EMPIR EURAMET Metrology for Future Energy Transmission

19ENG02 FutureEnergy

WP4: Metrology for HVDC grid condition monitoring

4.1 Validation of the PD procedure for qualifying PD analysers used for DC testing in the 1 - 30 MHz range (FFII)

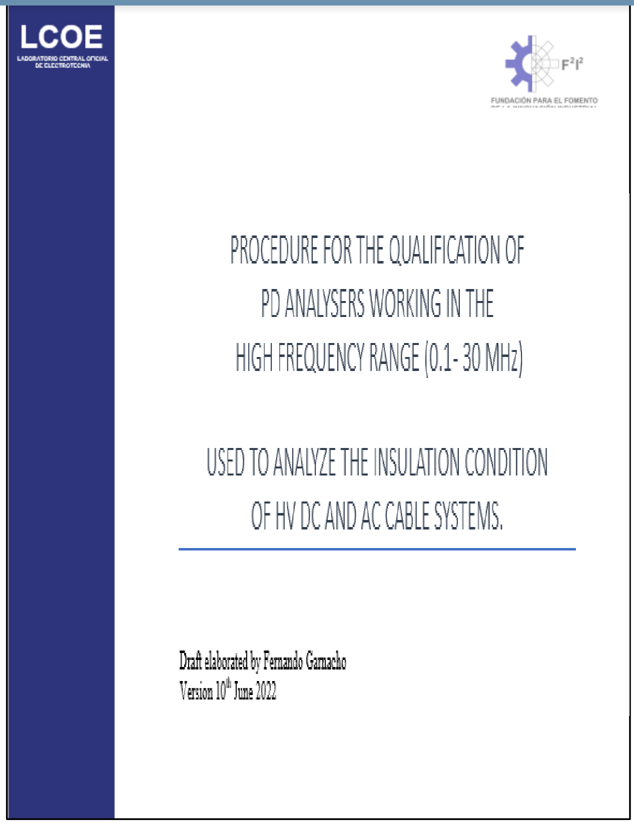
4.2 Procedure for charge evaluation in HVDC GIS using magnetic sensors measuring in the 30 - 300 MHz range (TUDelft)

F²I² LCOE · TU Delft · RI.SE · Tampere University · Universidad Politécnica de Madrid · DIAEL · BlueBOX technology · SuperGrid Institute

Workshop May, 24

Metrology for FutureEnergy Transmission

4.1 Validation of the PD procedure for qualifying PD analysers used for DC testing in the 1 - 30 MHz range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PROCEDURE FOR THE QUALIFICATION OF
PD ANALYSERS WORKING IN THE
HIGH FREQUENCY RANGE (0.1- 30 MHz)

USED TO ANALYZE THE INSULATION CONDITION
OF HV DC AND AC CABLE SYSTEMS.

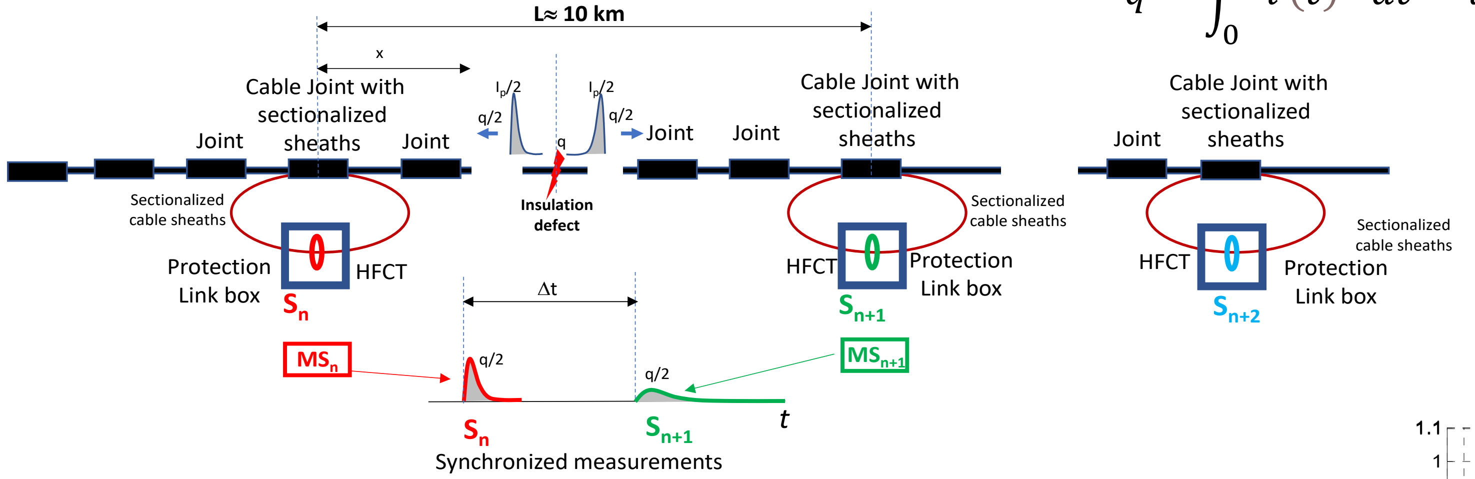
Draft elaborated by Fernando Garnacho
Version 10th June 2022

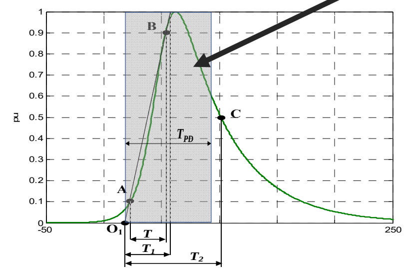
Synhtetic PD Calibrator

Why is the charge quantity important for PD monitoring in HVDC Cable Systems ?

PD Monitoring in HVDC Cable systems

$$q = \int_0^{\infty} i(t) \cdot dt = i_{peak} \cdot \int_0^{\infty} i_{pu}(t) \cdot dt = i_{peak} \cdot T_{PD}$$

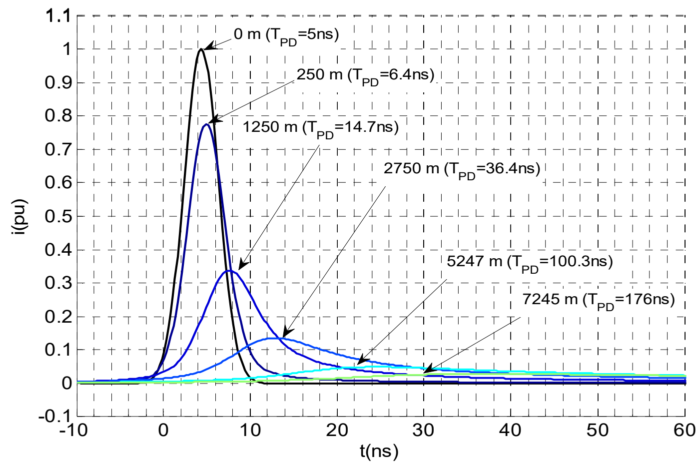




$$I_x(\omega) = I_0(\omega) \cdot e^{-\gamma(\omega)\cdot x} \qquad \gamma(\omega) = \sqrt{(r + j\cdot\omega\cdot l} \cdot \sqrt{(g + j\cdot\omega\cdot c}$$

$$\underline{q_x = I_x(0)} = I_o(0) \cdot e^{-(0)\cdot x} = q_o \cdot e^{-\sqrt{r\cdot g}\cdot x}$$

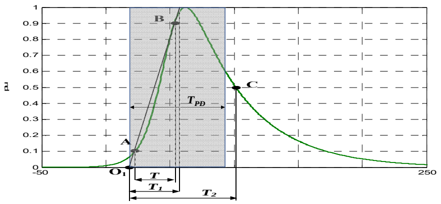
$$\boldsymbol{q_{10km} = q_o \cdot e^{-0.0039} = 0.996 \cdot q_o}$$

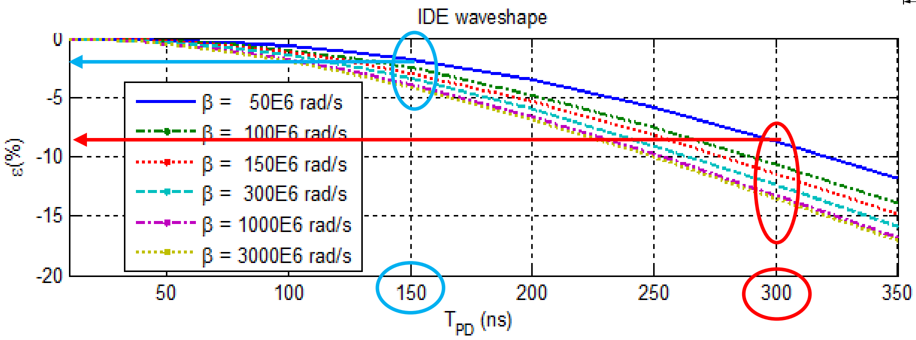


What is the limitation of the IEC 60270

T_{PD}=300 ns -> $Error_{min}$ ~ 8% < 10%

T_{PD}=150 ns -> $Error_{min}$ ~ 3% < 10%





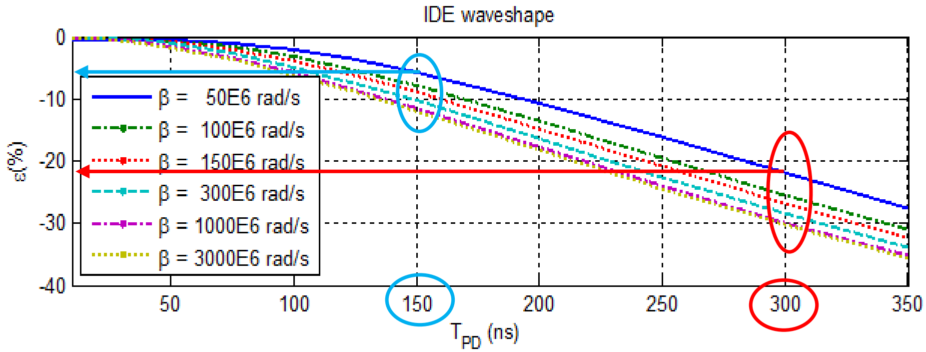
Current IEC 60270 Standard

$30\ \text{kHz} \le f_1 \le 100\ \text{kHz};$
$f_2 \le 500\ \text{kHz};$
$100\ \text{kHz} \le \Delta f \le 400\ \text{kHz}$

High Noise influence

T_{PD}=300 ns -> $Error_{min}$ ~ 22% > 10%

T_{PD}=150 ns -> $Error_{min}$ ~ 5% < 10%



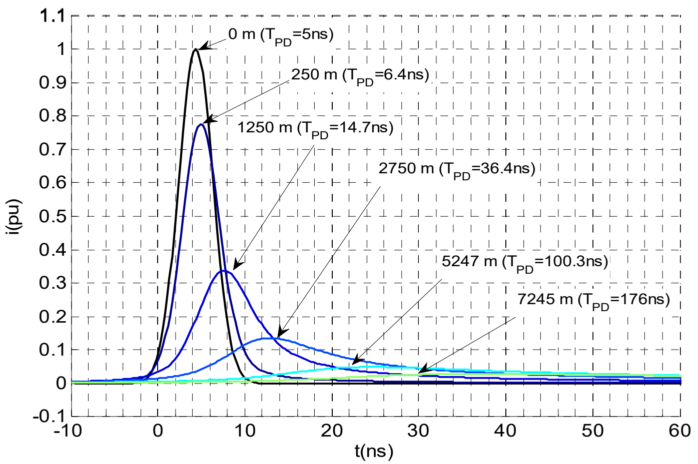
New IEC 60270 Standard

$30\ \text{kHz} \le f_1 \le 100\ \text{kHz};$
$f_2 \le 1\ \text{MHz};$
$100\ \text{kHz} \le \Delta f \le 900\ \text{kHz}.$

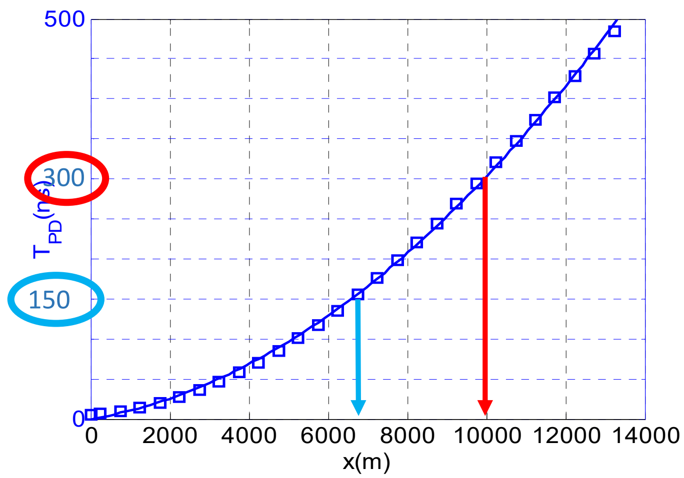
Future IEC 60270 for PD measurements of PD pulses with T_{PD}> 150 ns is not a good approach

What are the differences between HVAC and HVDC cable systems in relation to PD Pulse Width (T_{PD})?

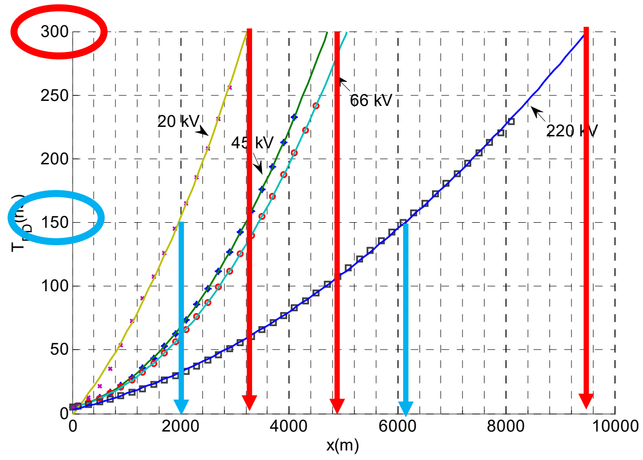
HVDC Cable Systems 320 kV



HVDC Cable System 320 kV



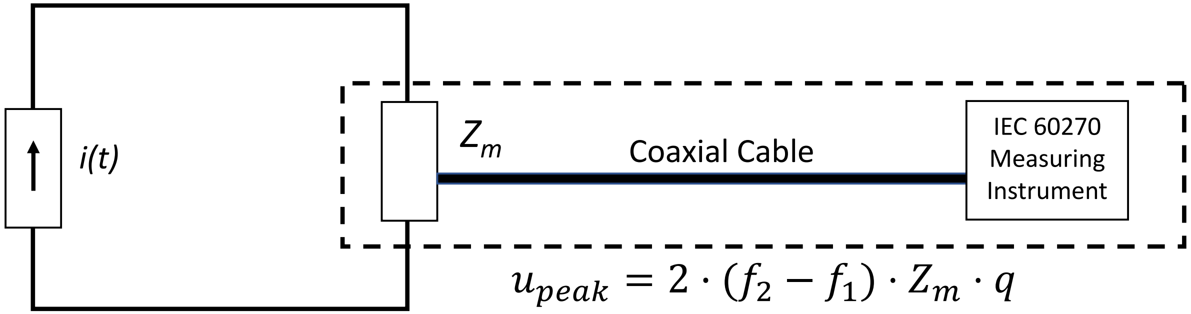
HVAC Cable Systems 20 kV – 220 kV



T_{PD}> 150 ns for HVDC are expected

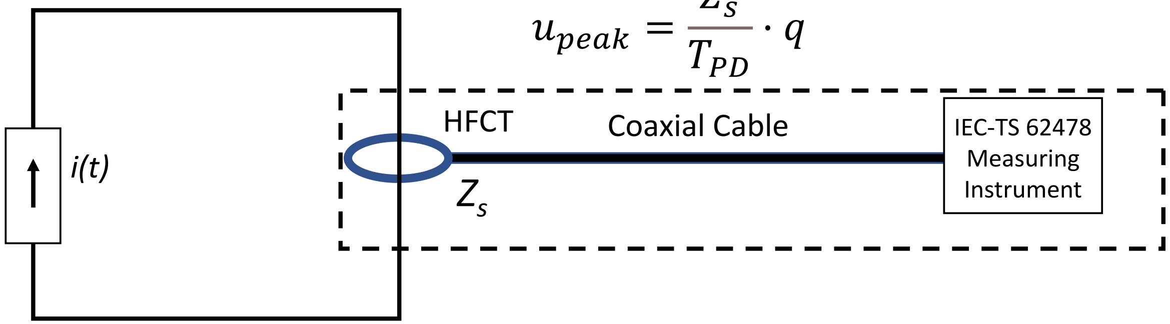
PD for HVDC Grids: Using HFCT sensors + i(t) integration

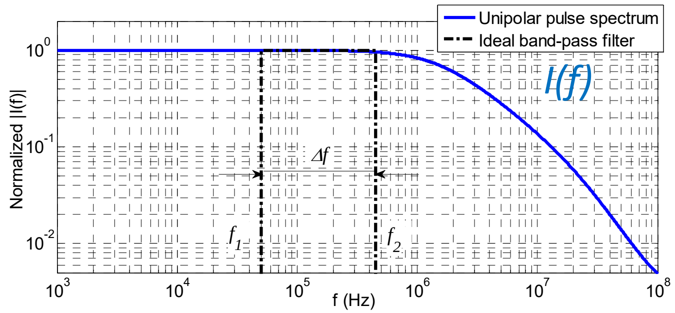
PD Measuring Systems approaches



$$u_{peak} = 2 \cdot (f_2 - f_1) \cdot Z_m \cdot q$$

$$u_{peak} = \frac{Z_s}{T_{PD}} \cdot q$$

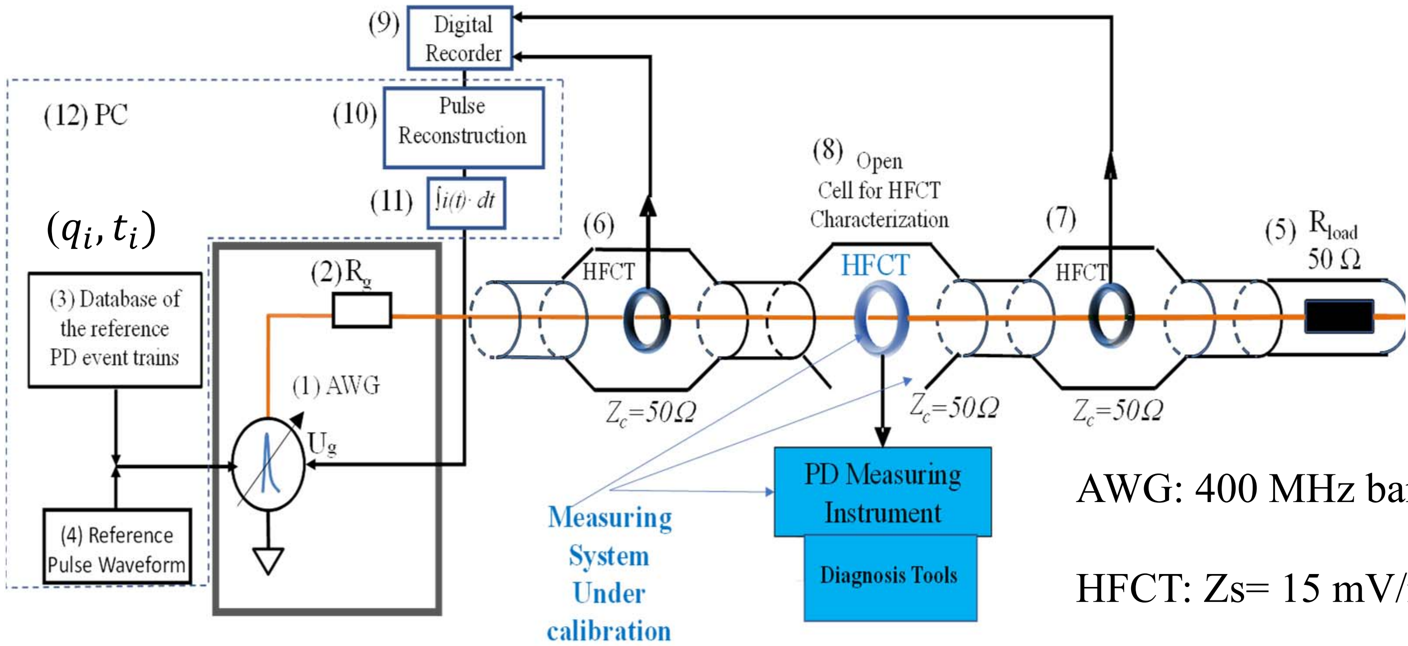


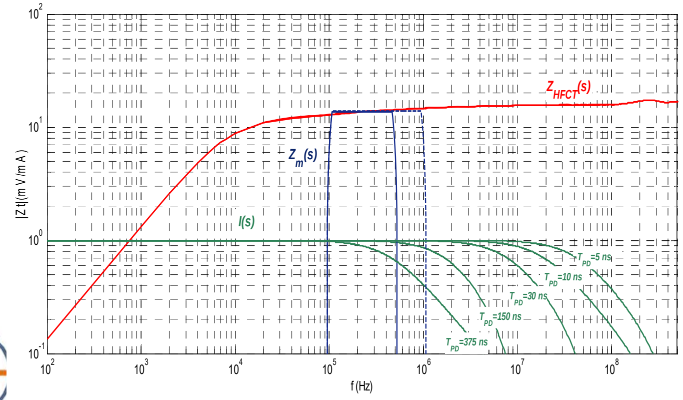


$$q(t) = \int_0^t i(t) \cdot d\tau$$

$$q_\infty = \int_0^\infty i(t) \cdot d\tau$$

PD calibrator electric circuit





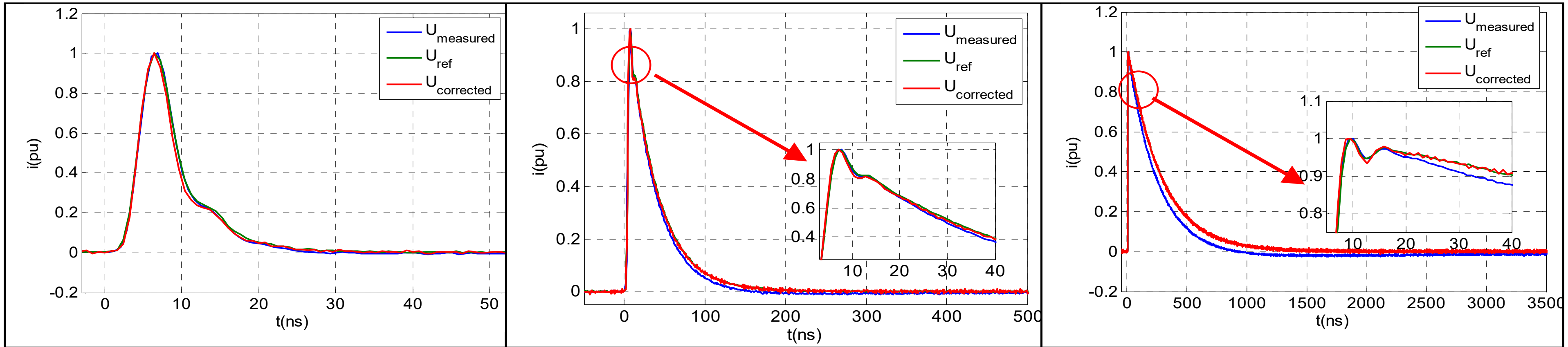
AWG: 400 MHz bandwidth, 1.25 Giga-Samples/s and 50 Ω

HFCT: Zs= 15 mV/mA; 30 kHz – 500 kHz

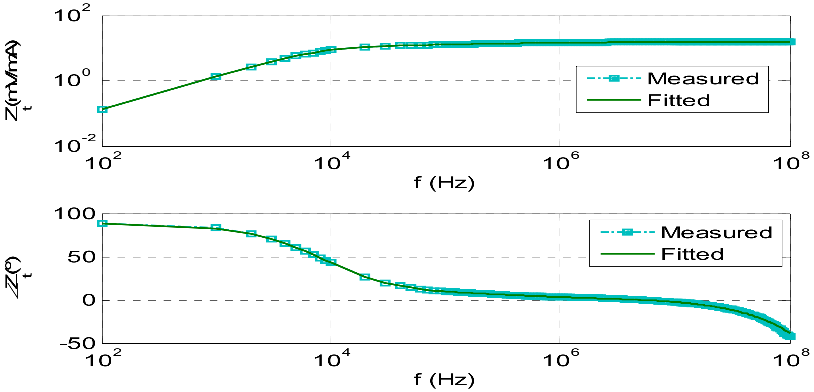
DR: 200 MHz bandwidth (1 Giga-Sample/s with 8 bits resolution - 0.5 GSamples/s with 12 bits resolution)

Internal memory of 4 GBytes
External memory of 240 GBytes.

Signal reconstruction

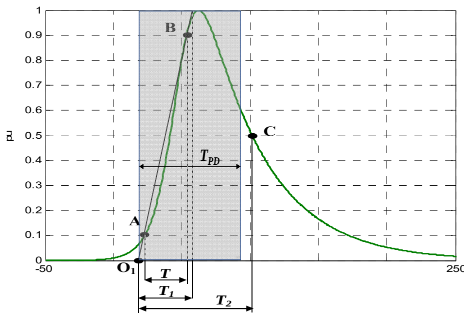


T_{PD}= 7 ns	T_{PD}= 37 ns	T_{PD}= 300 ns



Maximum and minimun magnitudes to be meausred by the Synthetic PD Calibrator

T_{PD} (ns)	q_{max} (pC)	q_{min} (pC)
8.0	320	2.0
16.0	640	2.0
37.5	1.500	2.0
75.0	3,000	2.0
150	6,000	4.0
375	15,000	10.0



T_{PD} of 75 ns → T_1/T_2= 31,2 /76 ns

uncertainty of less than ±2% or ±1 pC, whichever is greater

For example for T_{PD}=75 ns

q_{min}

Minimum peak value to be measured by the recorder of 0.4 mV_{peak}

$q_{min}=U_{min} / Z_{HFCT} \times T_{PD}$=0.4 mV / 15 mV/mA x 75 ns (pC/mA) =2 pC

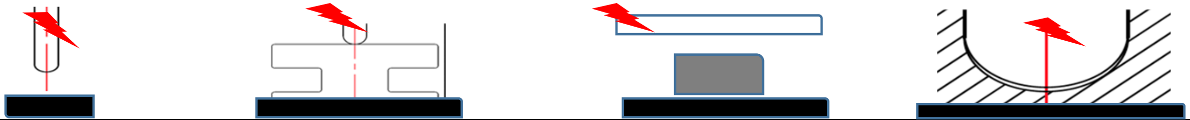
q_{max}

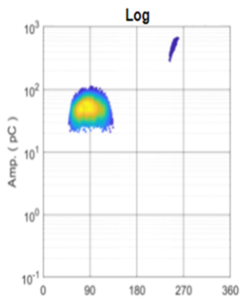
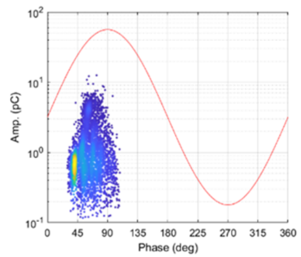
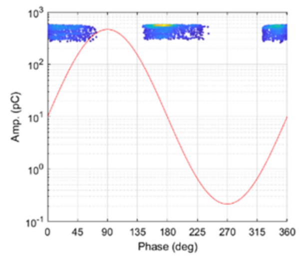
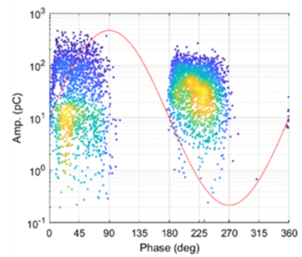
Maximum Current to be generated= 4V/ 100 Ω =40 mA_{peak}

$q_{max}=I_{max} \times T_{PD}$ =40 mA x 75 pC/mA = 3,000 pC

Reference Data Base of PD event trains (q_i, t_i)

For diagnostic Tests (HVAC and HVDC): Test cell of 20 kV(AC) 30 kV(DC)



	Corona (+)	Surface (+)	Floating	Cavity (+)
PRPD Pattern				

Aging > 1 year

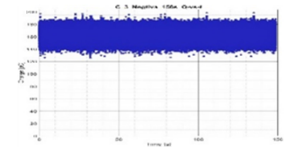
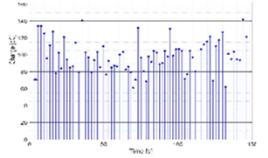
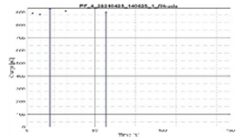
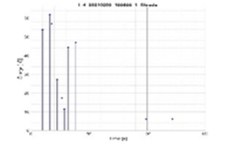
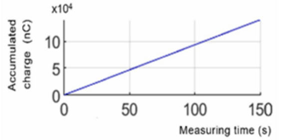
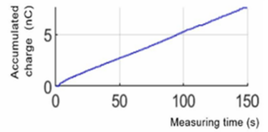
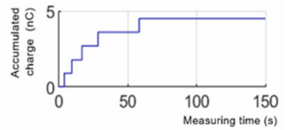
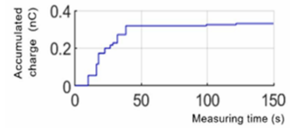
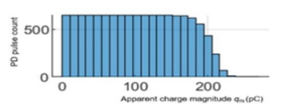
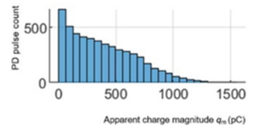
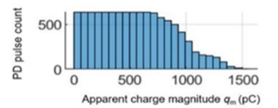
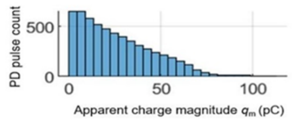
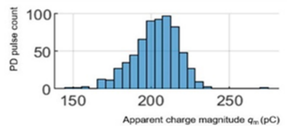
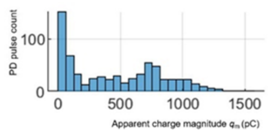
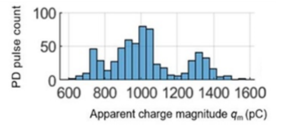
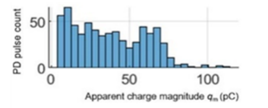
A data base of at least 1000 different reference PD pulse trains of each representative insulation defects (cavity, surface on air, floating potential, and corona) is available. The 95 % of the total PD pulse trains generated by test cells were used for training AI recognition tool.

The remaining 10% (at least 50 pulse trains for each PD defect) were reserved PD recognition test and PD clustering test.

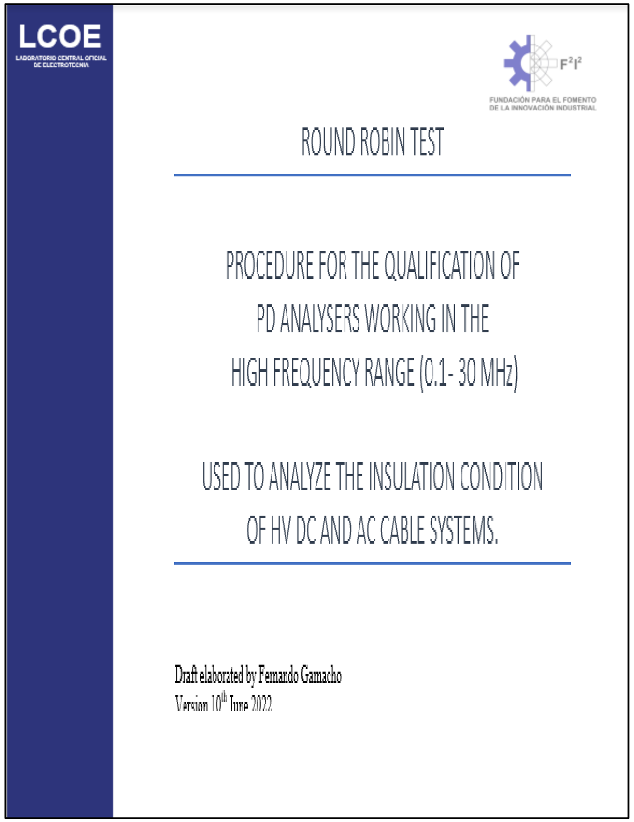
Reference Data Base of PD event trains (q_i, t_i)

PD graphs for HVDC

Aging > 1 year

Constant direct voltage			Changing direct voltage. $u(t)= Uo \cdot (1-e^{-t/\tau})$; $Uo=30$ kV; $\tau=16$ s		
PD Pattern	Corona (-)	Surface (-)	PD Pattern	Floating (-)	Cavity (-)
Apparent charge of individual PD pulses 150 s			Apparent charge of individual PD pulses at a voltage change		
Accumulated apparent charge 150 s			Accumulated apparent charge at voltage changes		
Monotonous decreasing PD histogram m=650 p			Monotonous decreasing PD histogram at voltage changes		
Charge intervals PD histogram m=650 p			Charge intervals PD histogram at voltage changes		

A 4.1.8. Round Robin Test (August 2022 - January 2023)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ROUND ROBIN TEST

PROCEDURE FOR THE QUALIFICATION OF PD ANALYSERS WORKING IN THE HIGH FREQUENCY RANGE (0.1- 30 MHz)

USED TO ANALYZE THE INSULATION CONDITION OF HV DC AND AC CABLE SYSTEMS.

Draft elaborated by Fernando Garnacho
Version 10th June 2022

PD Simulator

Validation of the Calibration Procedure to qualify PD

For Noise #1: According to future IEC-60270: A wideband PD instrument tunned in f_1=610 kHz f_2=770 kHz was the recommended PD measuring approach to mitigate the noise spectrum #1.


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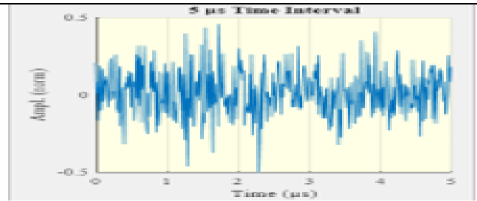
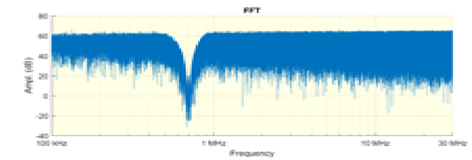
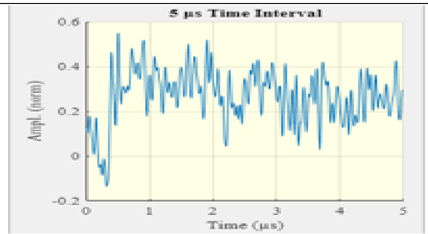
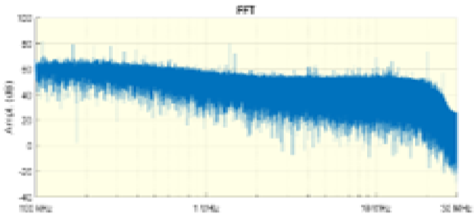
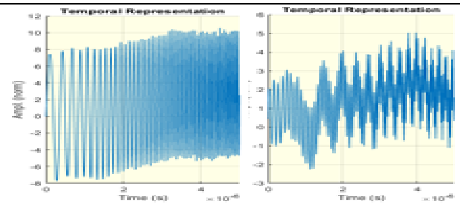
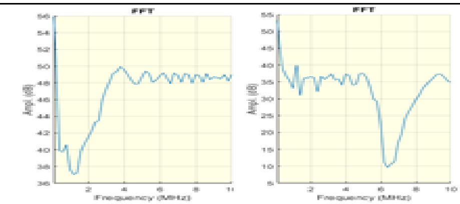
ROUND ROBIN TEST

PROCEDURE FOR THE QUALIFICATION OF PD ANALYSERS WORKING IN THE HIGH FREQUENCY RANGE (0.1-30 MHz)

USED TO ANALYZE THE INSULATION CONDITION OF HV DC AND AC CABLE SYSTEMS.

Noise types

	Time domain	Frequency domain
a) Invariable Noise #1 for PD Measurements according to IEC 60270		
b) Invariable Noise #2 for On-site PD Measurements according to TS IEC 62478		
c) Variable Noise #3 for Continuous PD Monitoring according to TS IEC 62478	 $t = t_1$ $t = t_2$	 $t = t_1$ $t = t_2$

4.1.8. Round Robin (Aug-22 to Jan-23)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ROUND ROBIN TEST

PROCEDURE FOR THE QUALIFICATION OF PD ANALYSERS WORKING IN THE HIGH FREQUENCY RANGE (0.1-30 MHz)

USED TO ANALYZE THE INSULATION CONDITION OF HV DC AND AC CABLE SYSTEMS.

Qualification	IEC 60270	Invariable noise TS IEC 62478	Variable noise TS IEC 62478
1) Noise rejection	Yes	Yes	Yes
2) Linearity (2 pc - 2,4 nC)	Yes	Yes	Yes
	Yes	Yes	Yes
3) Resolution time t_{res}	Yes	Yes	Yes
4) Error due to pulse width (T_{PD}=8 ns -150 ns)	Yes	Yes	Yes
A) PD Recognition	Not	Yes	
B) PD Clustering	Not	Yes	
C) PD Location	Not	Yes	

4.1.8. Round Robin (Aug-22 to Jan-23)

Requirements for Metrological tests


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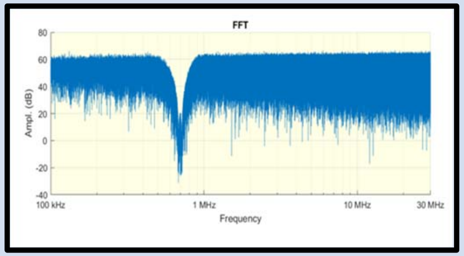
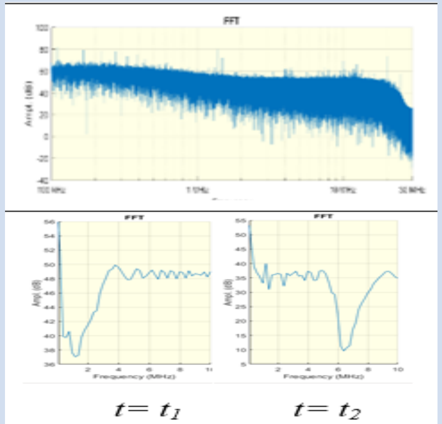
ROUND ROBIN TEST

PROCEDURE FOR THE QUALIFICATION OF PD ANALYSERS WORKING IN THE HIGH FREQUENCY RANGE (0.1-30 MHz)

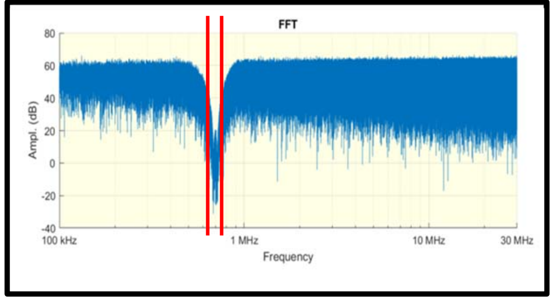
USED TO ANALYZE THE INSULATION CONDITION OF HV DC AND AC CABLE SYSTEMS.

Permissible errors	IEC 60270	IEC 62478
Charge value error	10%	30%
PD repetition rate error	2%	2%
Noise	50% Noise #1 	200% Noise #2 or #3 

4.1.8. Round Robin (Aug-22 to Jan-23)

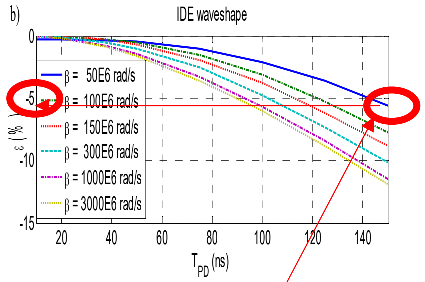
Summary for Noise #1

a) Invariable Noise #1 for PD Measurements according to IEC 60270



PD Analyser for off-line Measurements		PD Analyser A-1	PD Analyser A-2	PD Analyser A-3
f_1-f_2 (kHz)		40 – 400	40 – 800	610 – 770
Δf (kHz)		360	760	160
Charge measurement method		Quasi-integration	Quasi-integration	Quasi-integration
Filtering Method		None None	Manual Selection of f_1, f_2 and	trigger level
Metrological tests		Charge & PD repetition rate errors v.s. noise level Requirements Max ABS(ε_q) ≤ 10%; Max ABS(ε_n)≤ 2% under 50% noise level		
Noise Rejection q=100 pC	Noise range (%)			
	200	ε_q=248%	ε_q=151%	ε_q=61.9%
		ε_n>1000 %	ε_n>1000 %	ε_n=-0,4%
	100	ε_q=104.3%	ε_q=53,9%	ε_q=32.0%
		ε_n>1000 %	ε_n>1000 %	ε_n=-0,4%
	50	**ε_q=27%**	**ε_q=26%**	**ε_q=2.6%**
		ε_n>1000 %	**ε_n>1000 %**	**ε_n=-0,4%**
	20	ε_q=7,8%	ε_q=9,6%	ε_q=0,5%
		ε_n>1000%	ε_n=496%	ε_n=-0,4%
Linearity under 35% noise	**Charge range (pC)**	**Linearity error = (Max error – Min error) / 2 Requirement ≤ 5% under 35% noise level**		
	50 to 2.400	± 16,3%	± 6,2%	± 2,9%
	10 to 2.400	>100%	± 6,2%	± 2,9%
T_{PD} influence under 35% noise q=200 pC	**Pulse width T_{PD} range (ns)**	**T_{PD} error = (Max error – Min error) / 2 Requirement ≤ 30% under 35% noise level**		
	8 to 150	± 2,5%	± 2,5%	± 2,7%
Resolution Time under 35% noise q=200 pC	**t_{res} range (μs)**	PD repetition rate error Requirement ≤ 2% under 35% noise level		
	2,500 – 10	2.5 ms ; ε_n>2.0 %	2.5 ms ; ε_n>2.0 %	10 μs ; ε_n=1.3 %

wideband approach

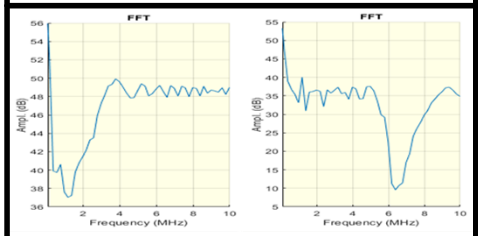


Max-Min=5,4%

4.1.8. Round Robin (Aug-22 to Jan-23)

Summary for Noise #3

c) Variable Noise #3
for Continuous PD Monitoring
according to TS IEC 62478



$t = t_1$ $t = t_2$

PD Analyser for Continuous PD monitoring		PD Analyser B-1	PD Analyser B-2	PD Analyser B-3	PD Analyser C
HFCT bandwidth f_1-f_2 (MHz)		0,2 – 20	0,08 -61	0.004 – 1,100	0,2 – 20
Charge measurement Method f_1-f_2 (MHz)		Quasi-integration f_1=1.0, f_2= 4.0	Direct reading of HFCT (1)	Integration in time domain	Quasi-integration f_1=2.45, f_2=3.95
Digitizer: Bandwidth (Sampling rate)		30 MHz (60 MS/s)	50 MHz (100 MS/s)	20 MHz (1.25 GS/s)	50 MHz (100 MS/s)
Filtering Method f_1-f_2 (MHz)		Passband filter Manual Selection of f_1, f_2 and trigger level f_1=1.75, f_2= 3.25	4th order passband filter Butterworth f_1=0,05, f_2= 45	8th order lowpass filter f_2= 20	Automatic Wavelet Filter to recognise PD pulses and pulsating noises
Metrological tests		Charge error & PD repetition rate errors v.s. noise level			
	Noise range (%)	Requirements Max ABS(ε_q)≤ 30%, Max ABS(ε_n)≤ 2% under 200% noise level			
Noise Rejection q=100 pC	**200**	**ε_q= 4.1 %**	**ε_q=-0.4 %**	**ε_q=-40,0%**	**ε_q=-11,7%**
		ε_n=0.0 %	**ε_n=0.0 %**	**ε_n=0.7 %**	**ε_n=-0,0%**
	100	ε_q=0.8 %	ε_q=0.0 %	ε_q=16,5%	ε_q=-1,6%
		ε_n=0.0 %	ε_n=0.0 %	ε_n=0.7 %	ε_n=-0,0%
	50	ε_q=-0.1%	ε_q=0.1 %	ε_q=8,7%	ε_q=1,7%
		ε_n=0.0 %	ε_n=0.0 %	ε_n=0.0 %	ε_n=-0,0%
	20	ε_q=0,0 %	ε_q=0.2 %	ε_q=3,5%	ε_q=1,7 %
		ε_n=0.0 %	ε_n=0.2 %	ε_n=0.0%	ε_n=-0,0%
Linearity under noise	**Charge range q(pC)**	Linearity error = ± ABS(ε_l)= ± ABS (Max error – Min error) / 2 Requirement ≤ 5% under 35% noise level			
	50 to 2.400	± 0.1%	± 0.5%	± 2.0 %	± 0.2%
	10 to 2.400	± 0.7%	± 11.0%	± 85.0 %	± 0.8%
T_{PD} influence under noise q=200 pC	**T_{PD} range (ns)**	T_{PD} error = ± ABS(ε_{TPD})= ± ABS (Max error – Min error) / 2 ABS(ε_{TPD}) ≤ 30% under 35% noise level			
	37.5 t0 150	± 24.1 %	± 2,1 % (*)	± 0.8 %	± 25. 5%
	8 to 150	± 28.7%	Not applicable	± 1.5 %	± 29.8%
Resolution Time under noise q=200 pC	**t_{res} range (µs)**	PD repetition rate error for decreasing time interval between PD pulses Requirement ≤ 2% under 10% noise level			
	2,500 – 10	10 µs, ε_n=0.0 %	20 µs, ε_n=0.0 %	2.5 ms, ε_n=0.5 %	10 µs,ε_n=0. %

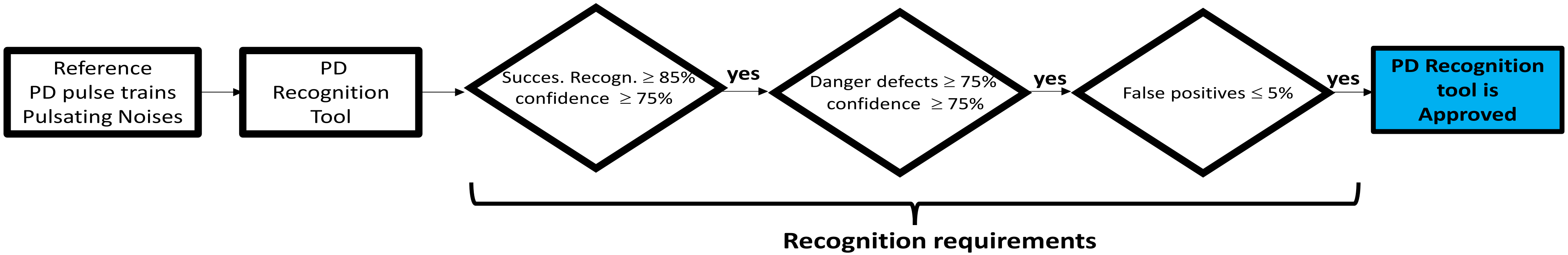
4.1.8. Round Robin (Aug-22 to Jan-23)

Diagnostic Tests

Qualification	IEC 60270	Invariable noise TS IEC 62478	Variable noise TS IEC 62478
A) PD Recognition		Yes	
B) PD Clustering		Yes	
C) PD Location		Yes	

4.1.8. Round Robin (Aug-22 to Jan-23)

A- Qualification of PD recognition tools.



Proposed requirement to approve an AI PD Recognition tool

An AI PD recognition tool is considered approved if 1) at least 85% of reference PD pulse or noise trains are correctly recognised with a confidence level not less than 75%.

2) at least 75% of Danger defects (solid, gas or liquid insulation media) are correctly recognised with a confidence level not less than 75% and not more 5% are false positive recognitions.

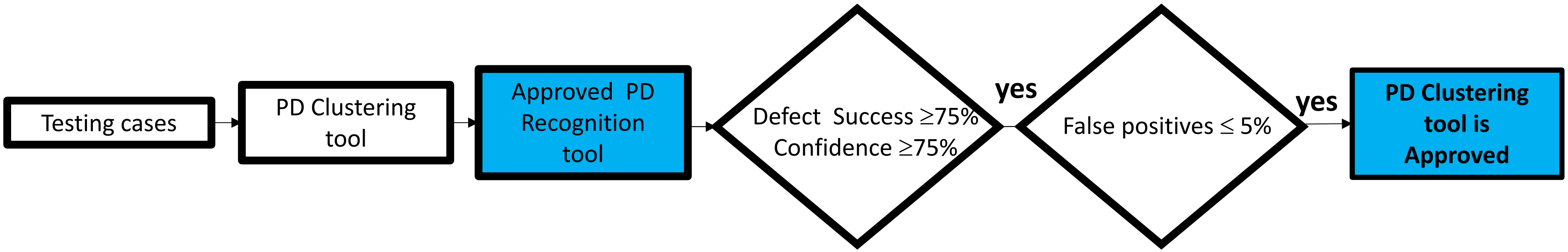
4.1.8. Round Robin (Aug-22 to Jan-23)

A- Qualification of PD recognition tools: ACR2 for HVAC grids and DCR2 for HVDC grids have been approved

Case	AC			DC (+)			DC (-)		
	Real	ACR1	ACR2	Real	DCR1	DCR2	Real	DCR1	DCR2
1	Cavity	Cavity (98%)	Cavity (91%)	Surface	Cavity (48%)	Surface (99%)	Floating	Floating (84%)	Floating (97%)
2	Corona	Corona (99%)	Corona (99%)	Cavity	Cavity (67%)	Cavity (89%)	Surface	Noise	Surface (97%)
3	Floating	Floating (99%)	Floating (98%)	Corona	Corona (82%)	Corona (95%)	Noise	Noise	Corona (45%)
4	Noise	Floating (46%)	Noise (100%)	Floating	Floating (83%)	Floating (95%)	Corona	Corona (91%)	Corona (97%)
5	Surface	Surface (90%)	Surface (100%)	Cavity	Cavity (83%)	Cavity (99%)	Floating	Floating (84%)	Floating (98%)
6	Floating	Floating (97%)	Floating (84%)	Noise	Noise	Noise (81%)	Cavity	Cavity (65%)	Cavity (99%)
7	Corona	Surface(61%)	Corona(100%)	Surface	Surface (57%)	Surface (79%)	Surface	Noise	Surface (95%)
8	Cavity	Cavity (99%)	Cavity (100%)	Floating	Floating (87%)	Floating (95%)	Cavity	Cavity (83%)	Cavity (98%)
9	Surface	Surface (96%)	Surface (100%)	Corona	Corona (82%)	Corona (100%)	Corona	Corona (78%)	Corona (100%)
10	Cavity	Cavity (99%)	Cavity (100%)	Surface	Cavity (63%)	Surface (94%)	Floating	Floating (78%)	Floating (78%)
11	Noise	Noise (49%)	Noise (100%)	Noise	Noise	Noise (97%)	Cavity	Cavity (67%)	Cavity (99%)
12	Corona	Corona(98%)	Corona(97%)	Cavity	Cavity (68%)	Cavity (98%)	Noise	Noise	Noise (72%)
13	Surface	Cavity (54%)	Surface (100%)	Corona	Corona (78%)	Corona (98%)	Corona	Corona (86%)	Corona (100%)
14	Floating	Floating (100%)	Floating (99%)	Floating	Floating (100%)	Floating (98%)	Surface	Noise	Surface (94%)

1

4.1.8. Round Robin (Aug-22 to Jan-23)



Proposed requirement to approve an AI PD Recognition tool

"A clustering tool is approved if 1) an approved AI recognition tool recognizes at least 75% of defect success with a confidence level >75%, after applying the AI automatic clustering tool under validation and 2) False positives ≤5% (1/24 is accepted).

4.1 Validation of the PD procedure for qualifying PD analysers used for DC testing in the 1 - 30 MHz range

A4.1.8 Round Robin Test

B) PD clustering capability [HVDC]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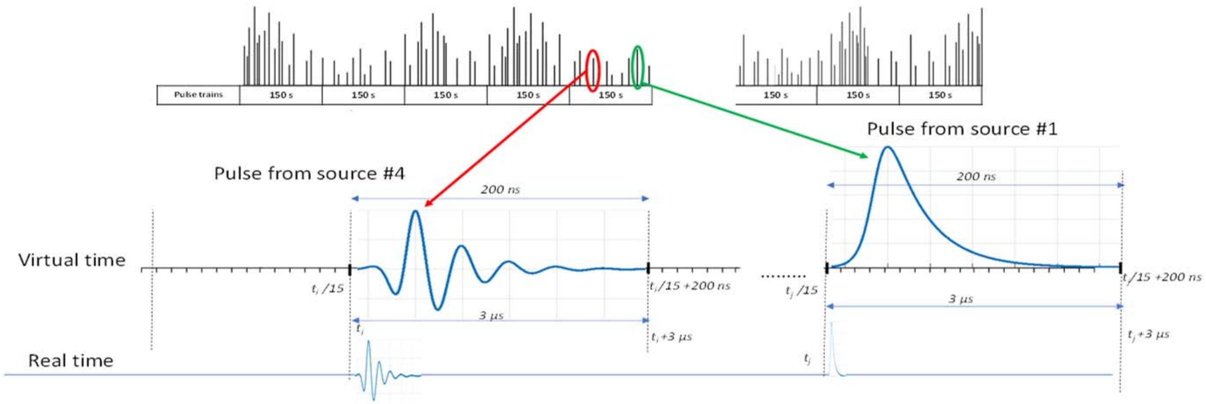
ROUND ROBIN TEST

PROCEDURE FOR THE QUALIFICATION OF PD ANALYSERS WORKING IN THE HIGH FREQUENCY RANGE (0.1- 30 MHz)

USED TO ANALYZE THE INSULATION CONDITION OF HV DC AND AC CABLE SYSTEMS.

The Synthetic PD emulator can generate in 20 minutes a set of 120 pulse trains of four superimposed pulse trains of 150 s each to reproduce an equivalent testing time of 5.0 hours (120x150s). In practice, this operation mode uses a speed multiplayer factor of 15 to play in 20 min the testing of 5.0 h. When there are no pulsating signals, the time plays back with a time multiplier of 15 times faster than the actual recording speed, but no time multiplier factor is applied when pulse signals are present, either from a PD pulse or from pulsating noise. When there is a pulse, the playback time is equal to the actual recording time, without causing any change in the acquisition time as in reality, as shown in Fig. 8.



4.1.8. Round Robin (Aug-22 to Jan-23)

B. Qualification of PD clustering tools.

C1 AI Tool should be improved

AC cases	Clustering Tool	Corona	Floating	Surface	Cavity	Noise #1	Noise #2
1	C1	49%		100%		100%	
2		31%	99%			100%	
3		46%			63%	97%	
4		80%		74%		100%	
5		No detected	99%			100%	
6		48%			-96% Floating	-100%Surface	99%
7			100%	99%		99%	
8				100%	Floating 85%	100%	
9			90%	90%		100%	
10				No detected	99%	99%	
11			99%		No detected	99%	
12			99%		97%	99%	

DC cases	Clustering Tool	Corona	Floating	Surface	Cavity	Noise #1	Noise #2
DC(+)	C1	90%		79%		68%	70%
DC(-)			84%		98%	92%	73%
Averages	83,8%	90,0%	84,0%	79,0%	98,0%	80,0%	71,5%
DC(+)	C2	93%		81%		81%	96%
DC(-)			90%		97%	100%	100%
Averages	91,6%	93,0%	90,0%	81,0%	97,0%	90,5%	98,0%

4.1.8. Round Robin (Aug-22 to Jan-23)

B. Qualification of PD clustering tools.

C2 has been approved

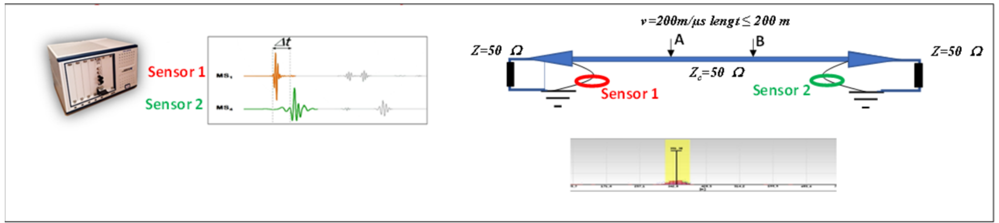
AC cases	Clustering Tool	Corona	Floating	Surface	Cavity	Noise #1	Noise #2
1	C2	No detected		100%		100%	
2		99%	100%			100%	
3		100%			100%	100%	
4		No detected		61%		100%	
5		100%	100%			99%	
6		99%			98%	100%	
7			100%	100%		100%	
8				100%	100%	100%	
9			100%	100%		97%	
10				100%	100%	100%	
11			100%		100%	95%	
12			100%		100%	99%	
Averages	93,0%	66,3%	100,0%	93,5%	99,7%	99,2%	99,2%

AC cases	Clustering Tool	Corona	Floating	Surface	Cavity	Noise #1	Noise #2
DC(+)	C1	90%		79%		68%	70%
DC(-)			84%		98%	92%	73%
Averages	83,8%	90,0%	84,0%	79,0%	98,0%	80,0%	71,5%
DC(+)	C2	93%		81%		81%	96%
DC(-)			90%		97%	100%	100%
Averages	91,6%	93,0%	90,0%	81,0%	97,0%	90,5%	98,0%

4.1.8. Round Robin (Aug-22 to Jan-23)

C. PD Location along a cable

Evaluation of the ability of a PD analyser to determine the location of a PD source along a cable is carried out using the synthetic PD calibrator. A coaxial cable is used as a model of a power cable with three intermediate injections points A, B and C. Both cable ends are matched by means of an impedance with the same value as the characteristic impedance of the coaxial cable (Z_c=50Ω). The coaxial cable has a propagation velocity of 196 m/µs a nominal length of 172 m.



Location error (m)							
D(from T1) (m)		LCOE	TUDELFT	RISE	TAU	UPM
C	24	-1,0	1,0	-0,7	1,1	-1,0
A	92	-0,4	0,0	0,2	1,5	0,0
B	117	0,6	0,0	0,1	1,4	0,3

4.1 Validation of the PD procedure for qualifying PD analysers used for DC testing in the 1 - 30 MHz range

CONCLUSIONS

- **A Synthetic PD Calibrator is available for qualification of PD analysers working in the 1-30 MHz:**
  Metrological Tests: Noise rejection test, Linearity, PD pulse width influence test (TPD) and Resolution time.
  Diagnostic Tests: PD Recognition Tests, PD clustering Test, and PD Location Test

- **A reference database of PD event trains acquired in laboratory tests provides an experimental and traceable reference of insulation defects in HVAC and HVDC to evaluate the efficiency of PD analysers.**

- **A Procedure for qualifying PD analysers (HVDC and HVAC) has been developed.**

- **Recognition and clustering tools for HVAC and HVDC have been approved**

- **A Round Robin Test was carried out to validate the developed Procedure for qualifying PD analysers.**

- **Final Version of the Qualification procedure May 2023**

- **4 Papers have been submitted.**


THANK YOU VERY MUCH
FFII-LCOE