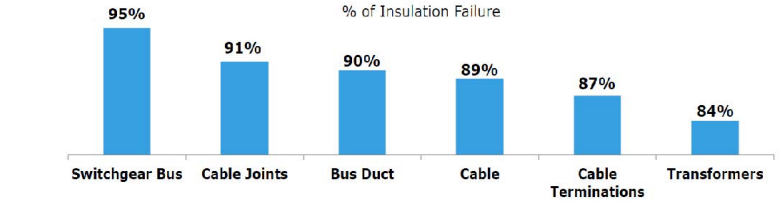
Partial discharge occurs in weaknesses within the insulation system of high voltage components.

The phenomenon breaks down the insulation until a breakdown occurs!

Installation error, manufacturing defects, mechanical damage or aging lead to partial discharges.

With strategic measurements through the grid, the source of the PD activity is located.

More that 80% of failures in HV/MV assets are related to Partial Discharge (PD) activity



This is WHY we are strongly committed to <u>on-line, accurate & reliable</u> PD testing

Source: 493-1997 - IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)

ANY ELECTRICAL EQUIPMENT FROM 3kV AND ABOVE

USES
ON HV AND MV COMPONENTS

- CABLE
- JOINTS
- TERMINATIONS
- SWITCHGEARS
- TRANSFORMERS
- ELECTRICAL MACHINES

- TO DETECT
- TO PREVENT
- TO MONITOR
- TO LOCALIZE

100%
CRITICAL DEFECTS DETECTED ON HV AND MV

UP TO 80%
AVOIDED FAULTS

ON-LINE TESTING WITHOUT SERVICE INTERRUPTION

HIGHEST PERFORMANCE FOR COMPLEX PD DIAGNOSIS AND DEFECT LOCALIZATION

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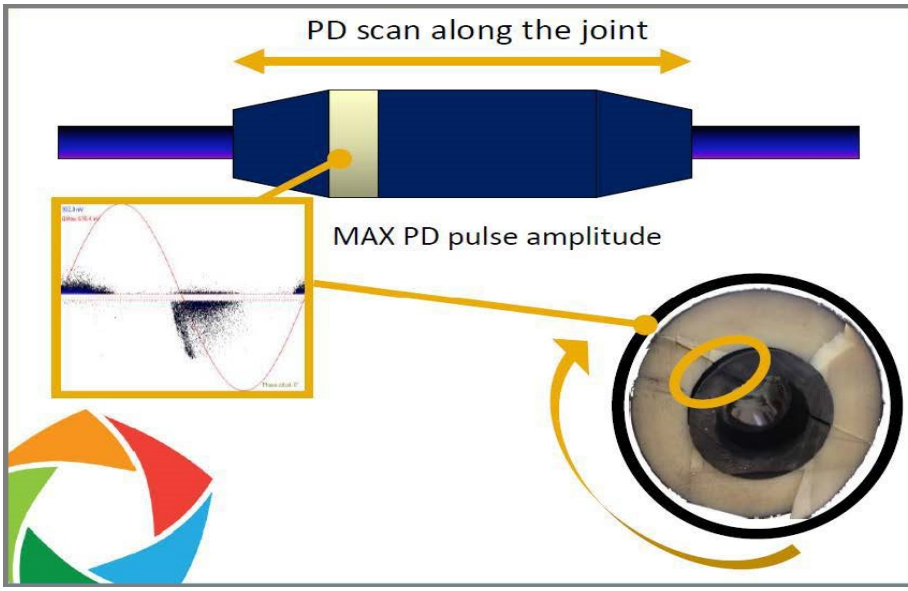
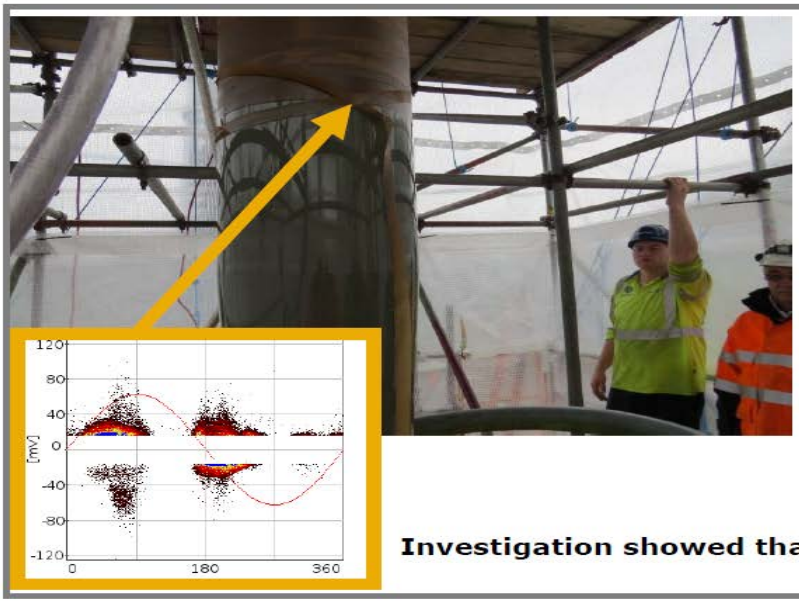


- HV joint
- PD scan along and around the joint by simply moving the Pry-Cam

Results with Pry-Cam:

- **Accurate defect localization**
- **Total cost saving**

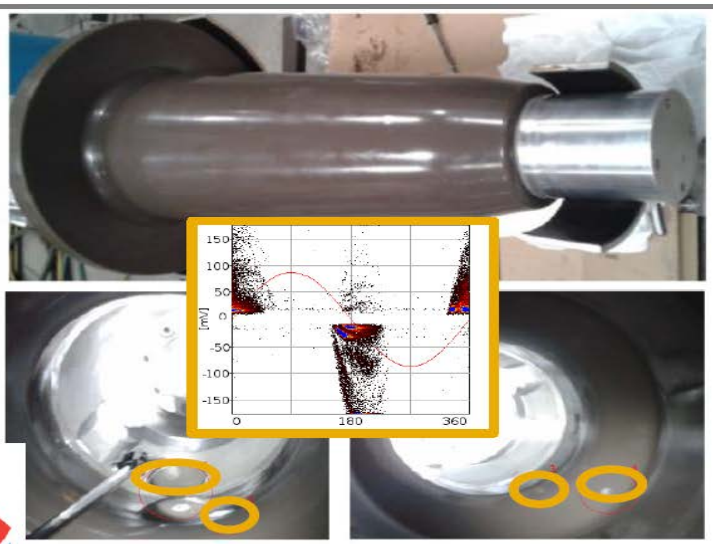


- OF Termination having high levels of dissolved gas
- Potential loss of generation and explosion risk

Results with Pry-Cam:

- **Internal PDs found on phase B in few minutes**
- **Faults prevention**

Investigation showed that papers were loose/unwinding



- 6 HV terminations investigated

Results with Pry-Cam:

- **Accurate and reliable diagnosis**
- **Detection of 4 PDs on 2 terminations**
- **Faults prevention**

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PD SURVEILLANCE ON CABLE INSTALLATIONS WHILE SOAK TEST

All new critical cable connections should be controlled for partial discharges (PD) when they are energized for the first time!

Poor workmanship, manufacturing defects, transport damage and excavation damage can generate insulation weaknesses which in turn cause partial discharges.

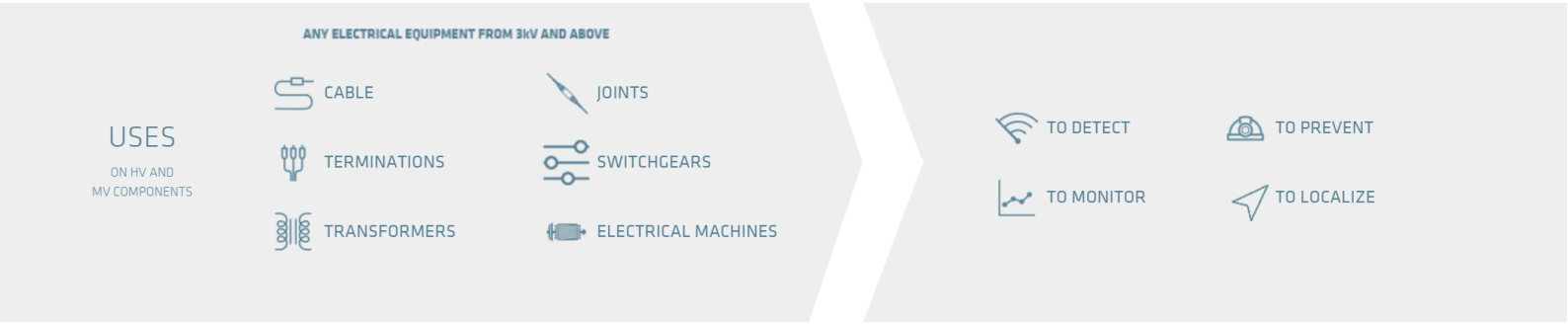
The PD activity will over time cause a breakdown!

SOAK test with PD surveillance

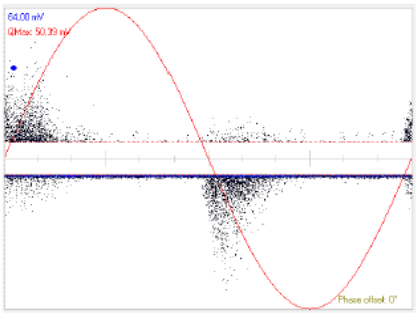
- Data is collected during the first 4 hours under SOAK
- Data collected during the last 4 hours under SOAK
- Total 2 days on site

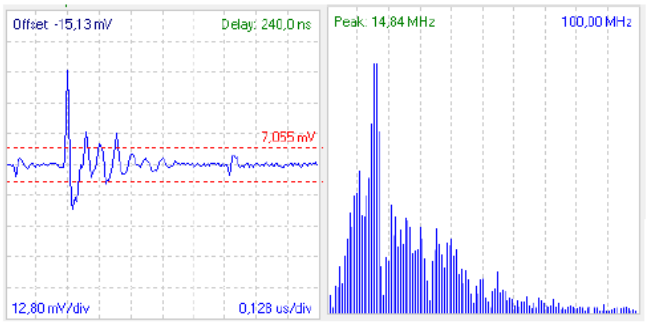
A SOAK test it self will only reveal significant errors!

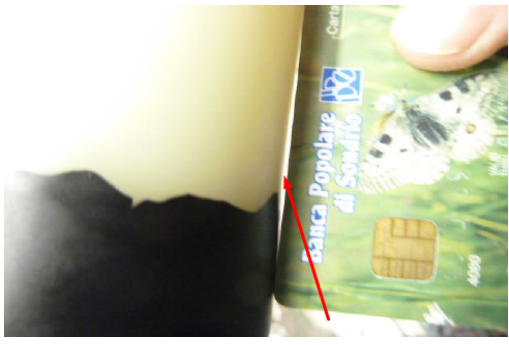
A SOAK test combined with PD surveillance will reveal small defects which over time will cause a breakdown!



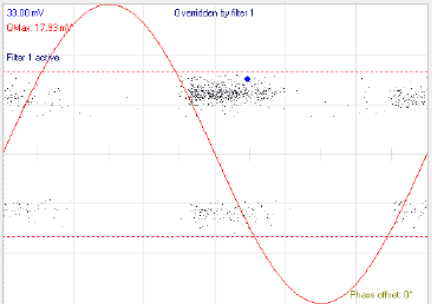
PD surveillance SOAK test 220 kV joint

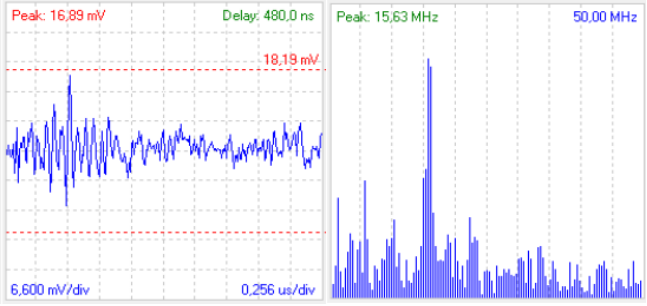






PD surveillance SOAK test 145 kV GIS termination





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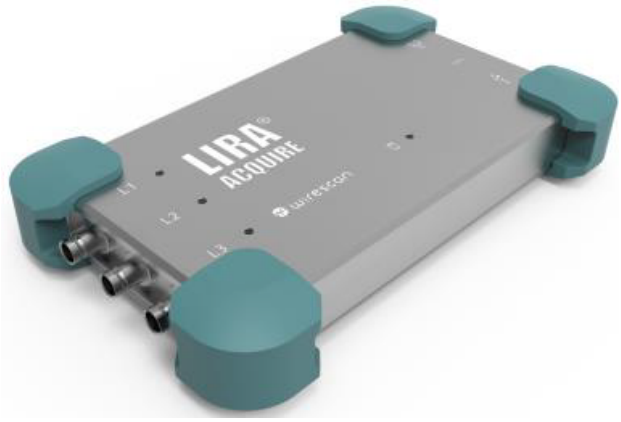
CONDITION ASSESSMENT WITH LINE RESONACE ANALYSIS (LIRA)



Cable diagnostics with LIRA

Sensitive to small changes of wire electric parameters, mainly the insulation permittivity, that are a significant condition indicator of the cable state (thermal and radiation aging, humidity, insulation defects, mechanical damage).

LIRA can detect:

All types of changes affecting the insulation capacitance

Dimensional changes as cable joints or splices between different cable types, areas influenced by extensive heating, radiation, water intrusion, corrosion, bends, scratches, mechanical impacts, fatigue, etc.

Global or local insulation material degradation (XLPE, PILC and others).

All types of changes affecting the insulation capacitance

LIRA might detect:

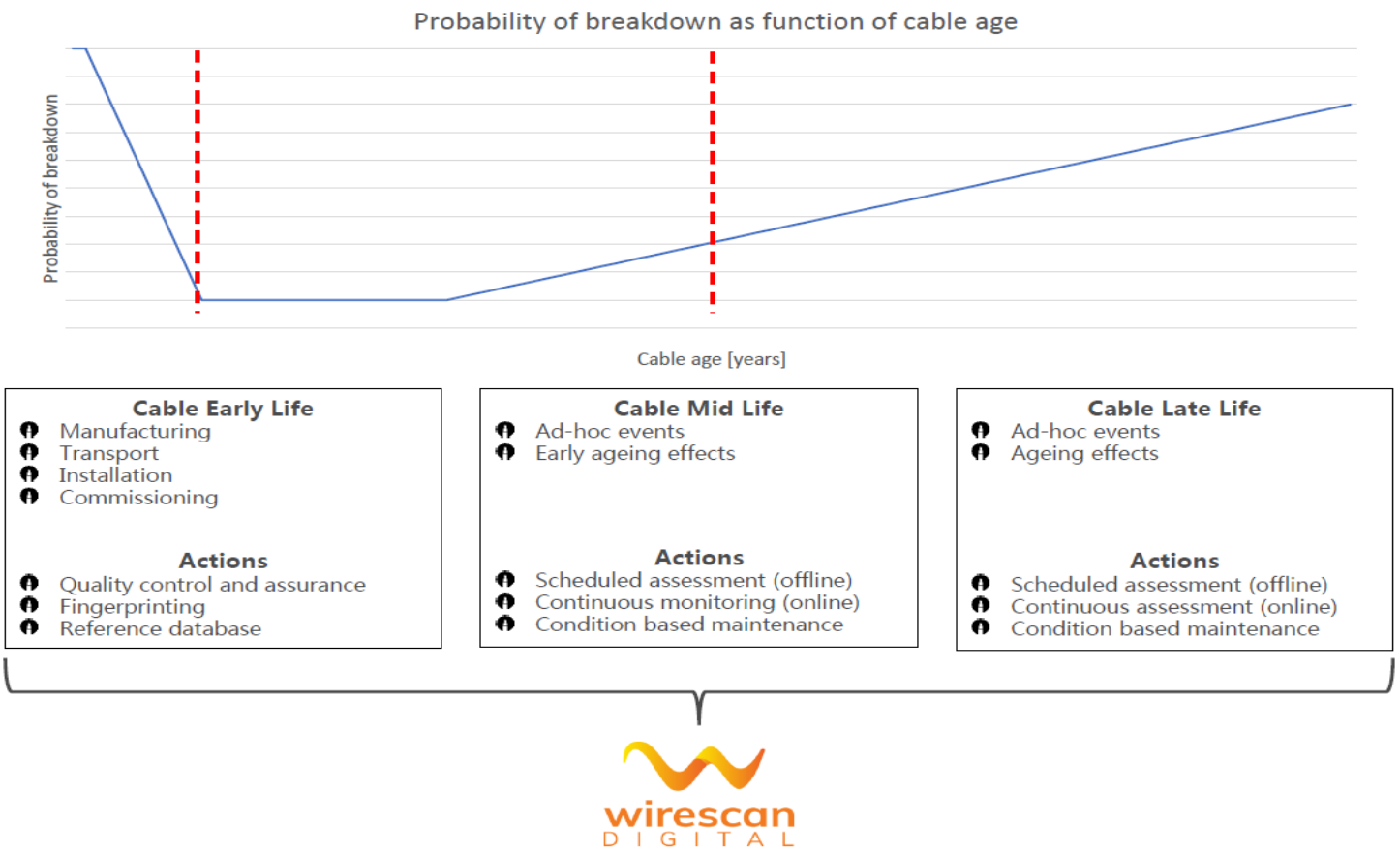
Damages in outer sheath only if water/ humidity or other factors directly or indirectly affects the capacitance of the insulation/screen system.

High resistance failure depending on extent of change and size.

LIRA cannot estimate the cable residual life time:

One measurement will give information of the cable condition at the time of measurement. Repeated measurements will generate increased information for a more accurately prediction of the cable status.

In most cases the LIRA system will detect consistent but in-significant features or global degradation along the cable. Repeated measurements will generate increased information of the development of these features/ degradations.



wirescan DIGITAL

LIRA Benefits

Accurate and fast location of defects, complementing existing tools

Reduced repair down time

Early warning of degradation facilitates preventive maintenance and prevents cable breakdown and the cost and hassle associated with power or signal outage

Extension of operational life time beyond initial design objectives
Reduced insurance cost due to less risks

Provides more than ten cable condition related results from one measurement

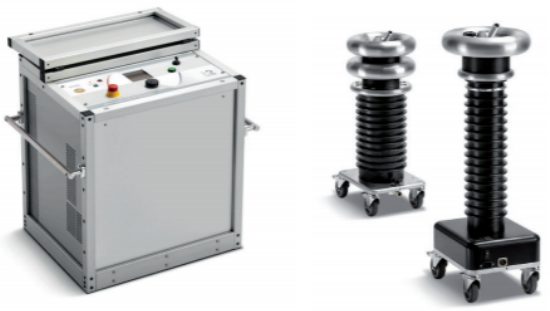
Provides information on global and local condition

More sensitive to changes in cable parameters compared to other solutions
Detects fault localization with accuracy 0.1 – 0.3% of cable length

Has excellent length capabilities, ranging from 30 m to 300 km

Is non-destructive

COMMISSIONING & CONDITION ASSESSMENT WITH VLF TD & PD



Commissioing and cable diagnostics

NEKA AS specializes in testing high voltage cables. We perform commissioning of new installations.

The cable diagnosis is a three-part commissioning that ensures that the quality of the installation is satisfactory

VLF COMMISSIONING WITHSTAND TESTING
Service aged XLPE cables
IEEE 400.2-2013:

System voltage	Test voltage (phase/earth)	Test time
24 kV	*24 kV(rms)*	*30 min*
36 kV	*33 kV(rms)*	*30 min*
69 kV	*63 kV(rms)*	*30 min*

VLF COMMISSIONING WITHSTAND TESTING
New XLPE cables
IEEE 400.2-2013:

System voltage	Test voltage (phase/earth)	Test time
24 kV	*32 kV(rms)*	*60 min*
36 kV	*44 kV(rms)*	*60 min*
69 kV	*84 kV(rms)*	*60 min*

TAN DELTA (TD) DIAGNOSTIC TEST
At 1,5 U0 for 66 kV kabel
To determine the quality of complete cable's insulation.

PARTIAL DISCHARGE (PD) TEST
At 1,5 U0 for 66 kV kabel
To indicate and localise points of weakness and insulation imperfections

TDR 'FINGERPRINTING'
To identify joint positions along the cable

Commissioing according to; IEEE 400.2 or IEC 60502-2

- Good insulation will be unaffected
- Reveals; Production deviations, poor workmanship, and aging
- Uses sinusoidal, 0.1Hz HV waveform
- Up to 30 km cable can be tested

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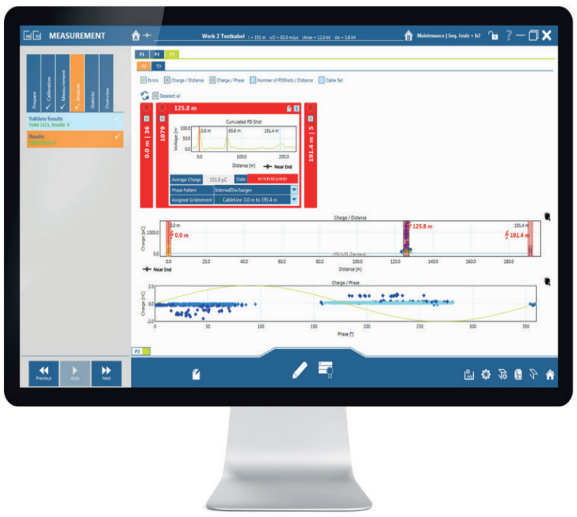
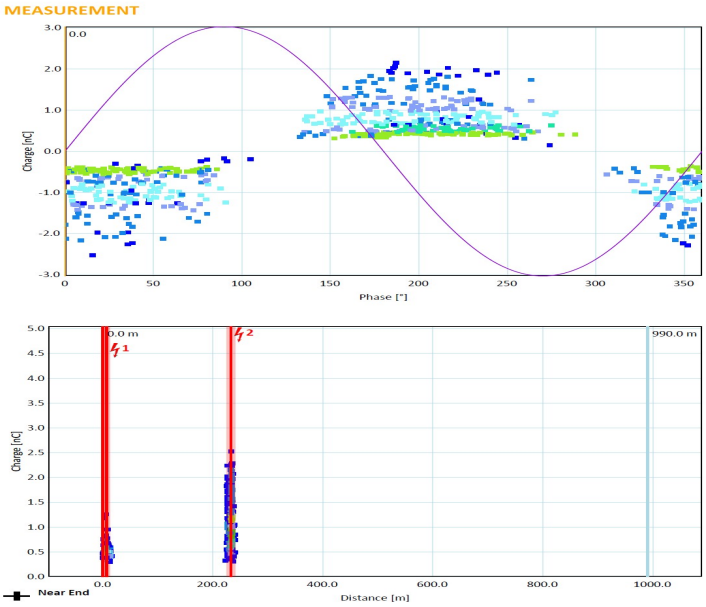
COMMISSIONING & CONDITION ASSESSMENT WITH VLF TD & PD

Benefits of VLF PD & TD Diagnostic Testing

- Complete assessment of the quality of the cablesystem. This helps to ensure that the installation is satisfactory and does not have weaknesses present that will fail at a later date
- Commissioning with VLF PD / TD verifies the installation and gives the owner a fingerprint of the cable installation for future control
- VLF partial Discharge (PD) reveals cable faults and the fault location.
- VLF Tandelta (TD) uncovers the general aging of the insulation and creates a fingerprint of the insulation system



PD mapping with PRPD and location on cable



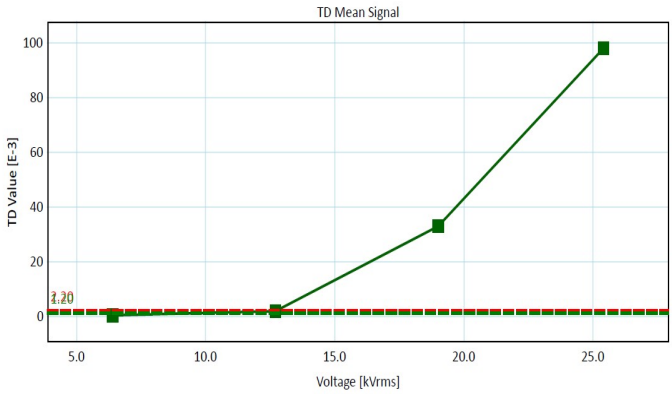
Defects in cable, joints and terminations are uncovered along the entire cable. The test also provides information about the type of fault, inception voltage and severity.

TD analysis according to IEEE 400.2

Phase P2 Overview

	6.4 kV	12.7 kV	19.0 kV	25.4 kV
Mean TD [E-3]	0.46	2.00	33.0	98.0
Standard Deviation TD [E-3]	< 0.1	0.22	0.24	0.27
Mean RMS Voltage	6.4 kV	12.7 kV	19.0 kV	25.4 kV
Mean RMS Current	10.1 µA	18.6 µA	27.8 µA	37.3 µA
Mean Load C	2.3 nF	2.3 nF	2.3 nF	2.3 nF

TD PHASE DIAGRAMM



TD analysis reveals the general aging of the insulation system in cable, joints and terminations. The values are checked against the requirements of IEEE 400.2.

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