High Voltage cables partial discharge test during commissioning

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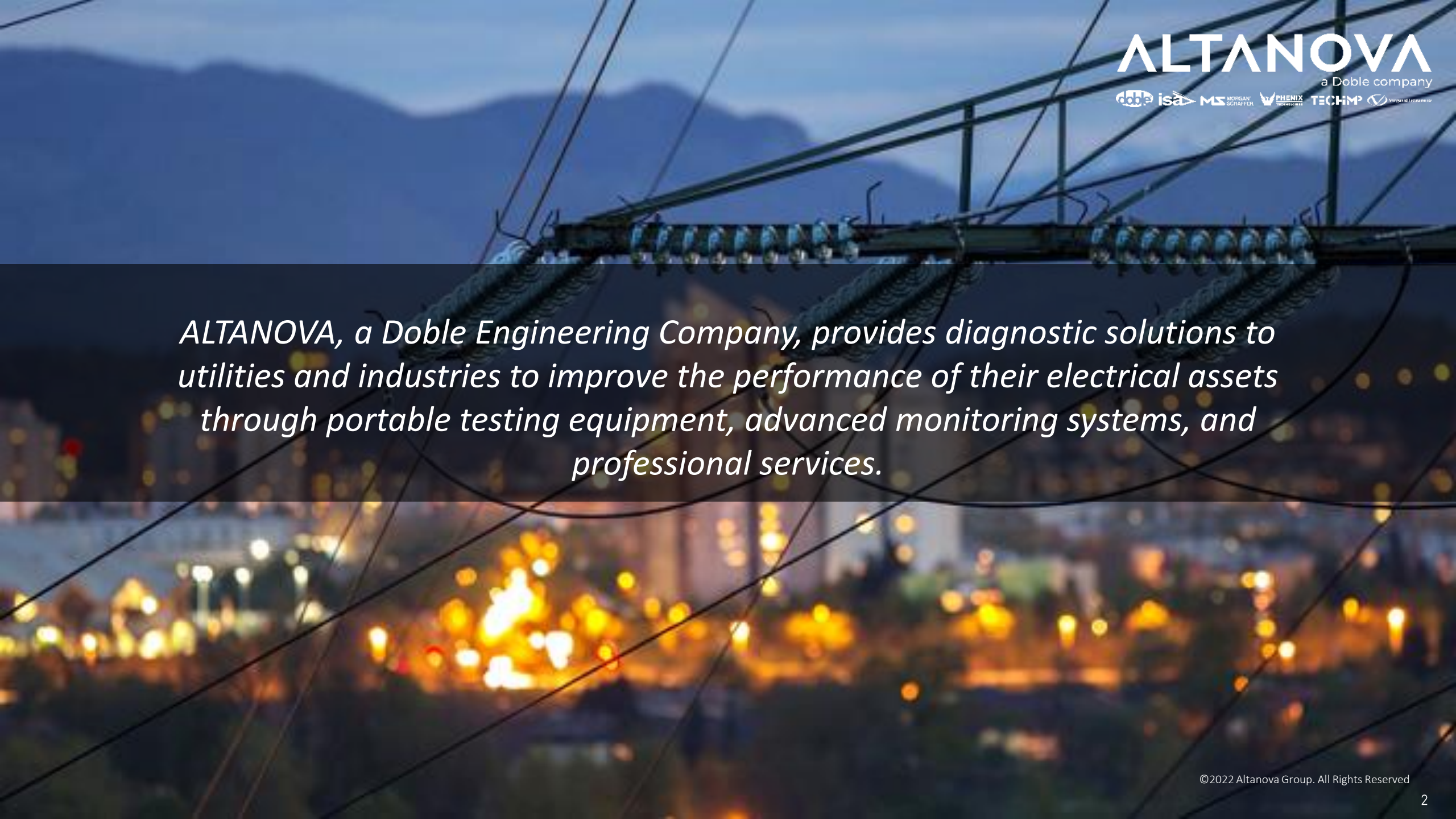


ALTANOVA
a Doble company

ALTANOVA, a Doble Engineering Company, provides diagnostic solutions to utilities and industries to improve the performance of their electrical assets through portable testing equipment, advanced monitoring systems, and professional services.

Altanova History

1938 I.S.A. Istrumentazioni Sistemi Automatici S.r.l. is established in Taino ITALY

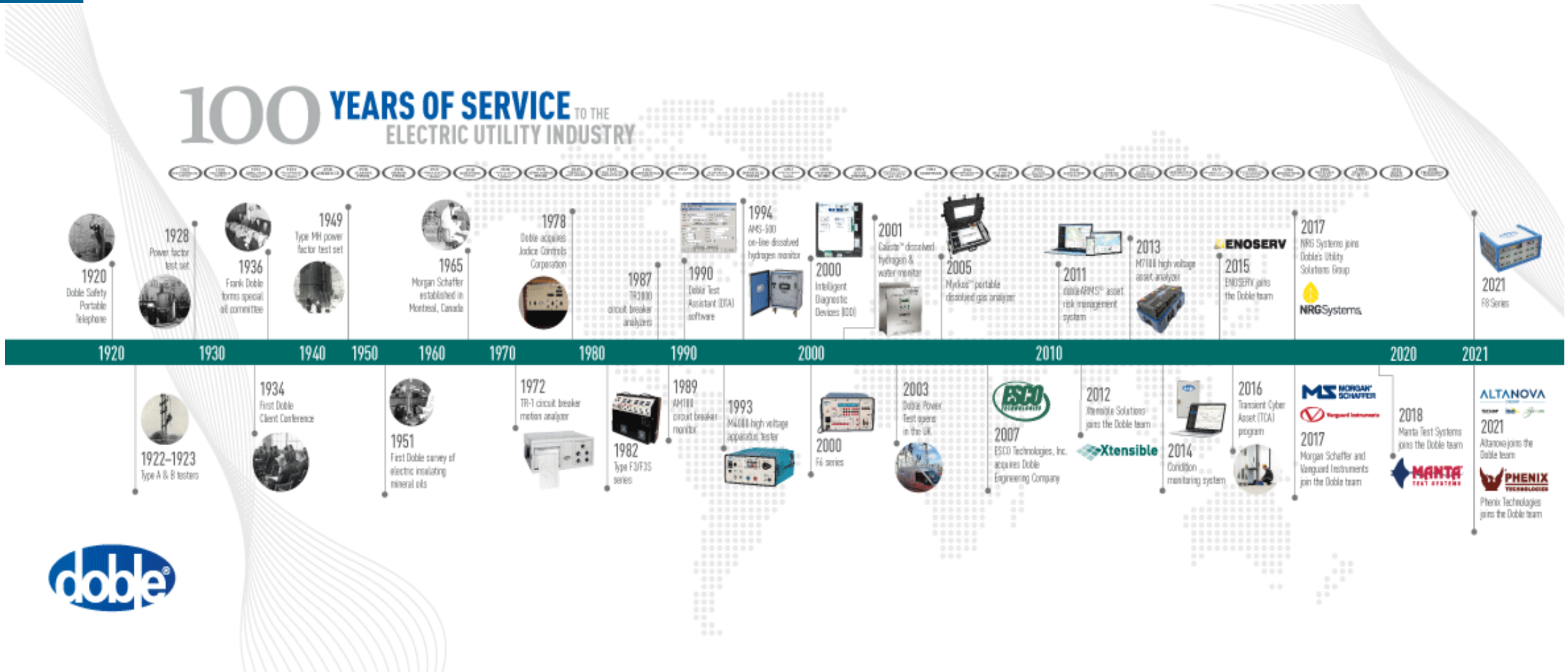
1999 TECHIMP was born as a spin-off from the University of Bologna ITALY.

2017 I.S.A. and TECHIMP merge giving birth to the ALTANOVA GROUP

2019 INTELLISAW joins ALTANOVA GROUP

2021 ALTANOVA GROUP becomes part of ESCO Technology Group and joins the Doble Engineering Company, as part of the Utility Solution Group (USG) division.

Doble History



Altanova Today

ALTANOVA
a Doble company

100
COUNTRIES

12
GLOBAL FACILITY LOCATIONS

150+
EMPLOYEES

150+
SALES PARTNERS

5550+
CUSTOMERS GLOBALLY

Part of ESCO Technologies' Utility Solutions Group

PRODUCT BRANDS

doble® isa MS MORGAN SCHAFFER PHENIX TECHNOLOGIES TECHIMP Vanguard Instruments

Our Solutions

Electrical Test Equipment

Essential for day-to-day maintenance tests of electrical assets. Useful in specific phases of the asset lifecycle:

- Procure
- Operate
- Maintain
- Decommission.

Professional Services

Diversified offer according to the electrical asset lifecycle:

- Installation and commissioning
- Diagnostic test
- Data analysis
- Consultancy
- Training.

Monitoring Systems

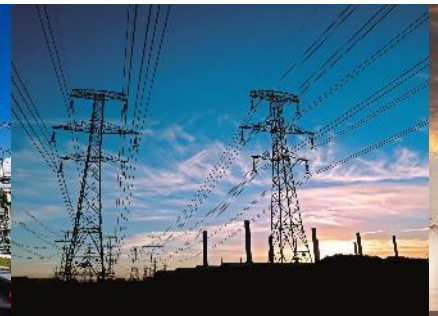
Shift from a time-based maintenance to a condition-based maintenance.

Focus on predictive maintenance and shift in focus from electric asset value cost to network outage costs.

Strong evolution of digitalization trend in the power industry.

Testing And Monitoring Solutions For:

- Power transformers
- Circuit breakers
- HV gas insulated switchgears
- MV/HV/EHV cables
- MV/LV switchgears
- Batteries
- Current & voltage transformers
- Protective relays
- Meters and transducers
- Rotating machines
- Variable speed drives
- Overhead lines



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HV cables after laying tests

Mains:

- Insulation Resistance
- Sheath Integrity (single / end to end)
- SVL Integrity
- Link Box contact resistance
- Conductor resistance
- HVAC
- PD test

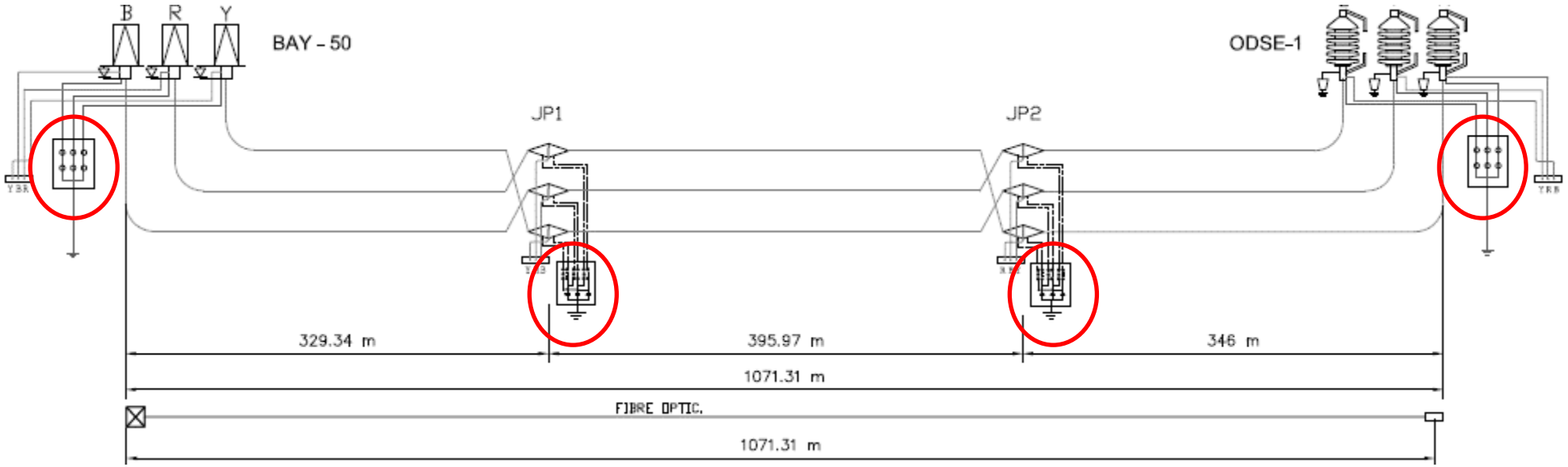
PD on HV cables

PD test are well established routine test in cables and accessories FAT: cable drums and HV accessories are deeply tested before leaving the factory. The percentage of PD found during HV cable commissioning is nowdays very low (<5%), the main rootcause of the insualtion defects are due to:

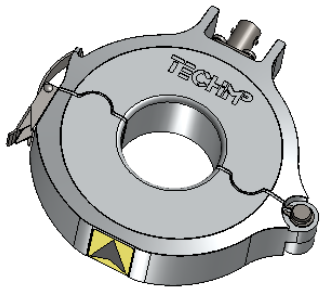
- Damages to the accessory components
- Poor installation
- Misplacements in the accessories
- Air pockets and trapped gas bubbles
- Stress control components defects

PD on HV cables

The weakest part of the cable circuit is therefore identified in the cable joints and terminations, these test objects are accessible or at least it is possible to approach the joint link box and pick up the signals.



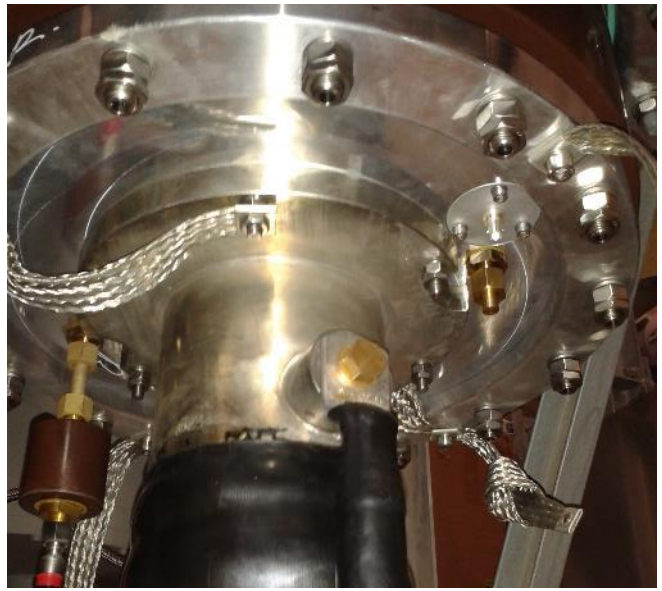
PD sensor for HV cables accessories



High Frequency Current Transformers are widely used during HV cables commissioning. By clamping the sensor around the ground leads of the termination/joint it is possible to detect amplitude shape and polarity of the partial discharge pulses flowing in the cable sheath.

PD sensor for HV cables accessories

HV accessory embedded Sensor: Cable manufacturer can provide HV accessories with embedded PD sensors upon customer specification to be directly connected to the PD instrument/oscilloscope to take the readings.



PD sensor for HV cables accessories

Flexible magnetic coupler: To be wrapped around the HV cable: low sensitivity but useful if ground lead not accessible.

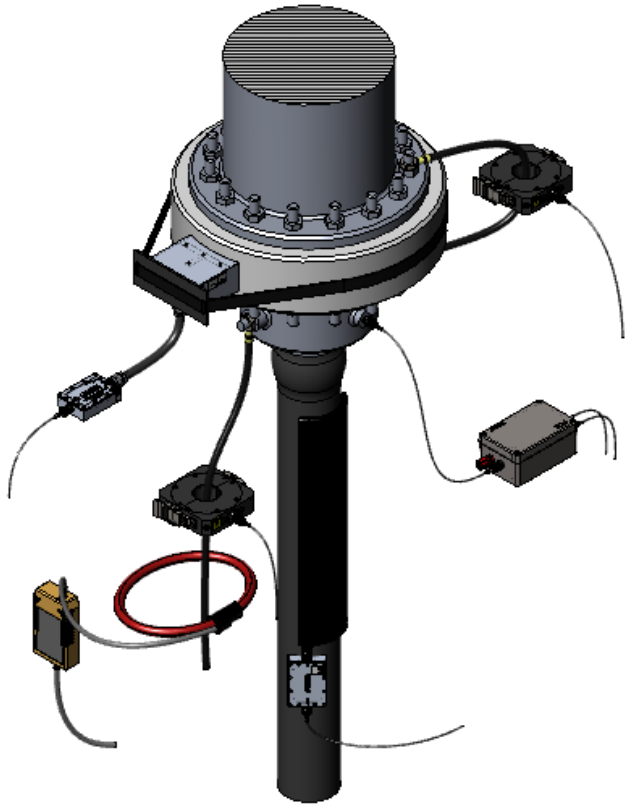
UHF antenna: Can detect PD activities occurring in GIS cable termination by picking up UHF signals.

PD sensor for HV cables accessories

GIS TERMINATIONS

PD tests at GIS termination can be carried out by means of

- HFCT on the ground leads/jumpers
- UHF measurements on insulating spacer
- Coupling with cable (FMC sensor)
- Eventual embedded sensors



Thanks to the GIS layout the background noise is usually very low and external disturbances are limited.

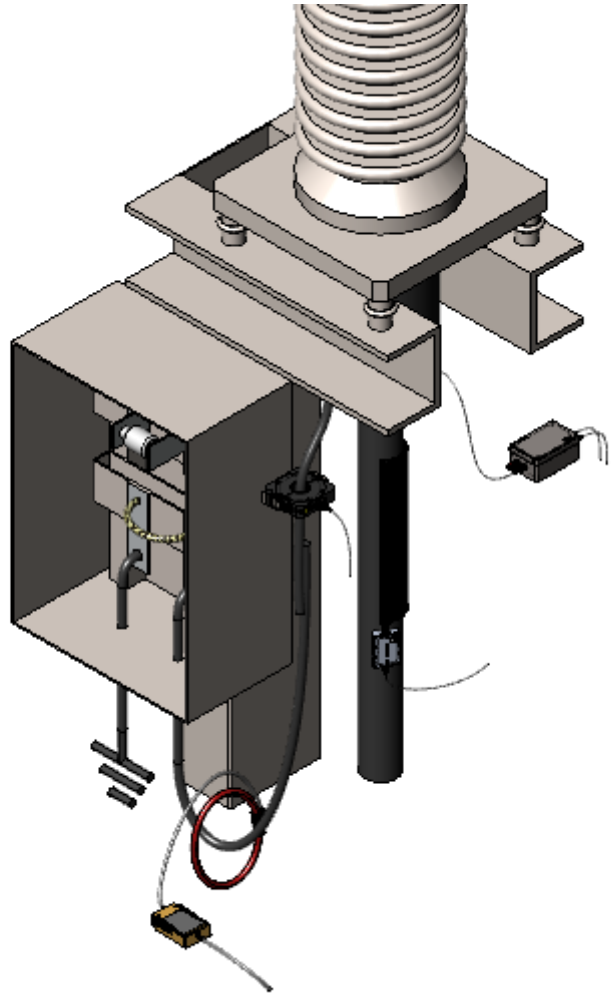
PD sensor for HV cables accessories

OUTDOOR TERMINATIONS

PD tests at outdoor terminations are carried out by means of

- HFCT on the ground leads
- Coupling with cable (FMC sensor)
- Eventual embedded sensors

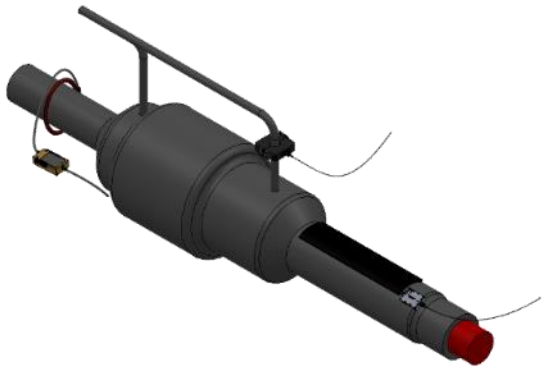
On outdoor terminations it is easy to have external surface disturbances and corona due to sharp edges exposed to air or to the temproary HV conncection, it is suggested to take precautions in this direction by installing corona rings and using large diameter pipes for the temporary HV conneciton

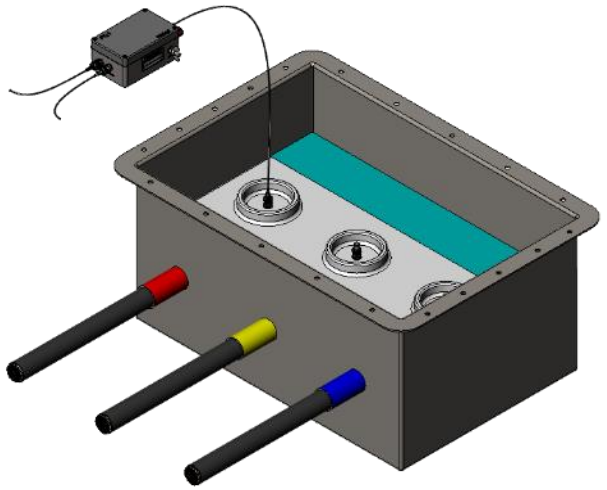


PD sensor for HV cables accessories

JOINTS

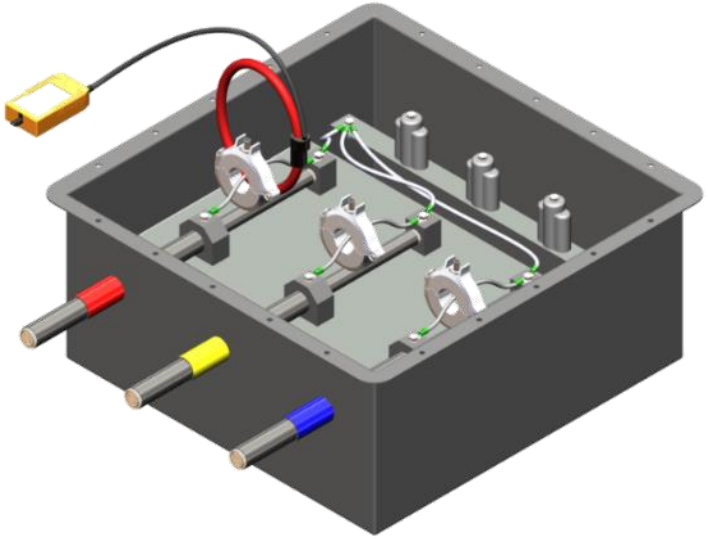
- HFCT around ground leads
- FMC along cable portion
- HFCT in the link boxes
- Eventual embedded sensors





Far from terminations all the substations disturbances are attenuated and the PD survey can be very sensitive.

The pulse polarity is important together with the pulse frequency and shape top investigate the PD source.




Pool #1

HV cable commissioning & PD test

According to IEC60840 and IEC62067 standards commissioning test is mandatory in order to verify the quality of installation:

- 60 minutes at 1.1 U_0 - 1.7 U_0 (**Off-line**);
- 24 hours at U_0 (**SOAK**).

PD test is carried out during those commissioning tests

Different PD test procedures are used according to the selected type of commissioning and circuit layout/characteristics.

HV cable commissioning & PD test

SOAK

When energizing the HV cable circuits with the grid the dielectric system is not subjected to overstress, the test duration is extended to 24h.

The PD data is recorded during the 24h time frame thanks to temporary montioring solutions and PD sensors installed in the cable accessories.

HV cable commissioning & PD test

Off-line: RTS

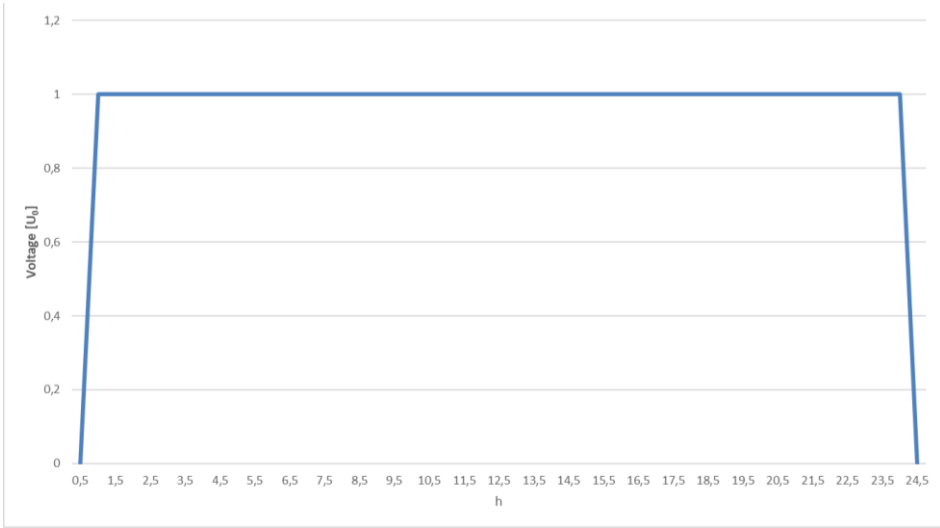
The fisr solution reccomendded by IEC is achieved thanks to resonant testing systems, those cane be with variable frequency or inductance.

Variable Frequency systems are widely used on trailers for site testing world wide, dependign on test voltage and cables length more than unit may be required.

SOAK vs Off-line

- PD measurement/monitoring is done during the 24 hours test
- No over-voltages applied, no voltage tuning
- Small PD may not be incepted because of the low electrical stress
- Noise and disturbances from the network
- All 3 phases are tested together

Rated Voltage U_0 for 24h continuously



SOAK vs Off-line

1h OFF-line test Vs 24h SOAK test: advantages and disadvantages

Issue	SOAK	OFF-line
Potential problem on the grid in case of failure	Y	G
Induced noise from the grid	R	G
Induced noise from adjacent phase	Y	G
No. Of companies and crews involved	G	R
Test Voltage Level and voltage tuning	R	G
Cost	G	Y

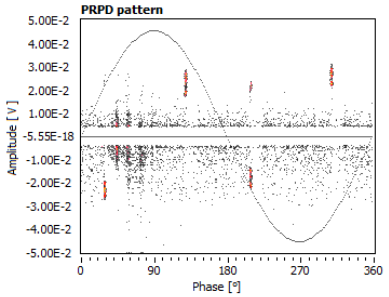
For PD testing the best solution is the OFF line test:

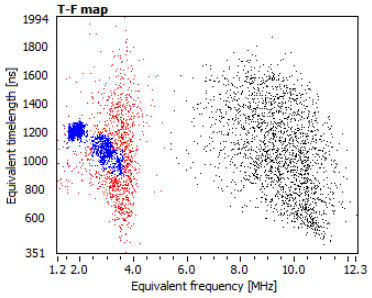
- The insulation is stressed over the rated voltage activating small defects.
- The senstivity is much higher due to abscence of grid & other phases noise.

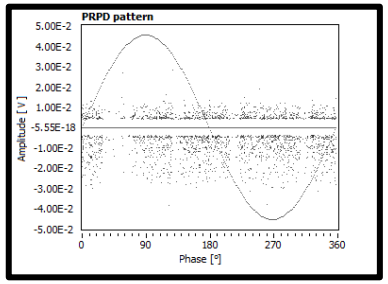
SOAK vs OFF-Line

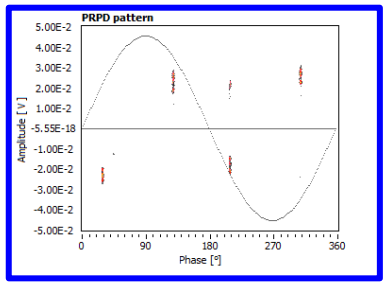
Same Acquisition:

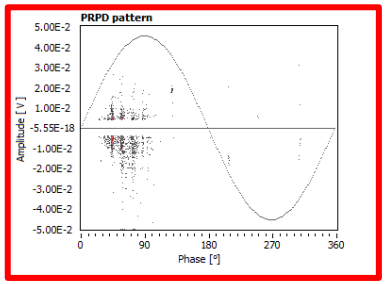
Synchronized with resonance frequency









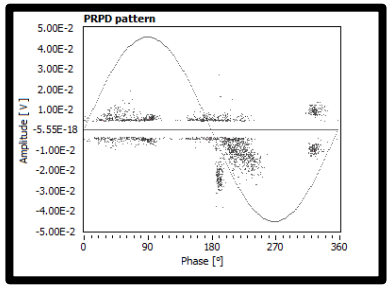


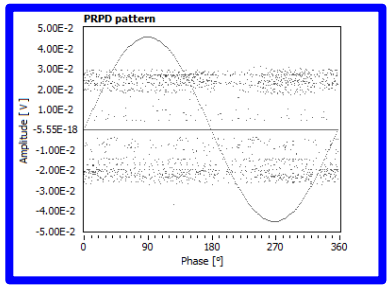
Substation disturbances

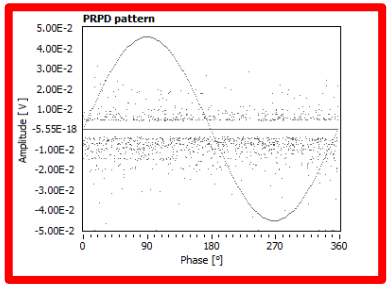
RTS noise

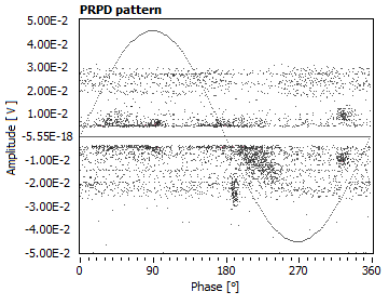
HV conncetion disturbances

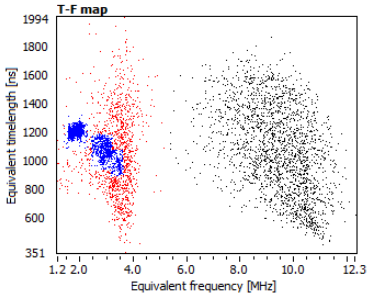
Synchronized with grid frequency









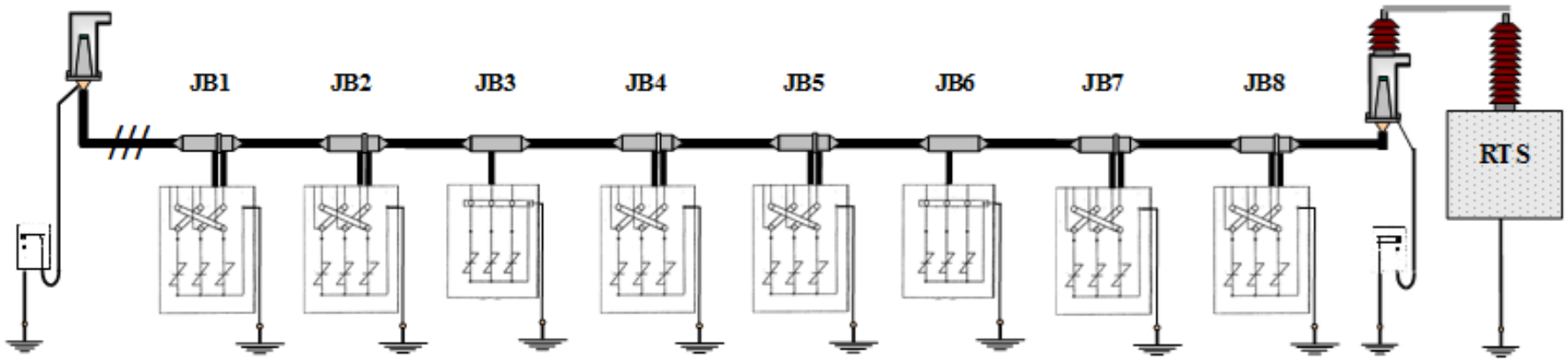


Off-line PD test

Simultaneous vs Sequential

Due to the HV cable circuit layout and site conditions 2 techniques can be used to perform the PD test:

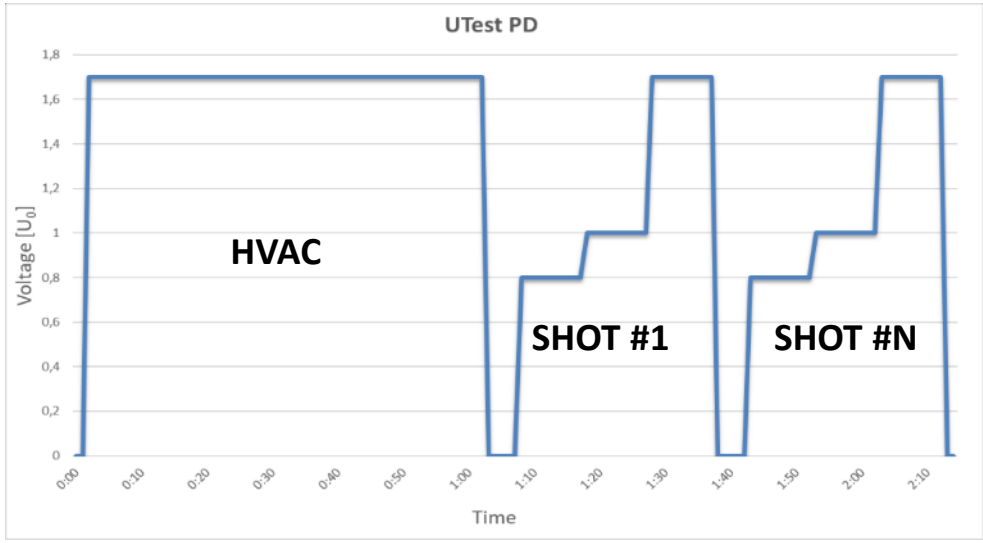
- **SEQUENTIAL** PD test: detection point are tested one by one moving along the circuit.
- **SIMULTANEOUS** PD test: all the detection point are checked together



Off-line PD test - Sequential

- PD measurement performed after the HVAC test
- Electrical stress is limited to the shot
- Several voltage applications in case of long circuit
- No communication/hardw
- All the accessories are tested after the AC test
- Voltage can be controlled

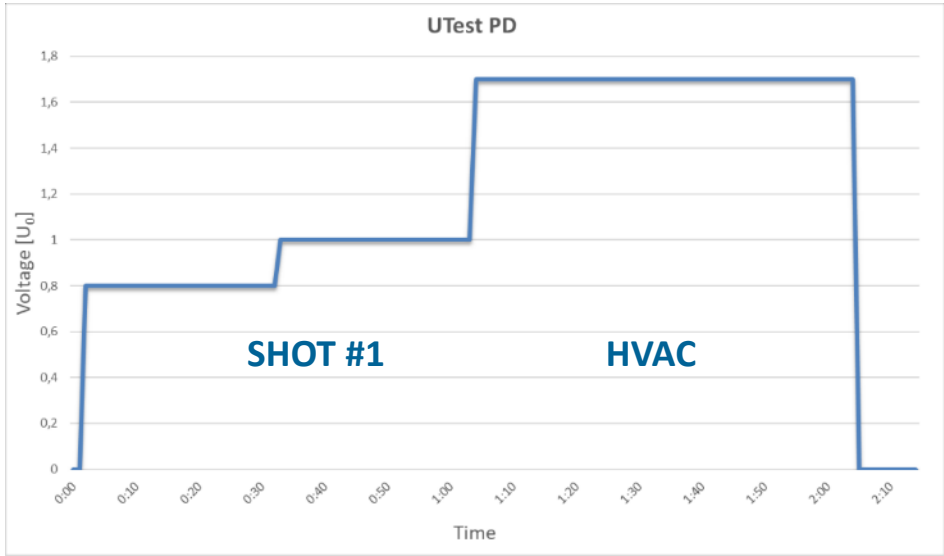
Overvoltage for 1h + PD test shots duration



Off-line PD test - Simultaneous

- PD measurement is done during the HVAC test
- Once hardware is set to test it is possible to test up to 4-5 cables per day
- Maximum electrical stress possible
- PD sensors and PD Hubs have to be pre-installed on all the cable accessories
- Fiber optic is required

Overvoltage for 1h



Off-line PD test

Offline test: SIMULTANEOUS Vs SEQUENTIAL

Issue	SEQUENTIAL	SIMULTANEOUS
Homogeneous stress on all the HV accessories	R	G
Check on different HV accessories due to extraordinary signal	Y	G
Test Preparation cost & effort	G	R
Test engineer cost	Y	G
Customer involvement in the process	Y	G
Effort from external contractors to prepare the test	G	R
Traffico Control	R	Y

For diagnositc purposes the best solution is the Simultaneous OFF line test.


Pool #2

PD test challenges

During HV cable commissioning some practical issues are:

- Lack of time
- PD data: substation external disturbances
- PD data: HV connection disturbances
- Long circuit ➔ cost explosion

PD test challenges – Lack of time

The PD test is the final step of very long project, time is always an hot topic due to:

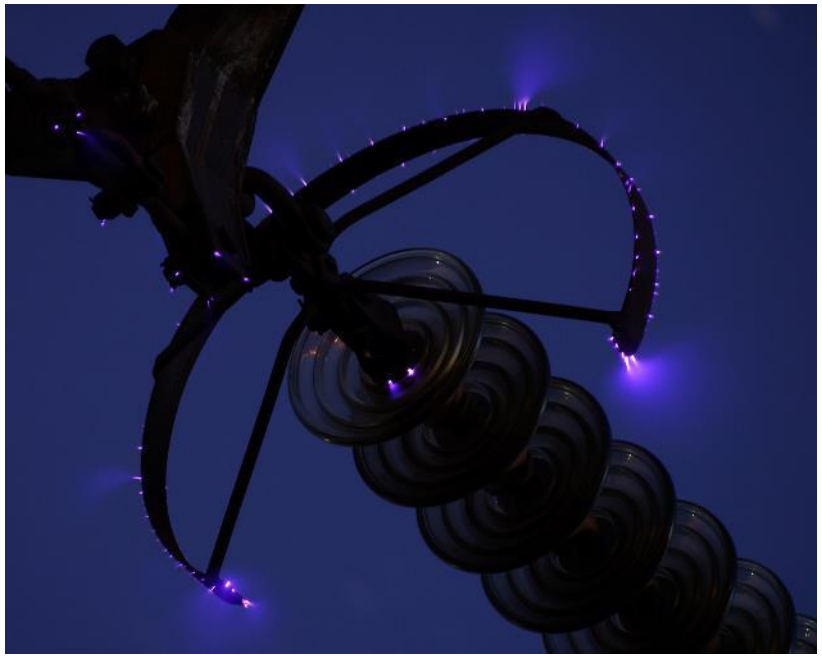
- Limit the voltage stress applied to the cable
- Reduce the site efforts: traffic crews, operations
- Reduce the rental costs (RTS, LV generator)
- Retrieve/minimize project delays

➔ Limit test time without affecting the quality.

PD test challenges – Substation disturbances

SOAK MAINLY

Many HV cables ends are localized in substations, where it is easy to find outdoor switchgears or outdoor powerlines, in all these assets can be affected by external PD activty (corona and surface discharges occurring) those can eb characterized by high amplitude and repetition rate.



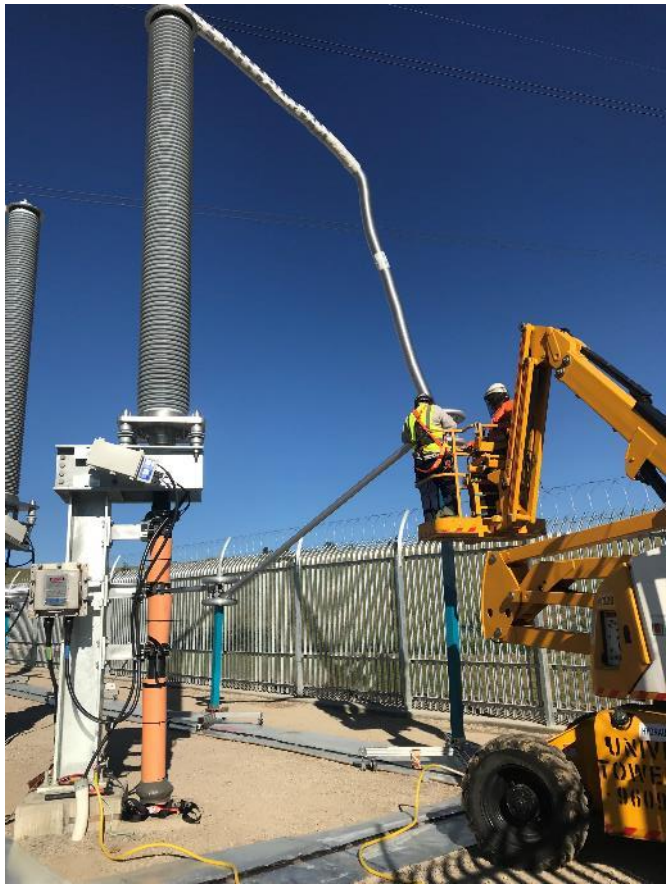
➔ Recognize and sort the external phenomena

PD test challenges – HV connection disturbances

RTS ONLY

The temporary connection between the cable under test and the RTS is made with solid or flexible aluminium pipes:

- Avoid sharp edges
- Clean the bushing surfaces before the test
- Use large diameter aluminium pipe
- Use double corona rings for connecitons

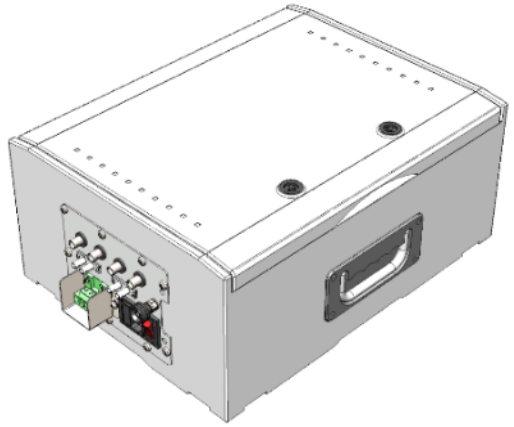


➔ Identify poor connecitons and rectify

PD test challenges – long circuit

Longer circuits will be characterized by huge number of accesorries (ie: 40 joints phase):

- Larger testing team
- Remote testing (communication and instruement)
- Temporary monitoring during the HVAC test



220kV long circuit project: 222 accessories in 4 days:

- Communication infrastructure + 37 temporary pdhub
- 6 operators. 1.5 day installation 2 days test 1 day removal


Pool #3

Localization Techniques

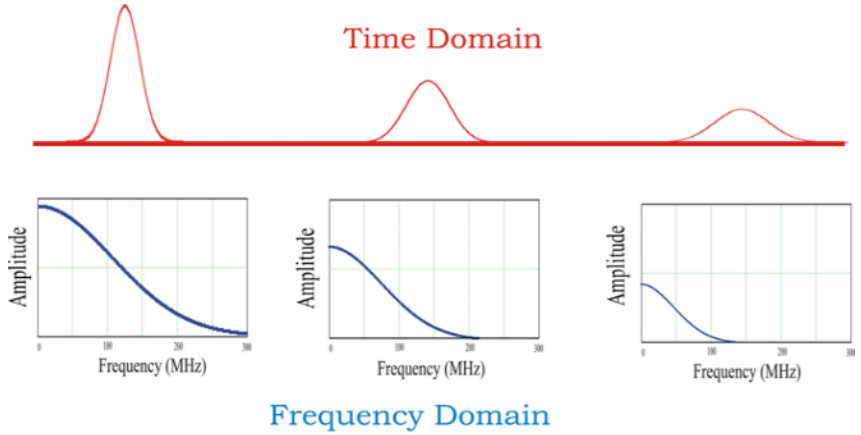
– In case of Internal Partial Discharges detected it is possible to apply three different techniques in order to locate the source of the phenomenon along the cable route:

1. **Amplitude – Frequency analysis (AF)**
2. **Time-Domain Reflectometry (TDR)**
3. **Arrival Time Analysis (ATA)**

Localization Techniques

1. Amplitude – Frequency analysis (AF)

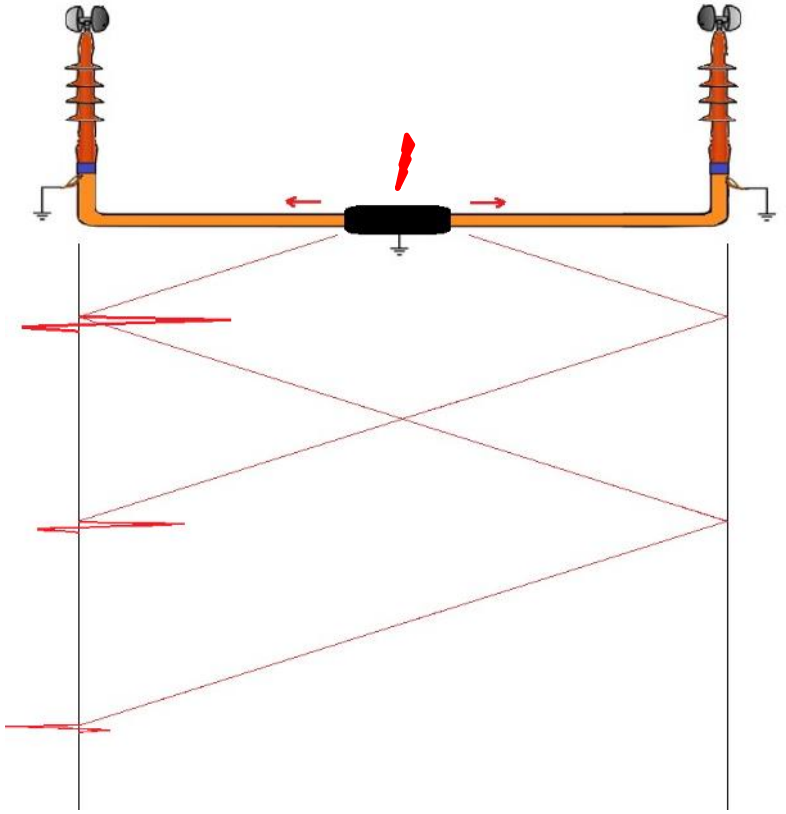
This type of localization is based on the attenuation analysis that the SP signal undergoes traveling along the cable.



Localization Techniques

2. Time-Domain Reflectometry (TDR)

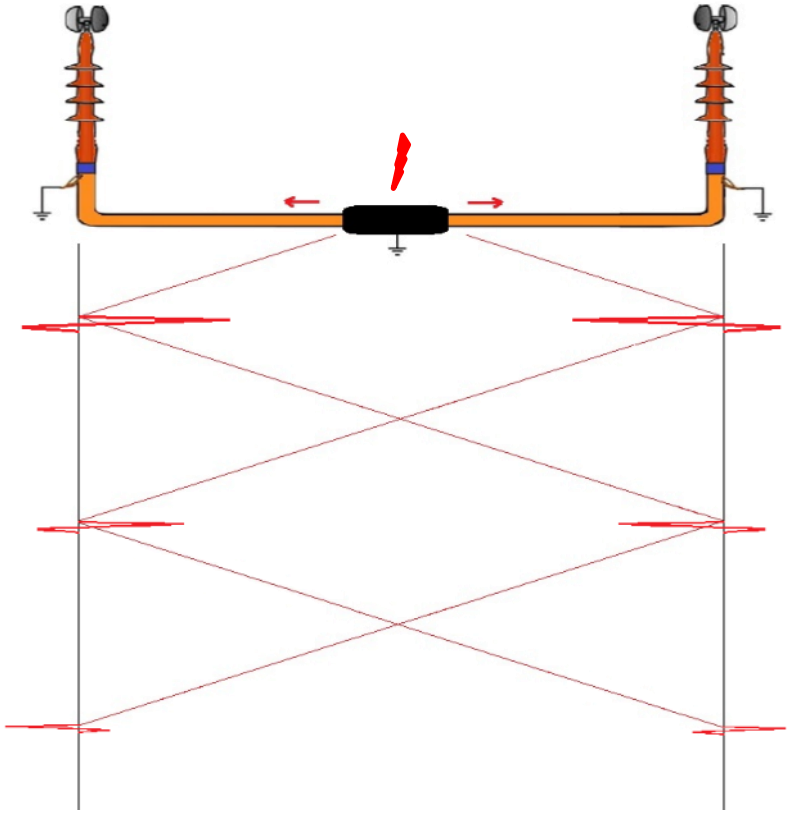
This type of localization is based on the analysis of the signal reflections, generated by the impedance variations present along the line (joints and terminals).



Localization Techniques

3. Arrival Time Analysis (ATA)

This type of localization is based on the analysis of the arrival times of the signal at different points of acquisition.



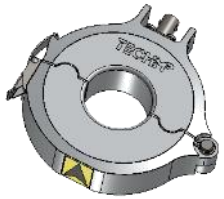
CS#1 132kV Cable Termination

Measurement Information:

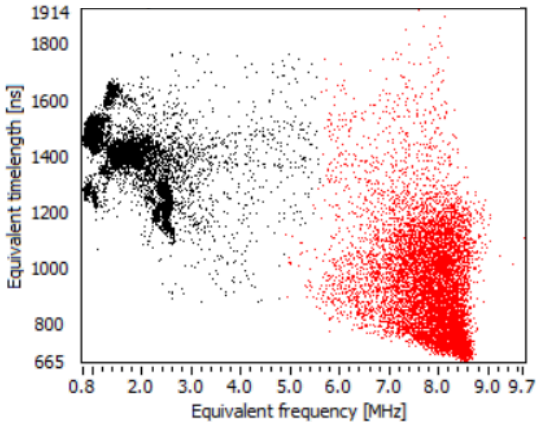
- Test type: Off-line PD Commissioning Test
- Measurement type: Sequential
- Termination type: GIS & Transformer
- PD sensor: HFCT & horn
- Equipment under test: 132kV HV Cable
- Length of the cable: 80m
- Insulation type: XLPE

CS#1 132kV Cable Termination

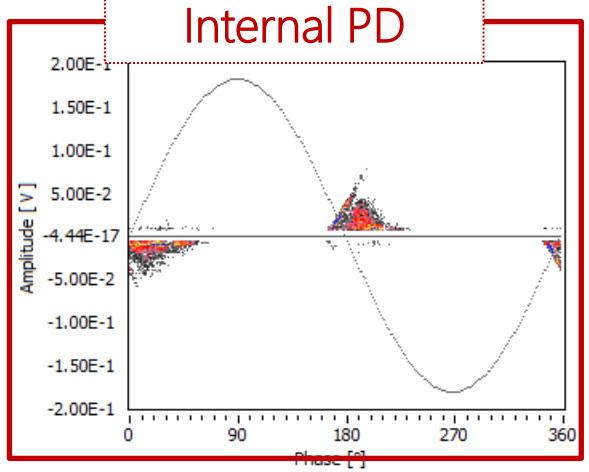
The 3 cabel termination at the GIS side of the circuit showed PD signals, the equivalent frequency range characterized by average values.



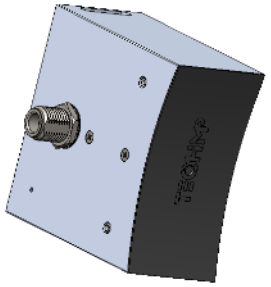
TF Classification Map



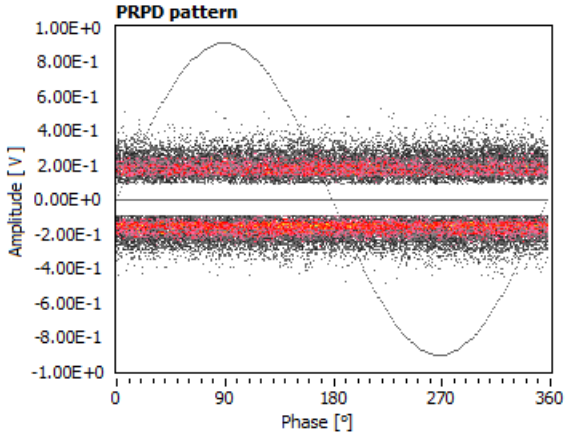
Internal PD



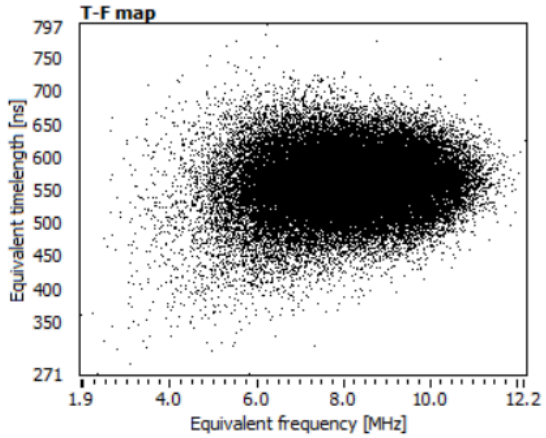
To double check PD source the same termination was tested with UHF Horn antenna.



Entire PRPD Pattern



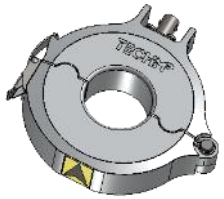
TF Classification Map



NOISE ONLY

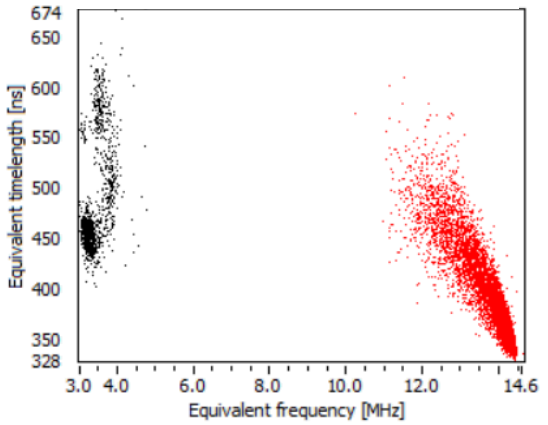
CS#1 132kV Cable Termination

The same test was immediately performed on the othe end of the cabel under test.

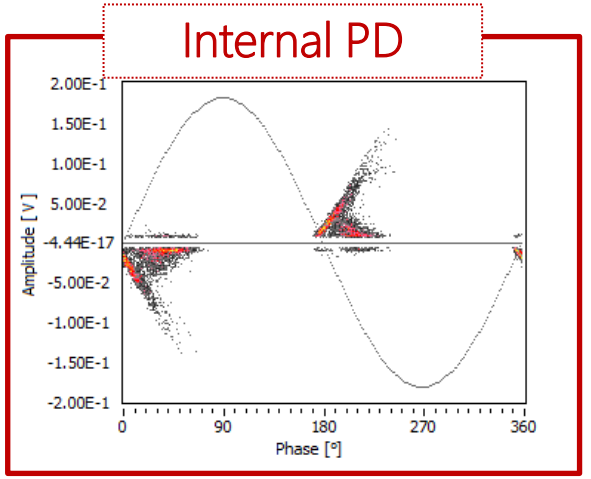


The recorded signals showed a much higher repetition rate and amplitude, the PRPD pattern was also very well defined.

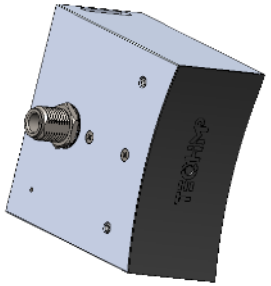
TF Classification Map



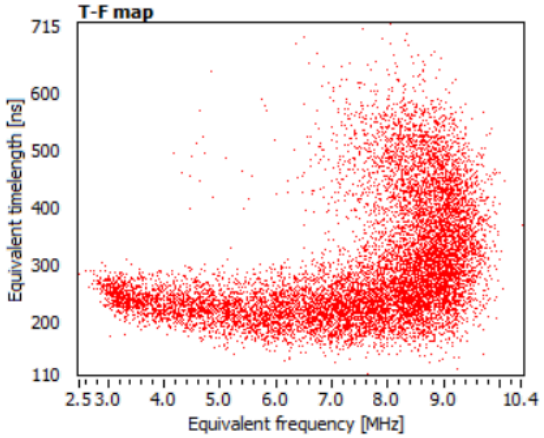
Internal PD



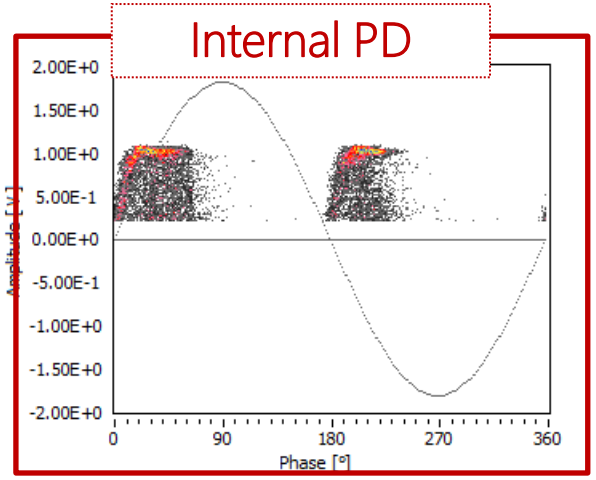
Doublechecked with UHF sensor



TF Classification Map



Internal PD



PD ACTIVITY DETECTED

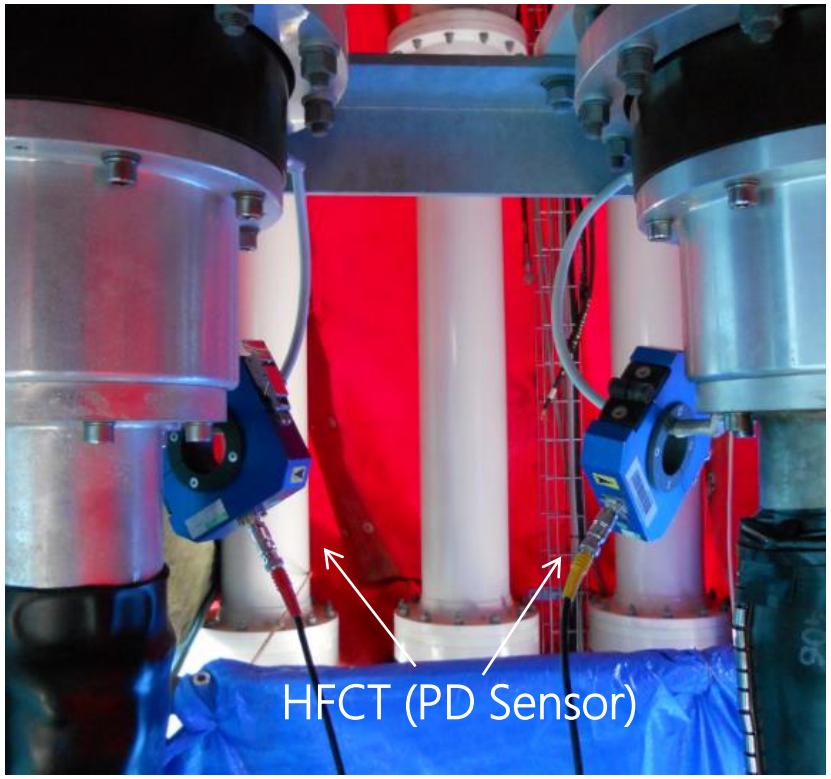
CS#2 132kV Cable Termination

Measurement Information:

- Test type: Off-line PD Commissioning Test
- Measurement type: Sequential
- Termination type: GIS & Transformer
- PD sensor: HFCT
- Equipment under test: 132kV HV Cable
- Length of the cable: 58m
- Insulation type: XLPE

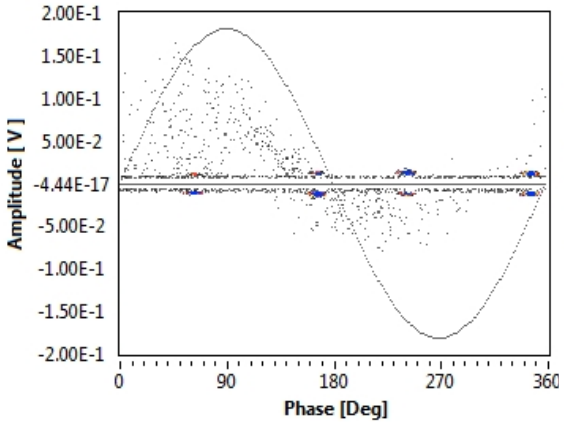
CS#2 132kV Cable Termination

GIS Termination Side

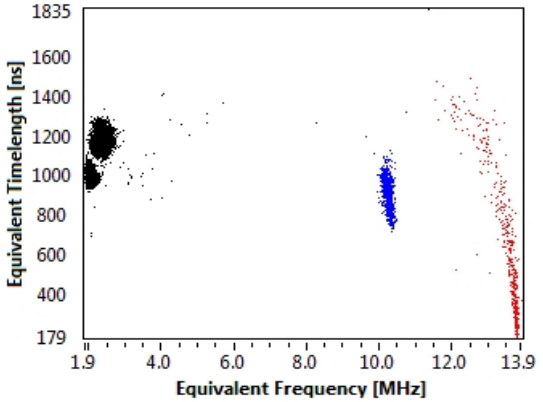


CS#2 132kV Cable Termination

Entire PRPD Pattern



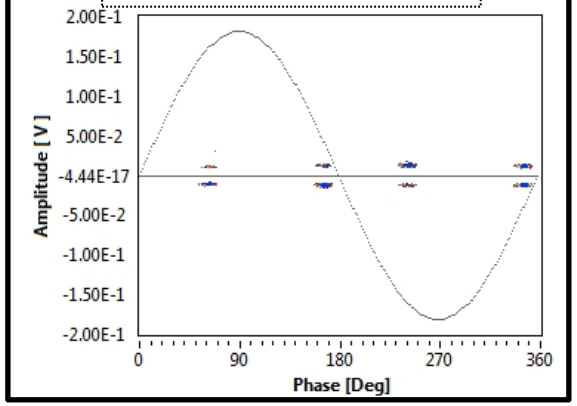
TF Classification Map



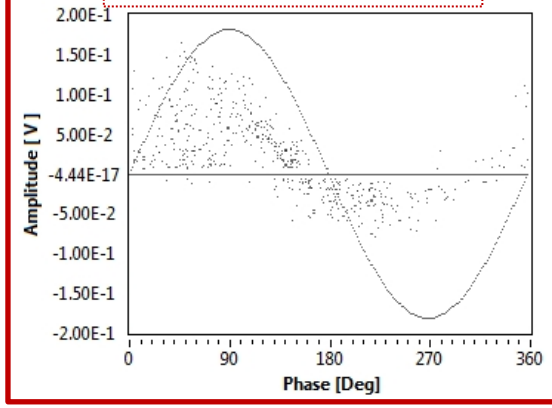
@90kV

Interface PD happening at the GIS termination on White phase

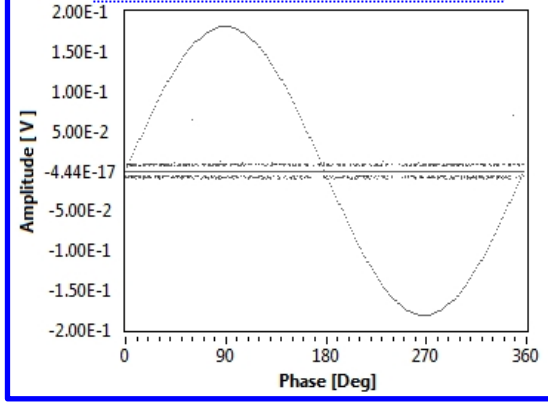
IGBT noise



Interface PD

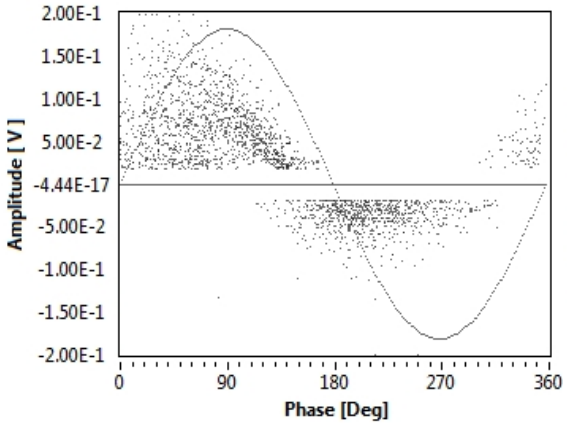


Background noise

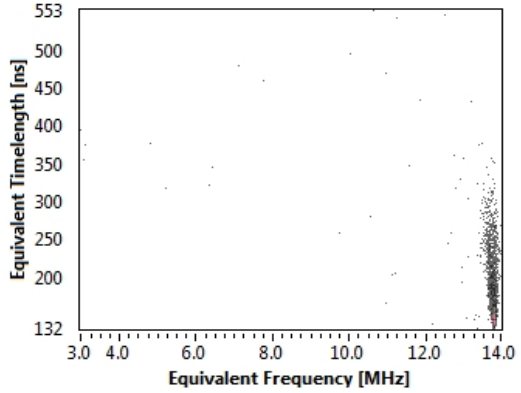


CS#2 Cable commissioning

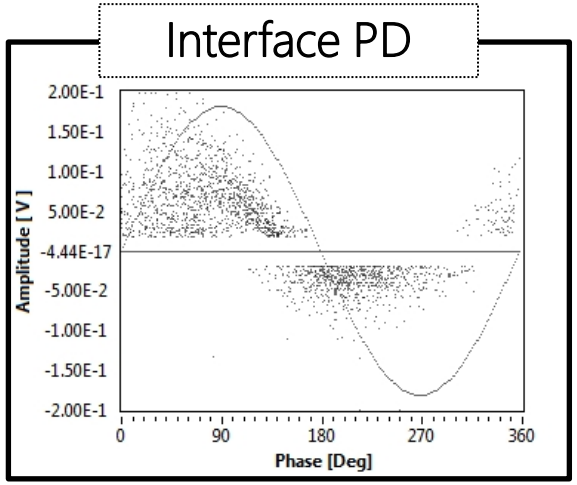
Entire PRPD Pattern



TF Classification Map



Interface PD



@100kV

Clear **interface PD** happening at the GIS

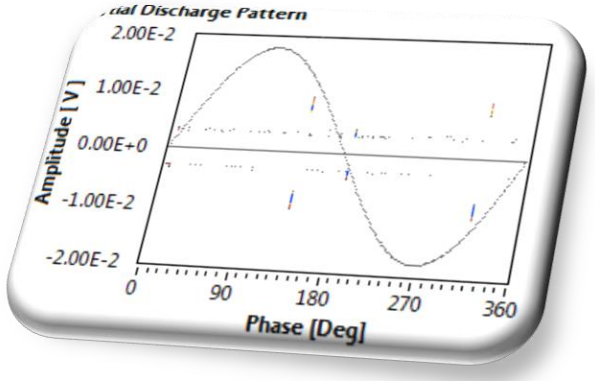
Waveform confirms very typical PD pulse shape

Termination replacement

CS#2 Cable commissioning

White phase GIS termination dissembled

Visual inspection



PD Commissioning test after replacement

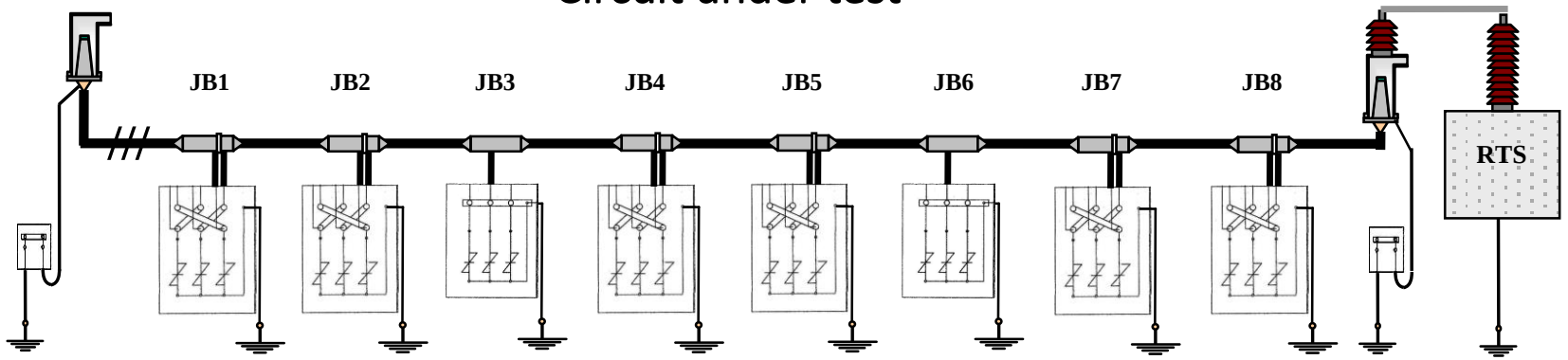
CS#3 Cable Commissioning

Measurement Information:

- Test type: Off-line PD Commissioning Test
- Measurement type: Sequential
- Termination type: GIS termination
- PD sensor: HFCT & embedded
- Equipment under test: 400kV HV Cable
- Length of the cable: 4200m
- Insulation type: XLPE

CS#3 Cable Commissioning

Circuit under test



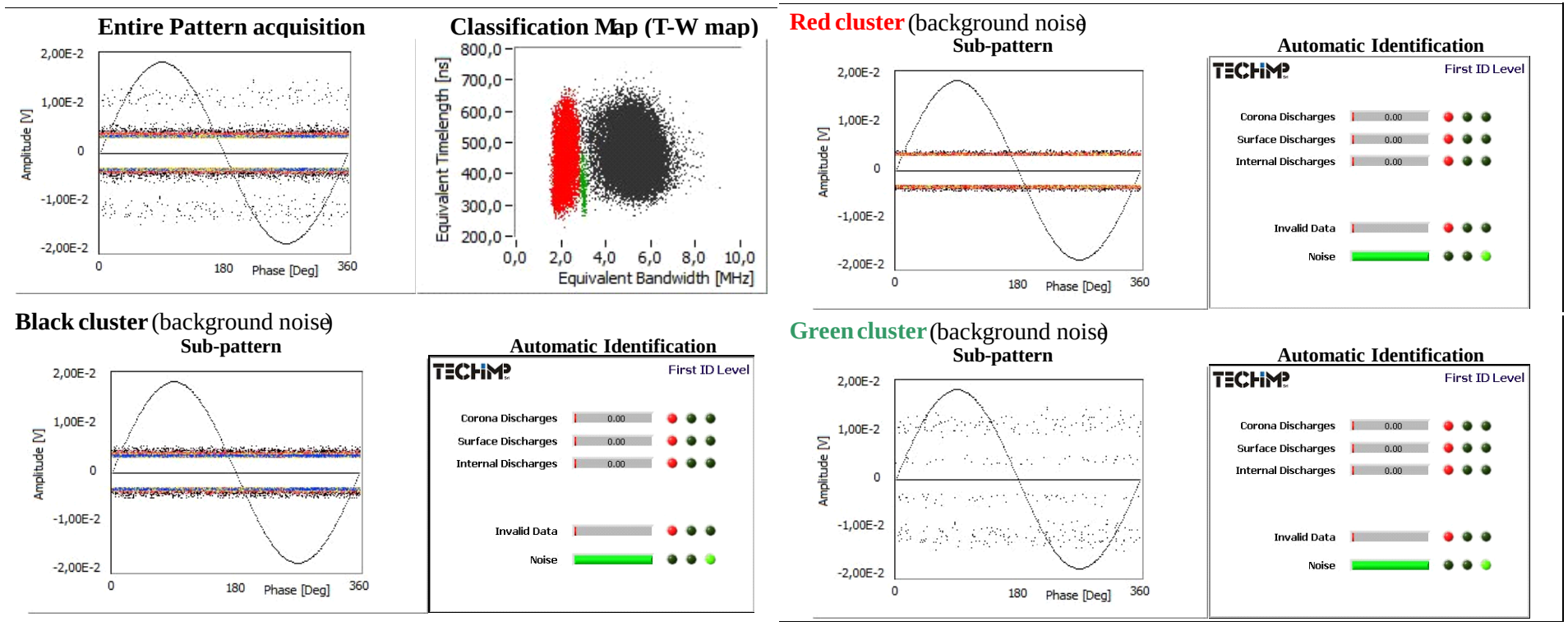
Sensors connection at terminations

Sensors connection at link boxes

CS#3 Cable Commissioning

...3° PD measurement after terminals replacement....

PD FREE!!



CS#3 Cable Commissioning

1° PD measurement

Results:

- PD activities detected at one side terminations of yellow and blue phases

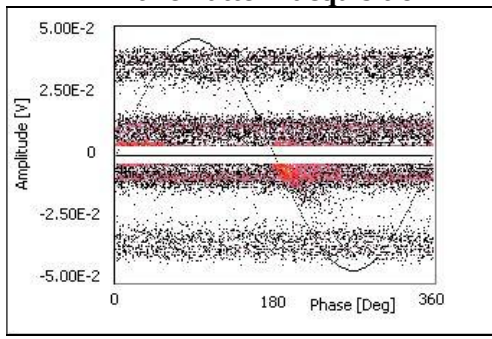
Taken action:

- inspection and cleaning of the outer part of the insulation system of two terminals

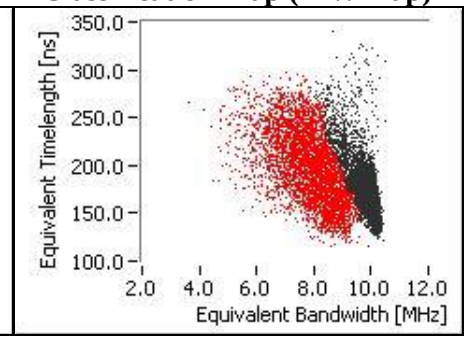
Re-installation..

…2° PD measurement…

Entire Pattern acquisition

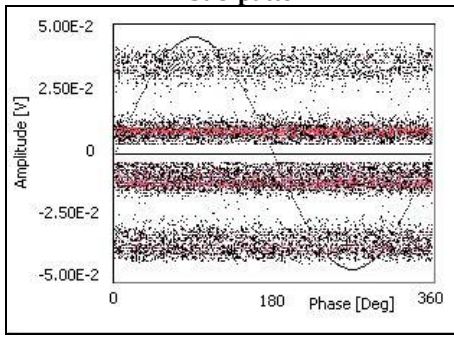


Classification Map (T-W map)

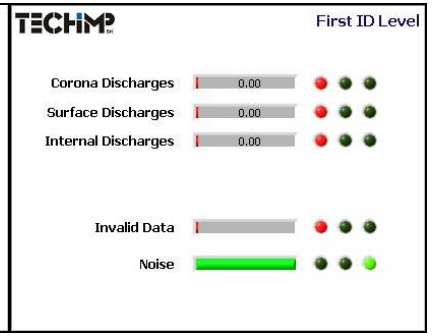


Black phenomenon(background noise

Sub-pattern

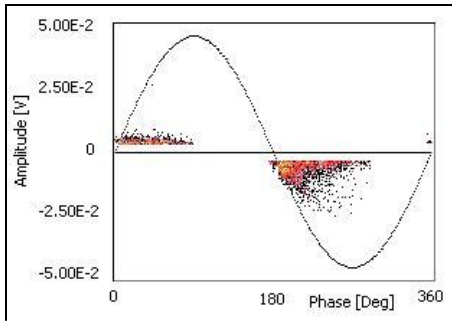


Automatic Identification

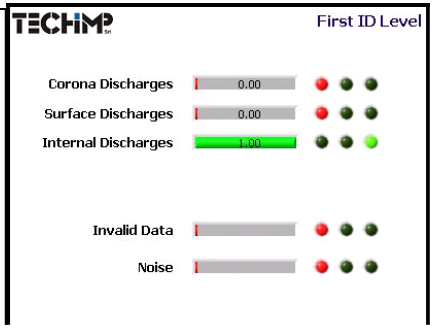


Red phenomenon(internal discharges)

Sub-pattern



Automatic Identification



CS#3 Cable Commissioning

2° PD measurement

Results:

- Again PD activities detected at the same terminations of yellow and blue phase

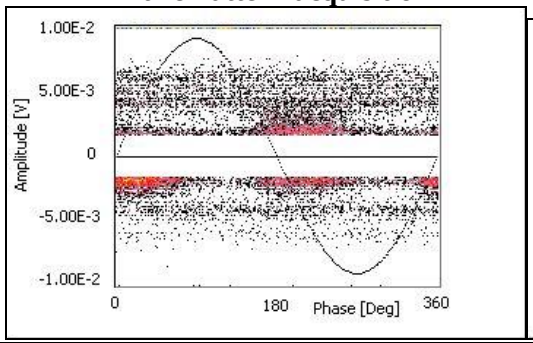
Taken action:

- To replace terminations!!!

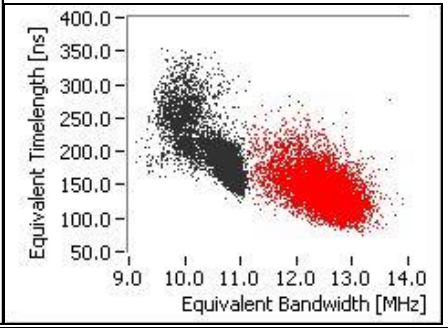
After replacement..

...3° PD measurement...

Entire Pattern acquisition

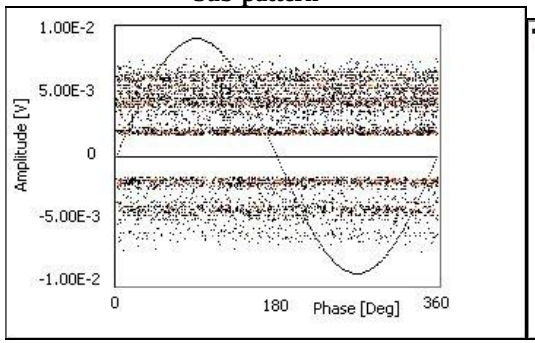


Classification Map (T-W map)

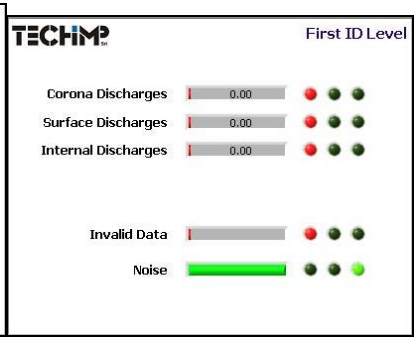


Black phenomenon (background noise)

Sub-pattern

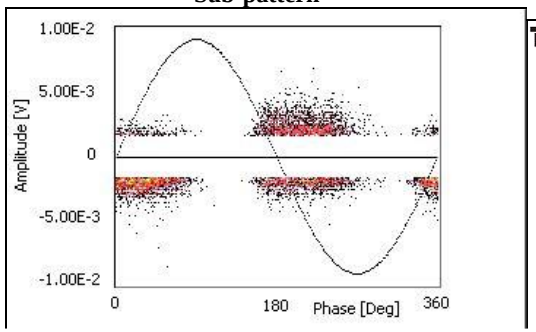


Automatic Identification

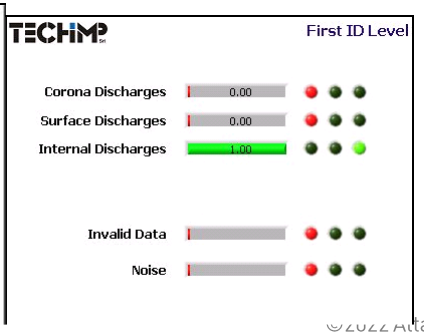


Red phenomenon (internal discharges)

Sub-pattern



Automatic Identification



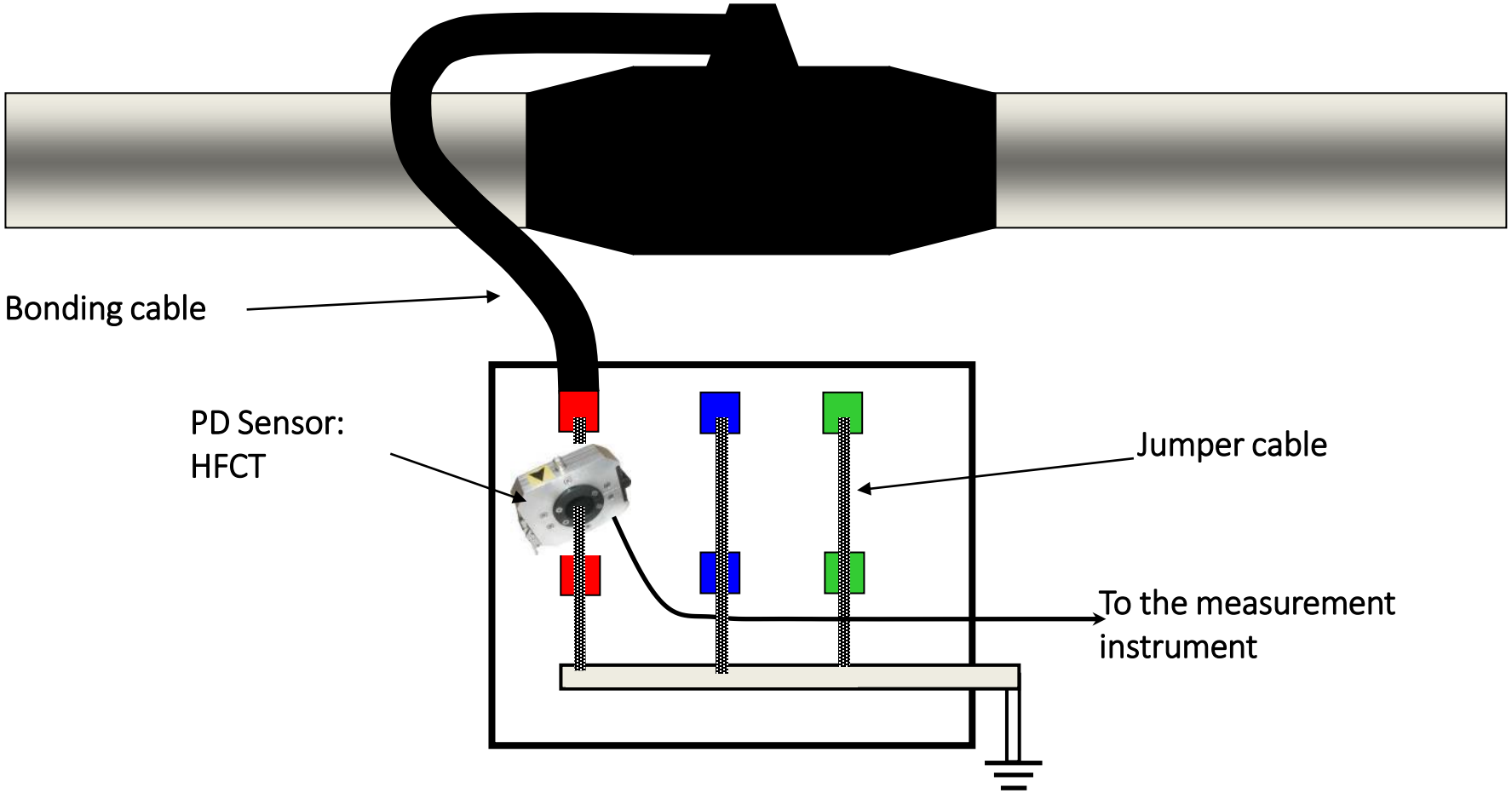
CS#4 Cable Commissioning

Measurement Information:

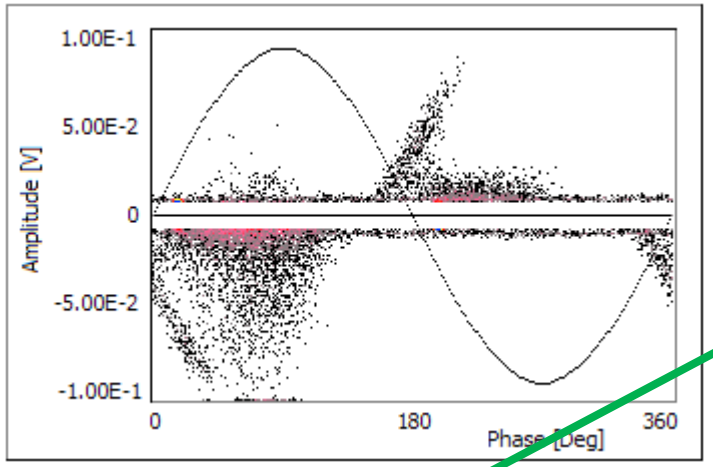
- Test type: Off-line Commissioning Test
- Measurement type: Sequential
- Termination type: Outdoor
- Measurement date: 2012
- PD sensor: HFCT
- Equipment under test: 220kV HV Cable
- Length of the cable: 1300m
- Insulation type: XLPE

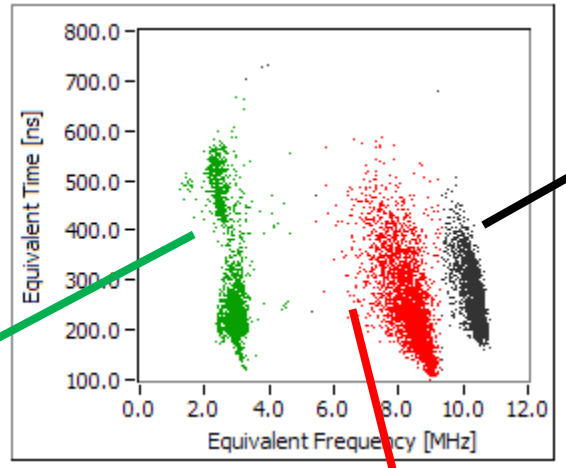
CS#4 Cable Commissioning

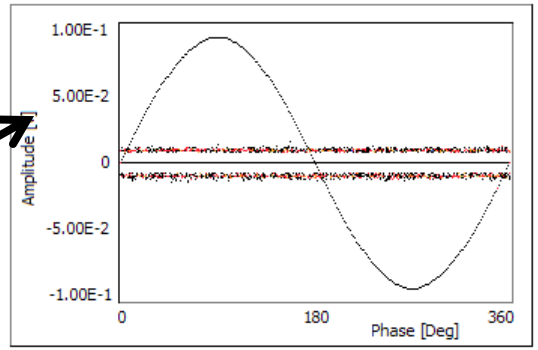
On site commissioning PD test on HV Cable: **PD detection**



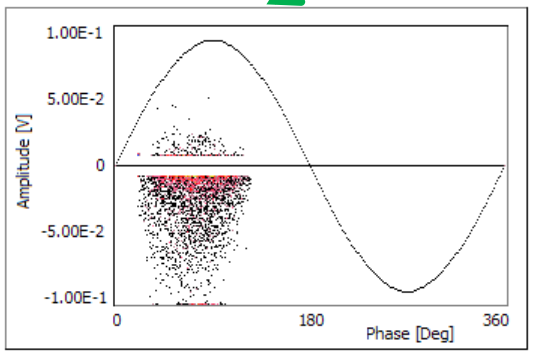
CS#4 Cable Commissioning



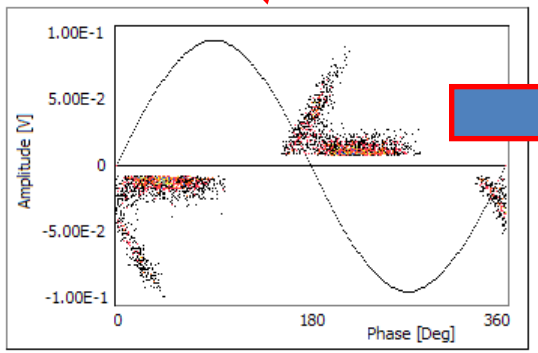


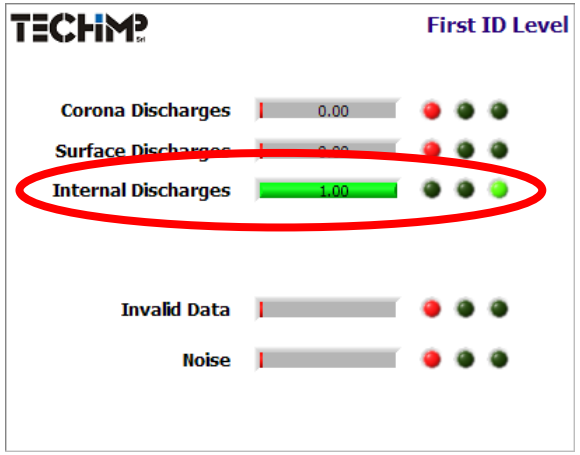


Background noise

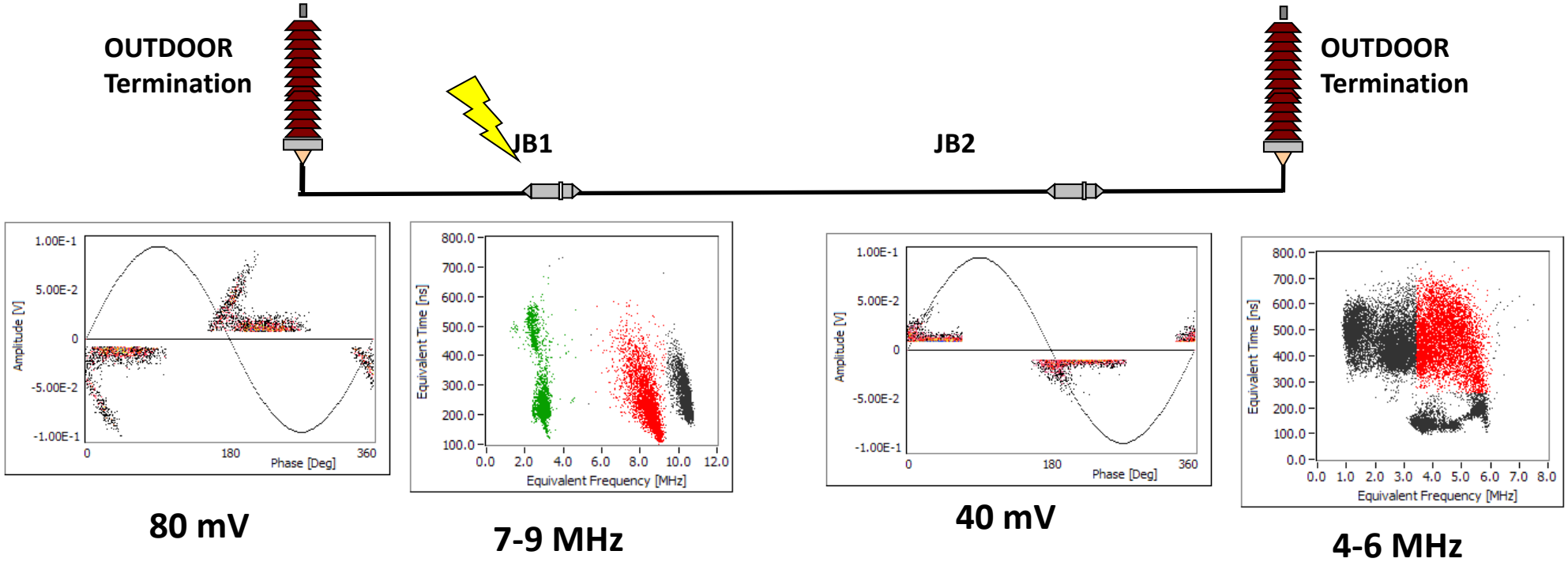


Surface/Corona discharges





CS#4 Cable Commissioning



Higer amplitudes and frequencies for PD measured on Joint Bay 1

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Next ALTANOVA **WEBINARS**

13 Apr — Offline testing of power transformer - APAC

19 Apr — Offline testing of underground cables with high level intro - APAC

4 Mag — Las diferentes herramientas de diagnóstico del Análisis de Gases Disueltos (DGA), cuándo / cómo usarlas de manera eficiente

10 Mag — Managing and visualizing transformer oil test data - EMEA

17 Mag — Managing and visualizing transformer oil test data - APAC

Thank you for attending our webinar!

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Senior Service Engineer
lpaschini@doble.com