TECHIMP SpA

Italy

TECHIMP **HV CABLES** CASE STUDIES

LIST OF CASE STUDIES

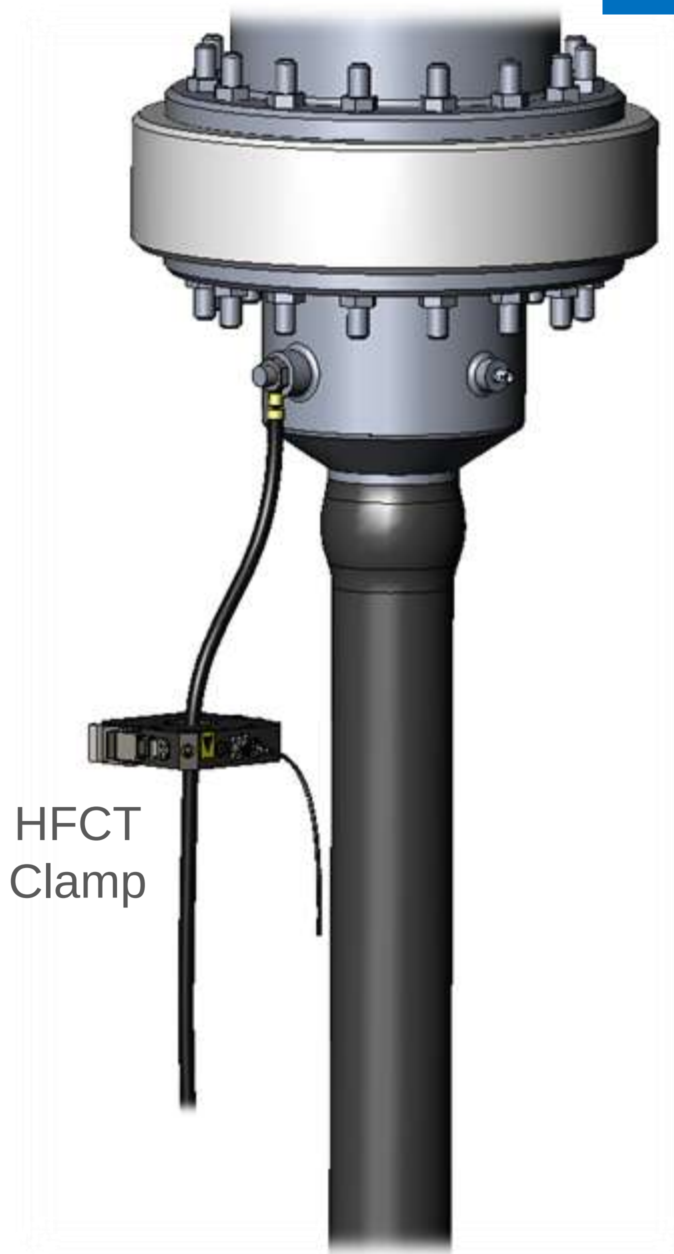
- 132kV GIS Termination – PD in the Stress Cone
- 132kV GIS Termination – PD in the Stress Cone of a New Cable System
- 400kV GIS Termination – PD in the Stress Cone
- 400kV Accessible Joint - PD in one Joint
- 220kV Link Box – PD in one Joint
- 230kV Link Box – PD Location with GPS
- 400kV Cable System – PD Location with TDR Analysis

TECHIMP SpA

LOCATION	**UAE**
EUT	**HV CABLES**
RATED VOLTAGE	**132 kV**
INSULATION	**XLPE**
LENGTH	**400 m**
VINTAGE	**15 YEARS**
TYPE OF TEST	**ON-LINE**

CASE STUDY

On-line PD detected inside the stress cone of one HV Termination.



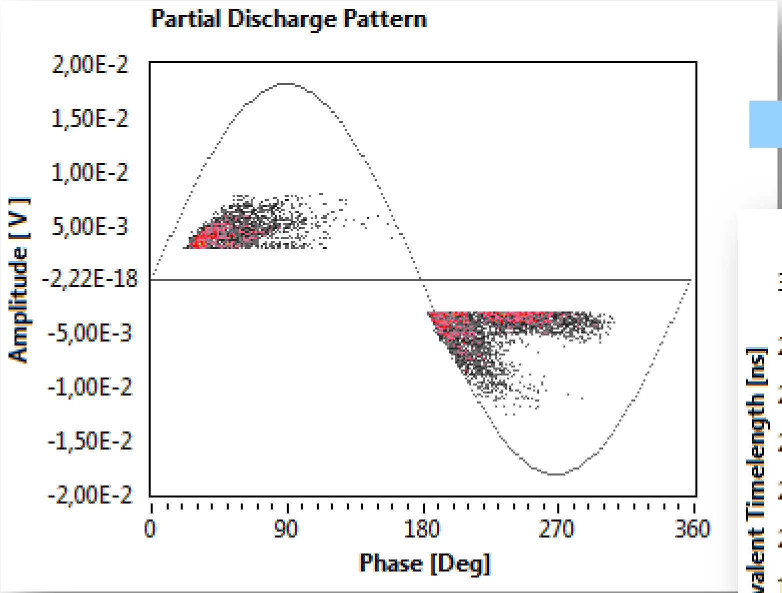
GIS Termination

High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the ground connection of the GIS Termination.

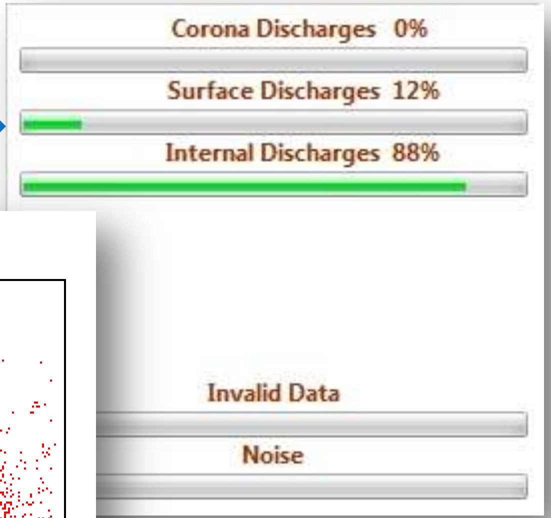
Thanks to the Clamp version of the HFCT it is possible to perform on-line PD measurements without ground lead disconnection or out of service of the EUT.

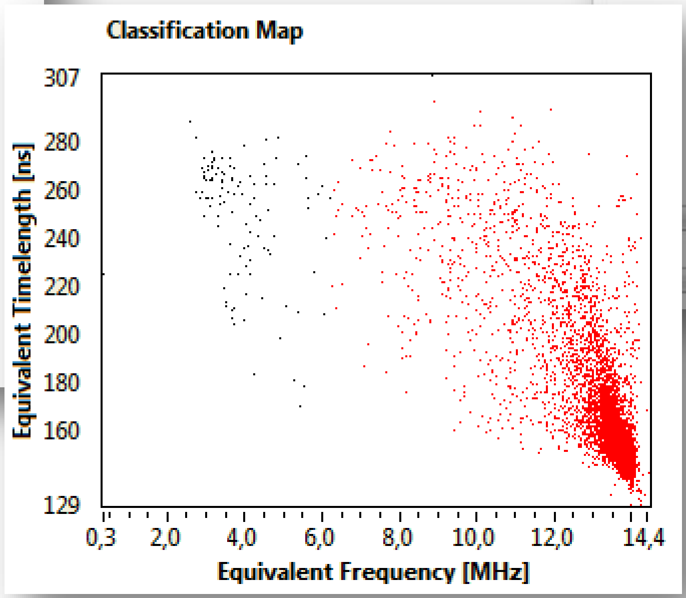
PD measurement results on Red Phase

RED PHASE



IDENTIFICATION



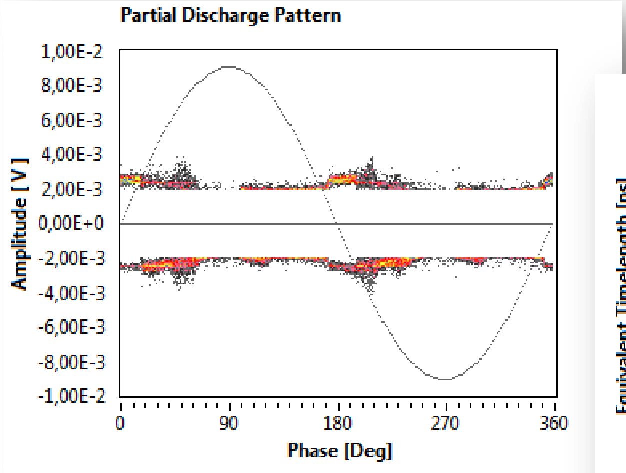


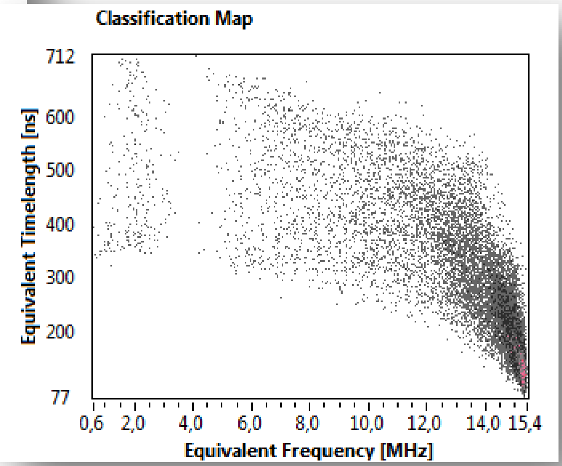
Equivalent Frequency analysis for the Internal/Interface PD activity detected on the TF Classification Map (Red Cluster) allows to conclude:

PD activity inside the stress cone of the phase under

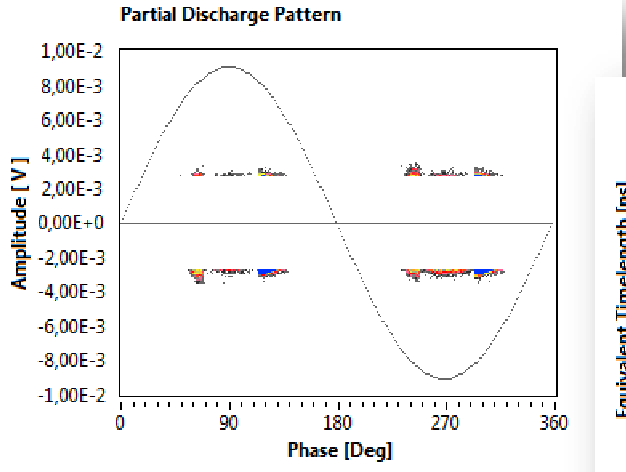
PD measurement results on other Phases

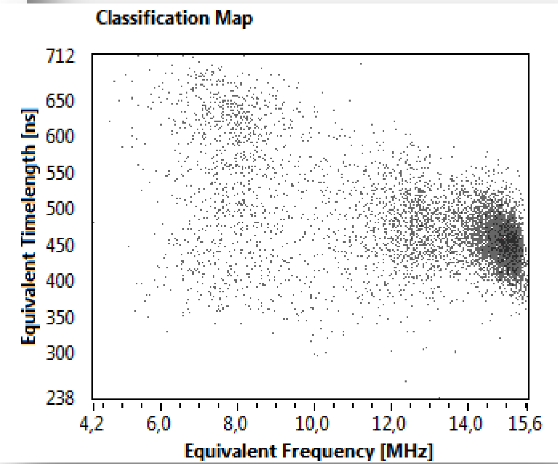
YELLOW PHASE





BLUE PHASE





PD

Suggested actions

Considering amplitude and repetition rate of detected PD it was suggested to:

1 – Monitoring the PD’s Trend

in order to verify that Internal PD activity in the Stress Cone does not increase too quickly. In this way the customer have to do maintenance only when really necessary.

Ti SOLUTION

2 – Regular basis PD Measurements

in order to avoid unexpected failures and consequent explosion during service due to aging of the cable.

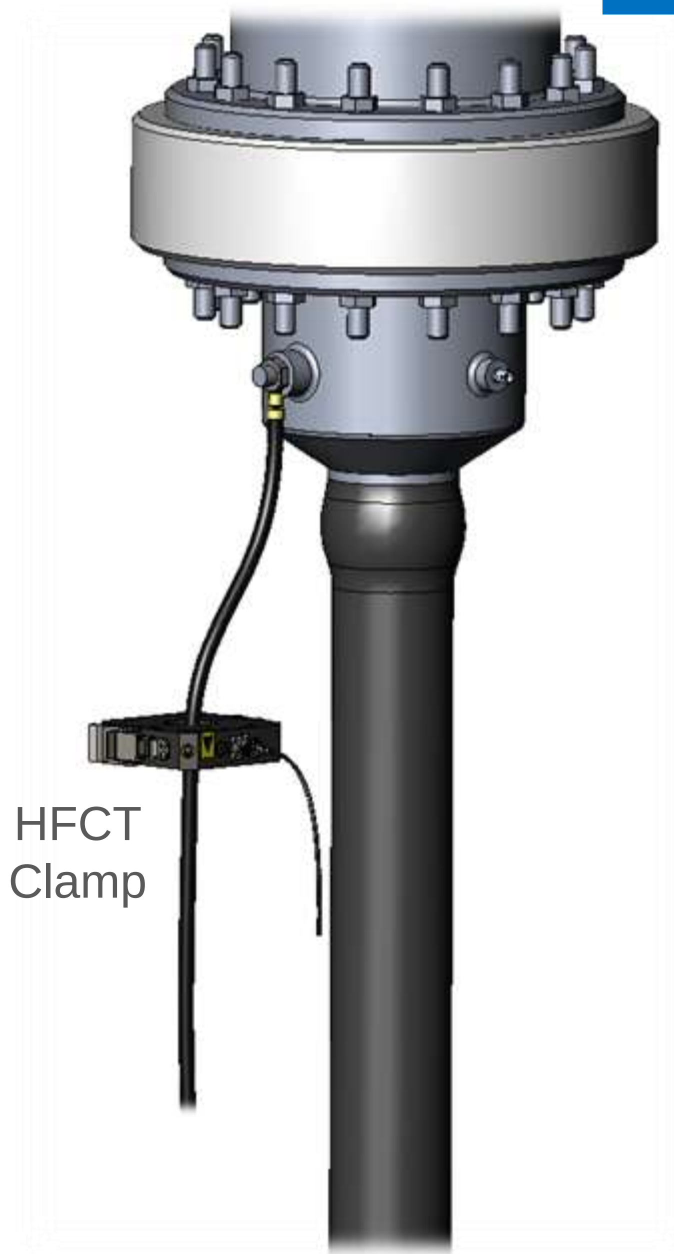
Ti SOLUTION

PD Measurement on/off-line with Techimp PPDC + PD sensors

LOCATION	**UAE**
EUT	**HV CABLES**
RATED VOLTAGE	**132 kV**
INSULATION	**XLPE**
LENGTH	**400 m**
VINTAGE	**NEW**
TYPE OF TEST	**ON-LINE**

CASE STUDY

On-line PD detected inside the stress cone of one HV Termination.



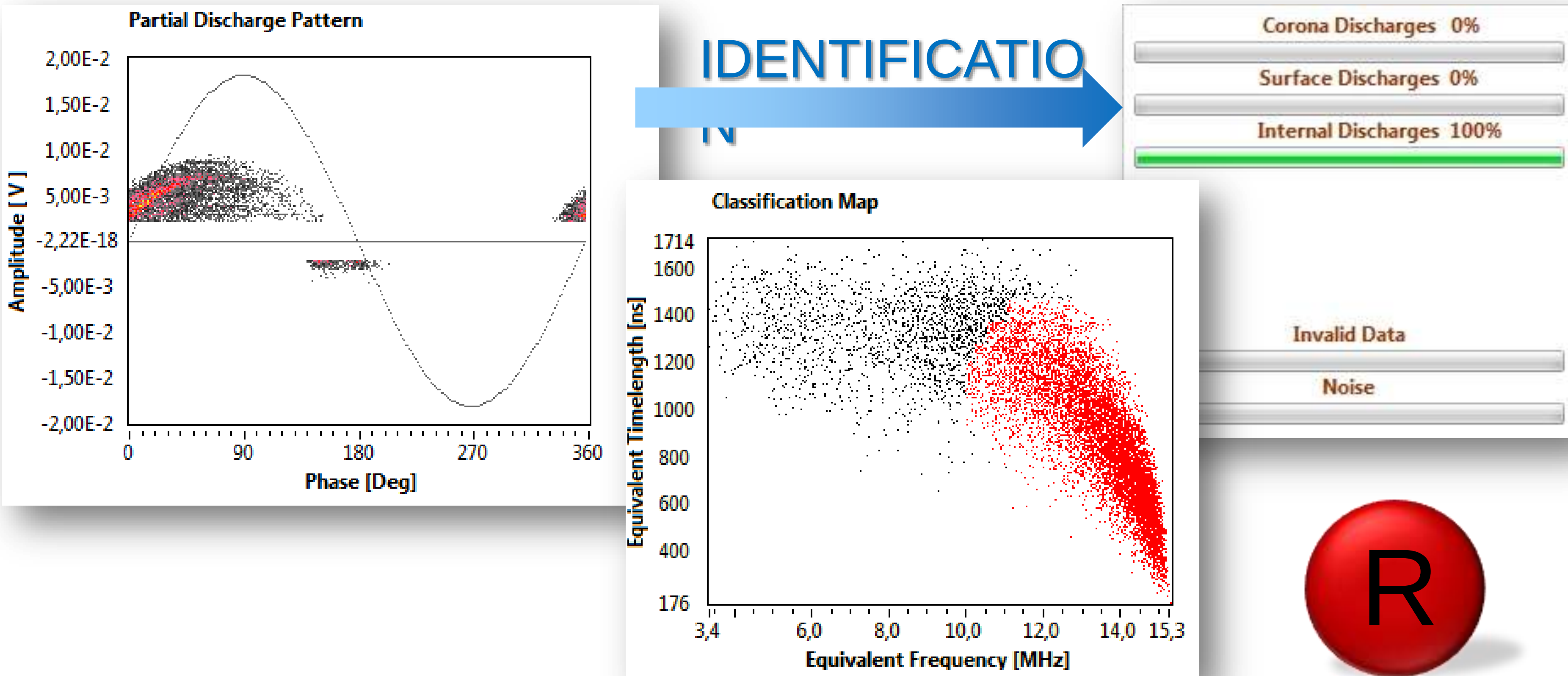
GIS Termination

High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the ground connection of the GIS Termination.

Thanks to the Clamp version of the HFCT it is possible to perform on-line PD measurements without ground lead disconnection or out of service of the EUT.

PD measurement results on Blue Phase

BLUE PHASE



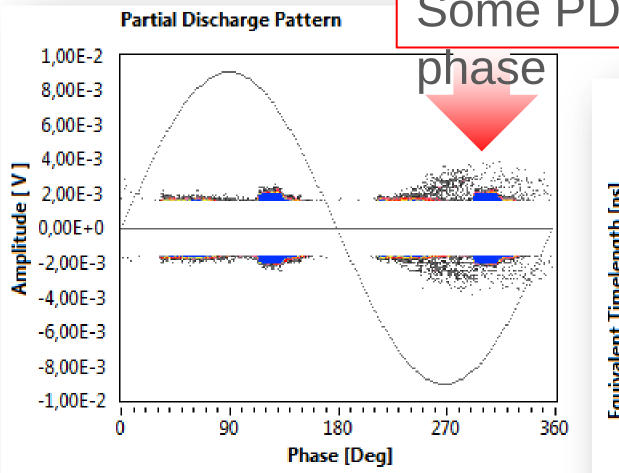
Equivalent Frequency analysis for the Internal PD activity detected on the TF Classification Map (Red Cluster) allows to conclude:

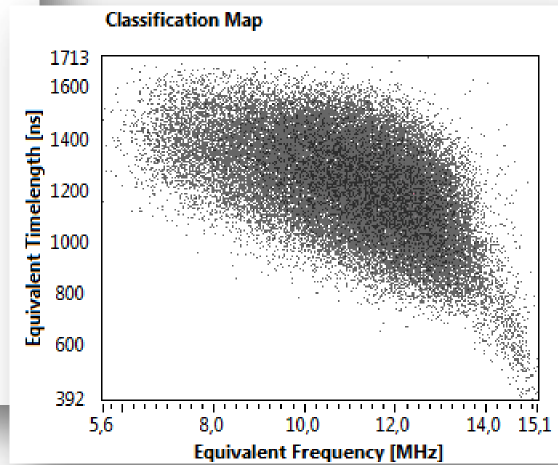
PD activity inside the stress cone of the phase under test

PD measurement results on other Phases

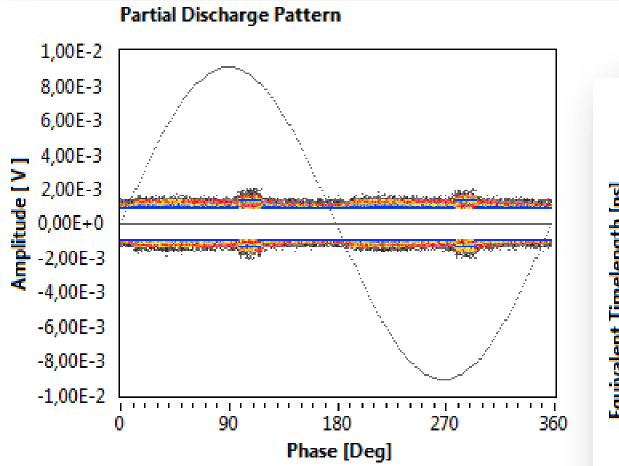
RED PHASE

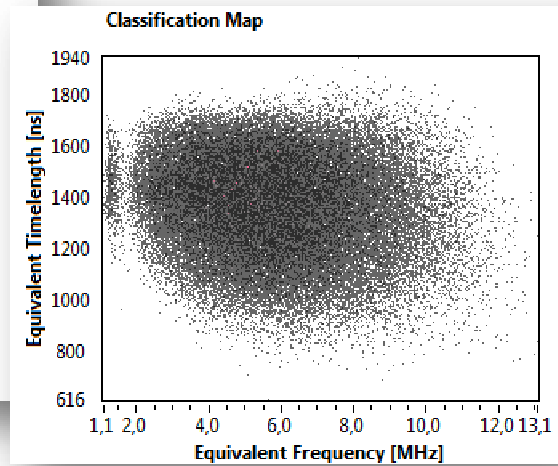
Some PD pulses are present on Red phase as crosstalk from Blue phase





YELLOW PHASE





PD

Suggested actions

Considering age of the cable, amplitude and repetition rate of detected PD it was suggested to:

1 - Replace the Terminations

affected from Internal PD activity in the Stress Cone in order to avoid unexpected failures and consequent explosion during service.

2 – Regular basis PD Measurements

in order to do a periodically check of the cable.

Ti SOLUTION

PD measurement on/off-line with Techimp PPDC + PD sensors

PD detected in the Stress Cone was probably a manufacturing defect due to lack of Quality Control during FAT. In order to avoid this kind of problem it is suggested to use:

Ti SOLUTION

- Techimp PD
II

- QCII Software

TECHIMP SpA

LOCATION	**UAE**
EUT	**HV CABLES**
RATED VOLTAGE	**400 kV**
INSULATION	**XLPE**
LENGTH	**120 m**
VINTAGE	**NEW**
TYPE OF TEST	**OFF-LINE**

CASE STUDY

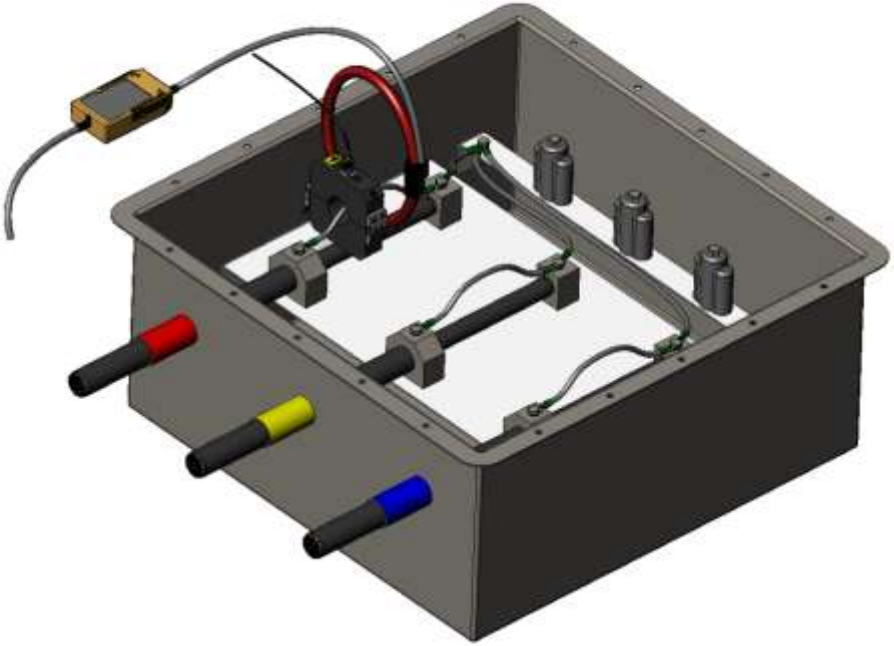
Off-line PD detected inside the stress cone of one HV Termination.

GIS Termination

High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the ground connection of the GIS Termination.

Thanks to the Clamp version of the HFCT it is possible to perform on-line PD measurements without ground lead disconnection or out of service of the EUT.

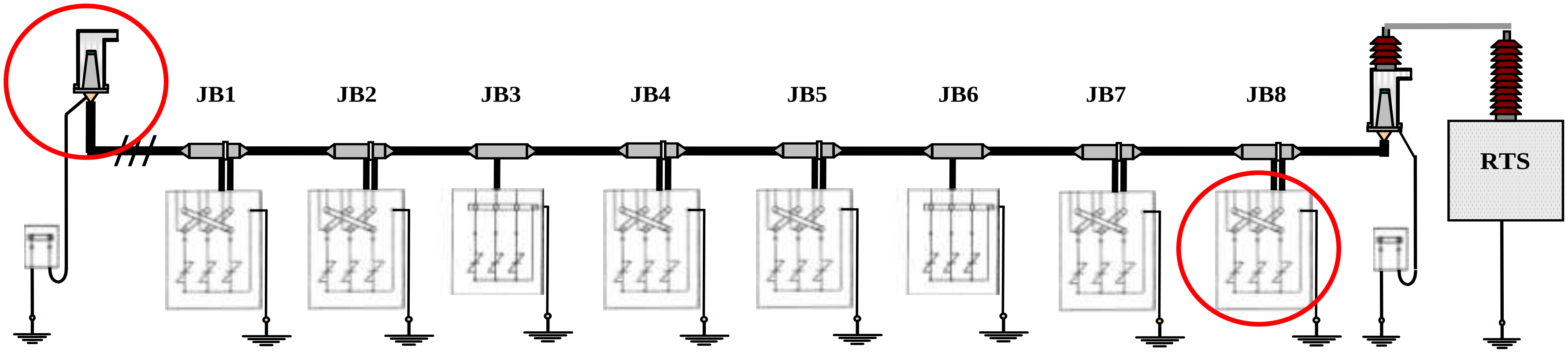
Link Box



High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the Jumper Cable connected from the inner to the outer pin inside the Link Box.

Circuit Under Test

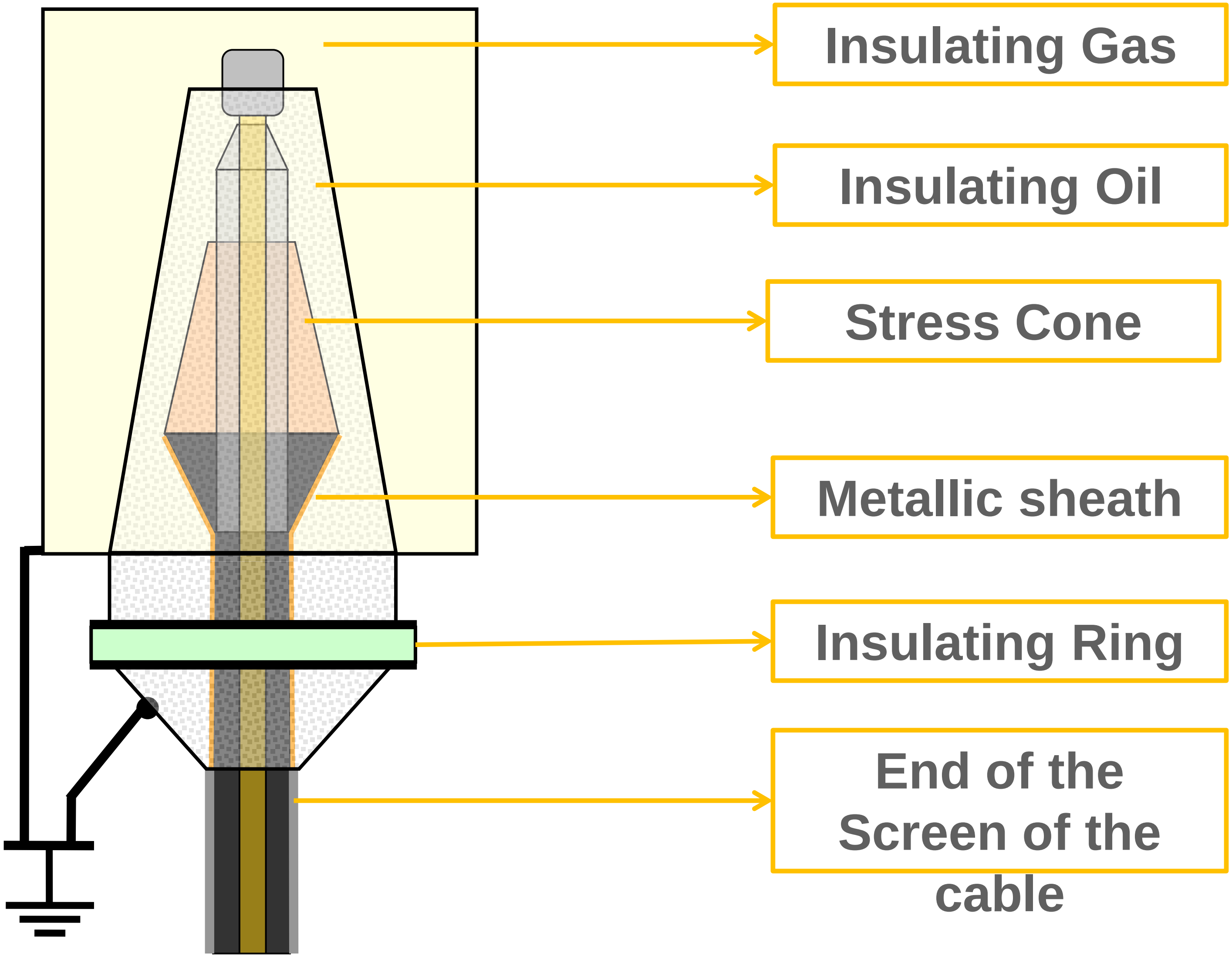
Here is reported the layout of the circuit under test and some pictures of the sensors connection:



Terminations

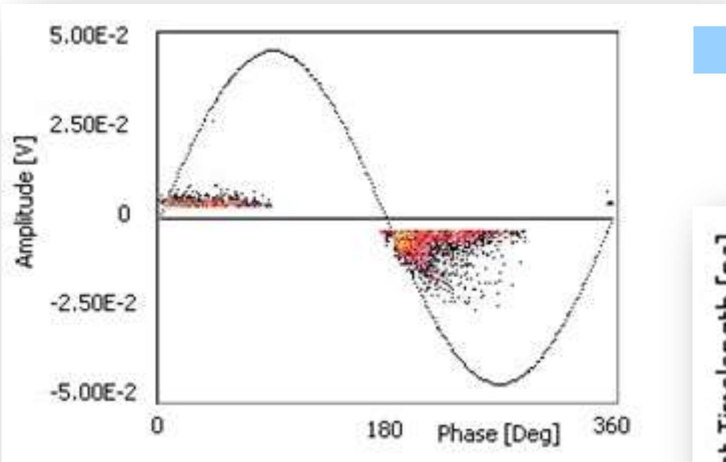
Link Boxes

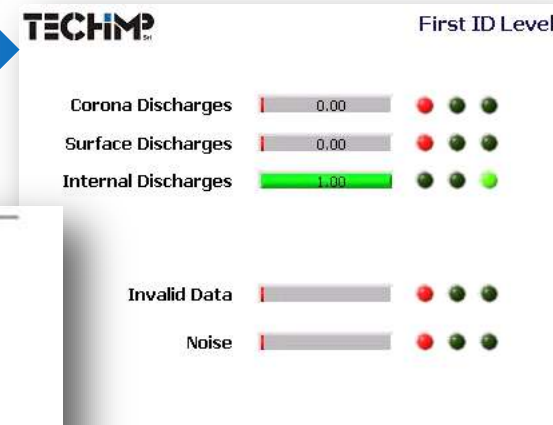
Insulation Technology of Terminations

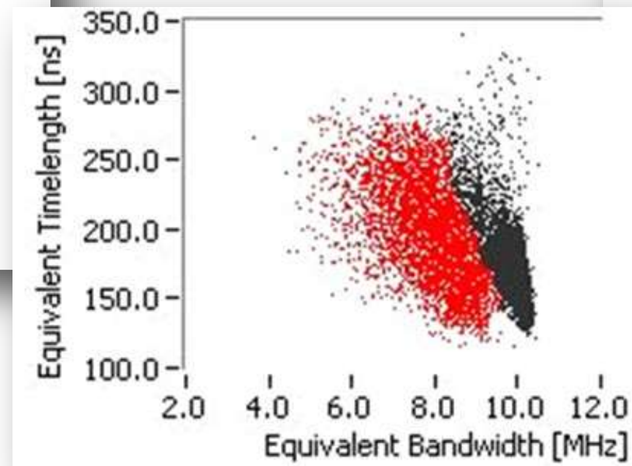


BLUE and YELLOW phases

IDENTIFICATION







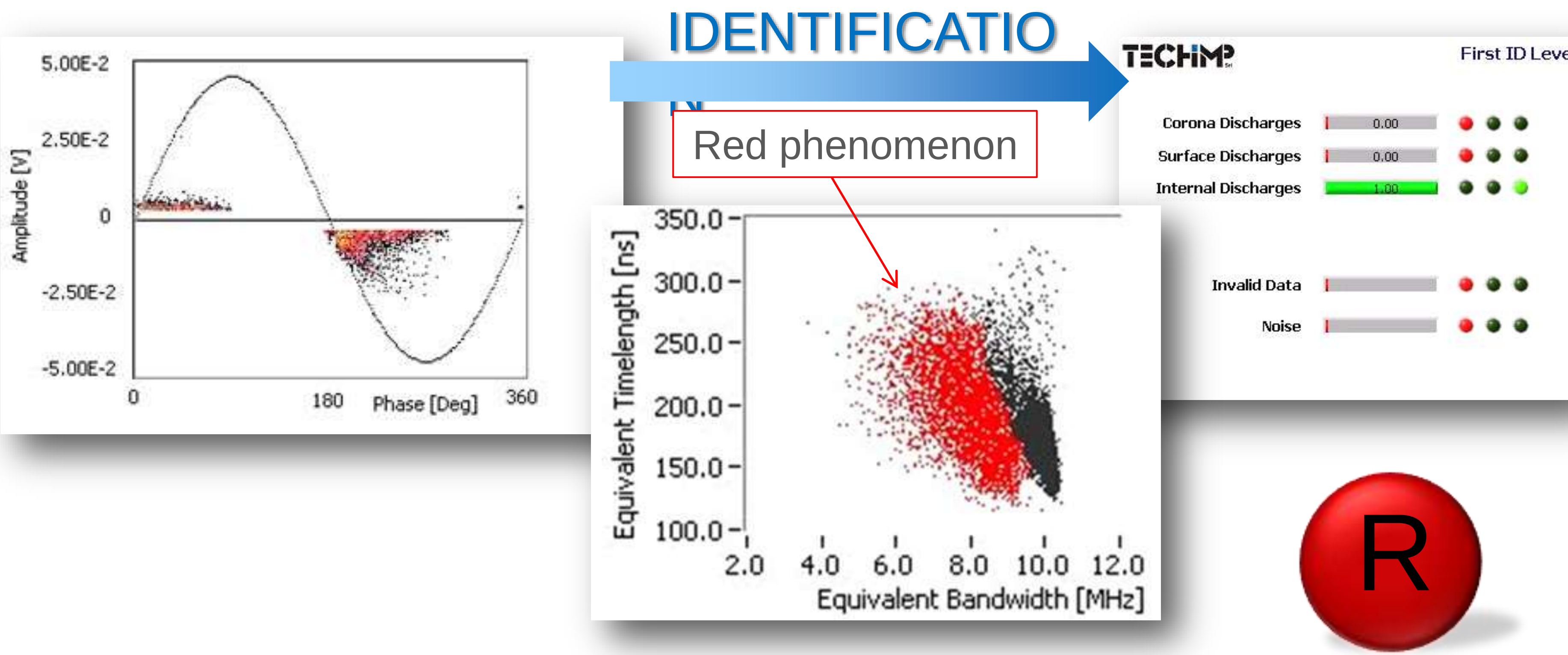
Equivalent Frequency analysis for the Internal PD activity detected on the TF Classification Map (Red Cluster) allows to conclude:

PD activity inside the stress cones

of Blue and Yellow phase

2° PD measurement results

The 2nd measurement was carried out after the inspection and cleaning of outer part of the insulation system of two terminations.



Again PD activities detected at the same terminations of yellow and blue phase. Costumer decided to replace the terminations.

Considering amplitude and repetition rate of detected PD it was suggested to:

1 - Replace the Terminations

affected from Internal PD activity in the Stress Cone in order to avoid unexpected failures and consequent explosion during service.

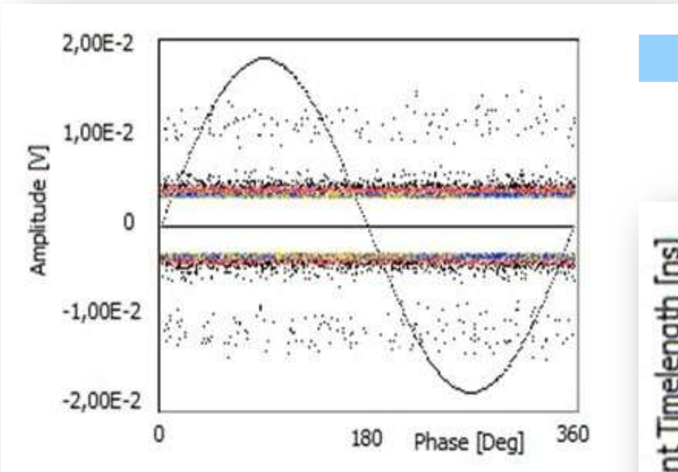
2 – Repeat PD Measurements

in order to check new terminations.

Ti SOLUTION

PD measurement on/off-line with Techimp PPDC + PD sensors

The 3rd measurement was carried out after the replacement of the terminations on Blue and Yellow phase.



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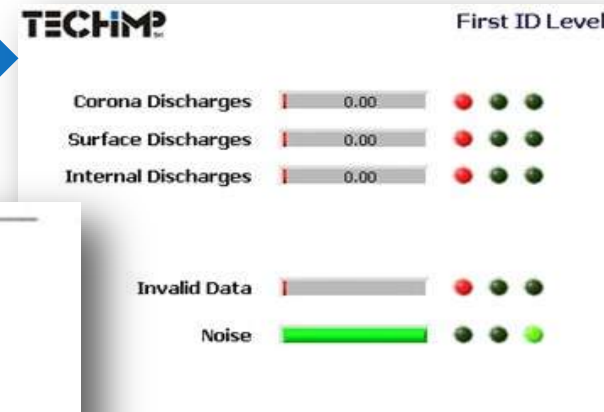
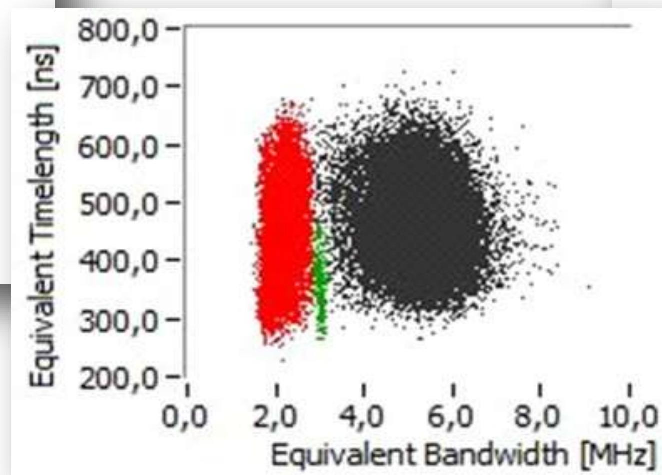




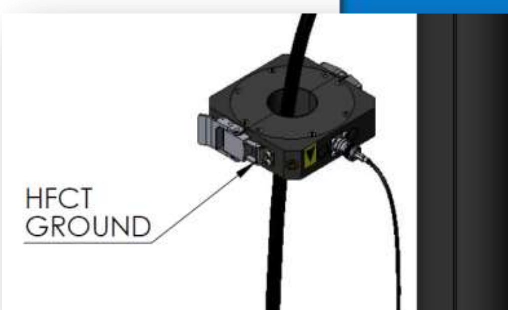
No PD activity was detected. During the inspection a defect was found in the stress cones of removed terminals.

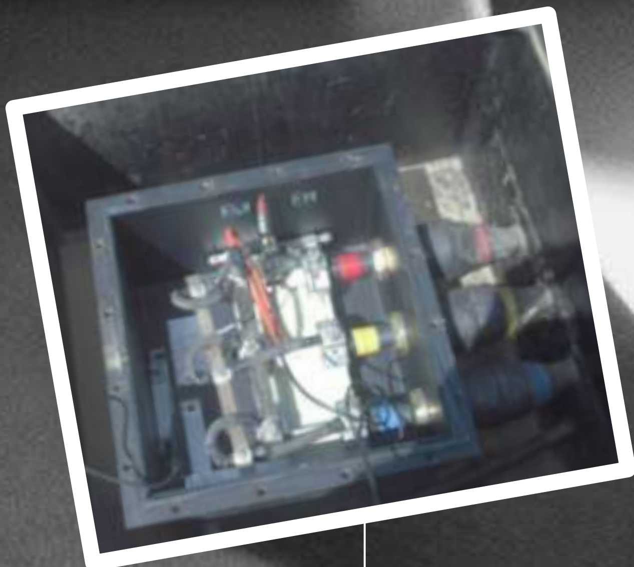
Regular basis PD Measurements

in order to do a periodically check of the cable system.

Ti SOLUTION

PD Measurement on/off-line with Techimp PPDC +
PD sensors





LOCATION	**EUROPE**
EUT	**HV CABLES**
RATED VOLTAGE	**400 kV**
INSULATION	**XLPE**
LENGTH	**12 Km**
VINTAGE	**NEW**
TYPE OF TEST	**OFF-LINE**

CASE STUDY

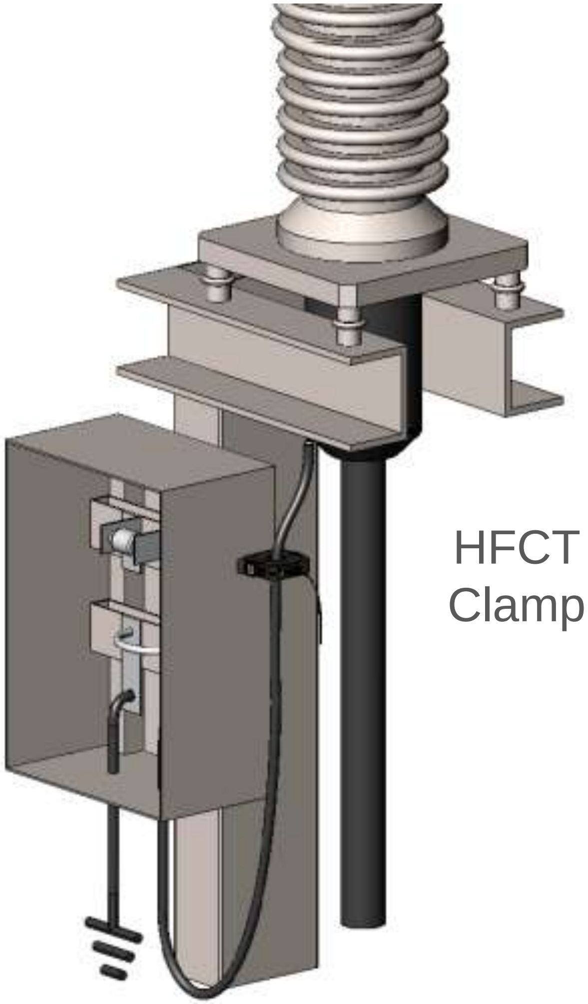
Off-line PD detected inside one joint of an HV Cable

GIS Termination

High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the ground connection of the GIS Termination.

Thanks to the Clamp version of the HFCT it is possible to perform on-line PD measurements without ground lead disconnection or out of service of the EUT.

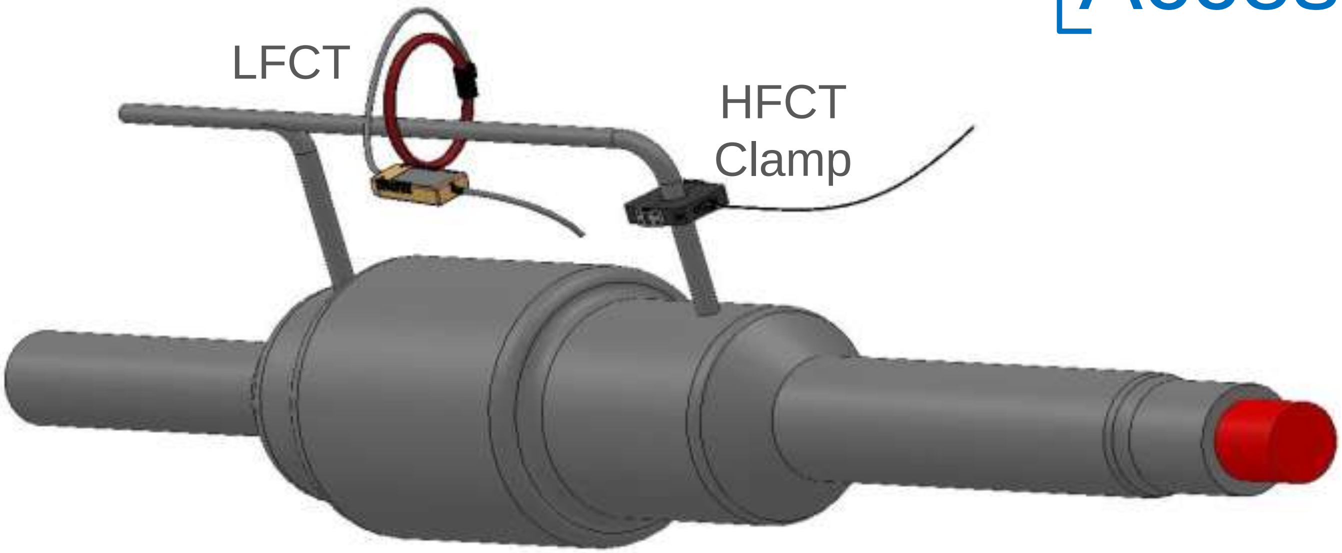
ODSE Termination



High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the ground connection of the ODSE Termination.

Thanks to the Clamp version of the HFCT it is possible to perform on-line PD measurements without ground lead disconnection or out of service of the EUT.

Accessible Joint

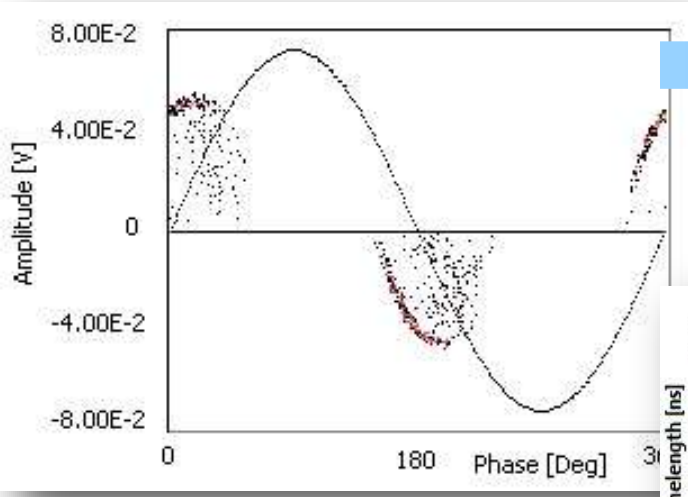


High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the ground connection of the Joint.

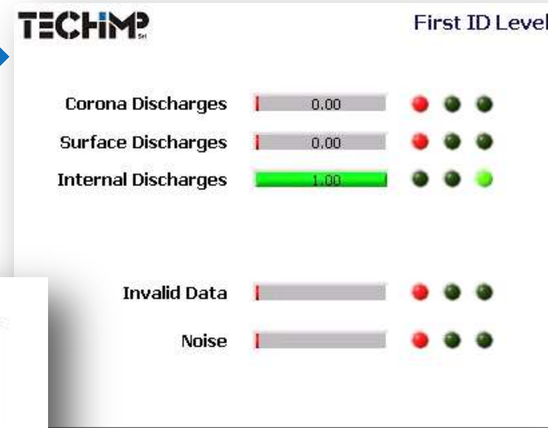
Thanks to the Clamp version of the HFCT it is possible to perform on-line PD measurements without ground lead disconnection or out of service of the EUT.

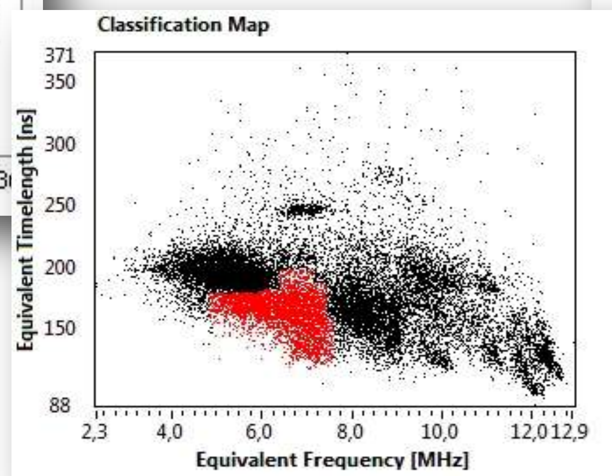
PD measurement results on Red Phase

RED PHASE



IDENTIFICATION



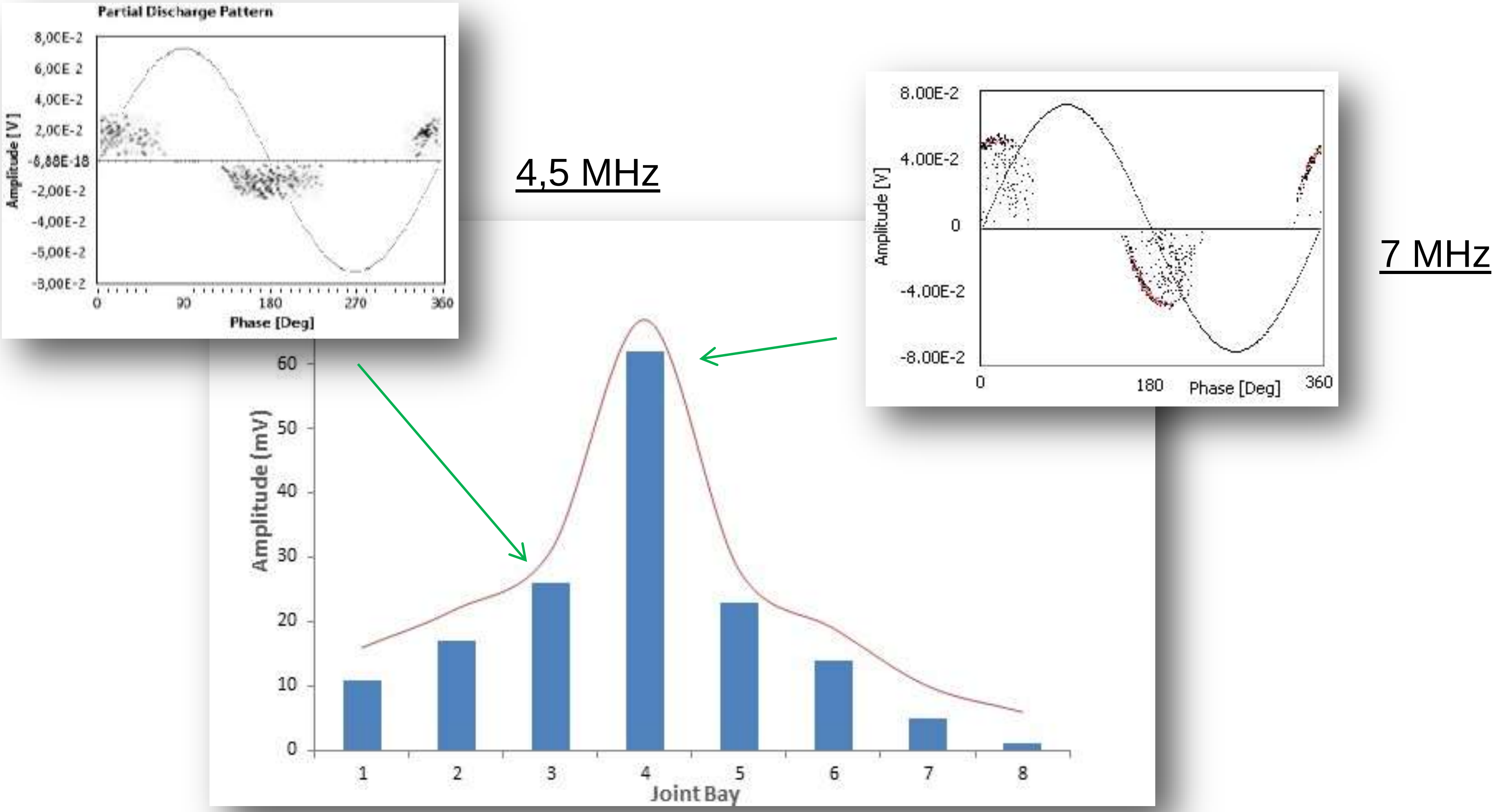


Equivalent Frequency analysis for the Internal PD activity detected on the TF Classification Map (Red Cluster) allows to conclude:

PD activity inside one Joint of the phase under test

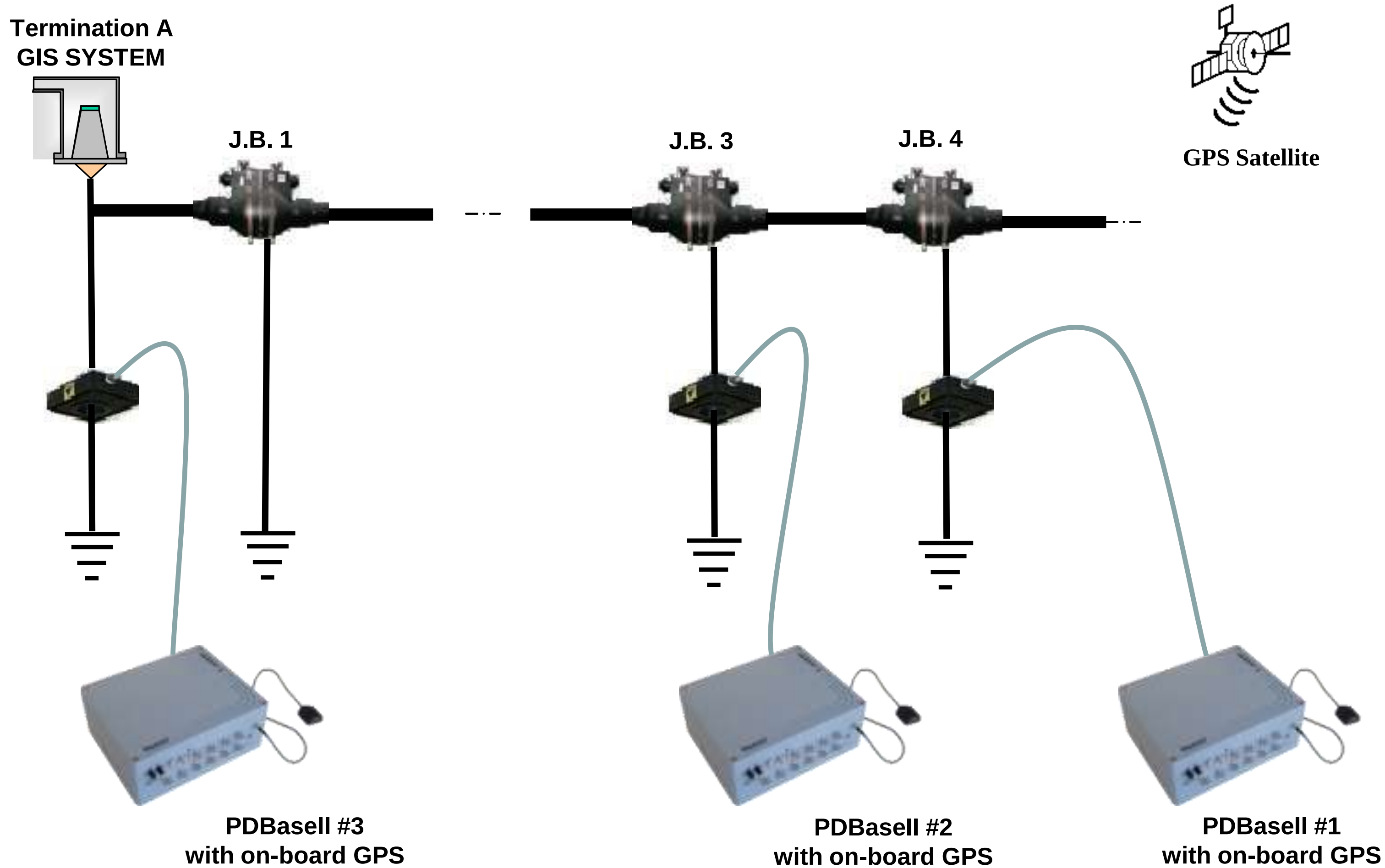
PD Location – Amplitude/Frequency Analysis

Techimp Instruments made it possible to localize the Joint where PD derived from through Amplitude-Frequency analysis (First Level of PD Location).



PD Location – Arrival Time Analysis

Second Level of PD Location consist of the Arrival Time Analysis with *GPS absolute time synchronization*. This analysis is 100% effective and conclusive to locate PD sources.



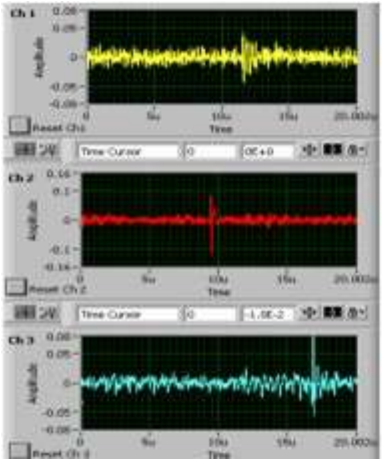
Results - Arrival Time Analysis

This method allows to localize the PD source thanks to the arrival time differences of the pulses between the three different locations.

J.B. 3

J.B. 4

Termination A



The PD was localized in J.B. 4

During the inspection, Techimp diagnosis was confirmed:

Burning traces were founded in the Joint Bay 4

Considering amplitude and repetition rate of detected PD it was suggested to:

1 - Replace the Joint

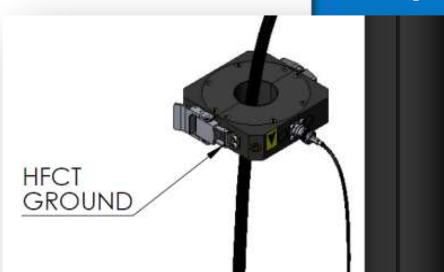
affected from Internal PD activity in order to avoid unexpected failures and consequent explosion during service.

2 – Regular basis PD Measurements

in order to do a periodically check of the cable.

Ti SOLUTION

PD measurement on/off-line with Techimp PPDC + PD sensors



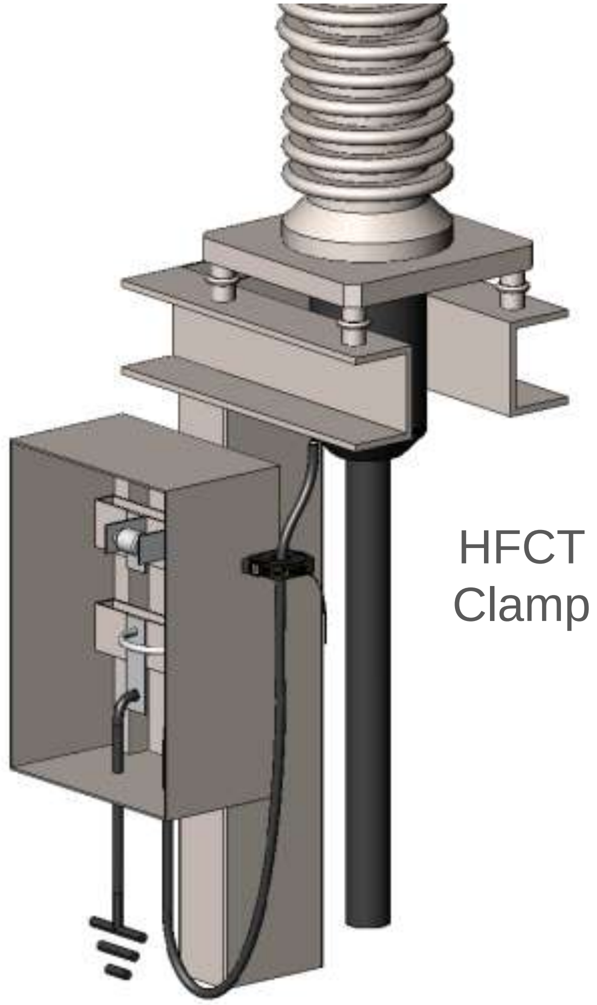
TECHIMP SpA

LOCATION	**EUROPE**
EUT	**HV CABLES**
RATED VOLTAGE	**220 kV**
INSULATION	**XLPE**
LENGTH	**1,5 Km**
VINTAGE	**4 YEARS**
TYPE OF TEST	**OFF-LINE**

CASE STUDY

On-line PD detected during the commissioning test on HV Cable

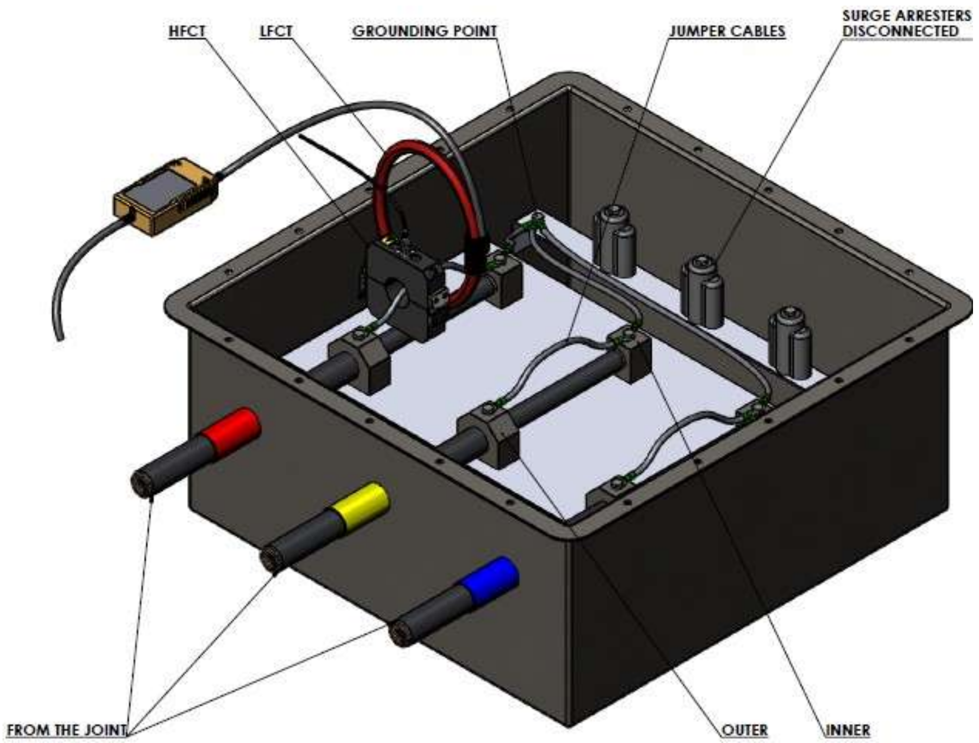
ODSE Termination



High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the ground connection of the ODSE Termination.

Thanks to the Clamp version of the HFCT it is possible to perform on-line PD measurements without ground lead disconnection or out of service of the EUT.

PD measurement setup



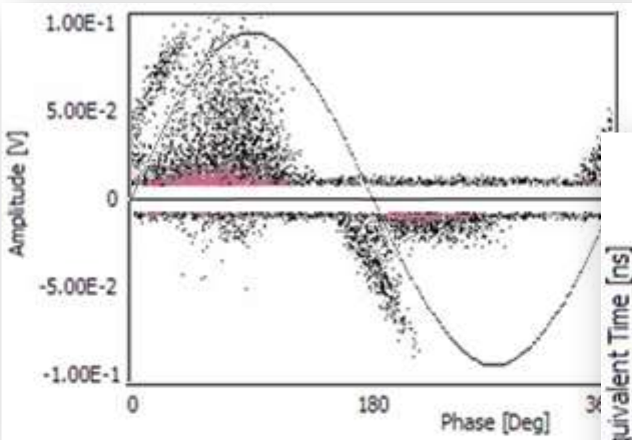
Link Box

High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the Jumper Cable connected from the inner to the outer pin inside the Link Box.

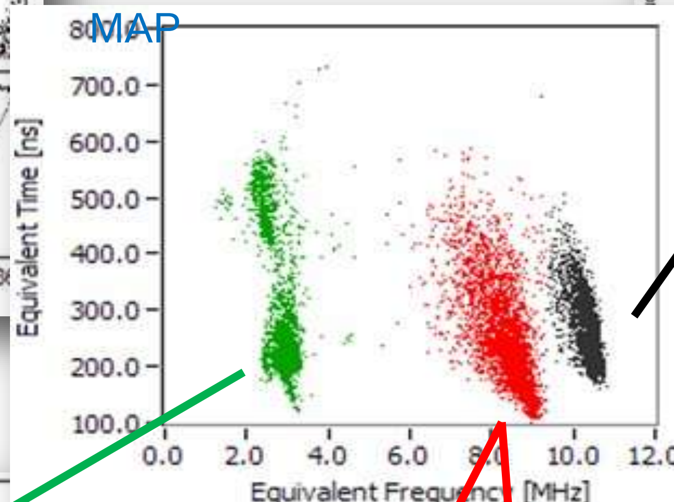
Thanks to the Clamp version of the HFCT it is possible to perform on-line PD measurements without ground lead disconnection or out of service of the EUT.

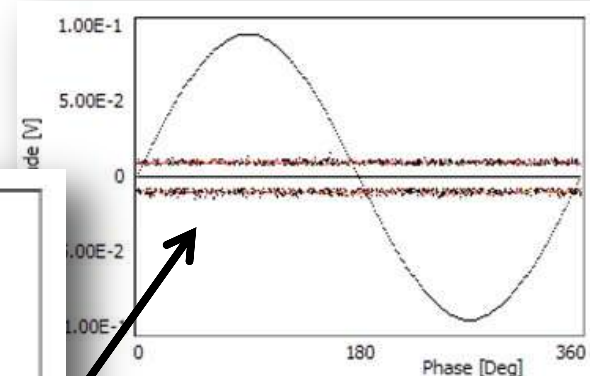
PD measurement results on Red Phase

PRPD PATTERN

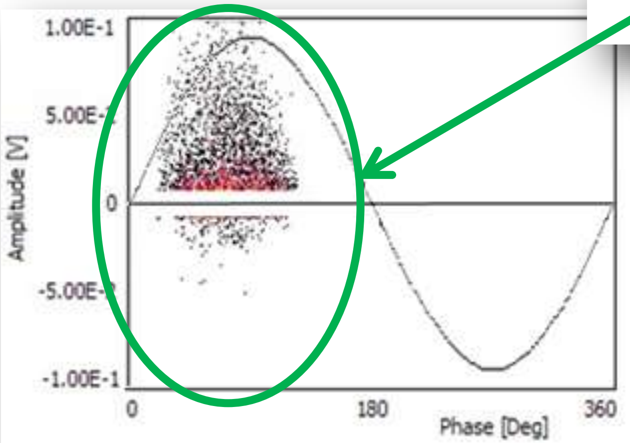


CLASSIFICATION MAP

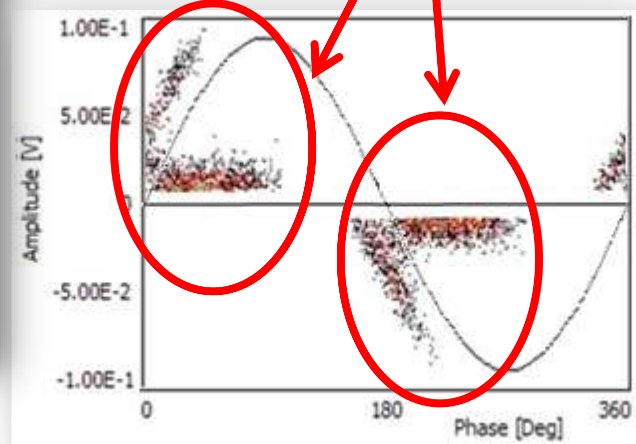




Background Noise



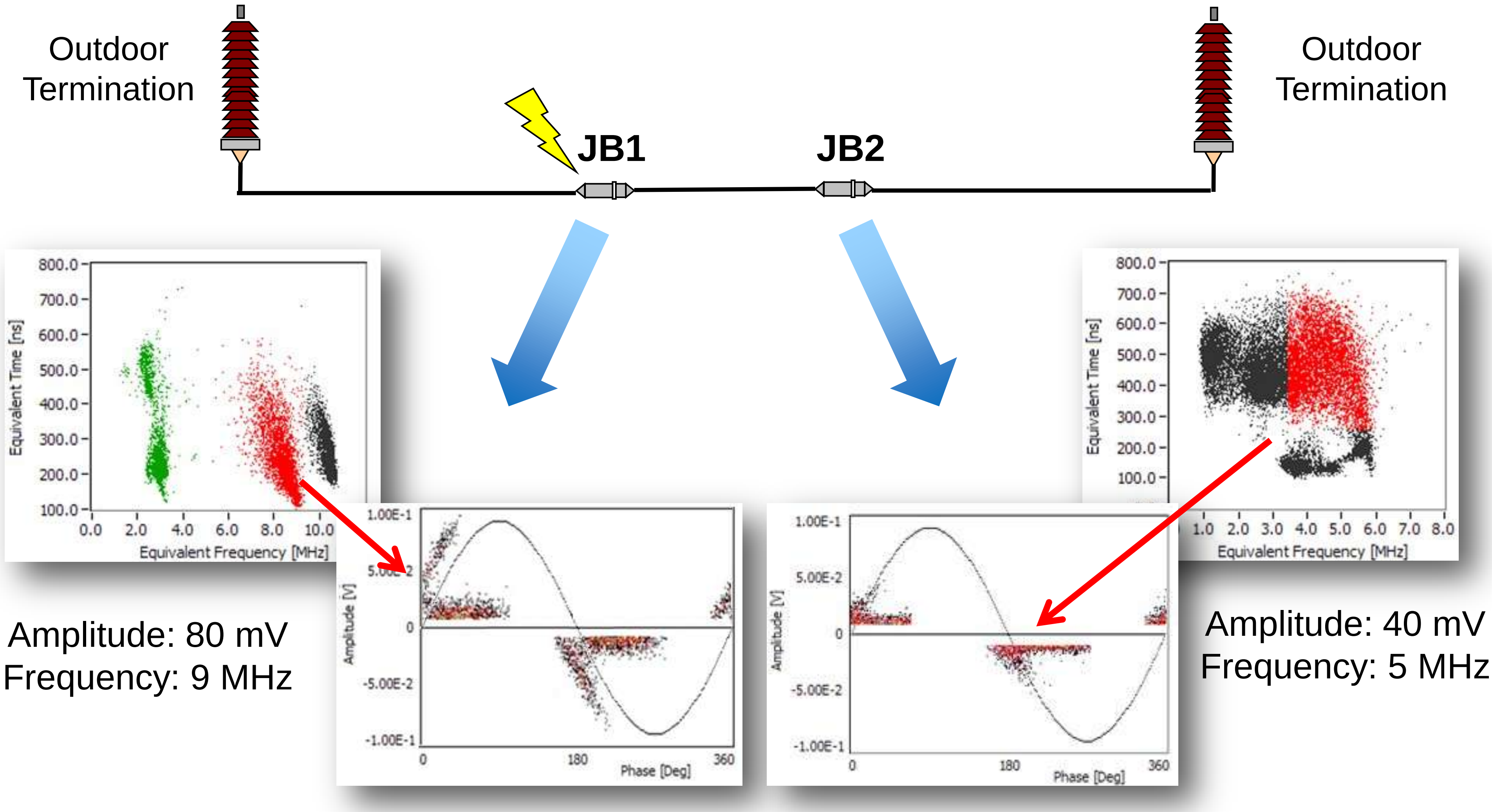
Surface Discharges



Internal Pd inside one Joint

PD Location – Amplitude/Frequency Analysis

Here is reported the layout of the circuit under test and the results of two points of measurement.



Considering amplitude and repetition rate of detected PD it was suggested to:

1 - Replace the Joint

affected from Internal PD activity in order to avoid unexpected failures and consequent explosion during service.

During the inspection a defect was found in J.B.1. Here is reported a scheme of the joint and the instrument installation (only for reference).

2 - Regular basis PD Measurements

in order to do a periodically check of the cable.

Ti SOLUTION

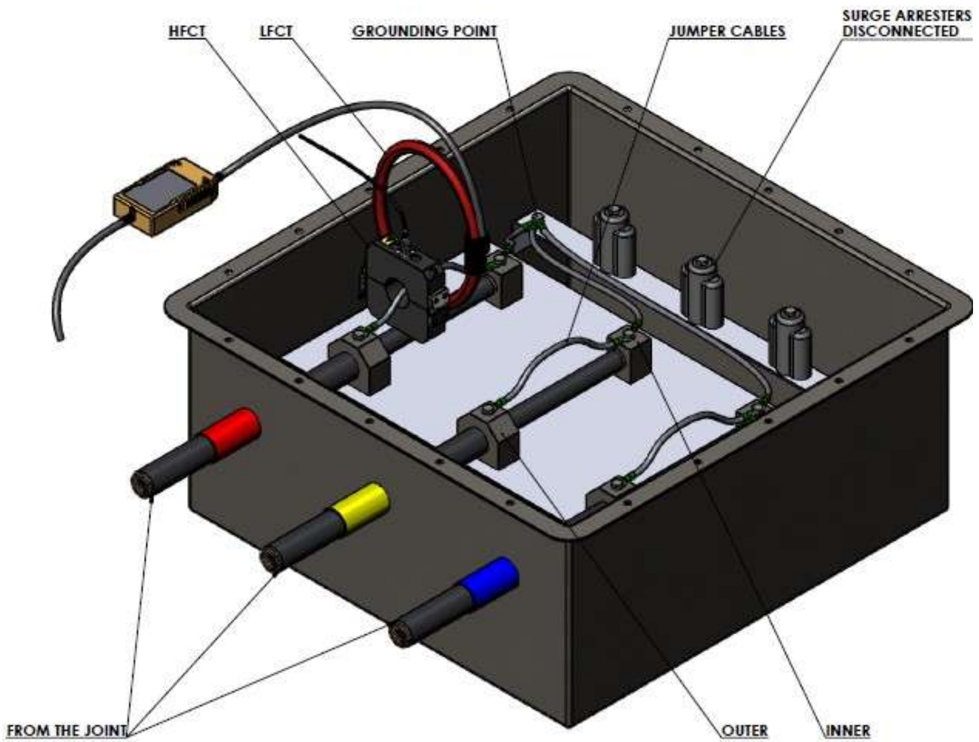
PD Measurement on/off-line with Techimp PPDC + PD sensors

TECHIMP SpA

LOCATION	**SINGAPORE**
EUT	**HV CABLE SYSTEM**
RATED VOLTAGE	**230 kV**
INSULATION	**XLPE**
LENGTH	**2,2 Km**
VINTAGE	**8 YEARS**
TYPE OF TEST	**OFF-LINE**

CASE STUDY

Example of PD Location with Arrival Time Analysis



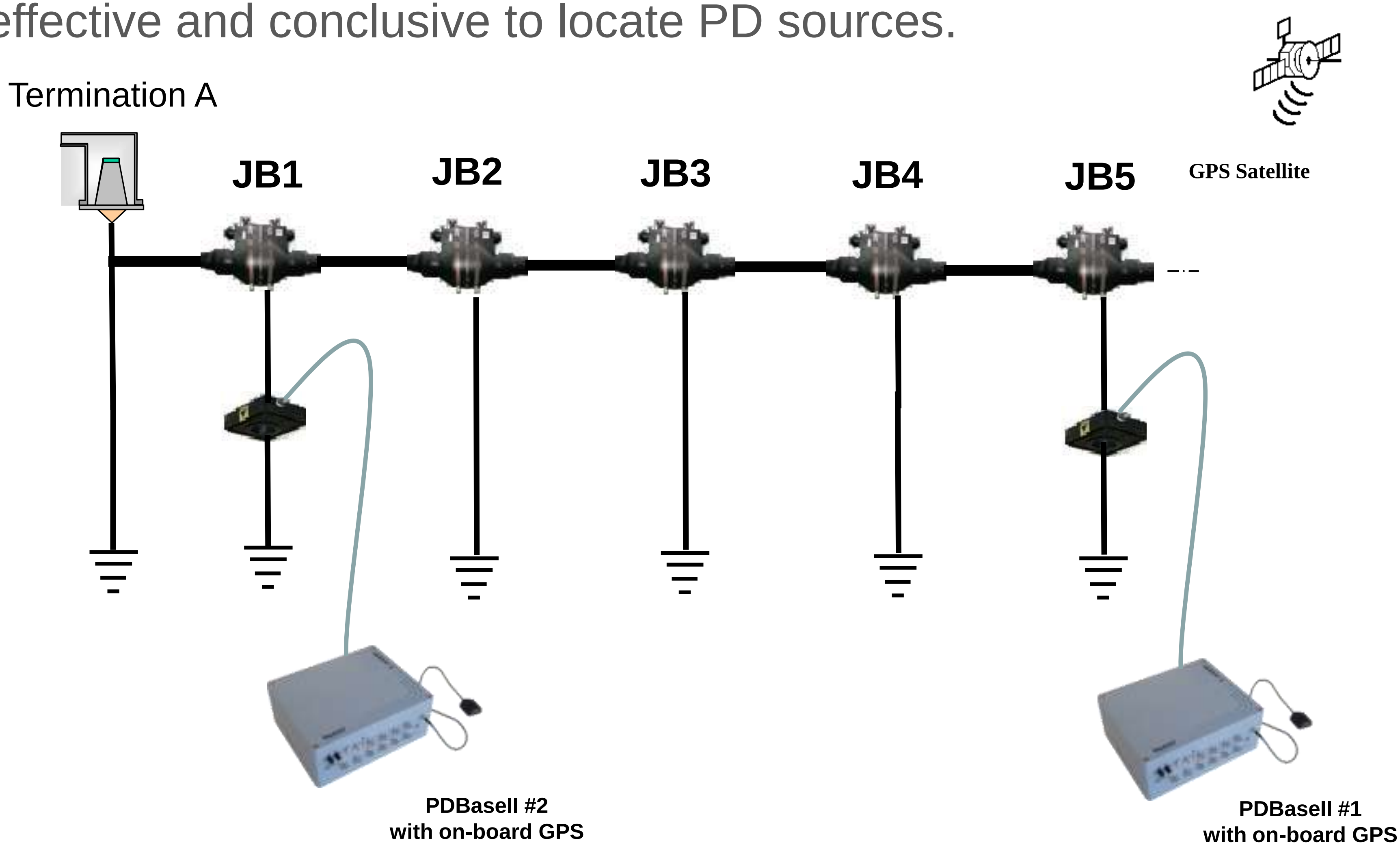
Link Box

High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the Jumper Cable connected from the inner to the outer pin inside the Link Box.

Thanks to the Clamp version of the HFCT it is possible to perform on-line PD measurements without ground lead disconnection or out of service of the EUT.

PD Location – Arrival Time Analysis

Second Level of PD Location consist of the Arrival Time Analysis with *GPS absolute time synchronization*. This analysis is 100% effective and conclusive to locate PD sources.



PD Location – Arrival Time Analysis

For this kind of measurement it is necessary to know the lenght of the cable. L_{CABLE} can be found on the scheme of the cable circuit:

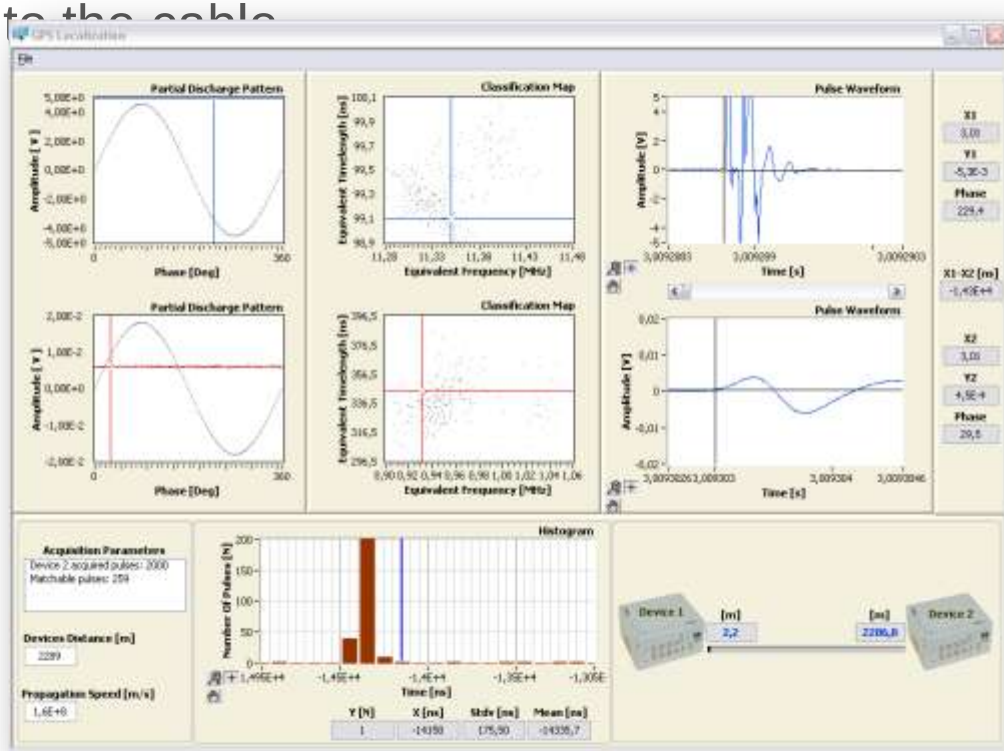
JB1-JB2	503m	+
JB2-JB3	504m	+
JB3-JB4	592m	+
JB4-JB5	610m	=
TOTAL	**2209m**	

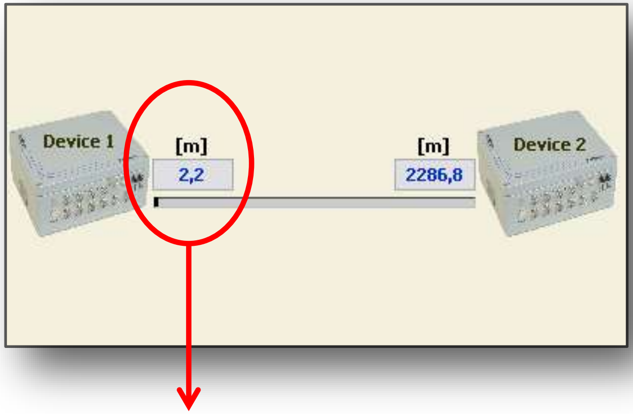
$L_{COAXIAL}$ can be supposed on the base of the data given from the customer. As an average length of coaxial cables from the Joints and the Link Boxes was given 10m. No information regarding the precision of this length was given.

With L_{CABLE} and $L_{COAXIAL}$ is possible to calculate L_{TOT}:

$$L_{TOT} = L_{CABLE} + L_{COAXIAL} = 2209 + 80 \approx \mathbf{2289m}$$

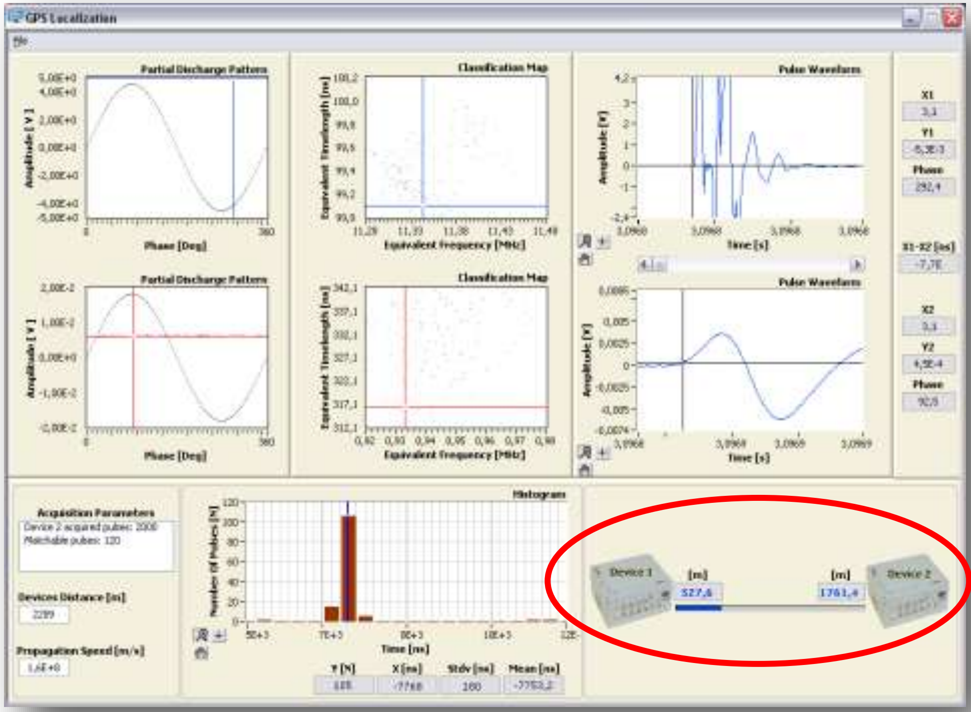
STEP 1: In order to calculate the propagation speed along the cable it was necessary to inject some pulses from JB1 by means of the Techimp HFCT+ Joint Locator. The propagation speed was estimated trough the analysis of the intertime between the acquired pulses. The software provides a distribution of the intertimes and selecting the pulses on the TW map it is possible to obtain the real propagation speed of the PD pulses into the cable.

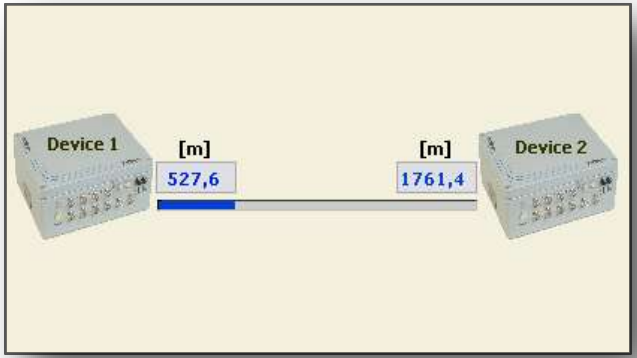




Pulse injected from JB1

STEP 2: The two PDBASE II units with HFCT sensors inside the link boxes were placed in joints 1 and 5. The PD was simulated with a pulse injected by means of the Joint Locator at JB2 and located with the PD Processing II – GPS Software. Here is reported the screenshot of the PDProcessing II software with the PD source location highlighted in red. The value obtained with the software computation shows excellent fitting with the real value provided by the customer.





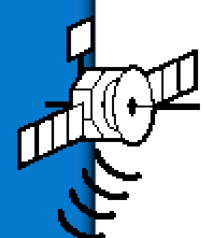
The value obtained with the software was 527,6 meters and the real distance from JB1 and JB2 was 502 meters of cable plus 20 meters of coaxial cable. The percentage error is the lowest with current technologies.

$$\frac{(JB1\text{-}JB2)_{SOFTWARE} - (JB1\text{-}JB2)_{REAL}}{(JB1\text{-}JB2)_{REAL}} = \frac{527,6 - (502+10+10)}{(502+10+10)} = 0,010 = 1\%$$

Techimp technology (patented) allows different PD phenomena to be classified and localized on the basis of their pulse shape, thus enabling further analysis to be carried out separately on each dataset.

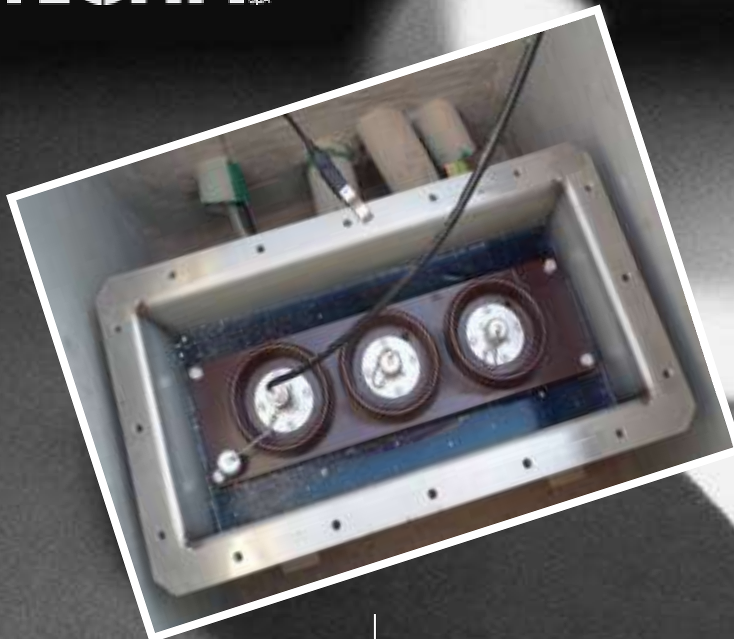
Ti SOLUTION

- Techimp PD
- e II



- GPS Technology

TECHIMP SpA

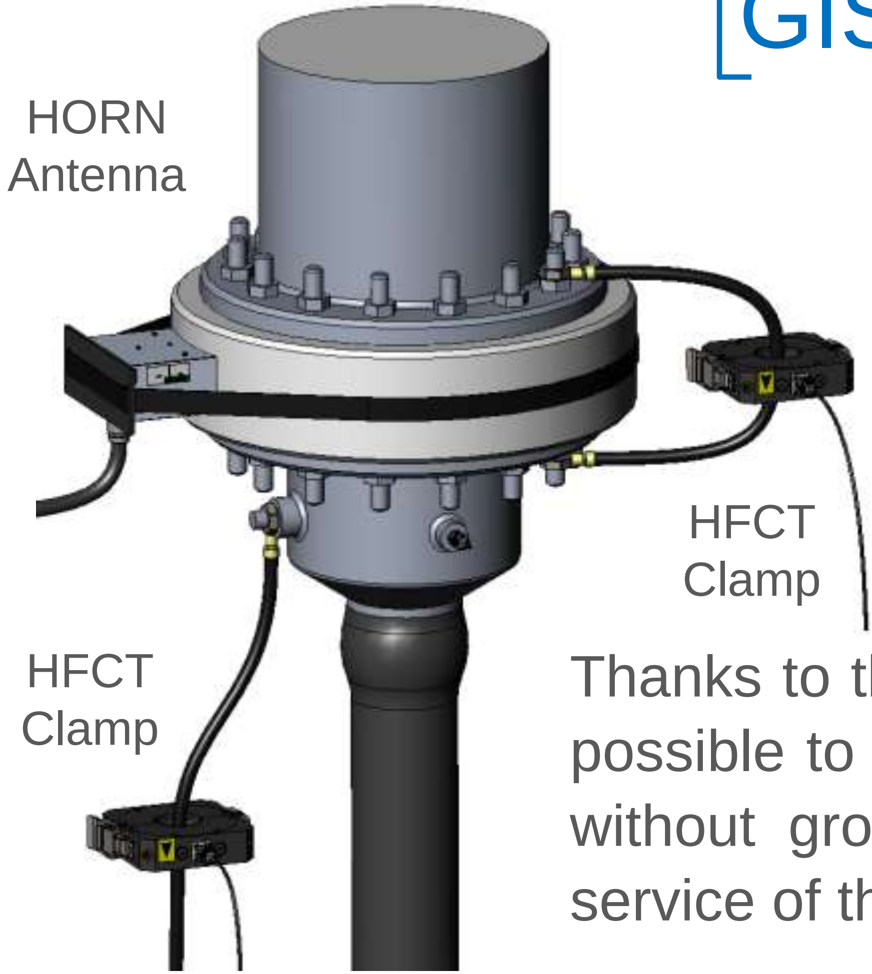


LOCATION	**UAE**
EUT	**HV CABLE**
RATED VOLTAGE	**400kV**
INSULATION	**XLPE**
LENGTH	**778 m**
VINTAGE	**NEW**
TYPE OF TEST	**OFF-LINE**

CASE STUDY

PD Location inside HV cable with TDR Location

GIS Termination

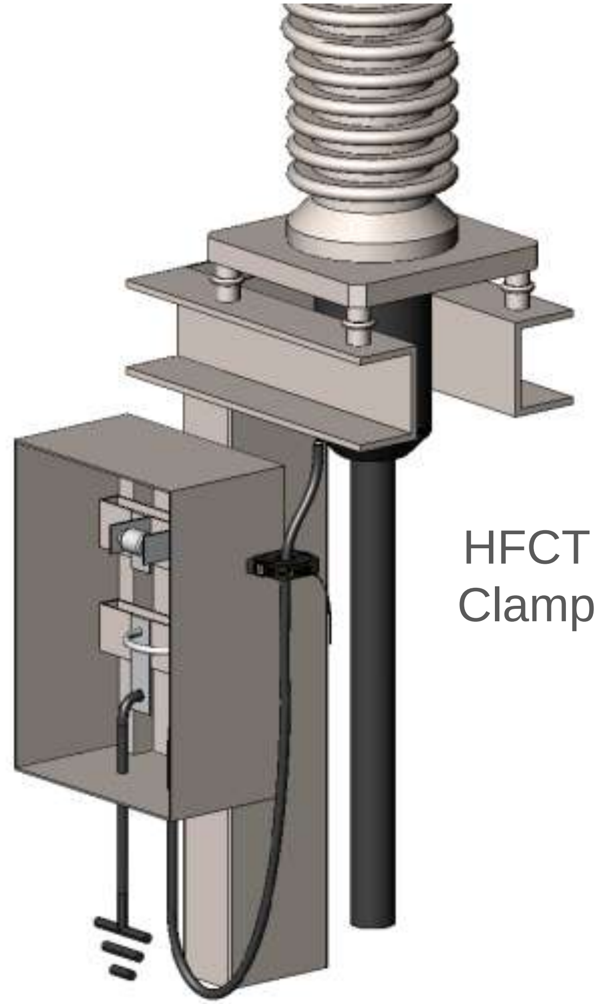


High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the ground connection of the GIS Termination or around the jumper cable.

Thanks to the Clamp version of the HFCT it is possible to perform on-line PD measurements without ground lead disconnection or out of service of the EUT.

HORN Antenna placed on the insulating ring.

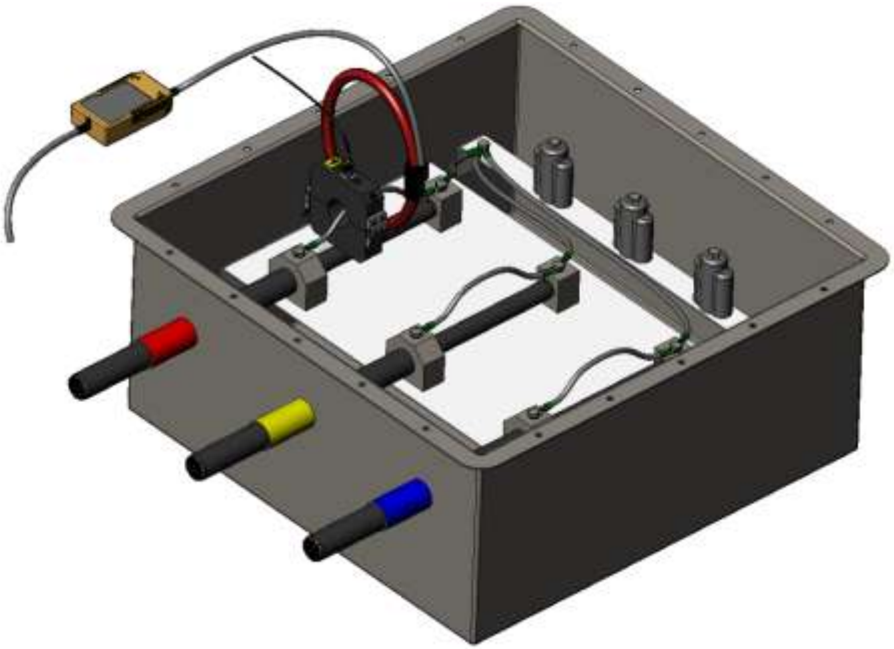
ODSE Termination



High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the ground connection of the ODSE Termination.

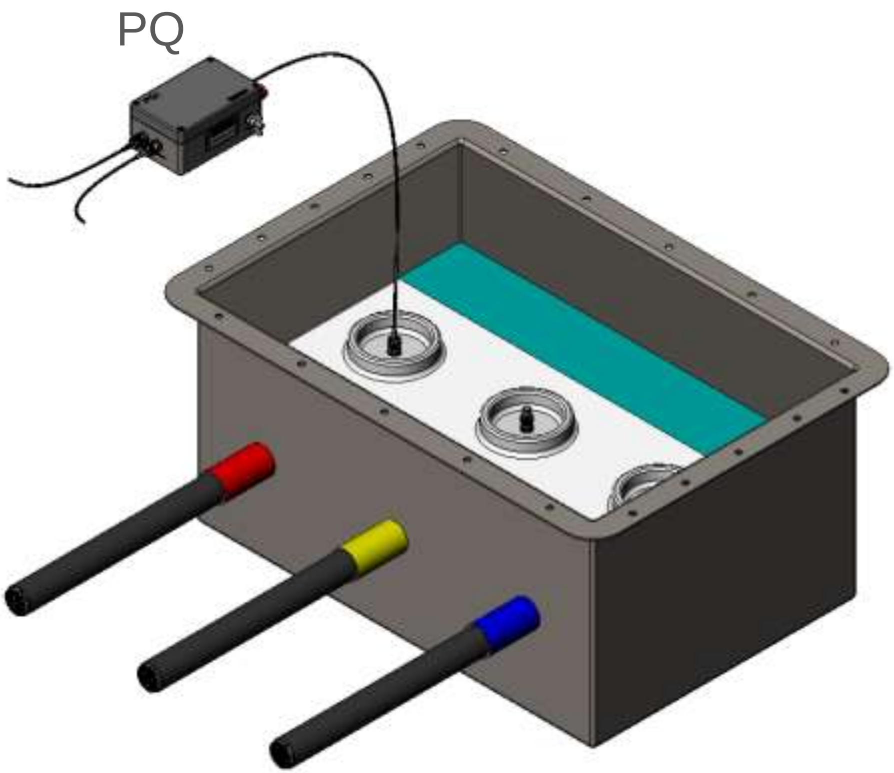
Thanks to the Clamp version of the HFCT it is possible to perform on-line PD measurements without ground lead disconnection or out of service of the EUT.

Link Box



High Frequency PD pulses were achieved by means of Clamp HFCT 39mm placed around the Jumper Cable connected from the inner to the outer pin inside the Link Box.

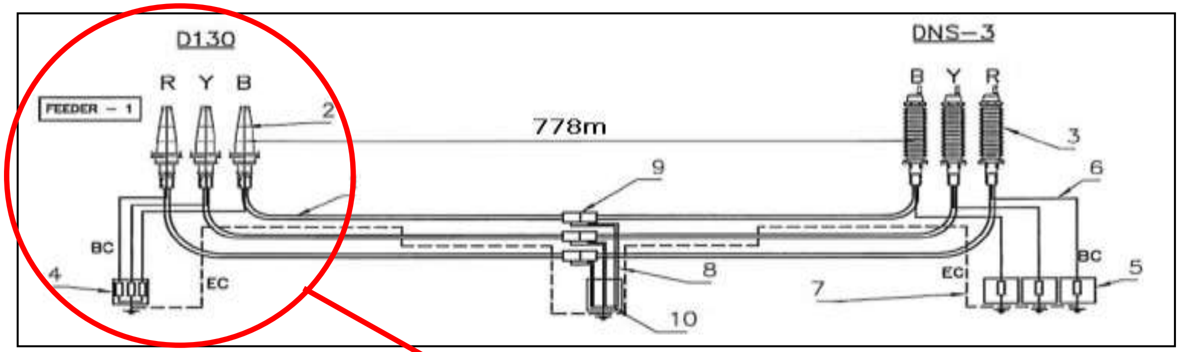
PD Box



PD signals were achieved from embedded capacitive sensor by a Resistive PQ. PQ is a quadrupole in which the signal coming from the sensor is filtered through a high pass filter providing the PD signal and a low pass filter providing the synchronization signal necessary for a correct reference voltage.

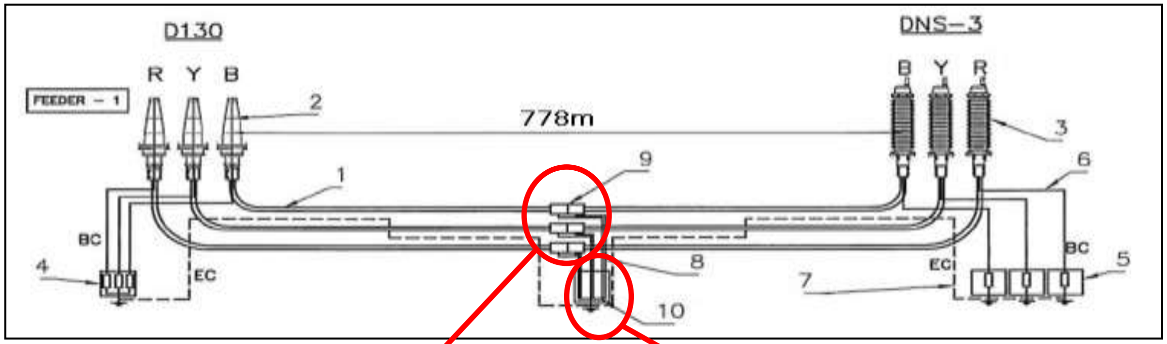
Circuit Under Test

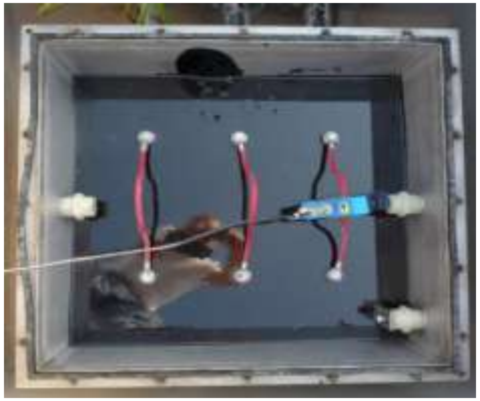
Here is reported the layout of the circuit under test and some pictures of the sensors connection:



GIS Termination

Here is reported the layout of the circuit under test and some pictures of the sensors connection:



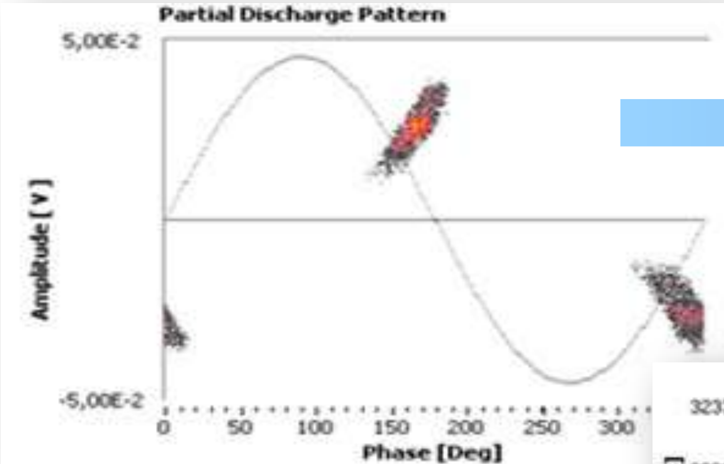


Link Box

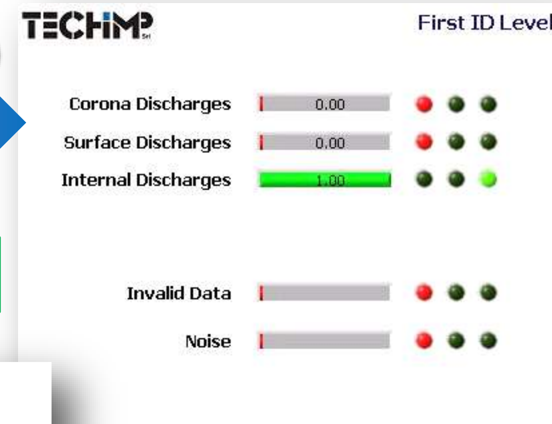
PD Box

PD measurement results on Red Phase

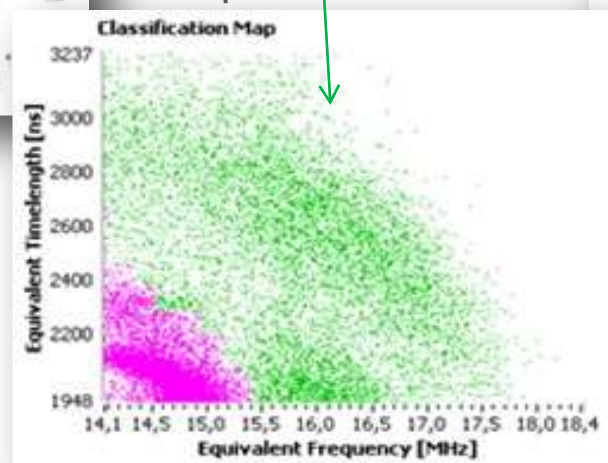
RED PHASE



IDENTIFICATION



Green phenomenon



R

Equivalent Frequency analysis for the Internal PD activity detected on the TF Classification Map (Red Cluster) allows to conclude:

PD activity inside the insulation system of the

PD Location – TDR Analysis

TDR Analysis (Time Domain Reflectometry) is a Reflectometric Technique based on the times between the reflections of PD pulses along the cable system.

The length of the cable spans, provided by the Customer, from ODSE to Joint Bay and From GIS to Joint Bay are respectively:

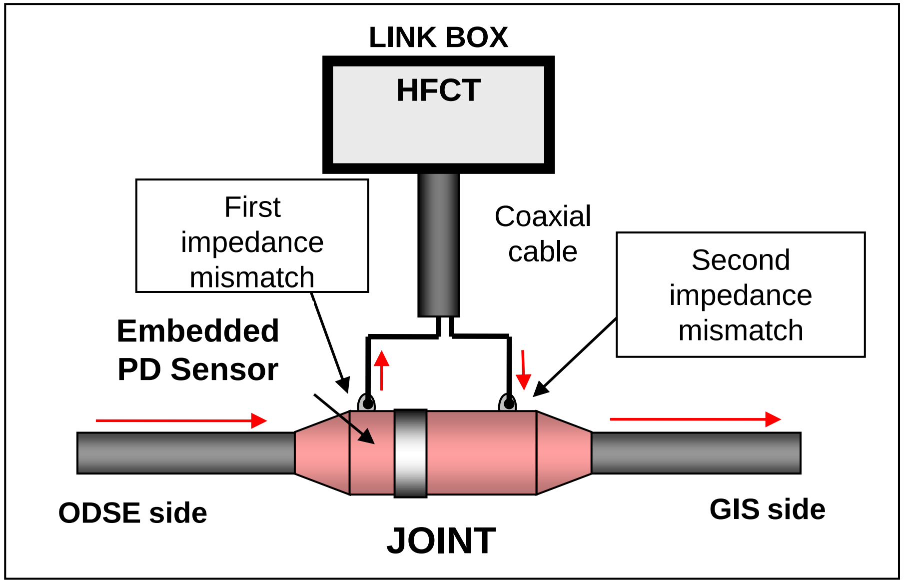
$L_{OR\text{-}Cable}$ (ODSE-JB) = 385.55m
$L_{GR\text{-}Cable}$ (GIS-JB) = 392.85m
Link Box Coaxial cable length = approximately 7.5m

Since the given lengths are those relevant to the inner cable conductor and the reflection of the pulses occur the discontinuities of the outer conductor, the length of the outer conductor have to be considered for localization purpose.

PD Location – TDR Analysis

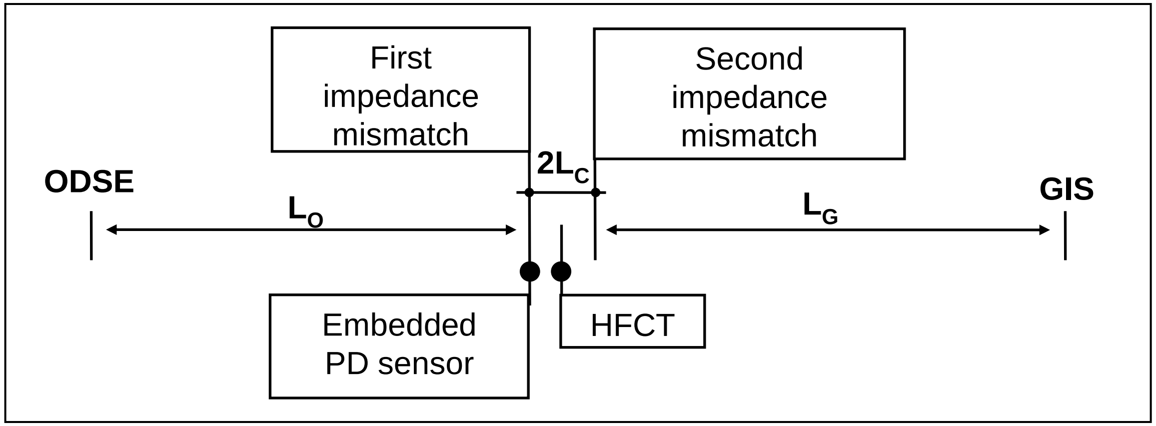
The values used for propagation speed calibration and localization are respectively:

L_{OR} (ODSE-JB) = 381.5m
L_{GR} (GIS-JB) = 391m
Link Box Coaxial cable length = approximately 7.5m



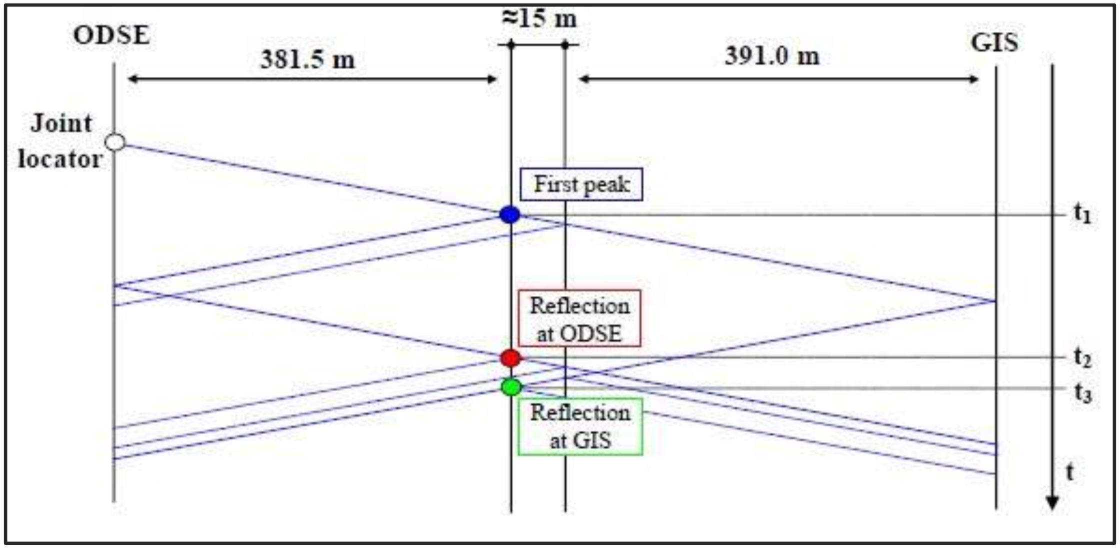
PD Location – TDR Analysis

The equivalent scheme used for location purpose is depicted in figure below.



In order to derive the pulse speed along the cable a pulse with high frequency content and large magnitude was injected in correspondence of the Outdoor termination (ODSE). The pulse and its reflection were acquired thanks to the large time-length of the PDBaseII system.

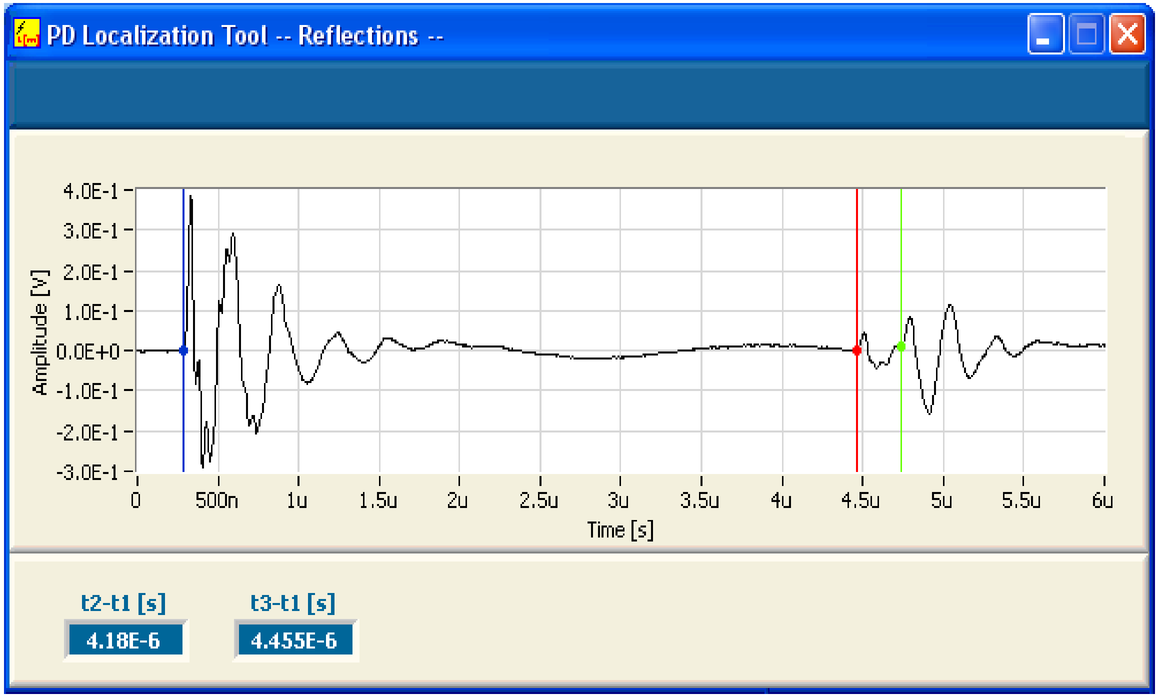
The joint locator pulse, injected at the ODSE termination, and its reflections on the RED phase acquired with the capacitive sensor at the Joint Bay are represented in figure below.



The time between first peak and reflection at ODSE is related to the double of the distance between ODSE and Joint Bay (763m).

The time between first peak and reflection at GIS is related to the double of the distance between ODSE and Joint Bay plus four times the length of the Link Box Coaxial cable (812m).

The two values previously evaluated have been used in order to calculate and verify the pulse propagation speed.

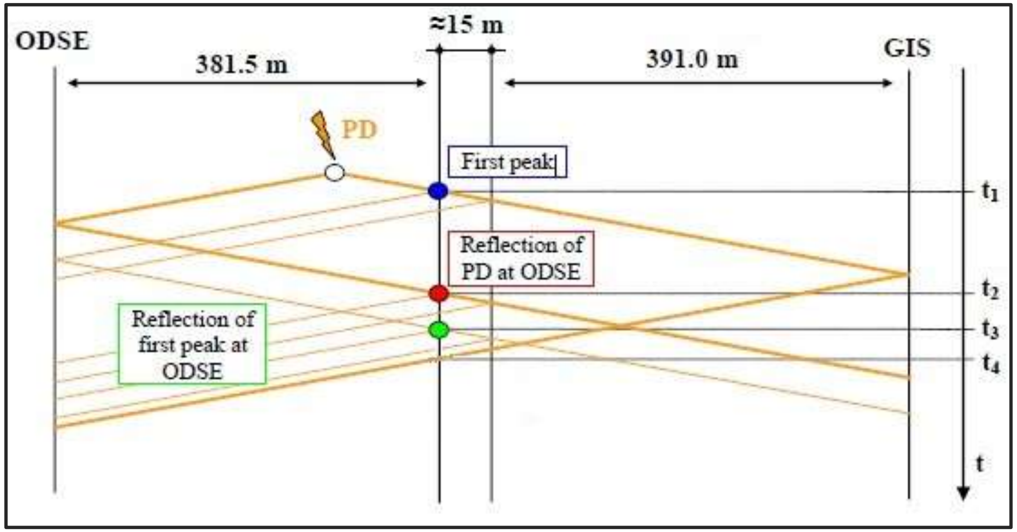


Time between first peak and first reflection (t2-t1) = 4.18E-6s.
Evaluation of the speed:

$$v_p = \frac{2L_O}{t_2 - t_1} = \frac{2 \cdot 381.5}{4.18E^{-6}} = 1.825E^{+8}$$

PD Location – TDR Analysis

The PD pulse and its reflections on the RED phase detected by means of the capacitive embedded sensor at the Joint Bay are depicted in the following figure. The arrival time of the reflections allows PD to be located.



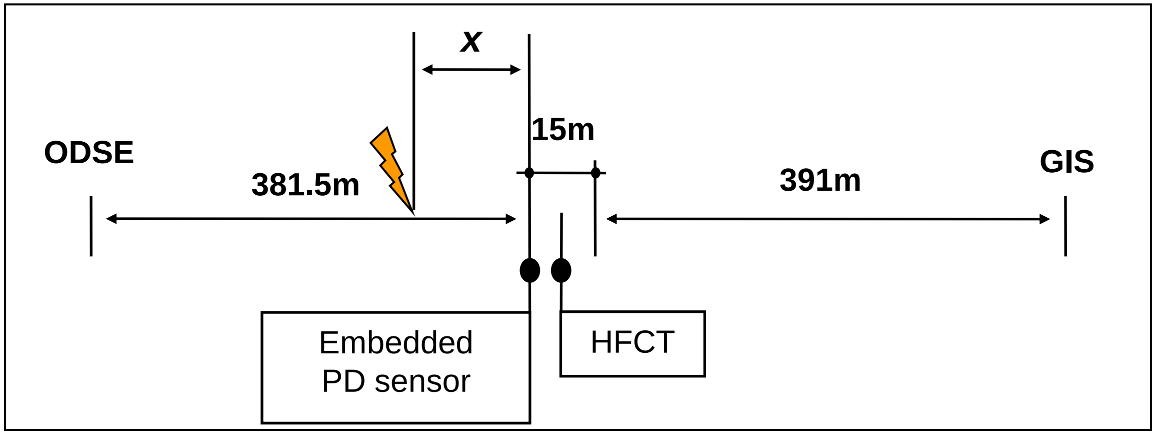
The time between first peak and reflection at ODSE is related to the double of the distance between ODSE and Joint Bay (763m).

The time between first peak (t1) and reflection of PD at ODSE (t2) permits to evaluate the distance of the PD from the measuring point.

PD Location – TDR Analysis

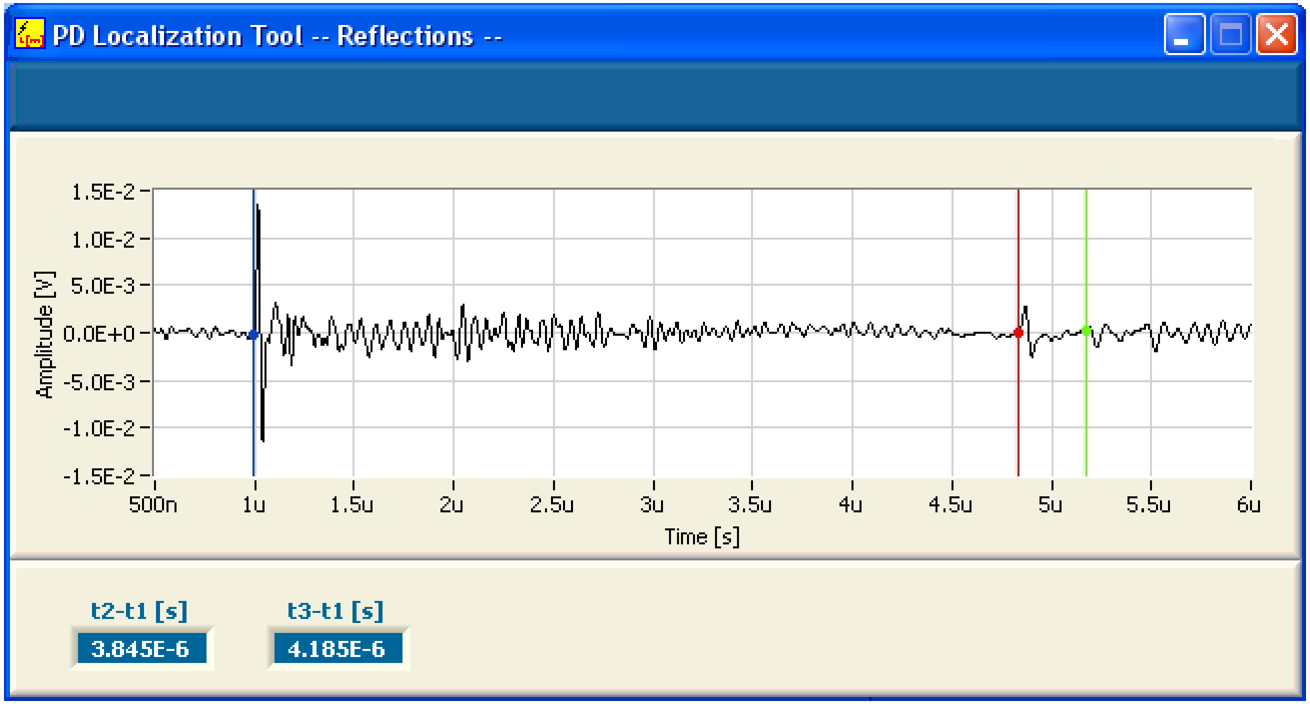
Location of the defect using TDR (Time Domain Reflectometry) can be performed on the base of the pulse propagation speed previously calculated and the polarity of PD phenomenon.

On the scheme reported below “x” represents the distance between the defect and the PD sensor measuring point.



PD Location – TDR Analysis

The PD pulse together with its reflections acquired by means of the capacitive embedded sensor at the Joint Bay is depicted in the following figure.



PD Location – TDR Analysis

In order to locate the PD source, the time (t2-t1) is used:

$$(t_2 - t_1) = \frac{2(L_{0R} - x)}{v_p}$$

Therefore, the distance x between the defect (PD source) and the Joint can be calculated as follows:

$$x = L_{0R} - \frac{(t_2 - t_1)\cdot v_p}{2} = 381.5 - \frac{3.845E^{-6}\cdot 1.825E^{8}}{2} = 31m$$

The uncertainty of the localization due to finite sampling time (5 ns) and to dispersion of the pulse reflections is equal to ±3m, thus:

x = 31±3 m

Considering amplitude and repetition rate of detected PD it was suggested to:

Replace 30m of Cable

at the point indicated by TDR Analysis in order to avoid unexpected failures during service.

The Costumer decided to replace 90m of the cable.

Conclusions

During the inspection a defect was found at the point indicated by TDR Analysis.