Condition assessment on HV and MV cable systems

Techimp PD Academy 2015

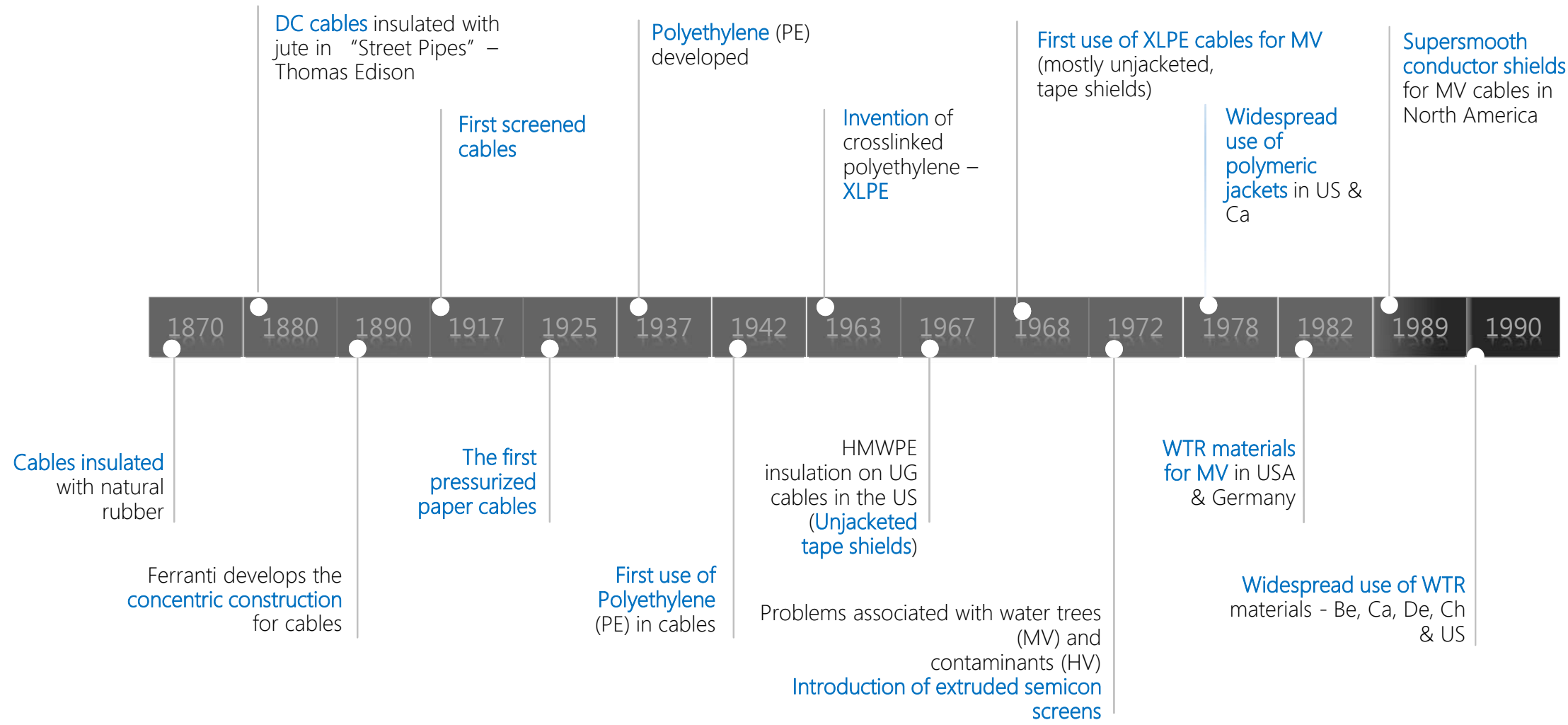
Outline

- Construction technology for Cable systems
- Sensor technology
- PD Measurements on HV Cables
  - ✓ Commissioning Test (offline) (sequential/Simultaneous/Soak Test/RTS)
  - ✓ On-Line test
  - ✓ Prerequisites for testing
- PD measurements on MV Cables
  - ✓ Commissioning Test (offline) (generally by Grid or VLF)
  - ✓ On-Line test
  - ✓ Prerequisites for testing
- Localization Techniques
- Tan-Delta tests on Cables
- Permanent monitoring
- DTS for HV Cables
- Case Studies

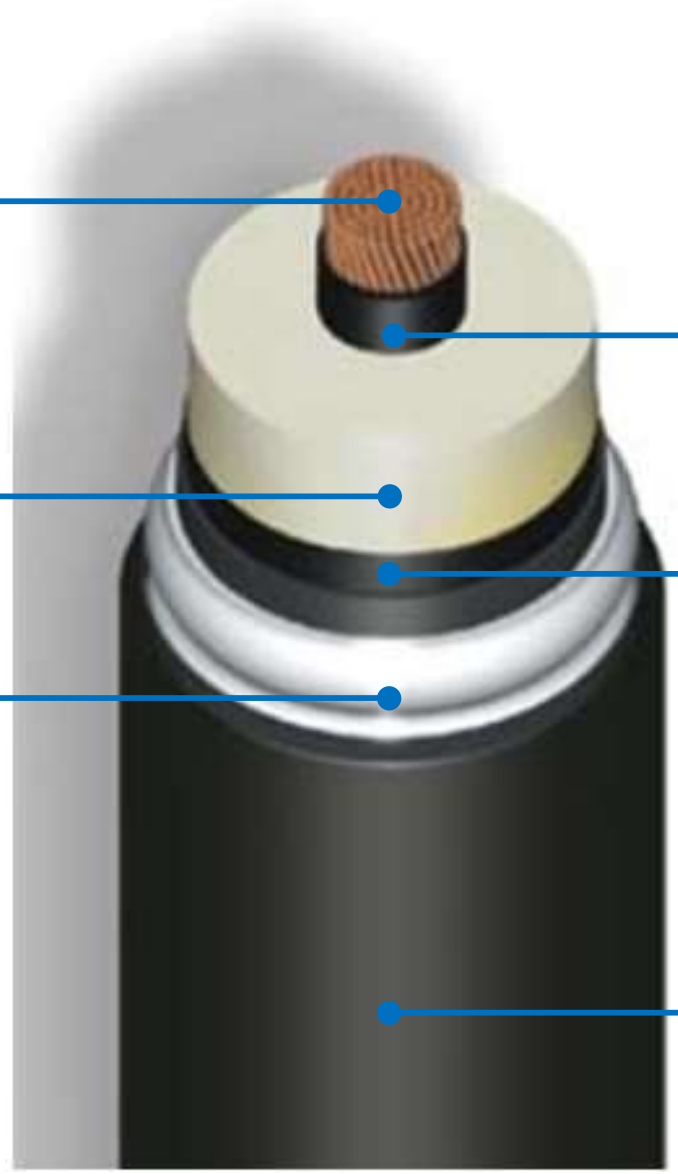
TECHIMP

Construction technology for Cable systems

Construction Technology



Construction Technology

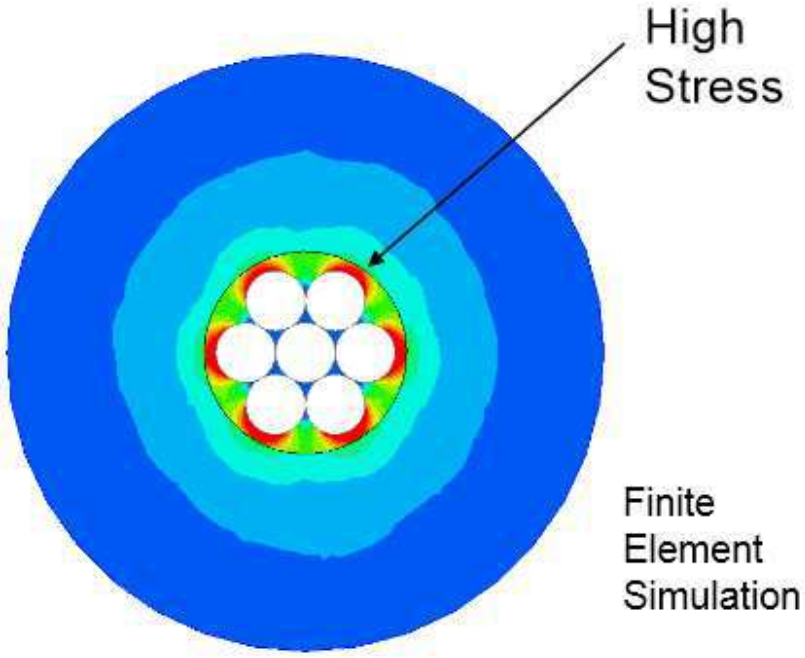


400kV XLPE Insulation 800mm^2

Construction Technology: Conductor shield

For conductor cross-sections larger than 1000 mm^2, segmented conductors must be produced to reduce considerably their resistance to alternating current by reducing the skin effect.

Conductor shield provides for a smooth interface between the conductor and the insulation.



With no conductor shield, electric field lines are concentrated, creating high stress points at the conductor/insulation interface.

Conductor shields are semiconductive.

Semiconducting materials are based on carbon black that is dispersed within a polymer matrix.

Construction Technology: Insulation

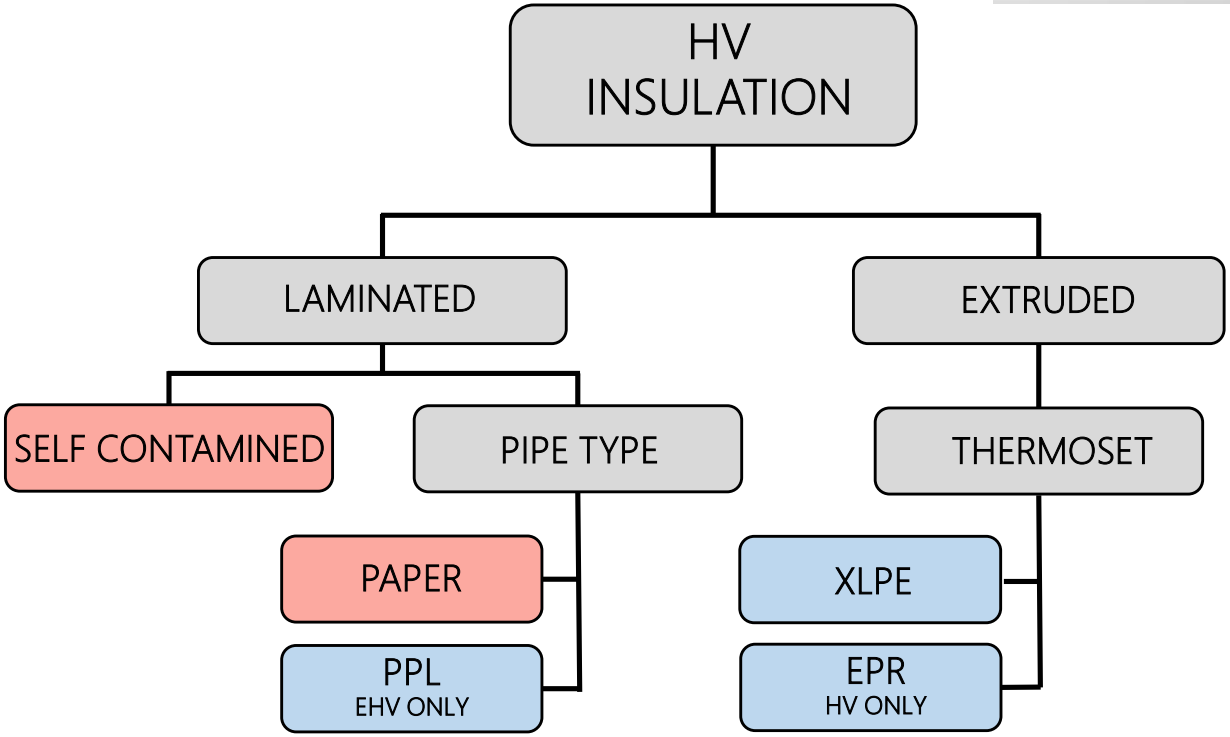
Contains voltage between the conductor and ground:

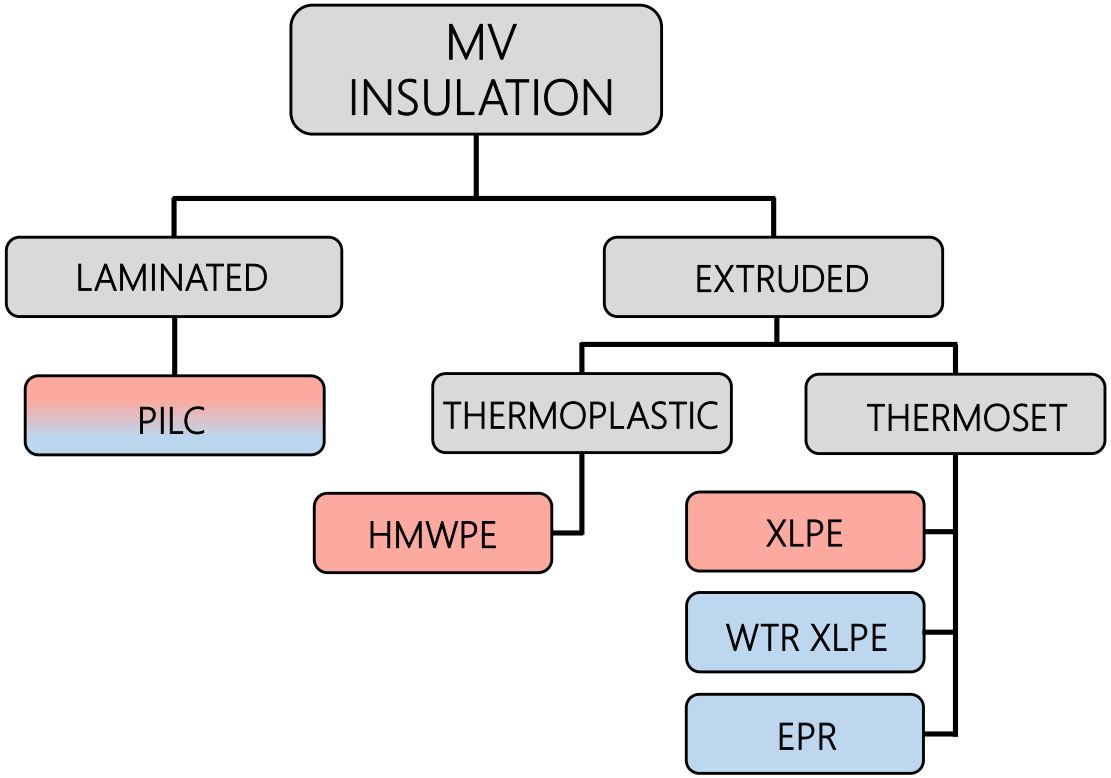
- Must be clean;
- Must have smooth interfaces with the conductor and insulation shields;
- Must be able to operate at the desired:
  - ✓ Electrical Stress
  - ✓ Temperatures

Higher service gradients require better insulation qualities. These materials should be **perfectly clean**, this is particularly important, as their long-term **performance can be considerably affected**, even by micro- impurities.

Precautions to ensure cleanliness should be taken both during the production of raw materials and throughout the entire cable fabrication process.

Construction Technology: Insulation





Prior Technologies

Today' s Technologies

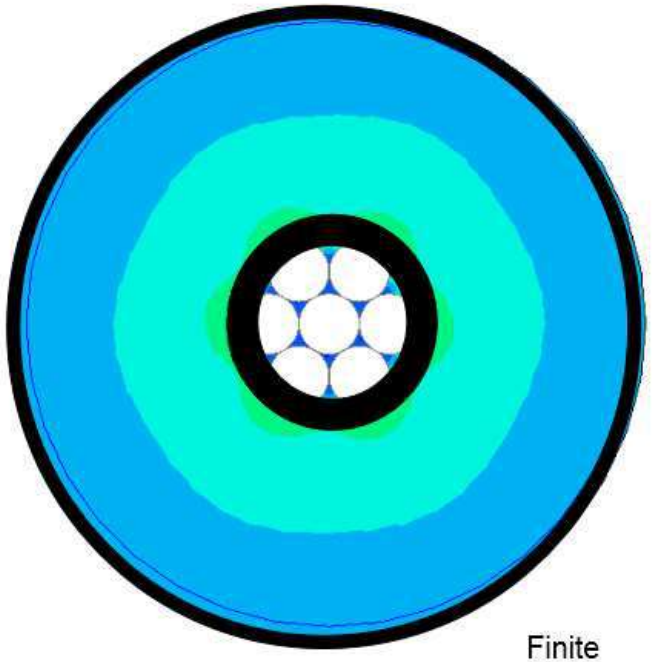
TECHIMP

For all cables, the external protection is provided by a polyethylene sheath. Over this insulation, the application of a waterproof metallic sheath, which also acts as a screen, is generally required.

When both shields are:

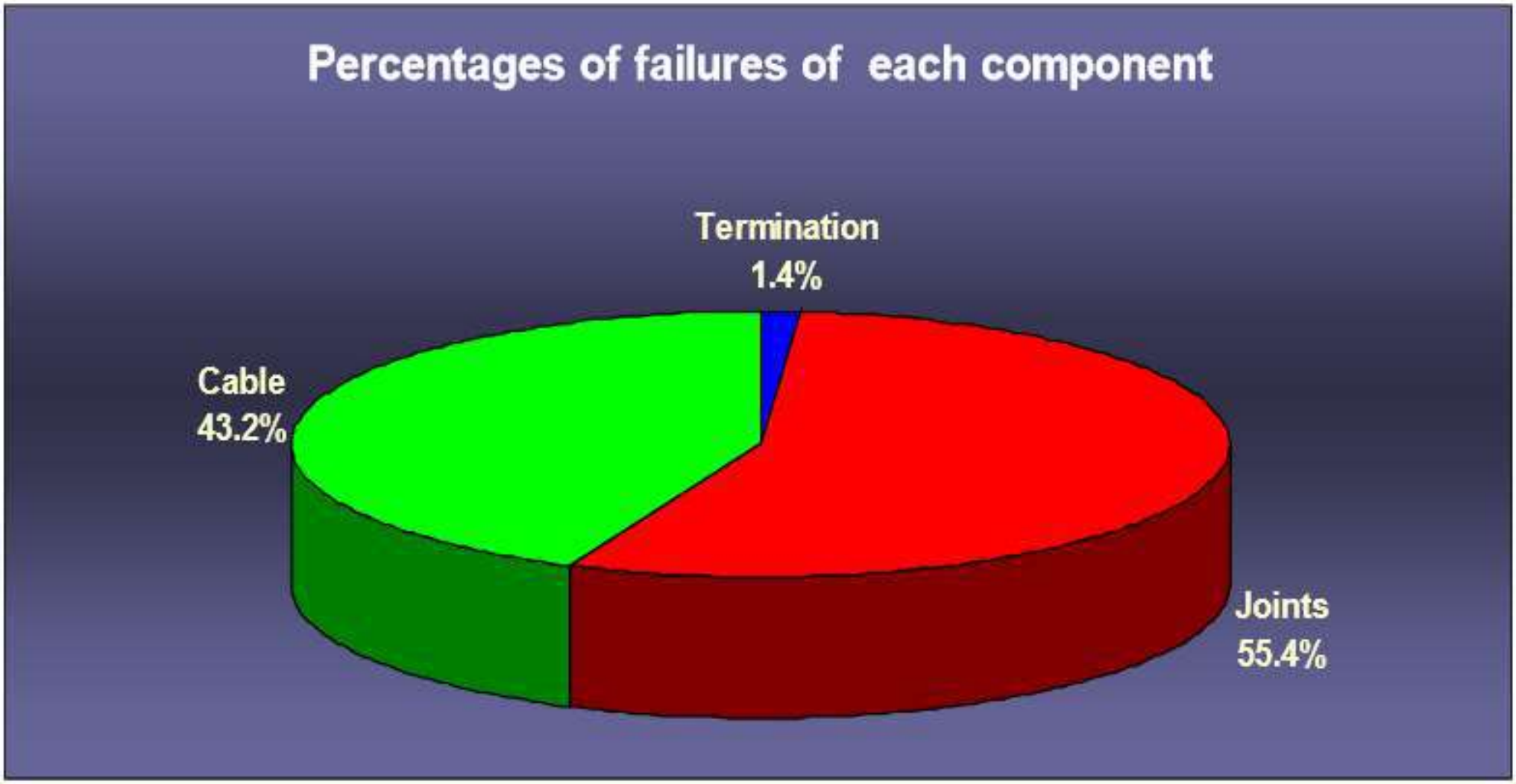
- Smooth;
- Intact;

Then, electric field lines are uniform, with a controlled electrical stress distribution.

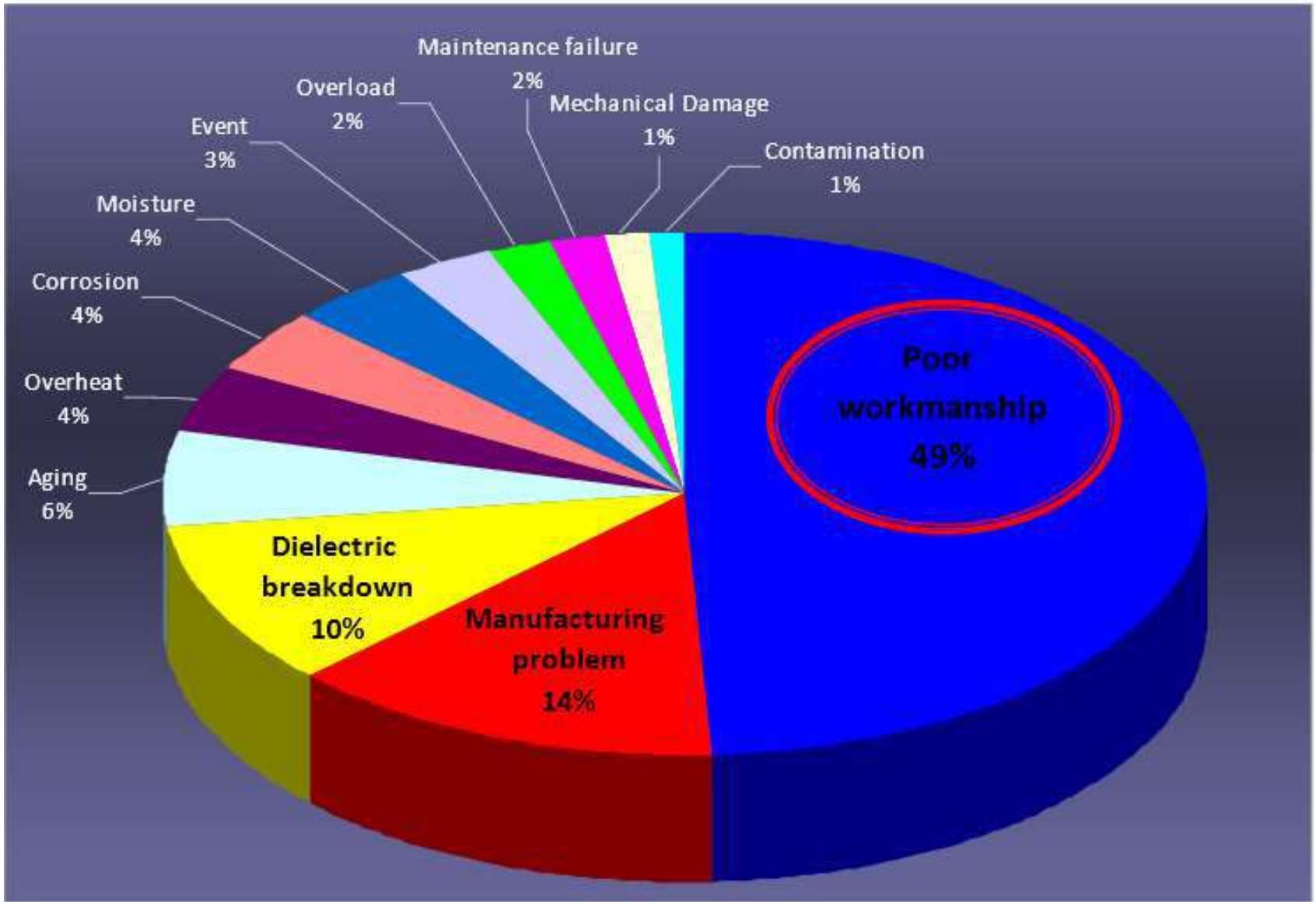


Finite Element Simulation

Failure modes



Failure modes

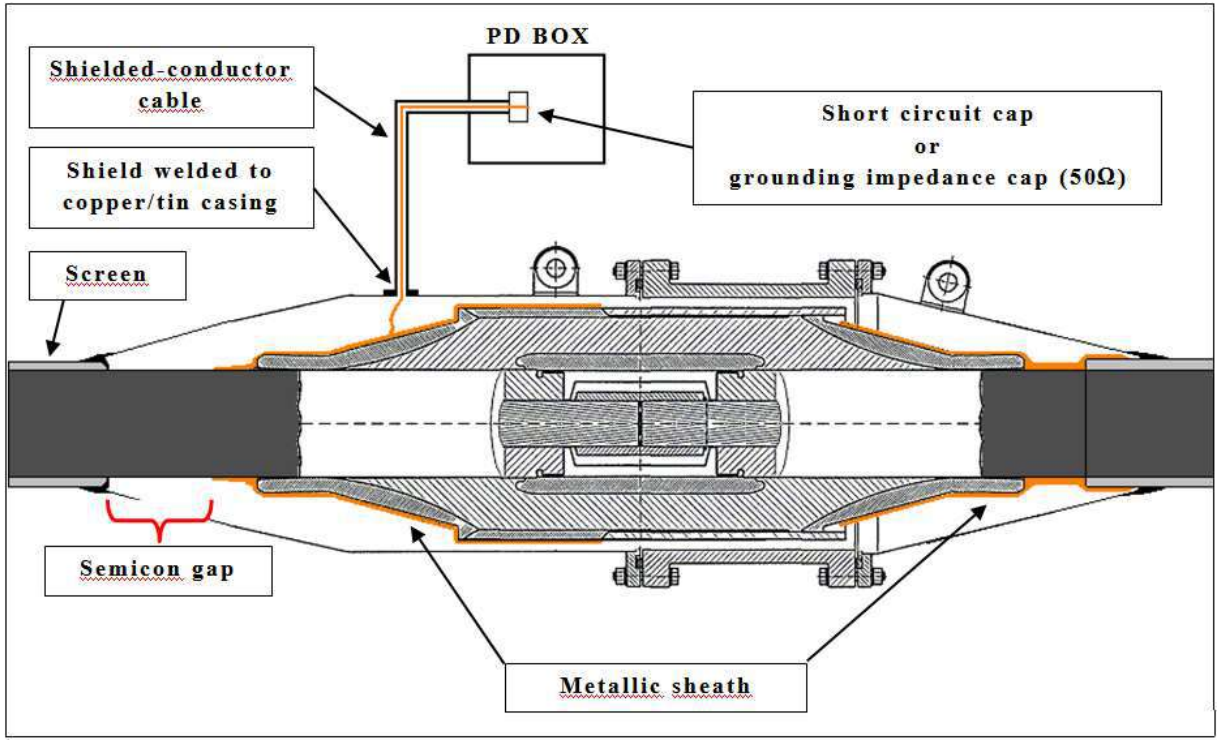


Sensor technology for Cables

Embedded Capacitive tap, if available, are provided by the cable manufacturer during the cable installation:

Typically used for:

- on/off line tests and permanent monitoring
- straight/sectionalized joints and terminations



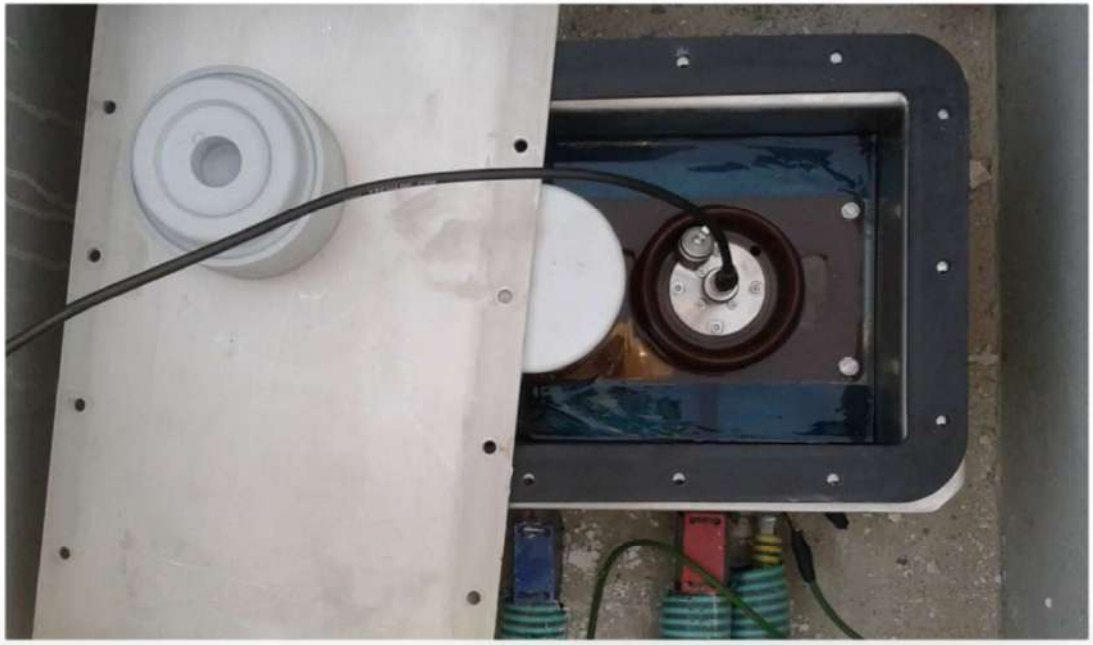
Techimp PQ is a quadrupole suitable for on site and factory tests.

When connected to the HV circuit through an High Voltage Impedance, e.g.:

- joint capacitive tap;
- condenser bushing capacitive tap;
- capacitive coupler;

It provides both synchronization and PD signal.

Sensor technology for cables



TECHMP

Techimp HFCT (High Frequency Current Transformer)

is an inductive sensor for partial discharge measurements.

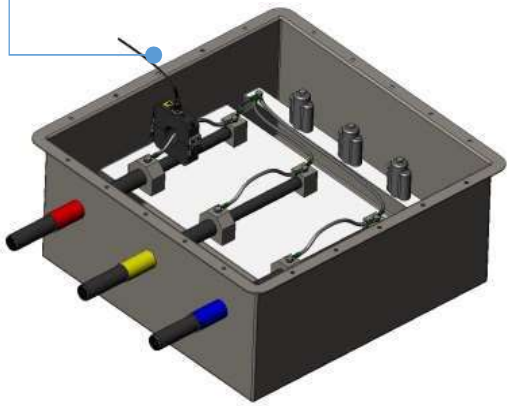
It is suitable for on/off line PD tests on many electrical systems (cables, transformers, rotating machine, etc..). It has to be applied to the ground connection of the system to be tested.

HFCT Clamp 39mm specifications	
Bandwidth	1 MHz ÷ 80 MHz
Load Impedance	50 Ω
Overall dimension	115 mm x 145 mm x 33 mm
Connector	TNC
Hole dimension	Φ 39 mm

Sensor technology for cables

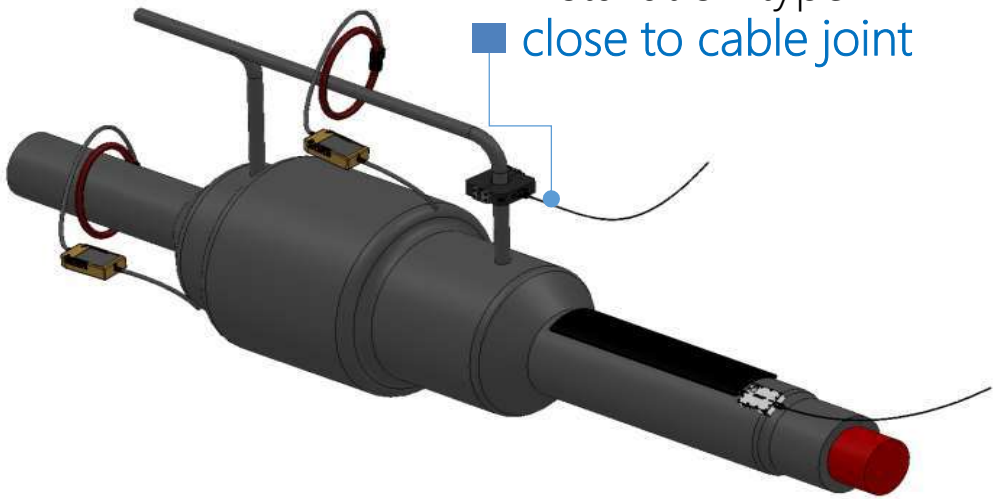
Sensor technology for cables

Installation type I
inside link box

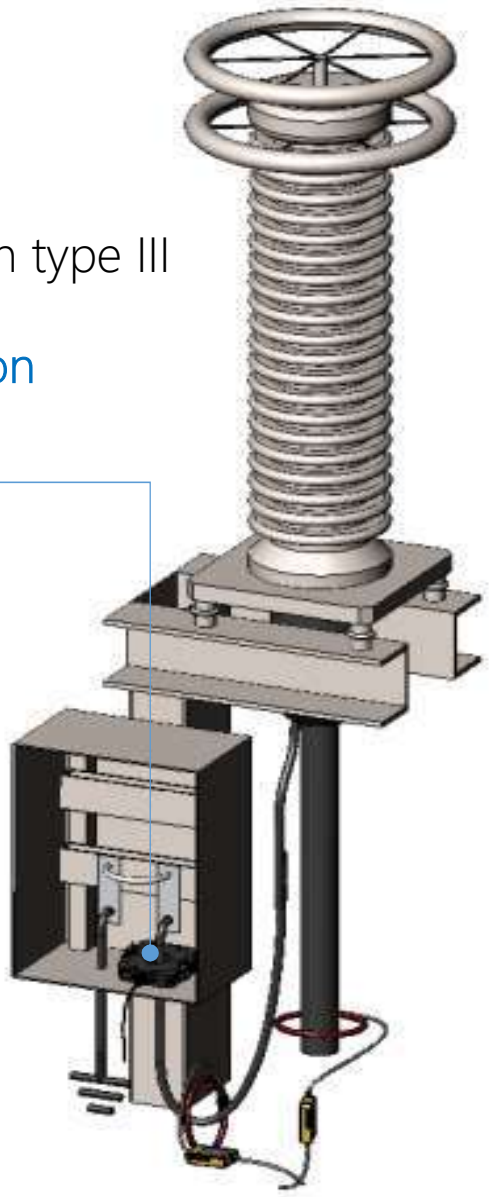


Note: Link boxes are use as a "joint" for the cable shield: left and right sides are connected Straight or CrossBonded.

Installation type II
close to cable joint

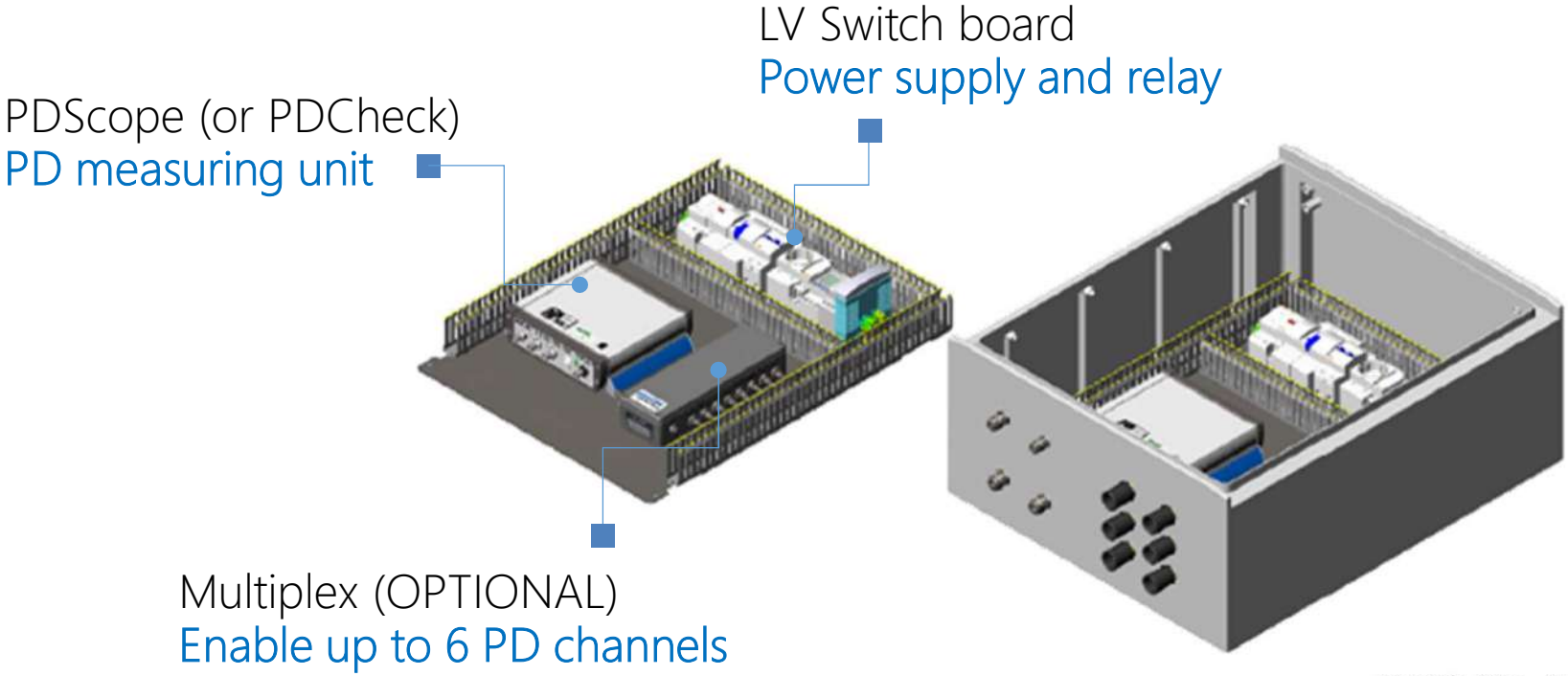


Installation type III
outdoor
termination



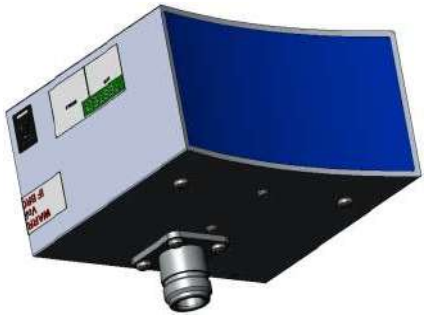
Sensor technology for cables

In case of monitoring systems Acquisition Box will be installed. Each one contains one acquisition unit connected to three (or six) PD sensors (through coaxial cables) and HF signals coming from the PD sensors will be acquired.



Sensor technology for cables

Techimp Horn antenna is a PD sensor designed to pick up electromagnetic (EM) waves generated by a PD.



- Optimized to operate in UHF frequency range;
- It can be placed directly on the insulating ring of a GIS termination;
- Suitable for on-line/ off line PD measurement and monitoring;

HORN antenna specifications	
Bandwidth	500 MHz ÷ 3 GHz
Gain	2.7 – 7.1 dBi
Load Impedance	50 Ω
Overall dimension	70 mm x 100 mm x 50 mm
Connector	Type N

Flexible Magnetic Coupler Sensor:

- direct magnetic coupling with the cable conductors
- wrapped around the HV cable in correspondence of the tested accessory (if the accessory is accessible);
- on/off line tests and permanent monitoring
- straight/sectionalized joints and terminations

FMC specifications	
Bandwidth	30 kHz ÷ 50 MHz (UWB amplifier)
Overall dimension	500 mm x 100 mm x 10 mm
Connector	BNC

Sensor technology for cables

PD measurements on HV Cables

Commissioning Tests (Off-line)

On-line tests

Commissioning Tests

A commission test can be considered as the composition of those test, to be carried out after the cable system installation, defined by international standards (IEC62067 par.16 for HV cables).

Purpose: insure that the cable installation was done properly.

IEC62067 mention two main tests:

- DC voltage test of the oversheath;
- AC voltage test of the insulation.

Note: some additional tests can be performed by the manufacturer in order to check the cable characteristics after the installation.

Since cable drums are subjected to Quality control Tests, AC voltage test of the insulation, after the installation procedure, is the most important since it' s main purpose is to check absence of installation defects.

> "The A.C. test voltage to be applied shall be subject to agreement between the purchaser and the contractor. The waveform shall be substantially sinusoidal and the frequency shall be between 20 Hz and 300 Hz. A voltage either according to Table 4, column 11 or with 1,7 $U0$, depending on practical operational conditions, shall be applied for 1 h.
>
> Alternatively, a voltage of $U0$ may be applied for 24 h."

Questions: how many defects (in terms of dimensions and positioning) can produce failure within one hour ad the test voltage?
Could it be possible that a defect does not produce a fault in a short time?

Assuming a probabilistic approach, answer would be: Yes.

So, even if PD tests are not mentioned in the standard, common practice is to perform it.
Considering Construction Technology aspects, even small impurities can reduce the expected life of the cable system.

Commissioning PD tests are carried in order to improve the degree of confidence that the cable system will be reliable.

Commissioning Tests

On-line Tests

On-line Tests

PD measurements on MV Cables

Commissioning Tests (Off-line)

On-line tests

Commissioning Tests

Localization Techniques

Localization Techniques

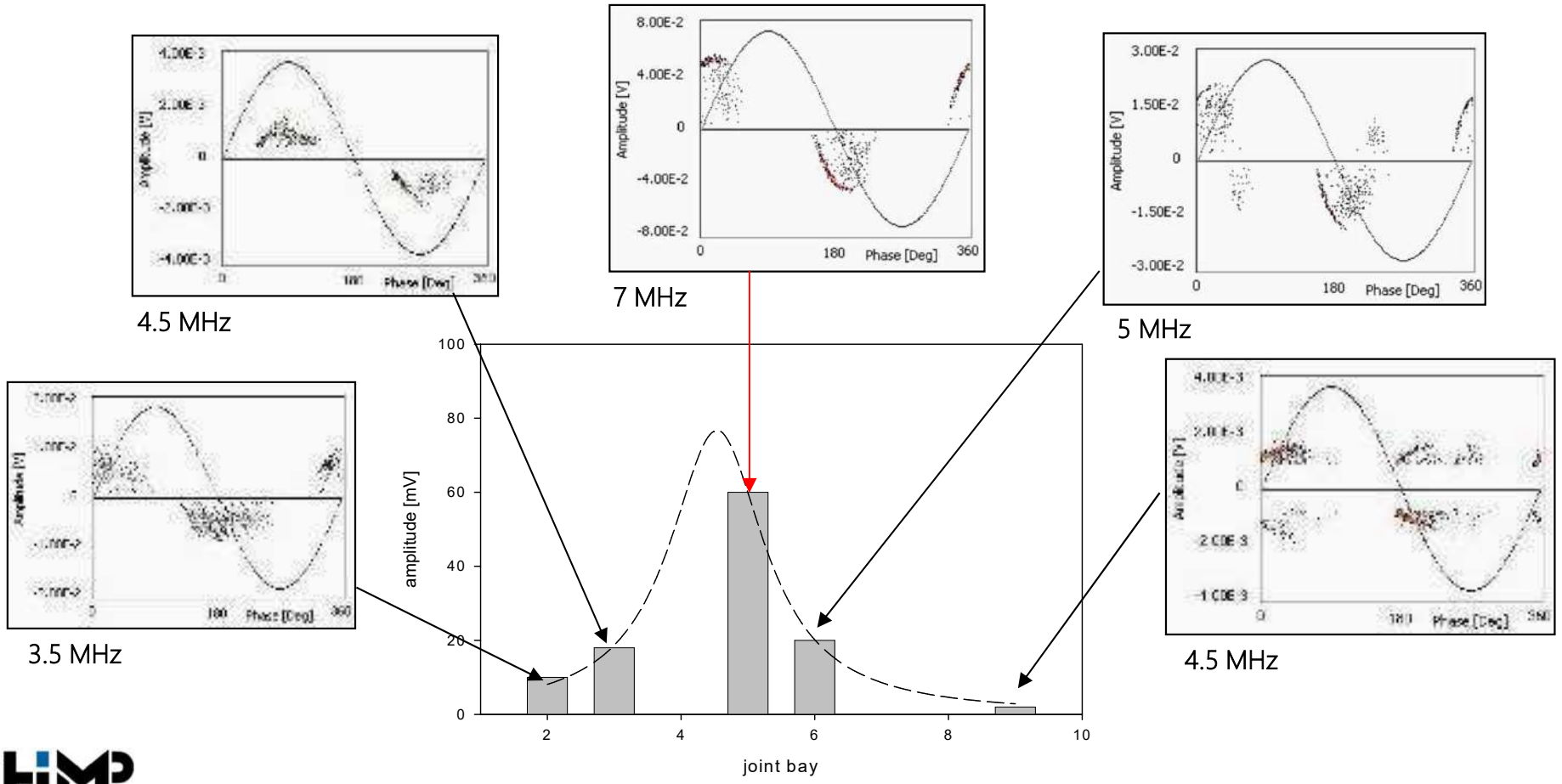
In case of Internal Partial Discharges detected it is possible to apply three different techniques in order to locate the source of the phenomenon along the cable rout.

- Techimp TF Map technology
- Time-Domain Reflectometry
- Arrival Time Analysis

All these techniques can be applied using Techimp Technology.

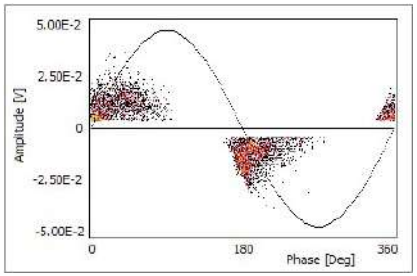
Amplitude – Frequency analysis through T-F map separation

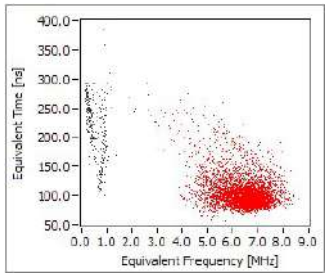
- PD phenomenon acquired in different location of the cable system
- Amplitudes (PD Pattern) and Frequencies (TF Map) are compared
- Detection point closer to the PD source can be identified



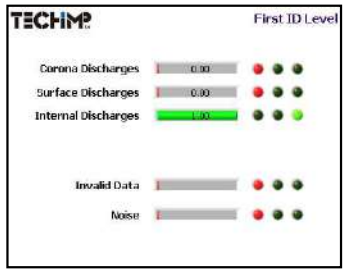
Reflectometric technique (TDR)

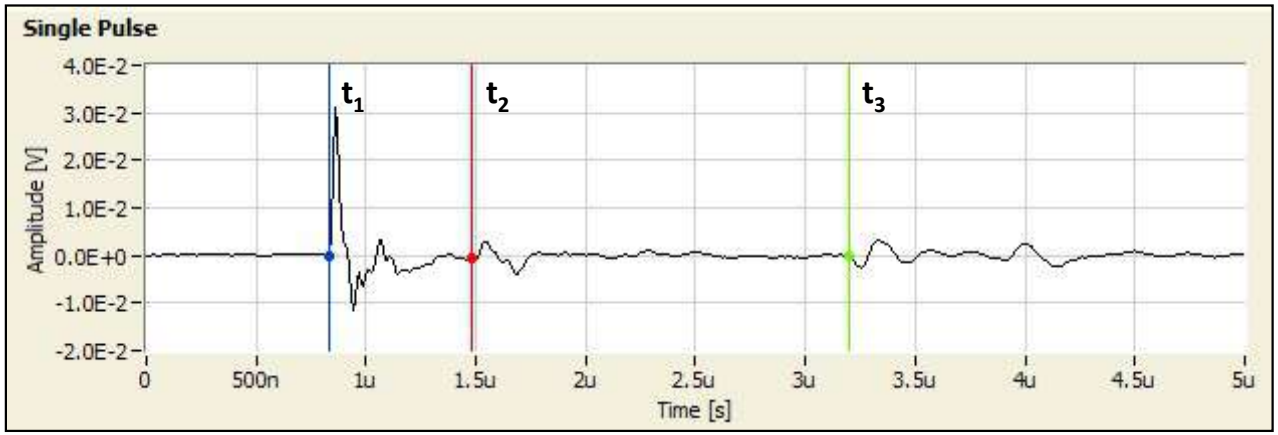
- PD phenomenon acquired with waveform information (right time-length)
- Distance from detection point and PD source is evaluated





Only one cluster PD pulses analysis

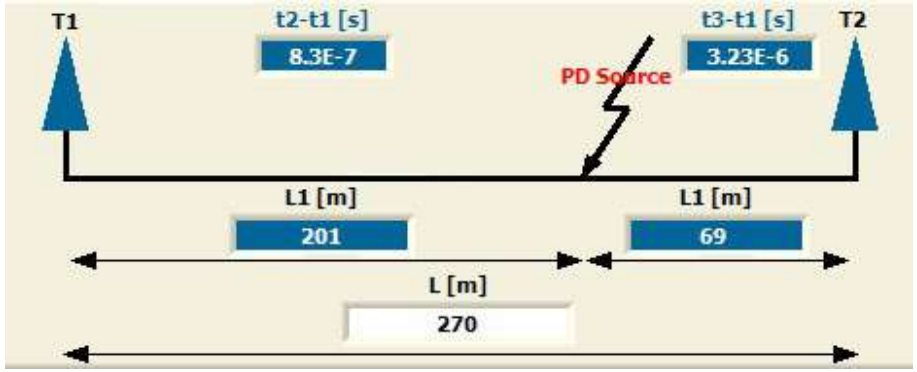




Measurement point

PD source, first reflection

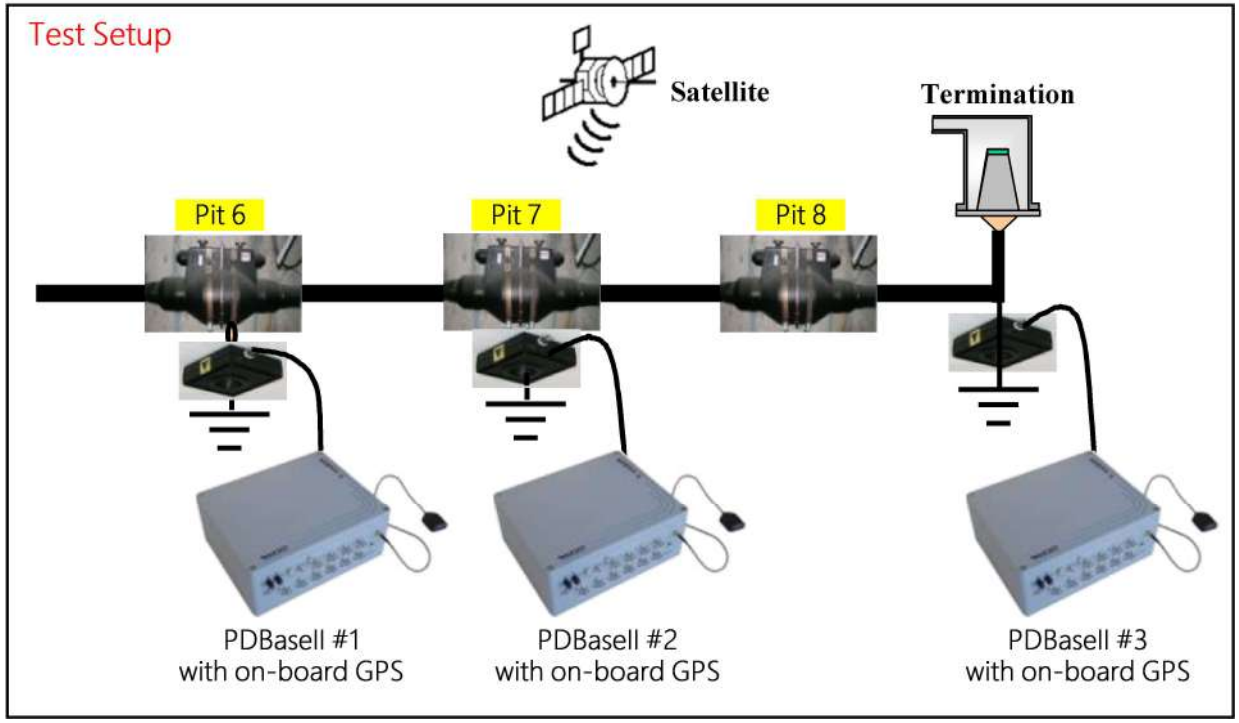
Second reflection



Arrival Time Analysis (ATA)

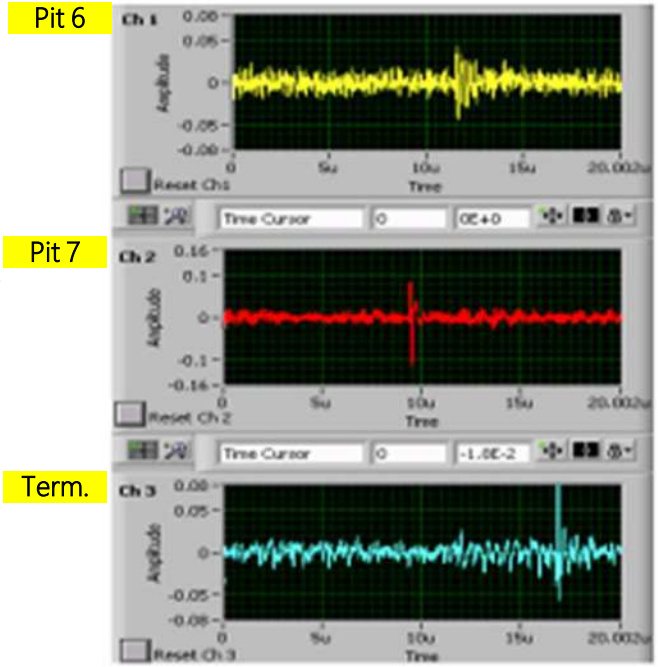
- 3 Acquisition Unit installed in 3 different locations
- The units are connected through fiber optic link or other means to 1 oscilloscope
- Simultaneous acquisition from the three channels
- Post processing software analysis for localization of the PD source

This analysis is 100% effective and conclusive to locate PD sources



Results

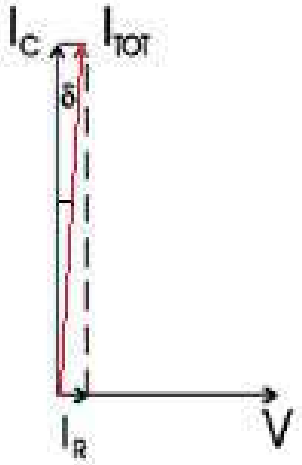
Pulse time sequence

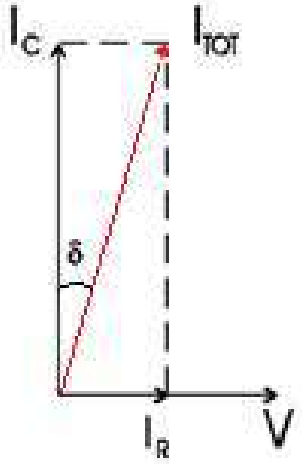


Tan-δ Tests on Cables

Tan Delta test, also called Loss Angle or Dissipation Factor testing, is a diagnostic technique for the cables (**especially for the MV**) useful to determine the quality of the cable insulation.

If the insulation of the cable is defects free (water trees, moisture, ect.) it acts like a ideal capacitance. The voltage and current are phase shifted of 90 degrees and the current that flows trough the insulation is almost only capacitive.

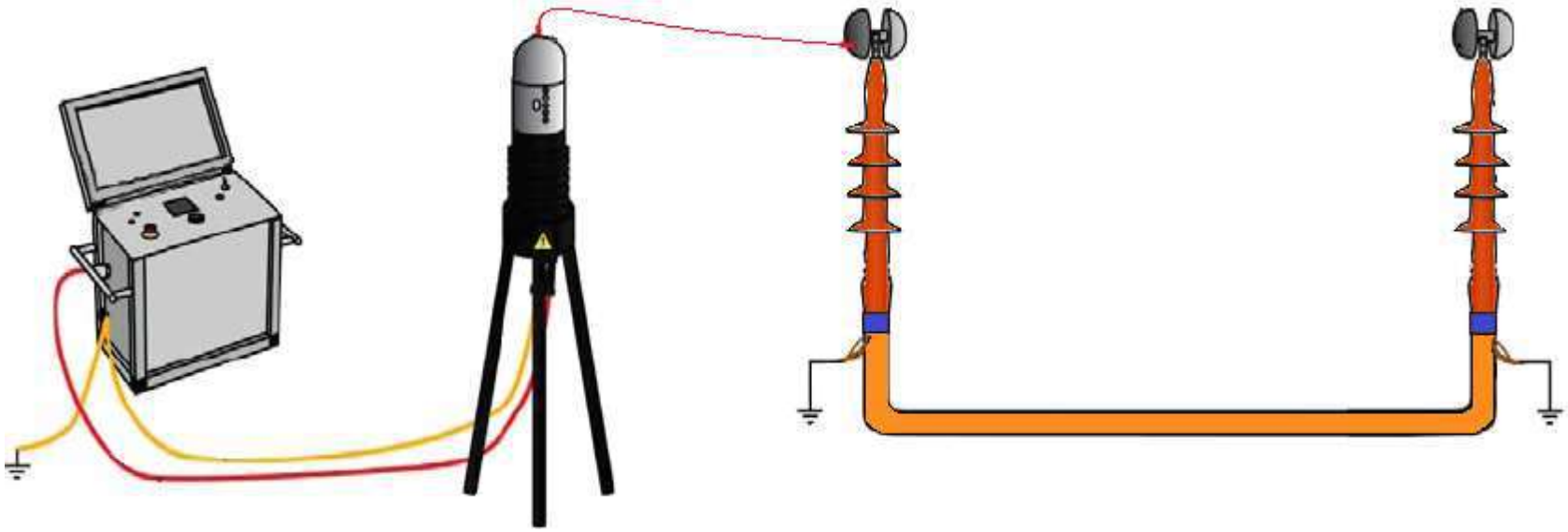




If there are some impurities in the insulation systems the related resistance degrease. Resulting in an increase in resistive current through the dielectric. The voltage and current are no longer phase shifted of 90 degrees, but something less (90-δ).

Tan Delta test is one of the tests reported in the International standard **IEEE 400.2** for MV cable systems using **Very Low Frequency** voltage.

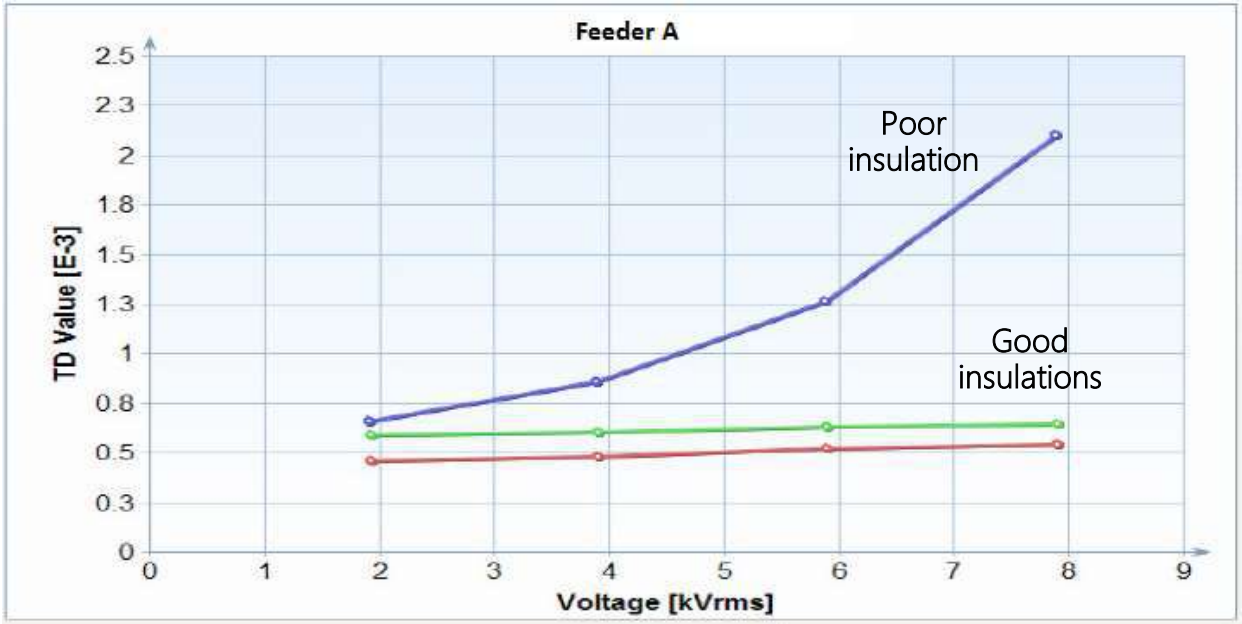
The cable must be disconnected from the network and connected to the testing kit.



VLF Generator Tan Delta sensor Cable under test

This test is performed applying the voltage by steps in order to avaluate:

- Differential VLF-TD between $0.5U_0$ and $1.5U_0$
- Mean VLF-TD at U_0
- VLF-TD Time Stability at U_0

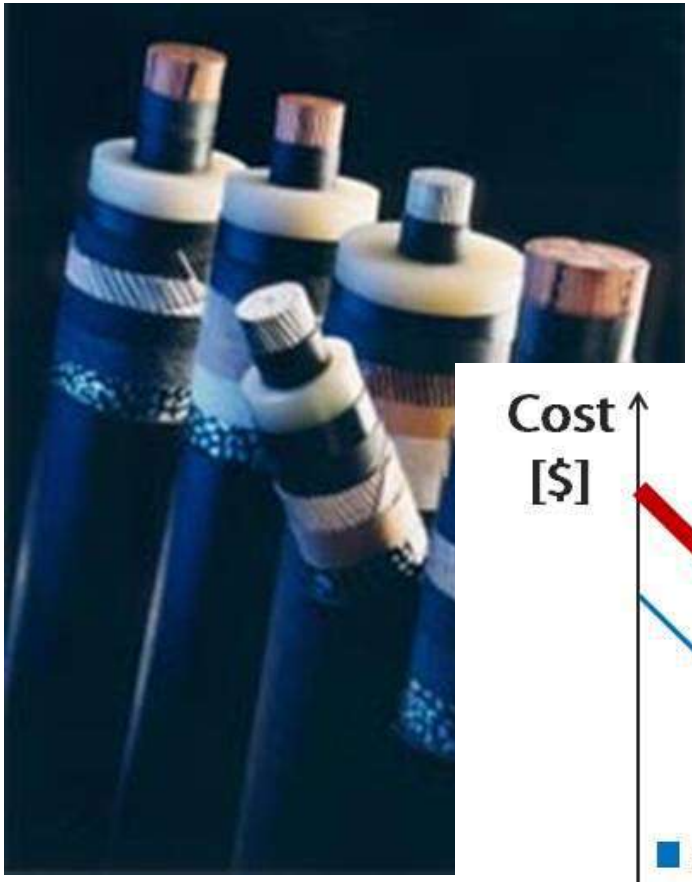


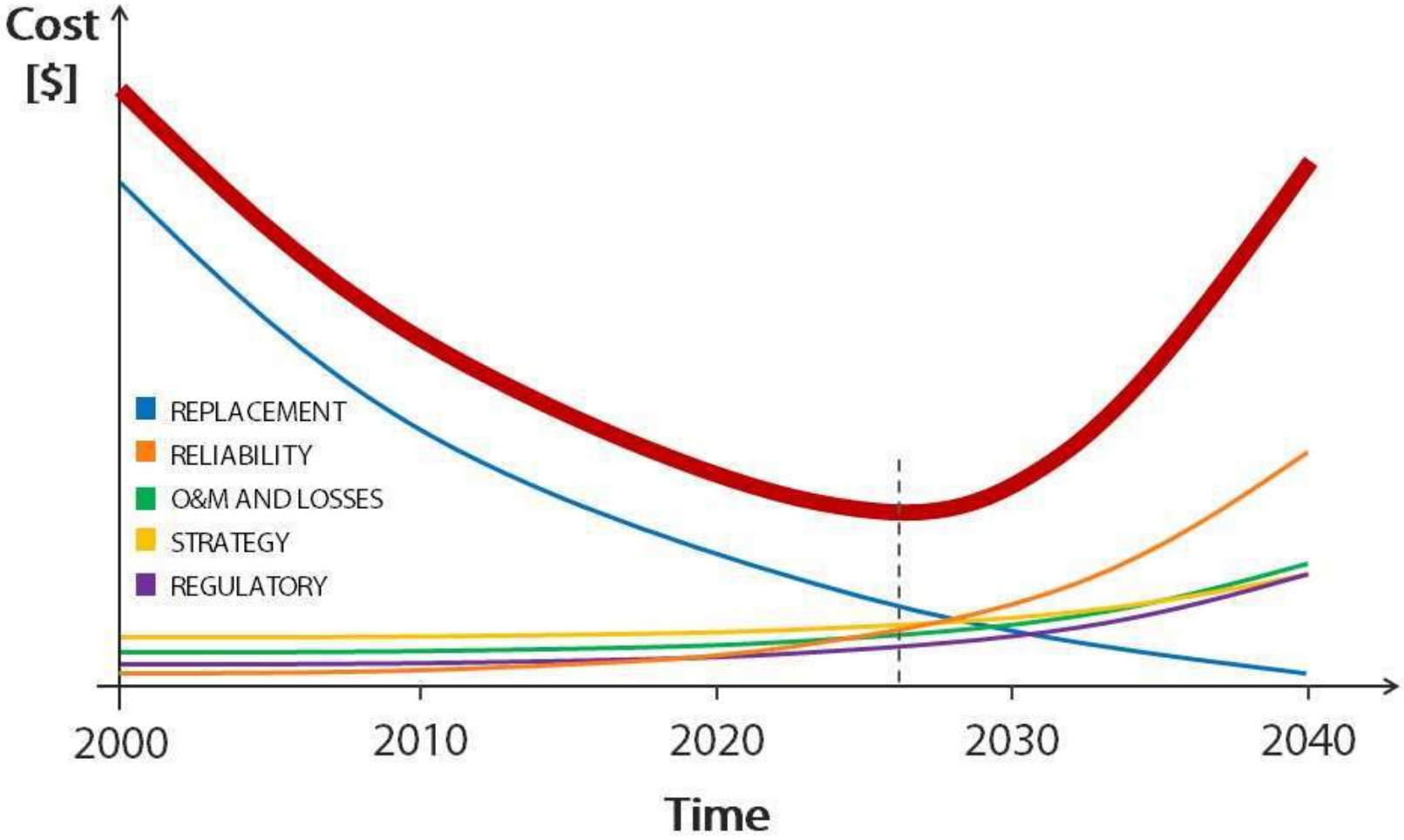
Good insulation has:

- Low value of mean VLF-TD at U_0
- Stability during the test time
- Stability at different voltage levels.

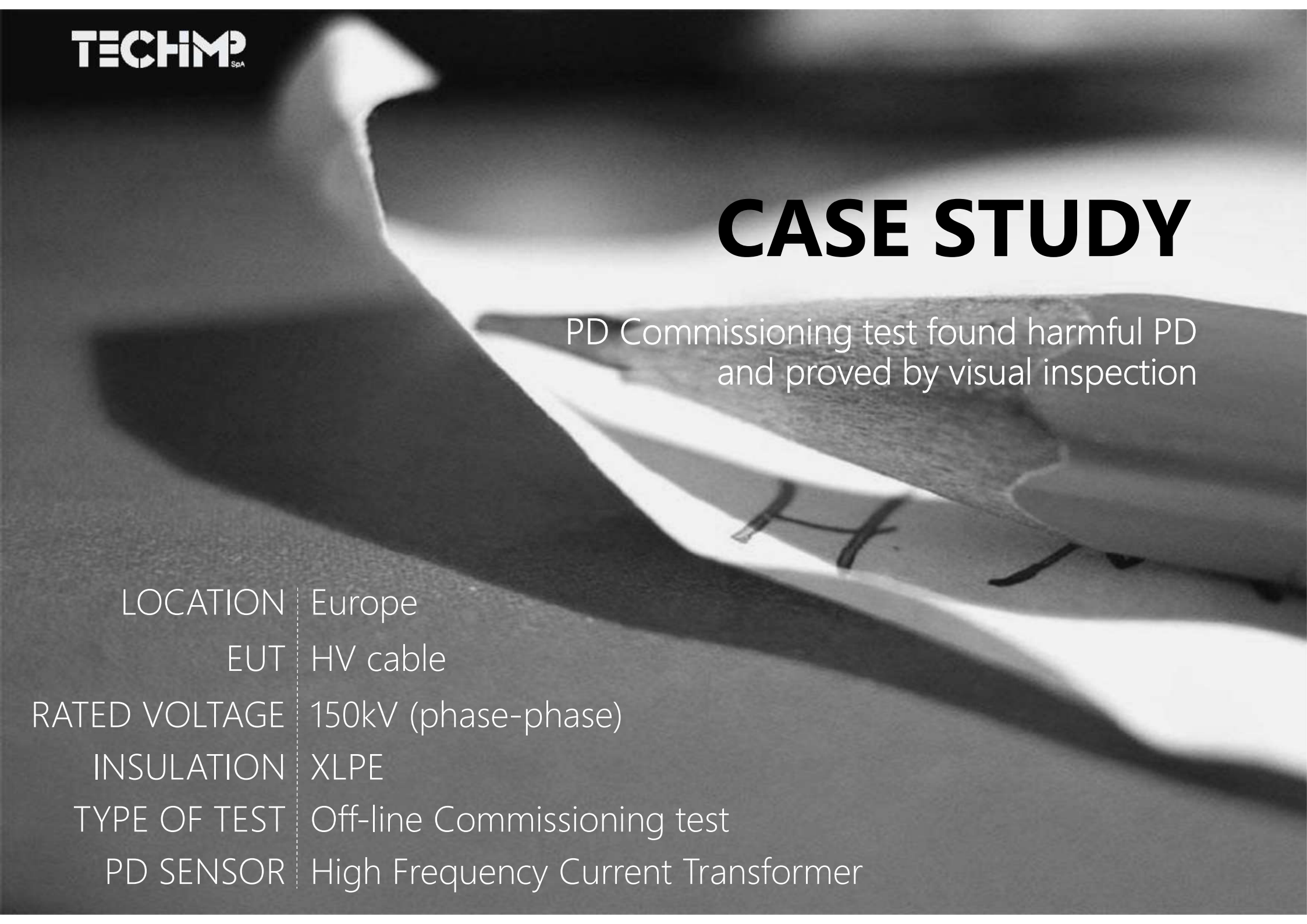
Asset management and condition monitoring

Construction Technology






Case Studies



CASE STUDY

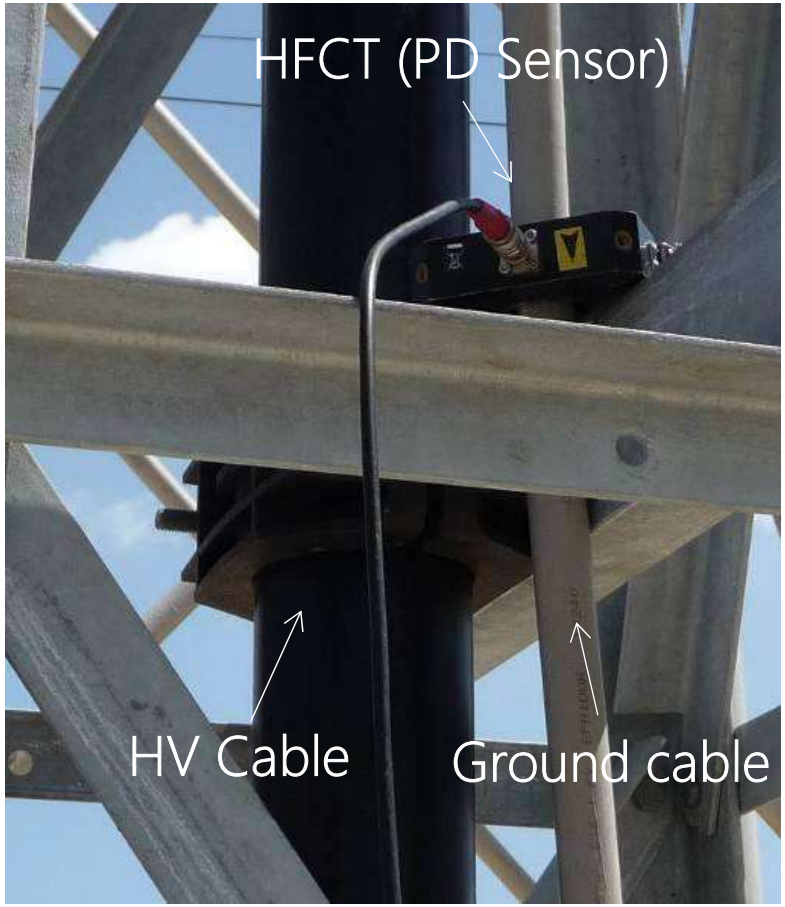
PD Commissioning test found harmful PD
and proved by visual inspection

LOCATION	Europe
EUT	HV cable
RATED VOLTAGE	150kV (phase-phase)
INSULATION	XLPE
TYPE OF TEST	Off-line Commissioning test
PD SENSOR	High Frequency Current Transformer

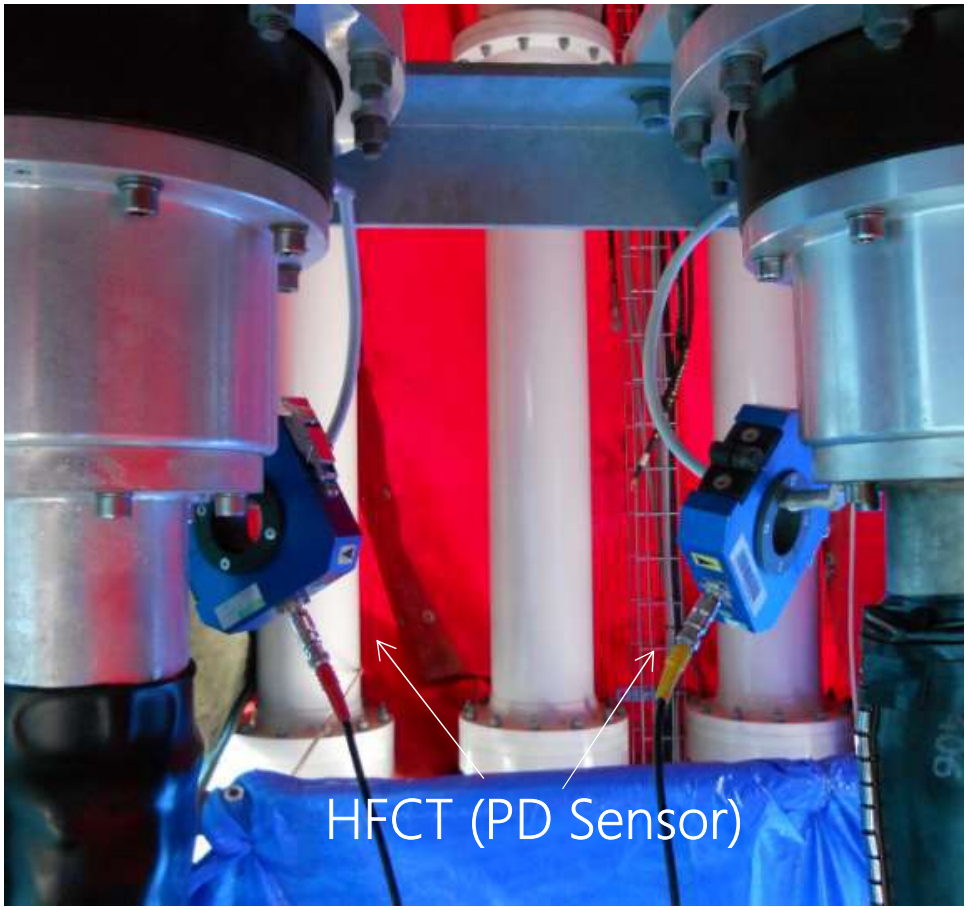
Measurement Information:

- Test type: Off-line PD Commissioning Test
- Measurement type: Sequential
- Termination type: Outdoor, GIS termination
- Measurement date: 2011
- PD sensor: HFCT (High Frequency Current Transformer)
- Equipment under test: 150kV HV Cable
- Length of the cable: 58m
- Insulation type: XLPE

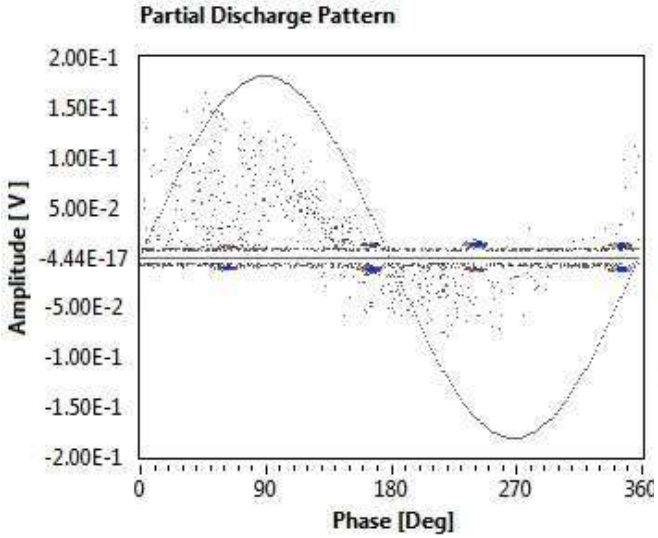
Site Photo (Outdoor Termination Side)



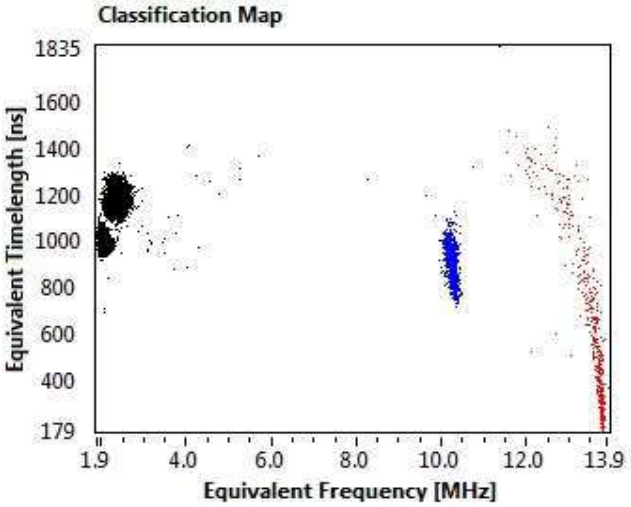
Site Photo (GIS Termination Side)



Entire PRPD Pattern



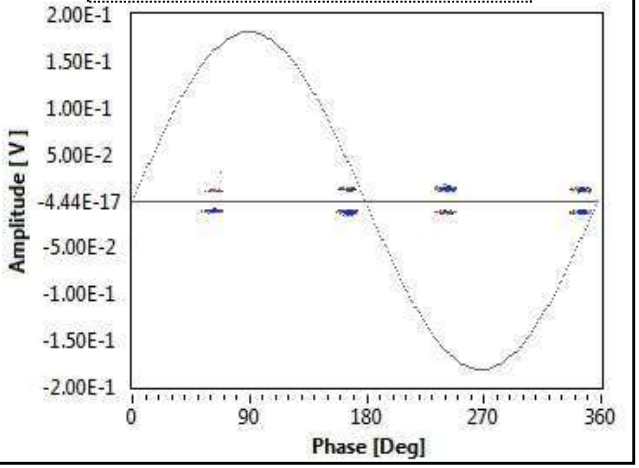
TF Classification Map



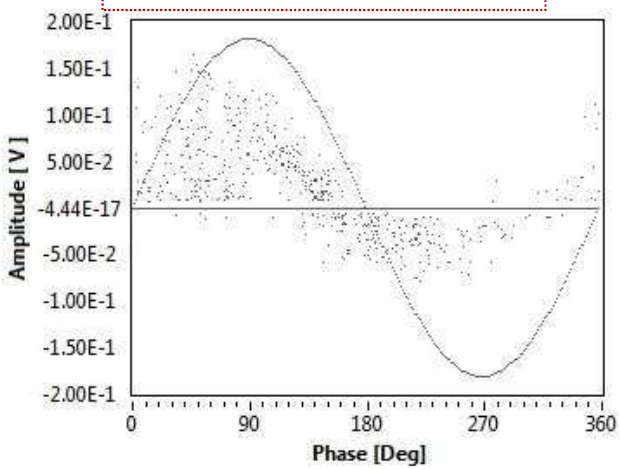
@90kV

Interface PD happening at the GIS termination on White phase

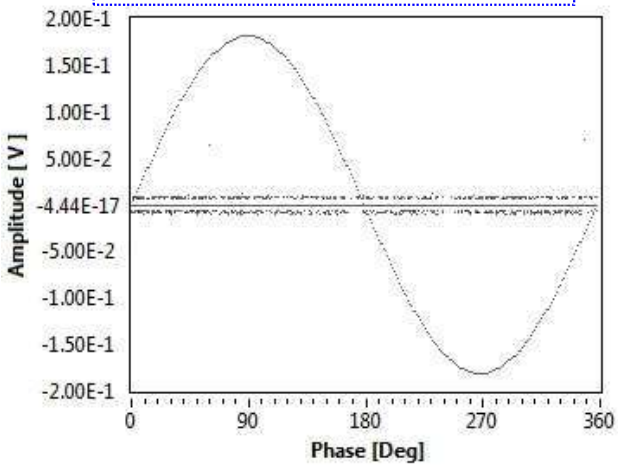
IGBT noise



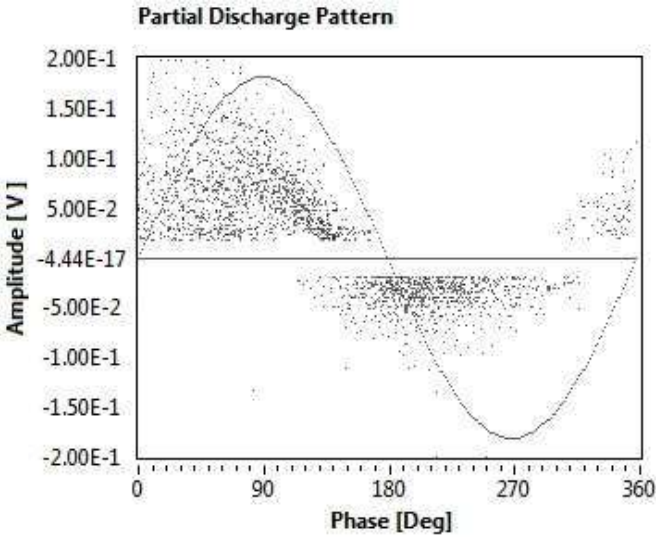
Interface PD



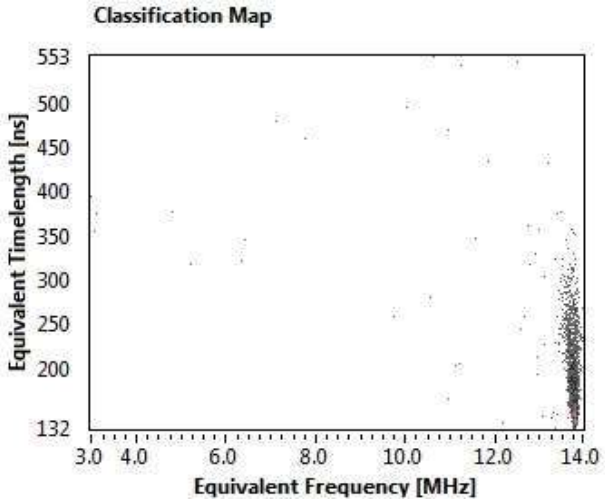
Background noise



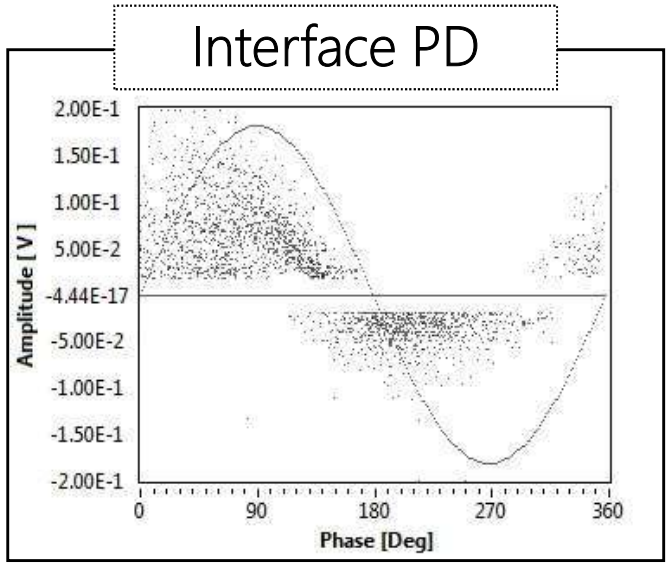
Entire PRPD Pattern



TF Classification Map



Interface PD



R

@100kV

Clear **interface PD** happening at the GIS

Waveform confirms very typical PD pulse shape

TECHIMP suggestion !!

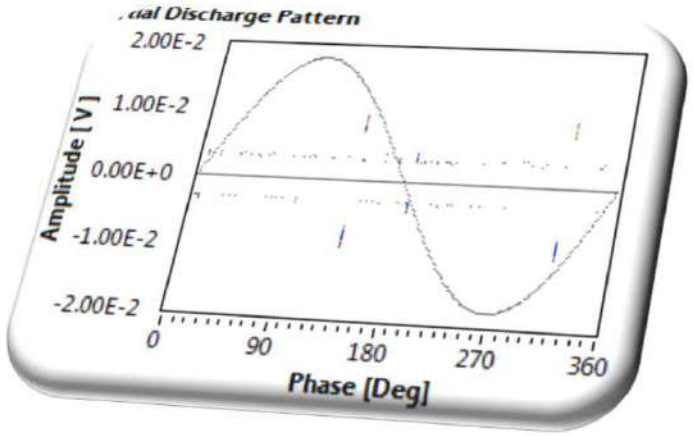
Replacement of Termination

Visual inspection

White phase GIS termination dissembled

It is clearly showed The burning trace had been found in the surface of stress con,

which is the evidence of PD activities in the GIS termination detected by TECHIMP PD commissioning test !!



PD Commissioning test after replacement