Partial Discharge On-Site Diagnosis of Distribution Power Cables at Oscillating Voltages

Edward Gulski

Delft University of Technology, The Netherlands
Haefely Test AG, Tettex Instruments Division, Switzerland

Power cable systems

Power cable insulation and PD

(A) 50% of failure in medium voltage power cable networks in related to insulation problems

(B) Insulation problems have different origins:
new cables: joint and termination poor workmanship
cables in service: degradation of cable insulation,
degradation of joints and terminations

(C) It is known from the past, that partial discharges are very sensitive diagnostic method for presence of insulation problems.

(D) The presence of partial discharges can be described by PD inception/extinction voltage, PD amplitude and PD phase-resolved patterns.

Power cables insulation defects

Distribution power cables diagnostic tool requirements

1. Non-destructive for the cable insulation and uses for service conditions representative AC voltage stress

2. To support the interpretation uses number of generally accepted quantities and parameters.

3. Provides distinction between different types of insulation problems.

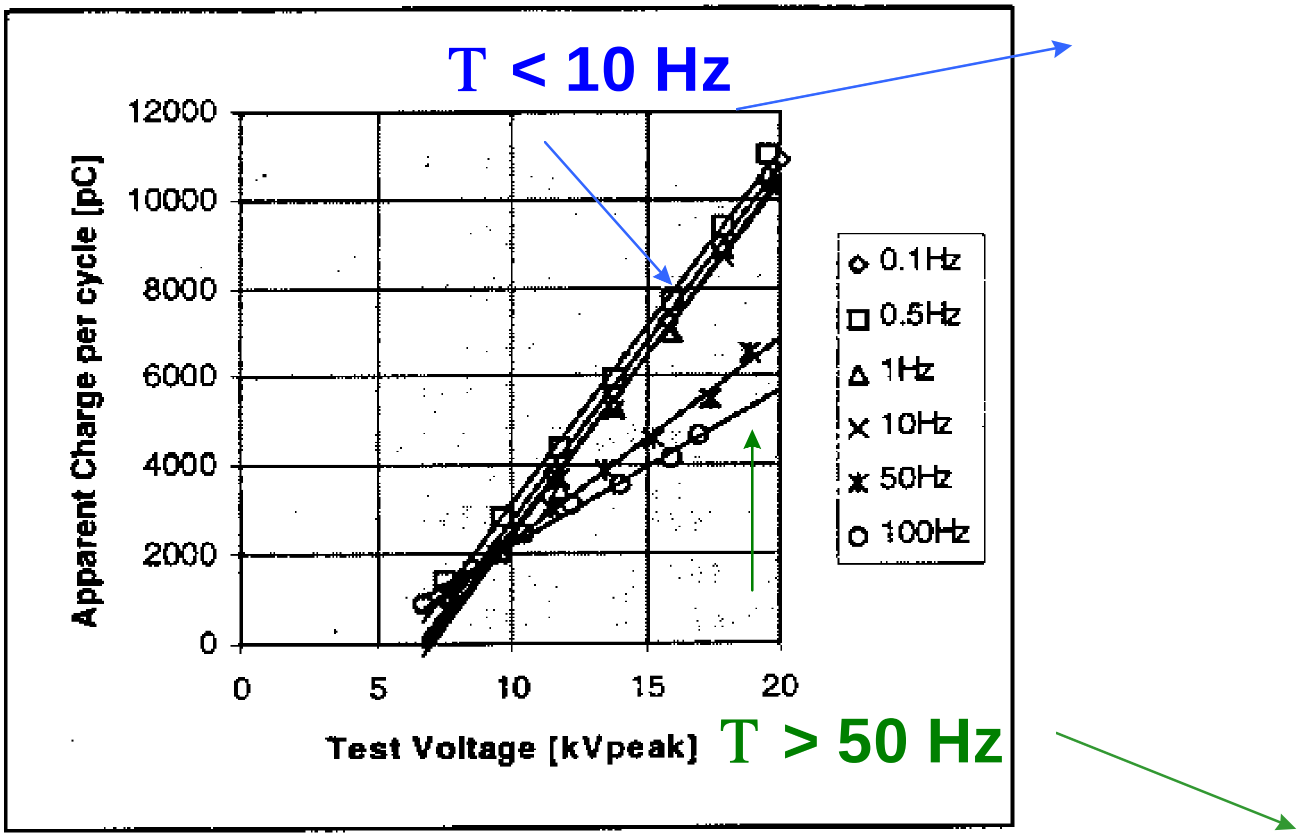
4. Provides indication of the potential fault location.

5. Compact, user friendly solution which can be easily operated under different circumstances.

PD recognition [Cigre, 1969]

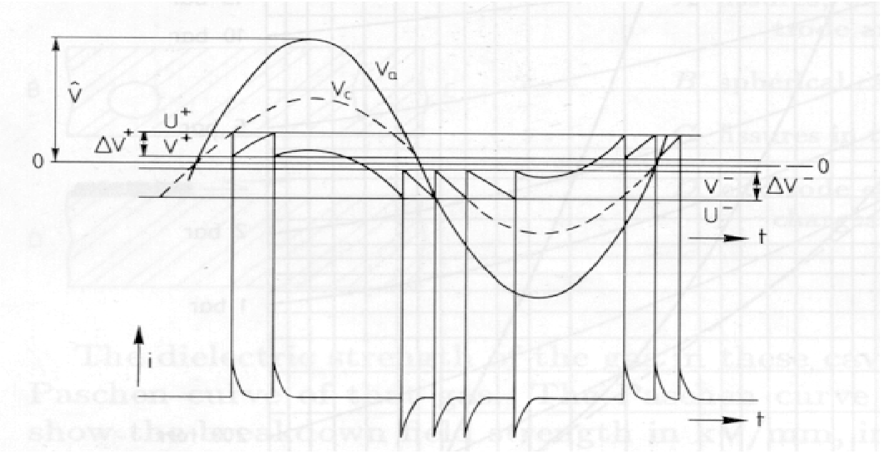
Fundamentals: *Trapped charge and frequency of the AC voltage*

Fundamentals: *PD inception processes in solid insulating materials at different power frequencies (1)*



Lit: [J.T. Holboll, H. Edin, 10th ISH, Montreal, Canada, 1997]

Fundamentals: *PD inception processes in solid insulating materials at different power frequencies (2)*



General assumptions

1. After each PD event the decay time for the surface charge inside a cavity is in the range of few milliseconds [Lit. F. Gutfleisch and L. Niemeyer, IEEE Trans. D&EI, Vol. 2 No. 5, 1995, pp. 729-743].

2. Without remaining charge the time lag for electrons due to natural radiation could be up to hundreds of milliseconds.

3. Within one voltage polarity the presence of surface charges inside a cavity decreases the number of PD events.

4. The PD magnitude of a PD event is proportional with the PDIV.

5. The presence of surface charge inside the cavity results in lower PDIV after polarity reversal of the voltage stresses.

Fundamentals: *PD inception processes in solid insulating materials at different power frequencies (3)*

	AC power frequency cycle < 20ms	**VLF power frequency cycle > 100ms**
Cavity surface charge decay time > time distance between particular PD events	YES	NO
Influence of surface charge presence during inception of a PD event	YES	NO
PDIV; voltage across defect at PD inception after voltage polarity change	Lower as compared to VLF	Higher as compared to AC
Number of PD events during power frequency cycle	Lower as compared to VLF	Higher as compared to AC
PD magnitude after voltage polarity change	Lower as compared to VLF	Higher as compared to AC
Dispersion in the PD process	NO, due to presence of initiating electrons	YES, due to unknown time before initiating electrons appears

PD diagnostics using AC and OWTS methods

Oscillating Wave Test System: *schematic*

Oscillating Wave Test System: *principles*

Oscillating Wave Test System: *OWTS®*

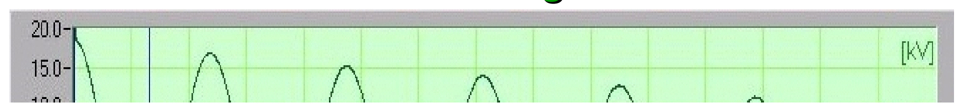
PD calibration: ***IEC60270, HF***

Oscillating Voltage Wave

PDIV, PD magnitude, PD pattern, PDEV

Oscillating Voltage Wave and PD occurrences

Example of typical PD pattern as observed for discharges in liquid insulation, e.g. surface discharges in oil



Example of typical PD pattern as observed for discharges in solid insulation, e.g. cavities

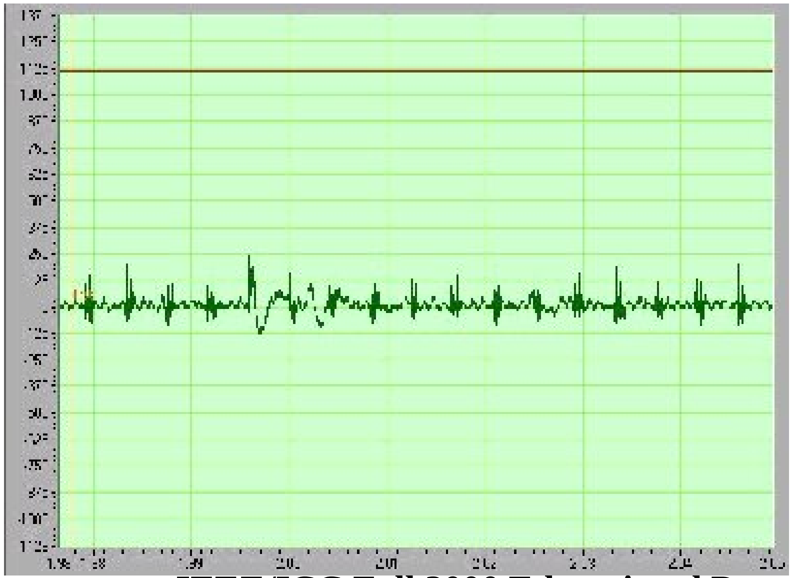
PD inception and extinction voltages versus service voltage

TDR

PD occurrence and TDR

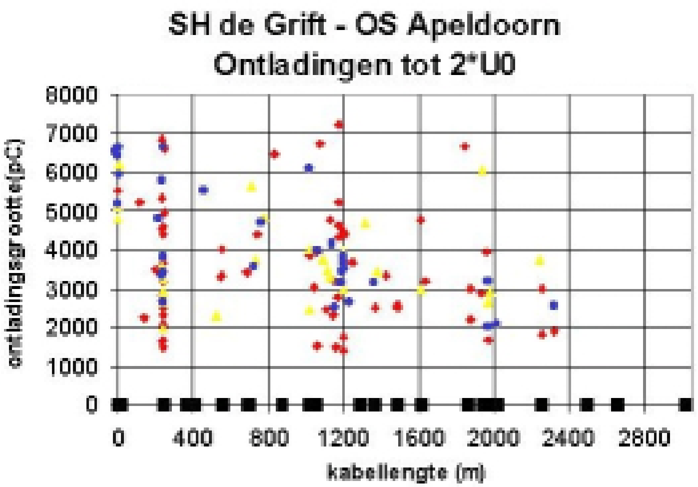
Distinction between disturbances and PD

PD pattern level



PD pulse level

PD quantities and parameters



50 Hz comparison (1)

Mounting faults in XLPE cable accessories

DEFECT	ac 50 Hz	OWTS 1066 Hz
Bad contact between semicon and the stress cone	2.6 kV → 25 pC	3 kV → 30 pC
Bad adjustment of the stress cone	15 kV → 20 pC	13 kV → 40 pC
Internal cavities	13 kV → 150 pC	14 kV →70 pC

50 kV 3235 m long PILC cable

Voltage	ac 50 Hz	OWTS 220 Hz
12 kV phase L1	450 pC	500 pC
12 kV phase L2	370 pC	450 pC
12 kV phase L1	500 pC	650 pC
16 kV phase L1	850 pC	950 pC
16 kV phase L2	700 pC	850 pC
16 kV phase L1	770 pC	900 pC

50 Hz comparison (2)

50 Hz comparison (3)

OWTS different frequencies comparison (1)

PD analysis service aged PILC cables (1)

PD occurrence at different voltage levels measured on 4 short length PILC power cables.

Cable 1 230 m	L1 (pC)	L2 (pC)	L3 (pC)
U0	-	-	-
1.5 U0	1700	1200	-
2 U0	3000	3000	

PDIV $> U_0$
PD at $2U_0$ ~ 3 nC
Status: o.k.

Cable 2 260 m	L1 (pC)	L2 (pC)	L3 (pC)
0.5 U0	3200	3850	3100
U0	3900	4200	4300
1.5 U0	4200	4700	5100
2 U0	4800	4700	5900

PDIV $< U_0$
PD at $2U_0$ ~ 5 nC
Status: ??

Cable 3 260 m	L1 (pC)	L2 (pC)	L3 (pC)
U0	-	-	-
1.5 U0	-	1250	-
2 U0	-	2000	-

PDIV $> U_0$
PD at $2U_0$ ~ 2 nC
Status: o.k.

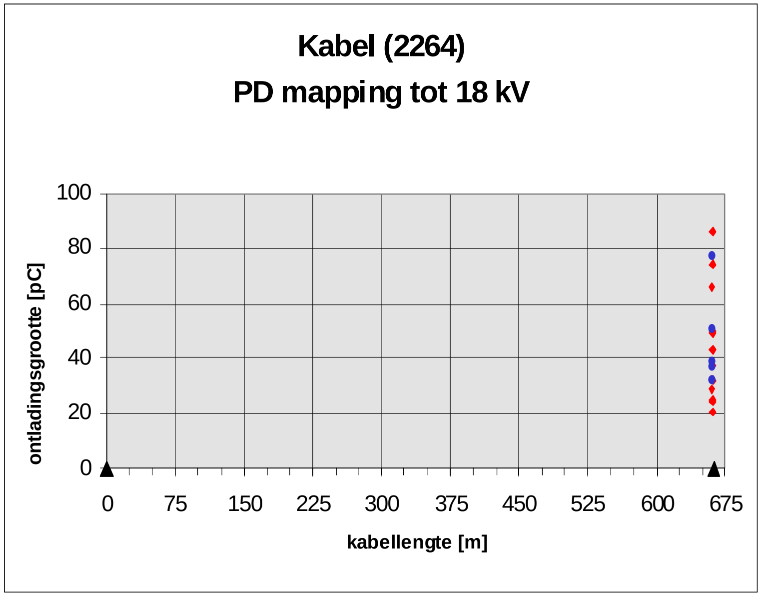
Cable 4 30 m	L1 (pC)	L2 (pC)	L3 (pC)
U0	-	-	-
1.5 U0	-	-	-
2 U0	3200	2700	-

PDIV $> 1.5U_0$
PD at $2U_0$ ~ 3 nC
Status: o.k.

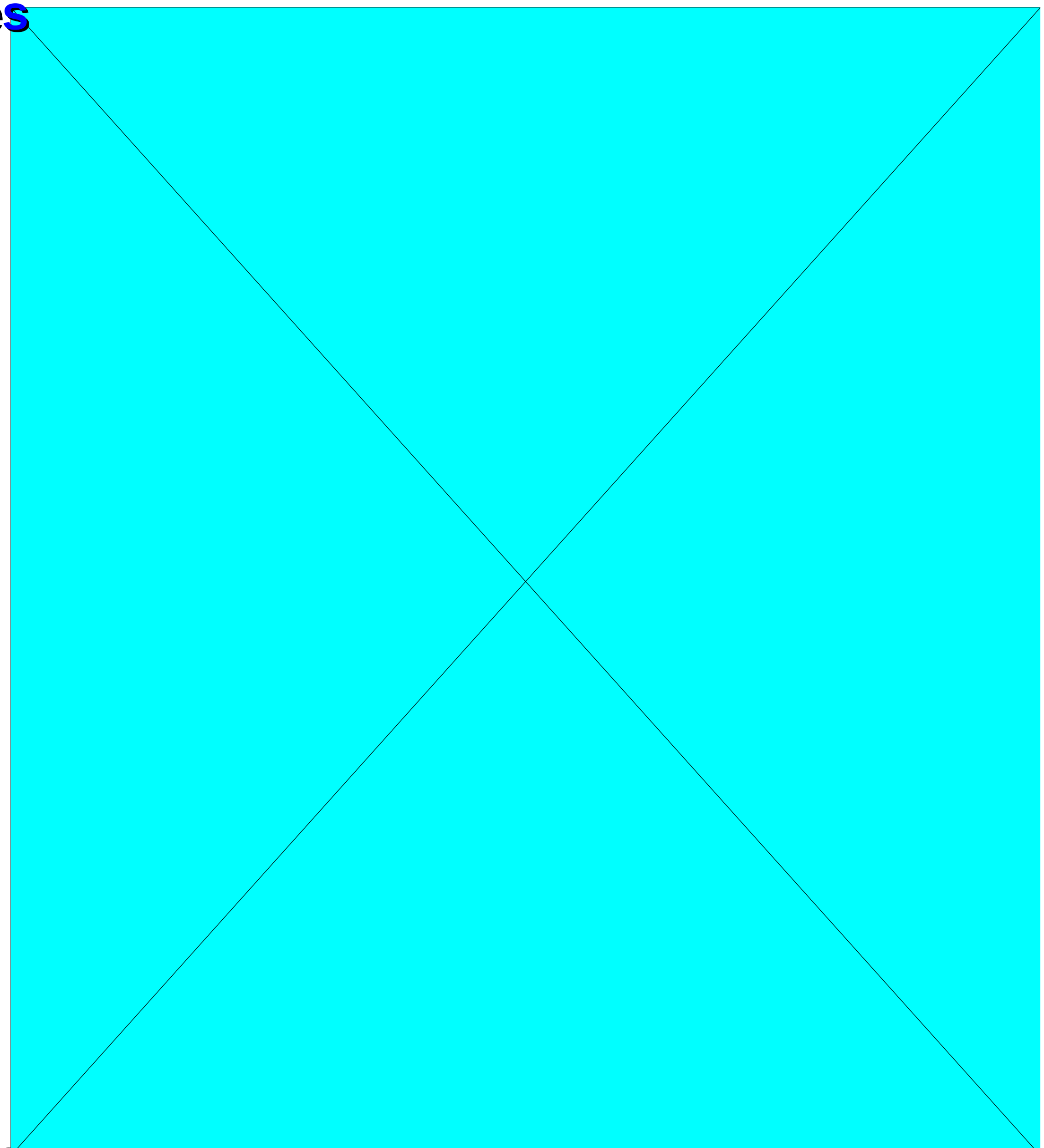
Analysis of service aged PILC cables (2)

After-laying test XLPE cables

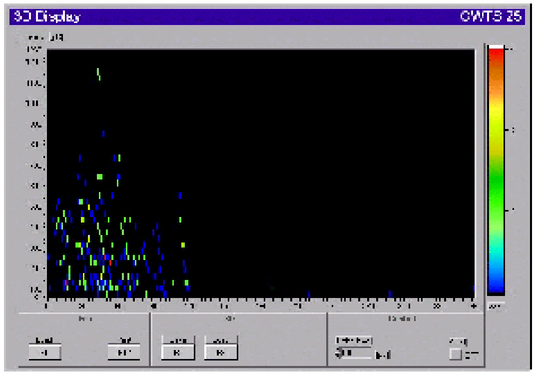
Cable: 6 kV XLPE
Length: 662m

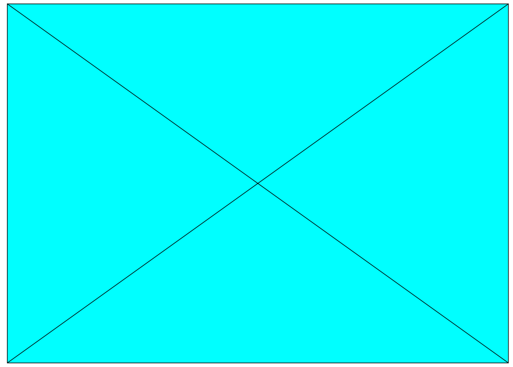


PD in a large flat cavity
in the termination



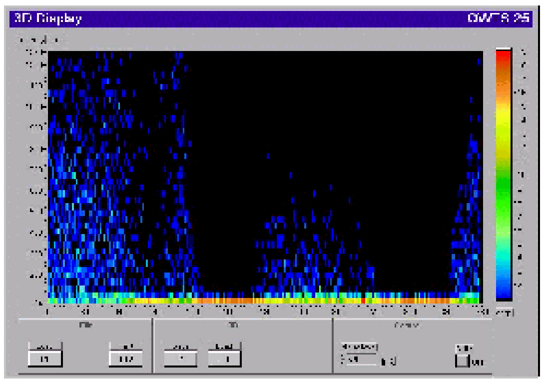
PD analysis and location of multiple discharge sites

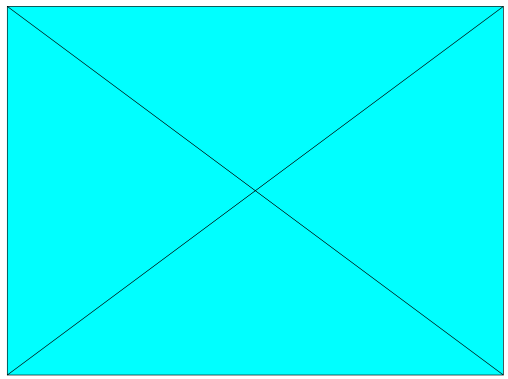




Cable: 6 kV XLPE
Length: 644m

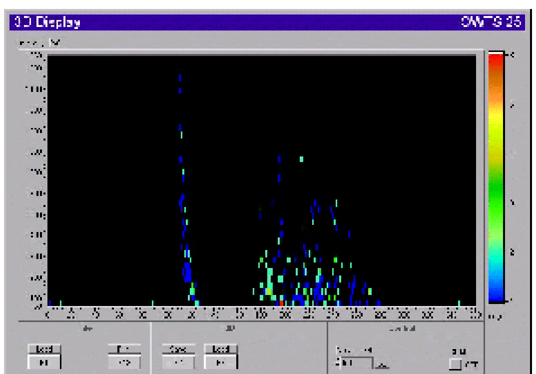
Test voltage: *6 kV*
PD location: 1) *remote cable termination*

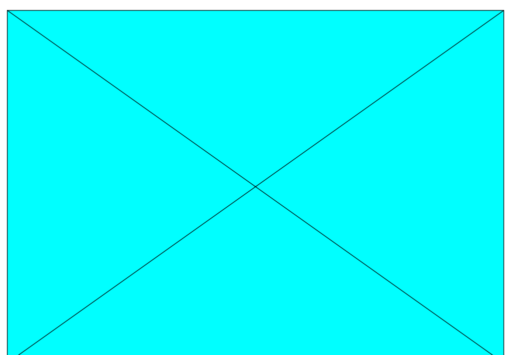




Test voltage: *12 kV*
PD location: 1) *remote cable termination*

2) cable insulation at 208m site





Test voltage: *12 kV*
PD location: 1) *cable insulation at 208m site*

APPLICATIONS

1) After-laying test of new cables

2) After-repair testing of cables

3) PD diagnosis of existing cables

DIAGNOSIS

1) For different cable systems
systematic collection of PDIV/PDEV, magnitudes, intensity, pattern, mappings

2) Application for new cables: (a) as after-laying tests, (b) getting starting conditions for CBM

3) Application for service aged cables: depending on insulation type analysis of defects induced degradation --> interpretation rules for CBM