Insulated Conductors Committee

Testing and PD Diagnosis of MV Cable Systems with DAC Voltage

Educational Session
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St Pete Beach, Fl

by

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THE BEST IN CABLE FAULT LOCATING TECHNOLOGY

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Partial Discharge Diagnosis on Cable Systems

- With partial discharge diagnosis local weak spots can be found, which are related to gas filled gaps or voids or which have defects in interface areas.
- It is not the target to initiate electrical trees in the cable insulation.
- The diagnosis at all must be “non destructive”.

Local weak spots in cable systems can be located in :

- **Cable insulation (mainly PILC)**
- **Joints**
- **Cable terminations**

- PD diagnosis can be performed on every type of cable, PE, XLPE, EPR, PILC,PVC and mixed cable systems.
- The type of excitation voltage for PD diagnosis should be similar to power frequency to obtain equivalent PD parameter as under service conditions.
- New installed cable systems should be PD free up to 1,7…2 Uo
- Values of interest in case of PD diagnosis on aged cable systems :

- PDIV above or below Uo ?
- PD level at Uo
- Location of PD faults

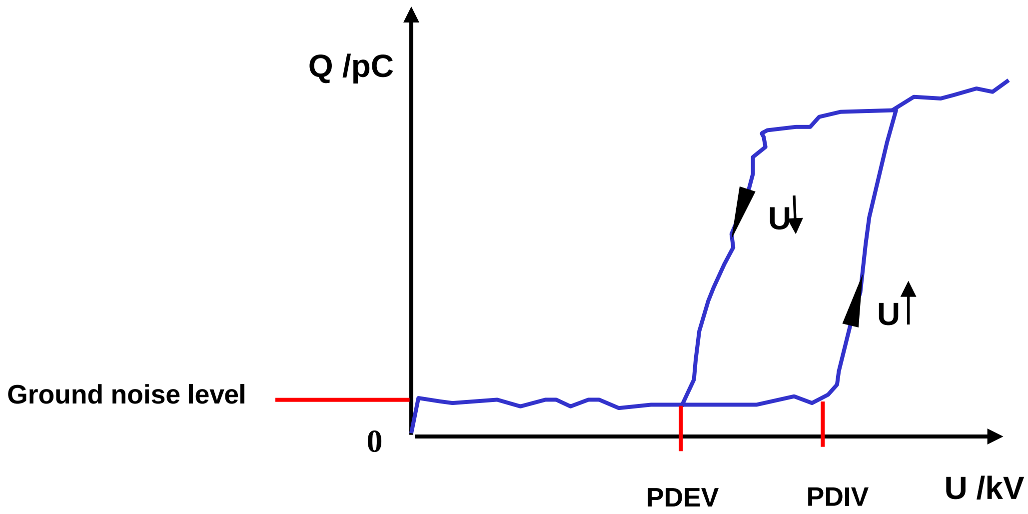
Partial discharge diagnosis – Parameter (1)

Partial Discharge Inception Voltage - PDIV:

Voltage level where first measureable PD pulses are to be seen, determined by stepwise increase of the test voltage, PDIV should be higher than Uo (nominal service voltage)! That means the cable is under normal service condition PD free!! New installed cables should be PD free up to 2 Uo!

Partial Discharge Extinction Voltage - PDEV:

Voltage level where PD pulses extinct, PDEV is often below PDIV



PDEV is often lower than PDIV due to hysteresis effect, dependend from type of pd defect

Partial discharge diagnosis – Parameter (2)

PD-level at U_0:

Average and max. PD Level in pC at nominal voltage. For specific type of insulation and accessories empirical trending or limiting levels are known.

Ground noise level:

Interferences of external noise sources like radio stations, corona from OH-lines, bad grounding conditions PD signals below ground noise level can be not determined ground noise level on site normally between 20 to 100 pC .

Calibration:

Injection of known charges to test object to calibrate the measurement system according to standard IEC 60270.

PD mapping /fault location:

Localization of PD on the well known principle of Time Domain Reflectometry (TDR).

To perform an accurate fault location, the propagation velocity *v* has been calculated during calibration of the measurement system.

Because of the repetitive behaviour of the discharges a distribution of the PD weak spots as function of the cable length can be made.

PD-pattern recognition:

With PD as function of the phase-angle of the voltage it is possible to determine the origin of the discharge; (cavity completely surrounded by a dielectric, or one side bounded by an electrode, corona, interfacial, etc.)

PD diagnosis using excitation with Damped AC voltages

Why using Damped AC voltages?

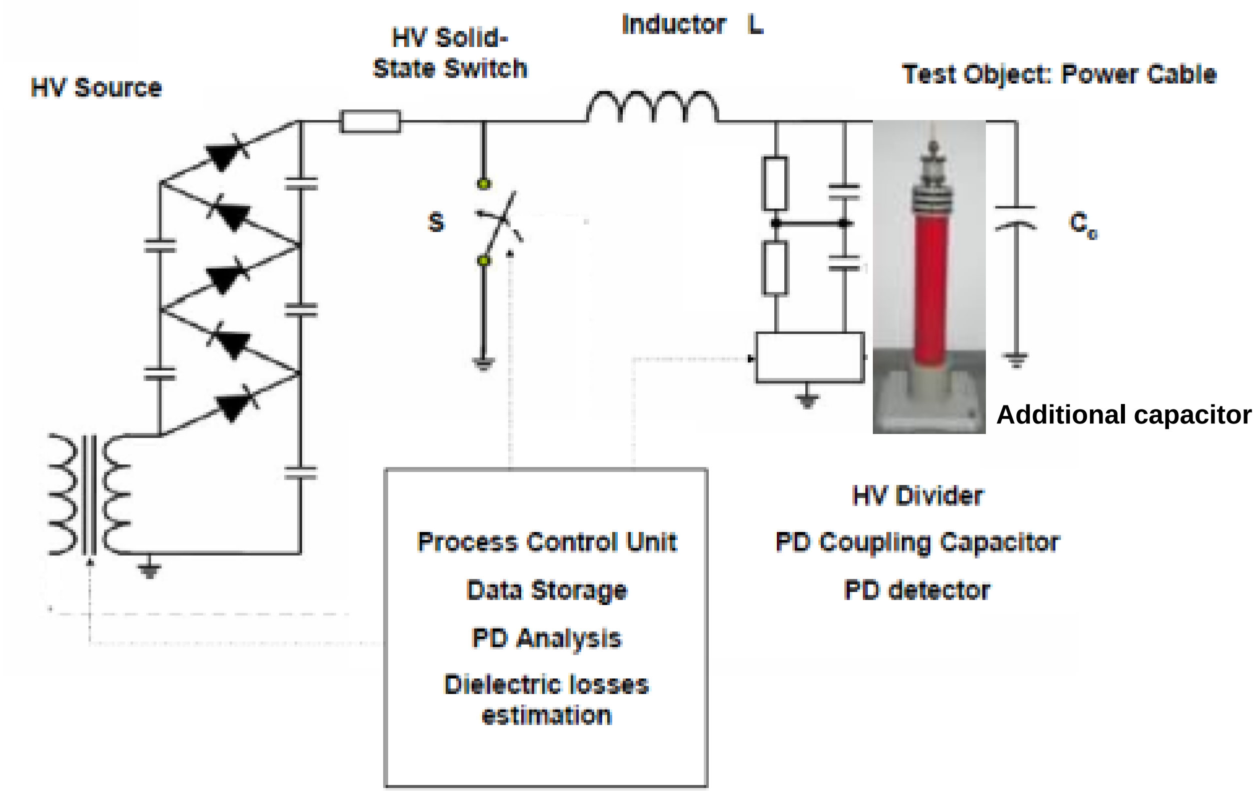
- Damped AC voltages are accepted test voltages for on-site testing:
  - IEC 60060-3, (High Voltage test techniques –Part 3: Definitions and requirements for on-site testing);
  - IEEE 400, (Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems);
  - IEEE 400.3, (Guide for PD Testing of Shielded Power Cable Systems in a Field Environment).

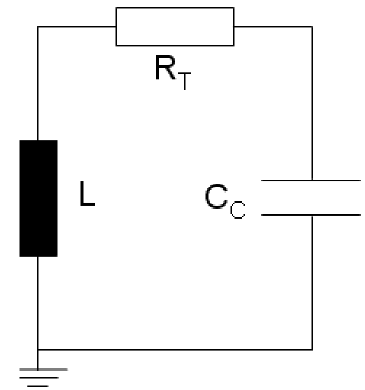
- Can be combined with PD-measurements, with a PD sensitivity according to:
  - IEC 60270, (Guide for Partial Discharges Measurements);
  - IEC 885-3, (Test methods for Partial Discharges measurements on lengths of extruded power cable);
  - IEEE 400.3, (Guide for PD Testing of Shielded Power Cable Systems in a Field Environment).

- Due to the resonance principle between cable capacitance and inductor a low-weight solution has been obtained.

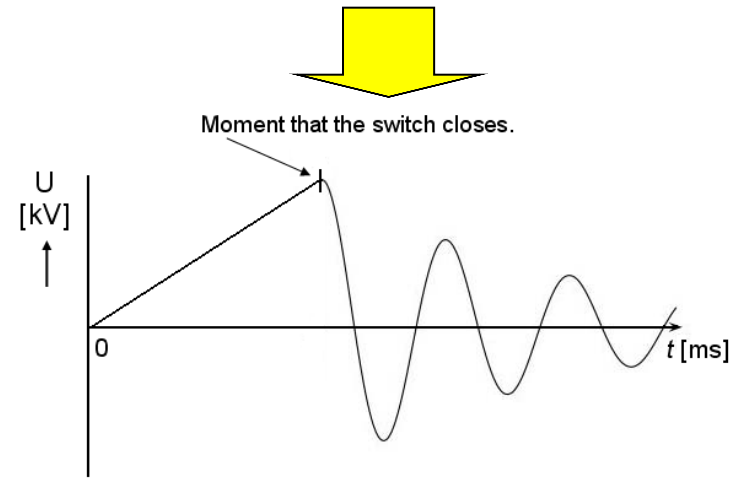
- Due to shorter duration and decaying characteristic of DAC stresses the destructiveness of DAC over-voltages for a local defect is lower as compared to withstand voltage testing with continuous AC.

Generation of DAC - OWTS principle





Resulting circuit
after switch closes.



Resulting oscillating voltage of the OWTS.

Partial discharge diagnosis

First generation of OWTS 25 (more than 100 systems in service)

Partial discharge diagnosis

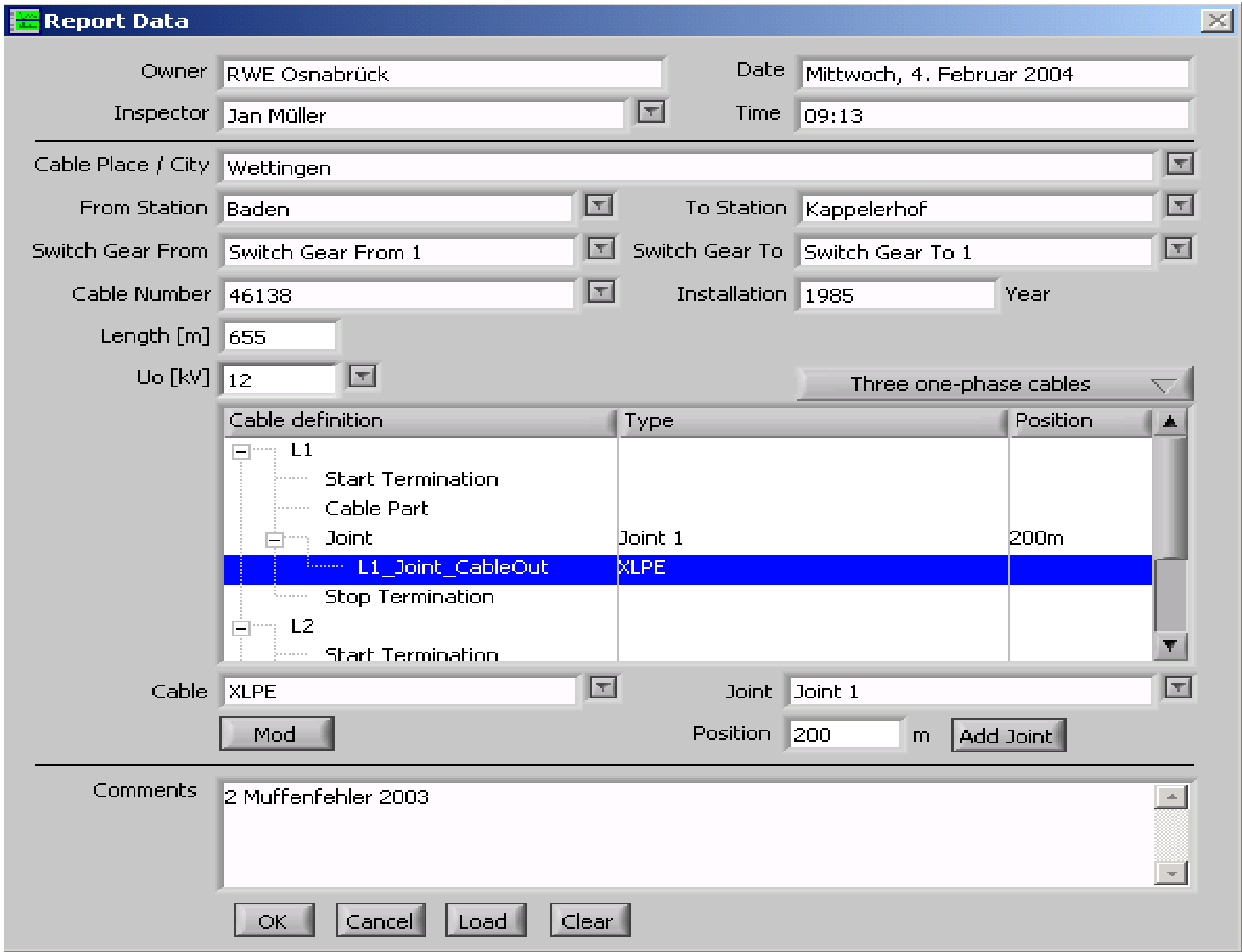
New generation of OWTS M series, OWTS M 28 and OWTS M 60

OWTS M 28

OWTS M 60

Partial discharge diagnosis - OWTS measurement

Test Object definition



Stage 1 is entering the data of the test object.

IMPORTANT

Fill in the right length of the cable, when unknown perform TDR-analysis (e.g. Teleflex) on forehand to measure the length of the cable.

Also when joints positions are unknown, locate them with TDR-analysis (e.g. Teleflex) and enter them in data mask.

Partial discharge diagnosis - OWTS measurement

Measurement

PD selection
- PD max [pC]
- PD [pC]

Frequency

Capacitance

Dielectric losses

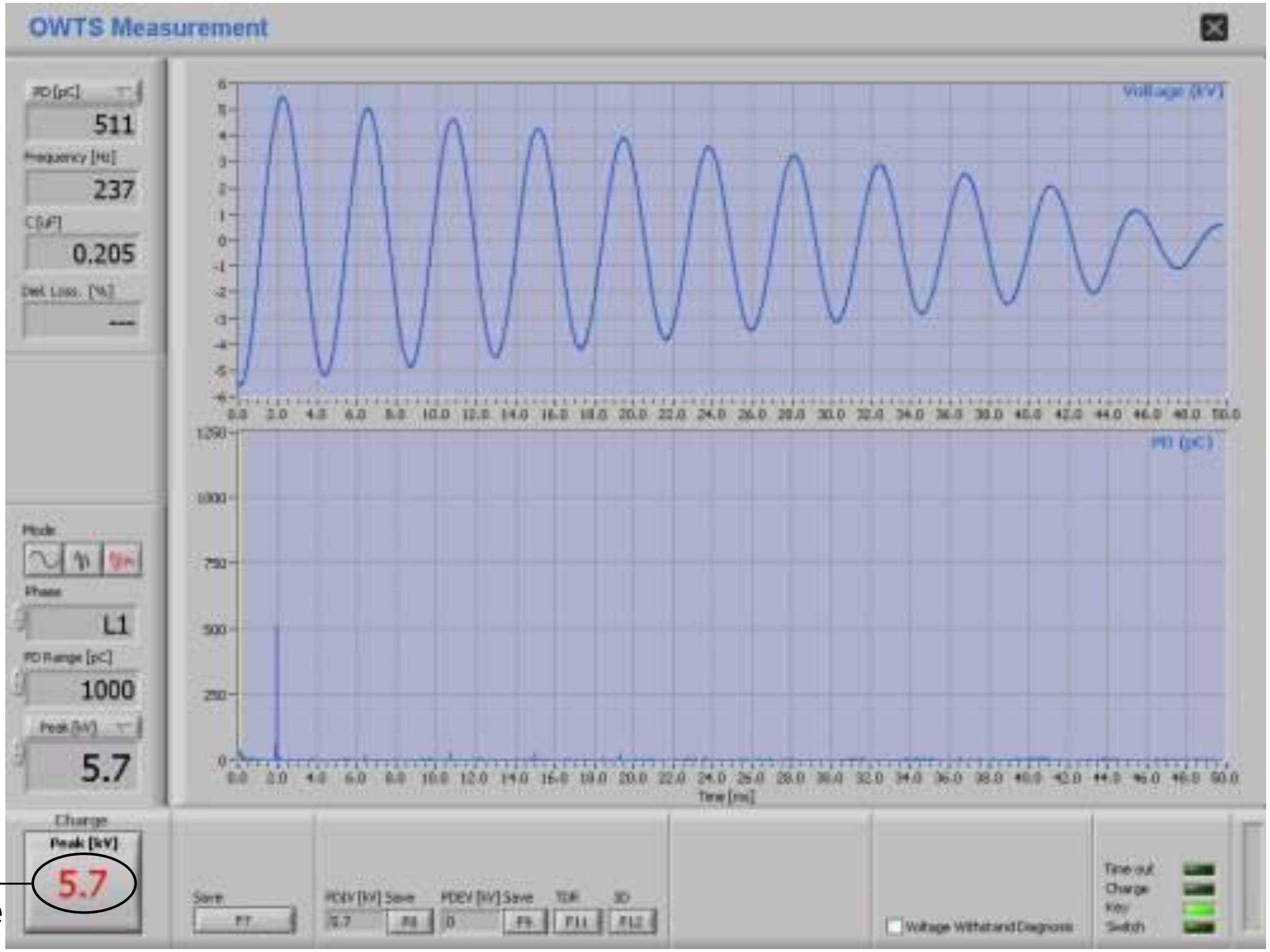
DAC selection mode
1, 8 or 16 AC cycles

Phase selection

PD Range selection

Voltage selection
- Peak [kV]
- RMS [kV]
- U_0 [times]

Applied voltage



Partial discharge diagnosis - OWTS measurement

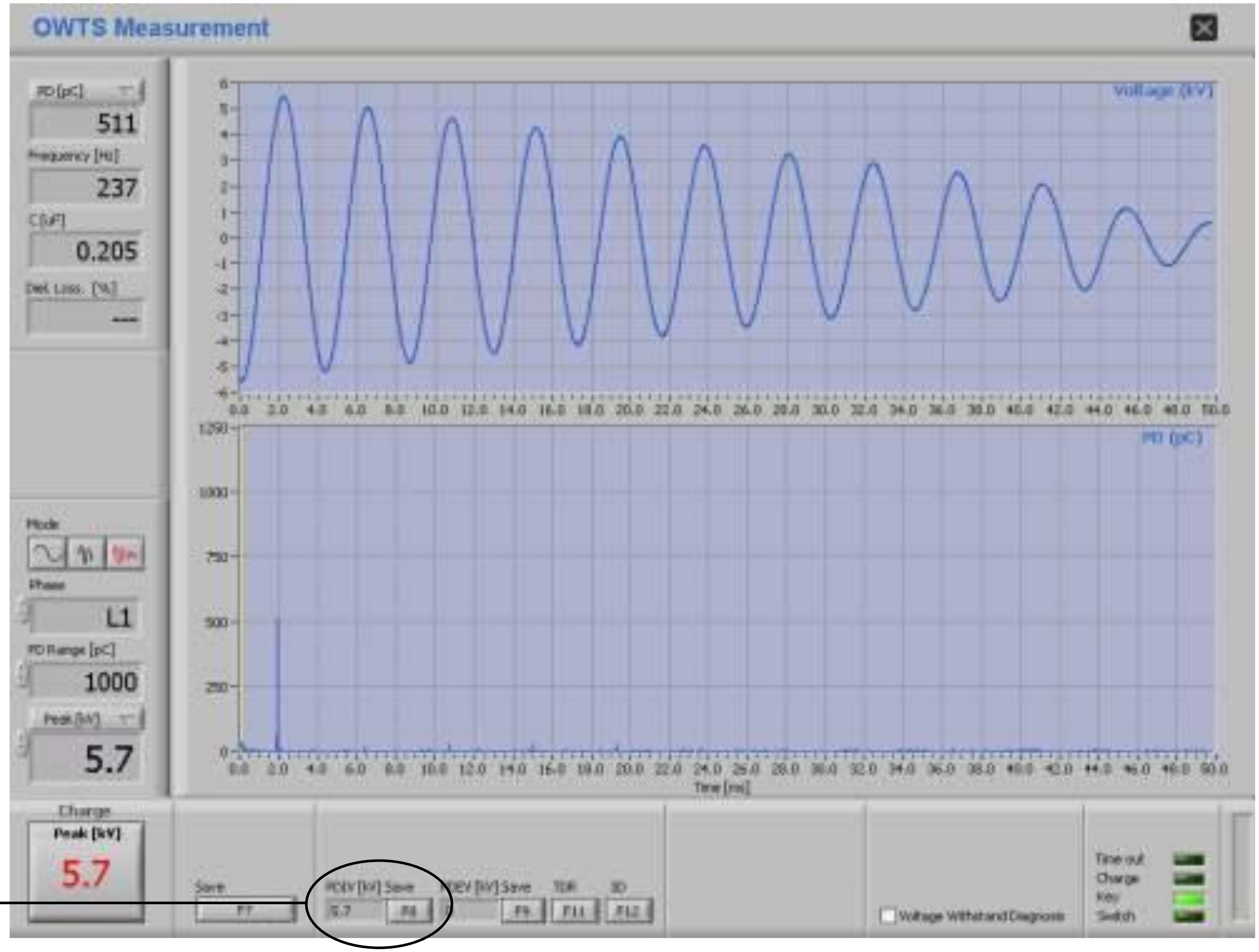
Measurement

Determination of PDIV

-Stepwise increase voltage until first discharges appear.

-Perform three shots, if discharge reappears 2 out of 3 times save as PDIV *F8*

-If the discharges do not appear anymore, increase voltage and repeat former step.



Save as “PDIV”

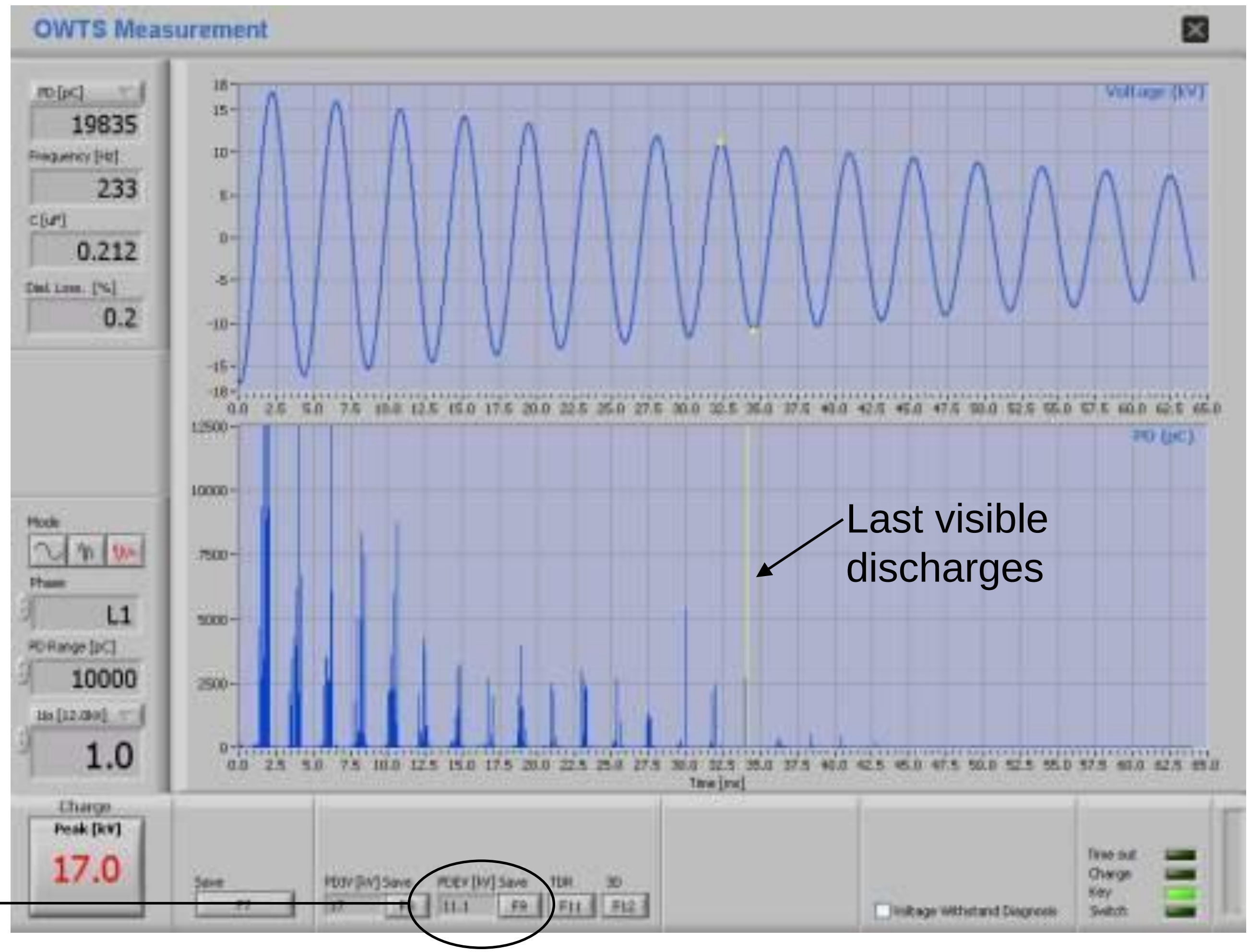
Partial discharge diagnosis - OWTS measurement

Measurement

Determination of PDEV

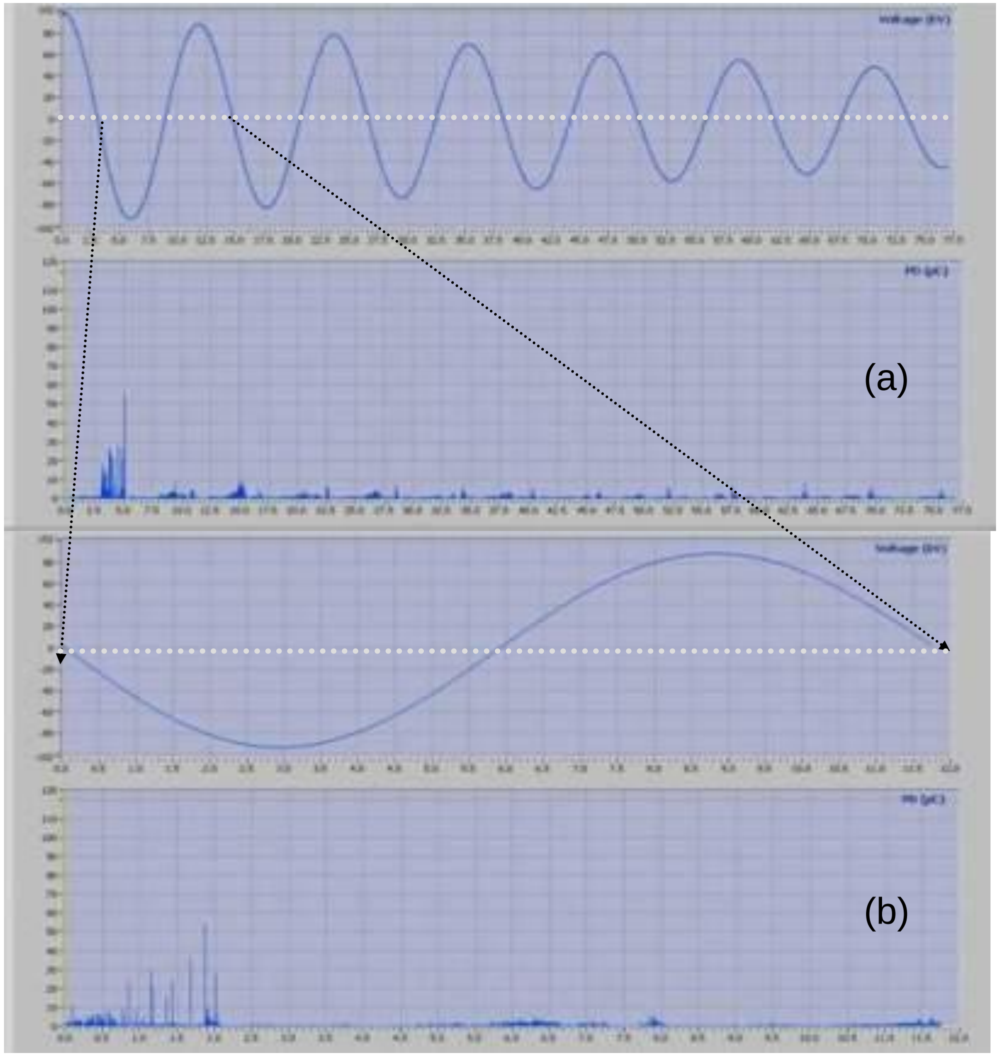
-Preferably perform a shot at $1.7U_0$ and DAC mode at 16 AC cycles.

-Move yellow line towards the last visible discharges and save as PDEV *F9.*



Save as “PDEV”

Advanced features OWTS M series



DAC display mode

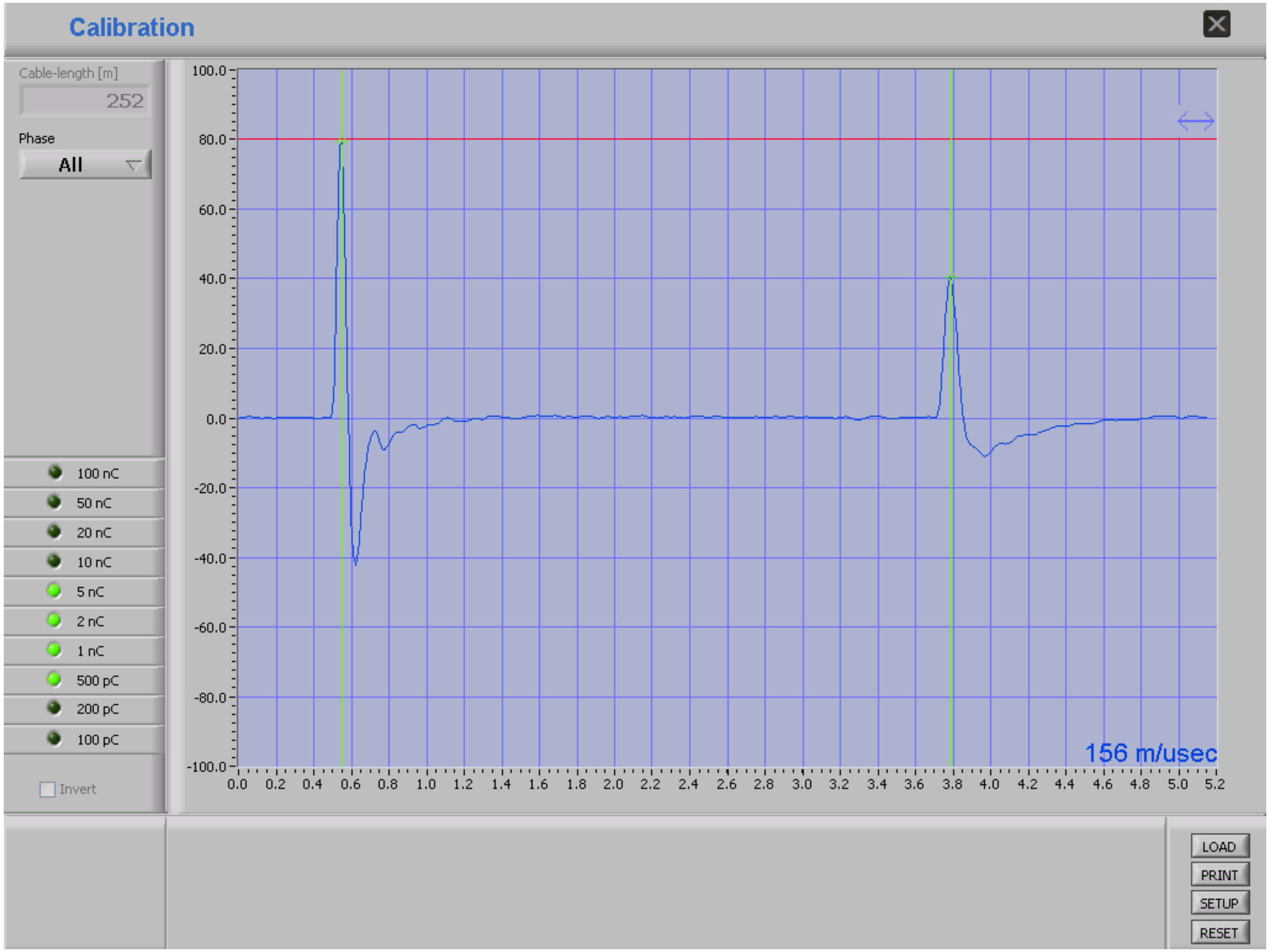
Possible selection between 1 AC cycle,

8 AC cycles and 16 AC cycles.

The 1 AC cycle mode is preferred for PD-pattern recognition

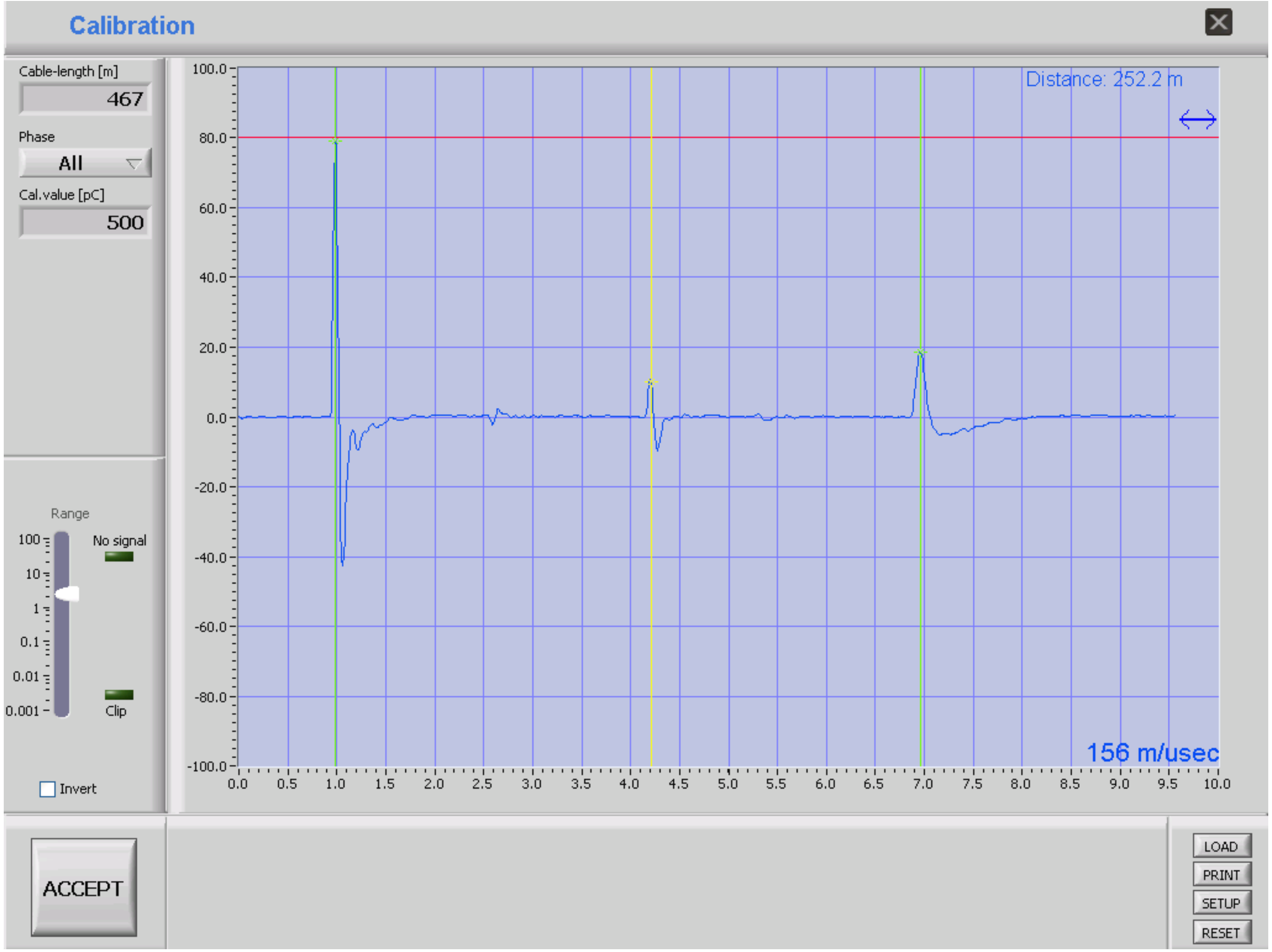
Advanced features OWTS M series

Fully automated calibration function

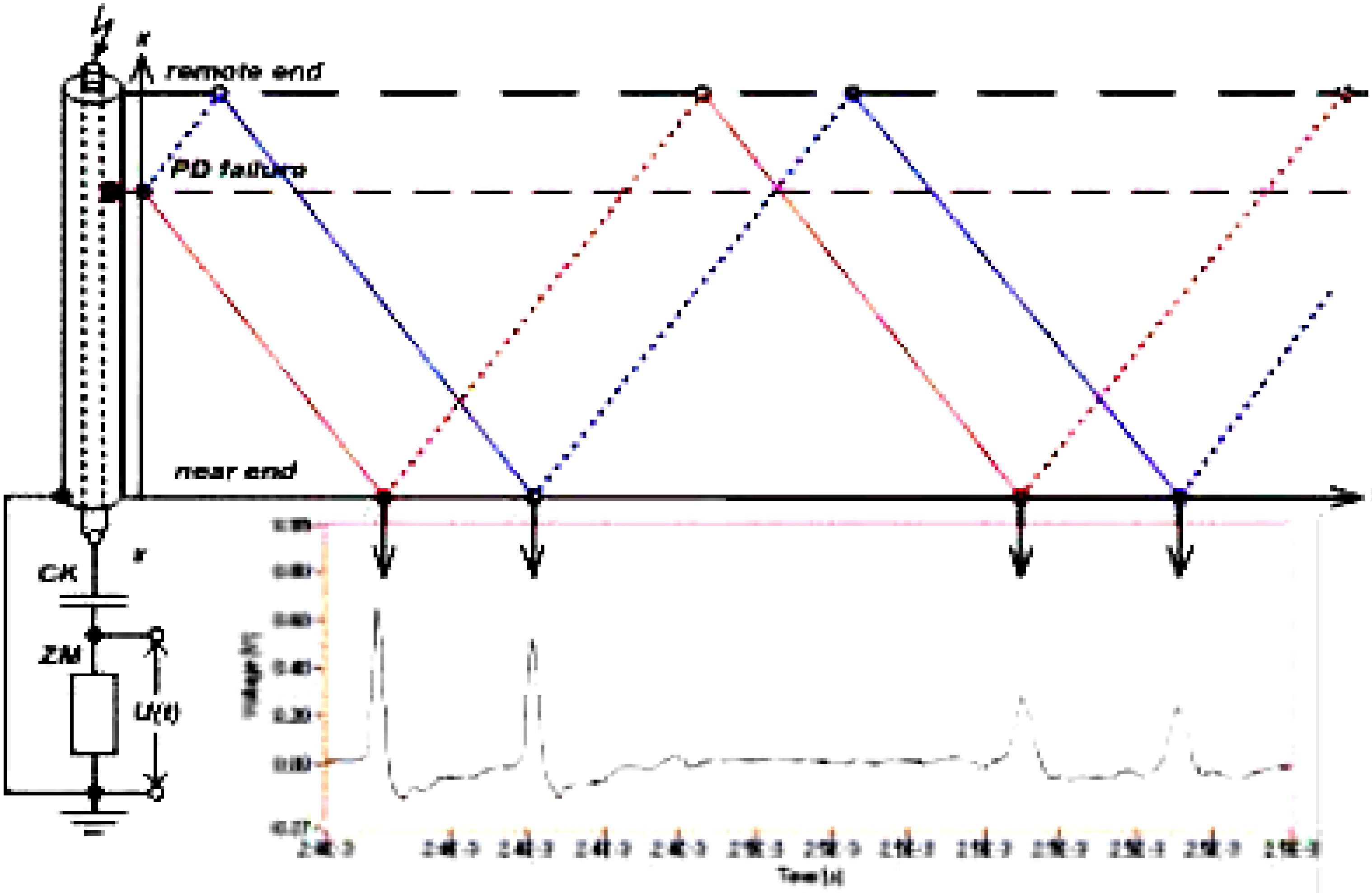


Advanced features OWTS M series

Localisation of joints
in calibration mode



Partial discharge diagnosis – Travelling wave principle



Partial discharge diagnosis - OWTS measurement

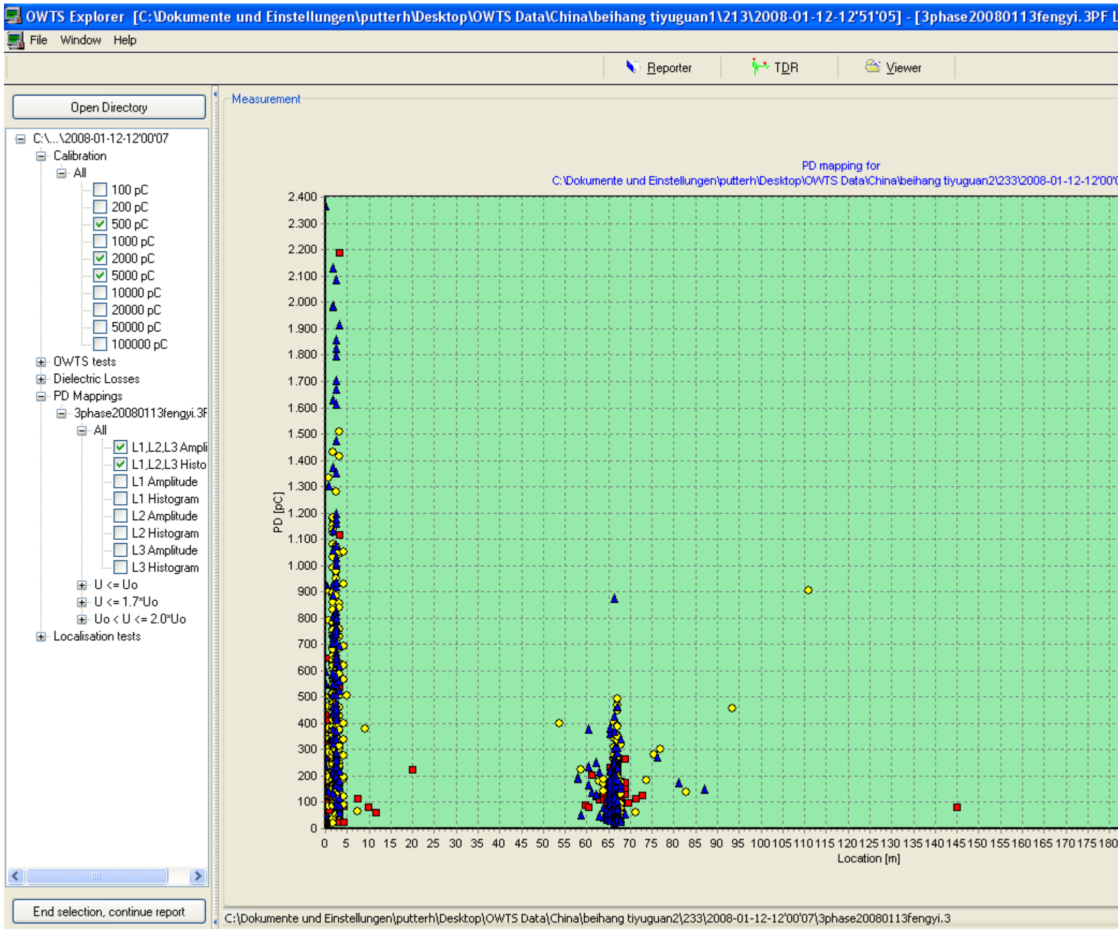
Explorer

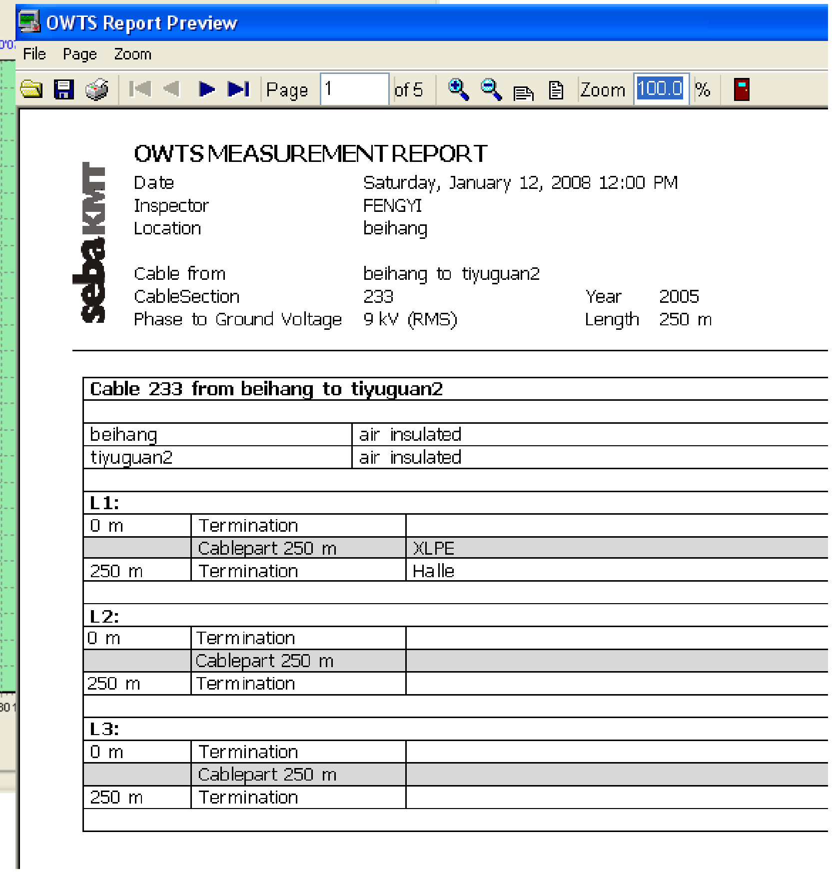
TDR analysis performed with Band-Pass filter

TDR analysis is simply matching the original pulse with the reflected pulse.

Partial discharge diagnosis - OWTS measurement

Explorer





OWTS MEASUREMENT REPORT

Date	Saturday, January 12, 2008 12:00 PM		
Inspector	FENGYI		
Location	beihang		
Cable from	beihang to tiyuguan2		
CableSection	233	Year	2005
Phase to Ground Voltage	9 kV (RMS)	Length	250 m

Cable 233 from beihang to tiyuguan2		
beihang	air insulated	
tiyuguan2	air insulated	
L1:		
0 m	Termination	
	Cablepart 250 m	XLPE
250 m	Termination	Halle
L2:		
0 m	Termination	
	Cablepart 250 m	
250 m	Termination	
L3:		
0 m	Termination	
	Cablepart 250 m	
250 m	Termination	

Generating OWTS measurement report

Partial discharge diagnosis – dielectric loss estimation

The OWTS is also capable of estimate the dielectric losses. The damping of the voltage wave is used to calculate the losses of the resonance circuit.

The internal losses are known and calibrated, the external losses are caused from dielectric losses.

The resolution of the loss measurement is in the range 1 E-3 and is used mainly for dielectric condition assessment of PILC and oil filled paper cables.

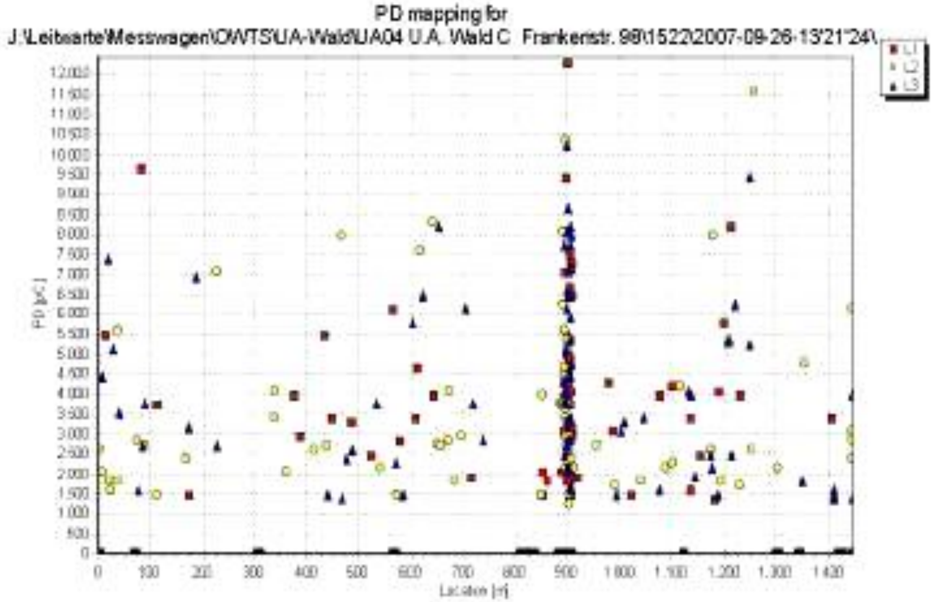
Values are given in percentages, according to the value of the dielectric losses the following distinctions can be made:

Tan delta	Condition of the cable
$0.1 < \tan\delta < 0.9\%$	dry
$0.9\% < \tan\delta < 2\%$	moisture
$\tan\delta > 2\%$	wet

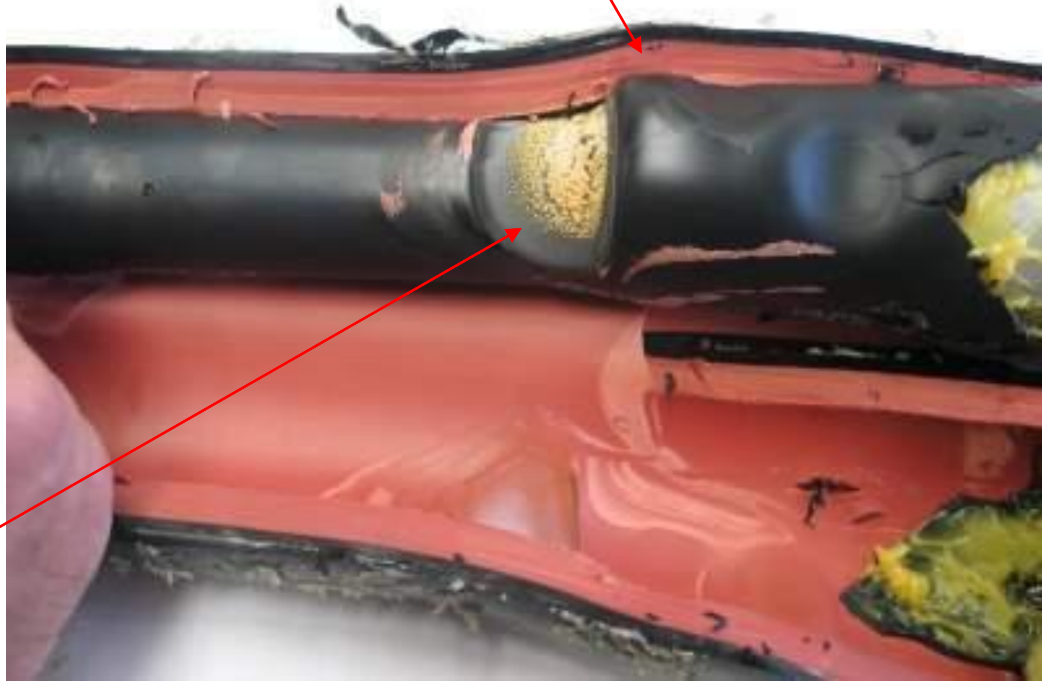
Important is that dielectric losses are strongly depended on the temperature, the higher the temperature the higher the losses will be.

Field results

Example 1



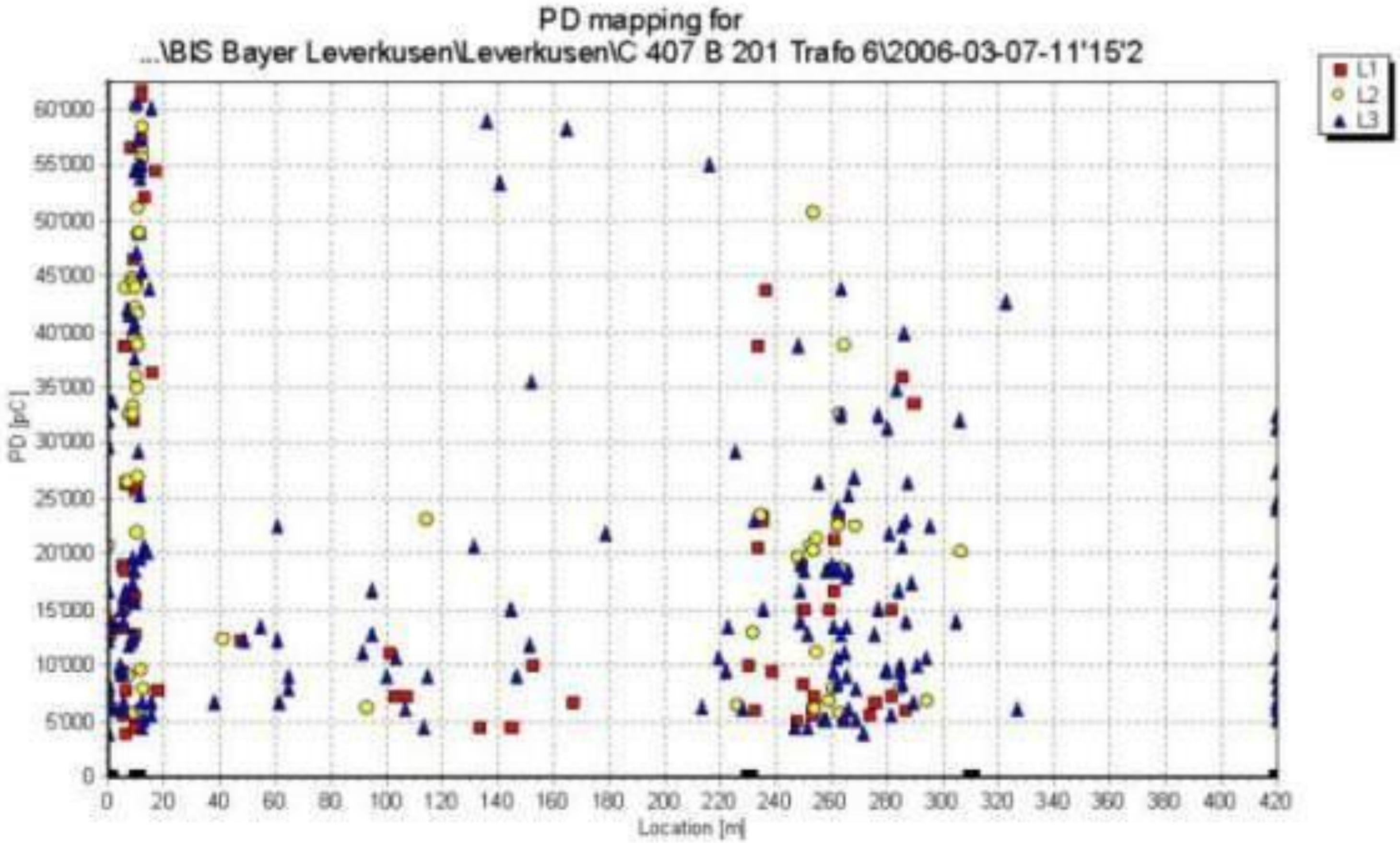
Wrong size bolted connector used.



Highly degraded insulation,
PD-tracks are clearly visible.
PDIV below U_0.

Field results

Example 2



PD in transition joint XLPE/ PILC, PD-level @ 1.7U_0 up to 60.000 pC.

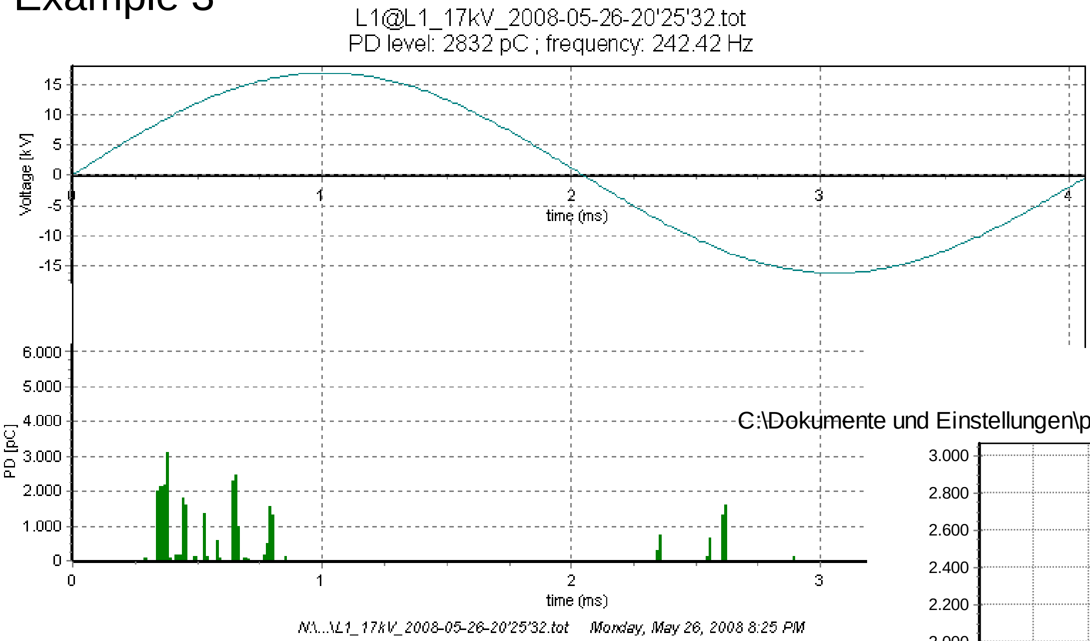
Field results

Example 2

1. Yellow mastic-tape bridges over insulation distance between main conductor connector and insulation shield on PILC side.
2. Uncompleted shrinking of insulation-tube.

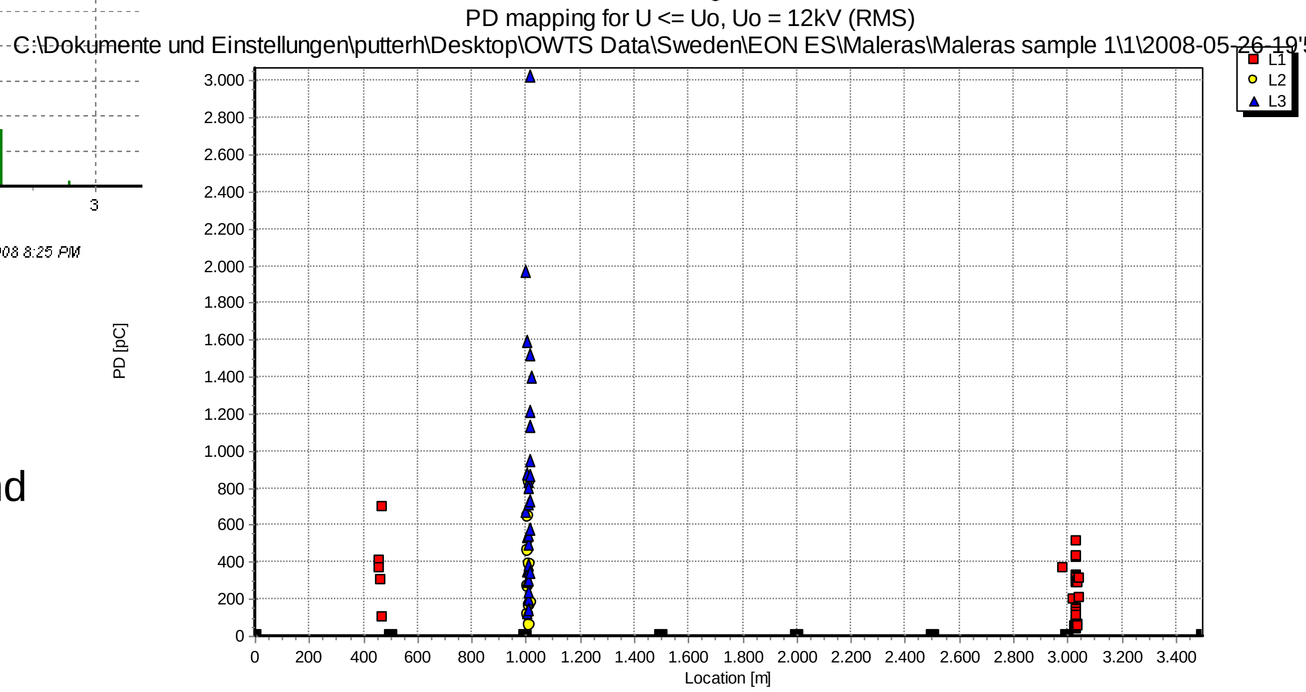
Field results

Example 3



PD-pattern @ U_0

After performing TDR-analysis a PD-mapping is obtained.



PD-mapping @ U_0

- Three weak spots, 500m, 1000m and 3000m

- PDIV @ $0.5U_0$

Field results

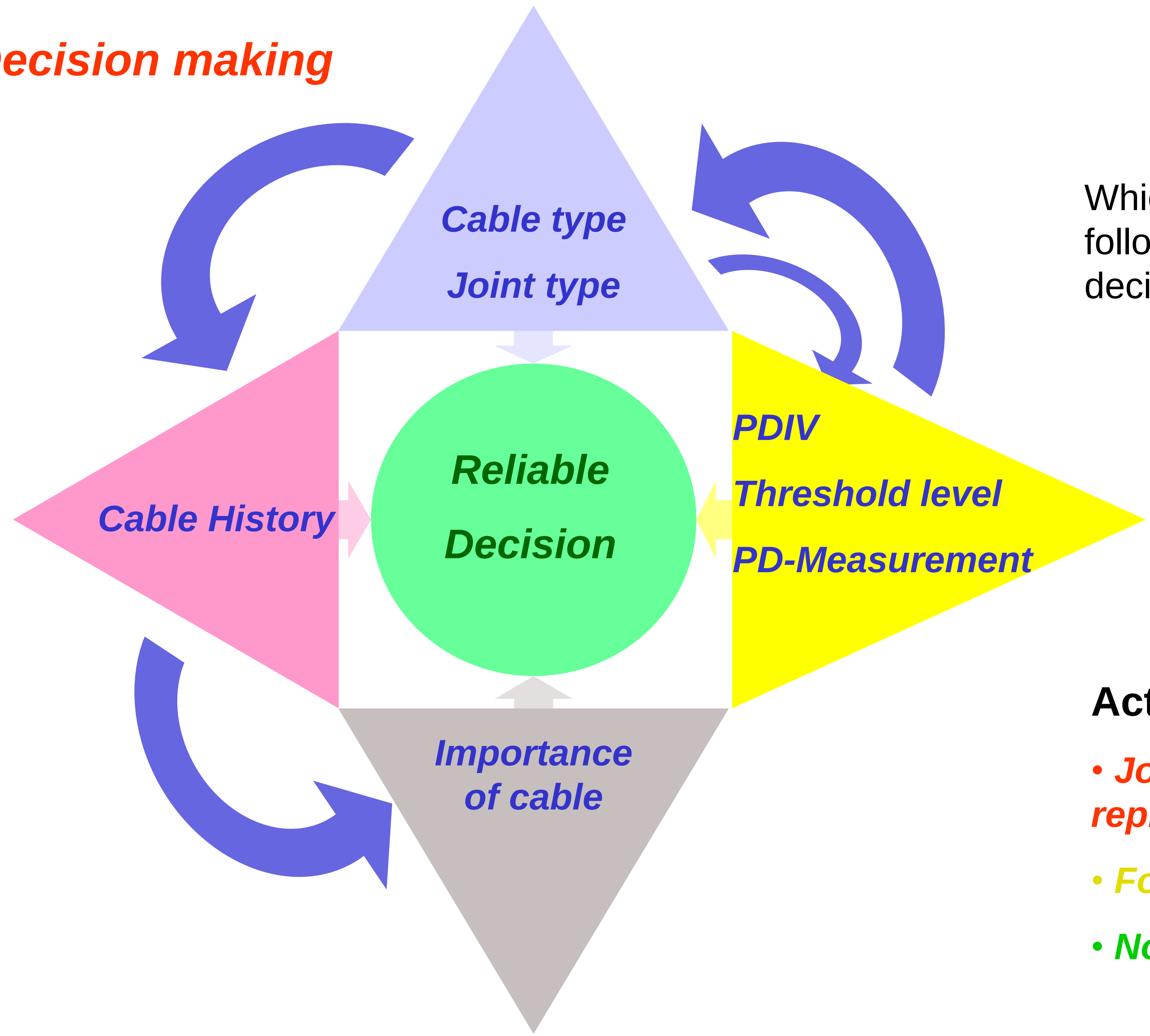
Example 3

Massive PD-tracking caused by bad workmanship:

Bad cut backk of outer semicon, cuts in insulation.

Yellow mastic tape bridges the insulation between connector and ground

Decision making



Which basic rules should be followed to create reliable decision making?

Actions:

- *Joint or cable(section) replacement*
- *Follow trend*
- *No action for next years*

Summary

- To detect and to localize weak-spots in cable insulation or accessories, partial discharges have to be measured and analyzed at voltages up to 1.7 U0.

- To estimate the integral insulation condition of a cable, integral diagnosis has to be performed complementary to local diagnosis.

- Based on field experiences knowledge rules can be determined to support the maintenance decision process.

- To support the knowledge rules, field data has to be transformed into conditioning indexes.

- With help from diagnostics and knowledge rules, the condition of MV-networks can be assessed and decisions regarding repair or replacement can be made.