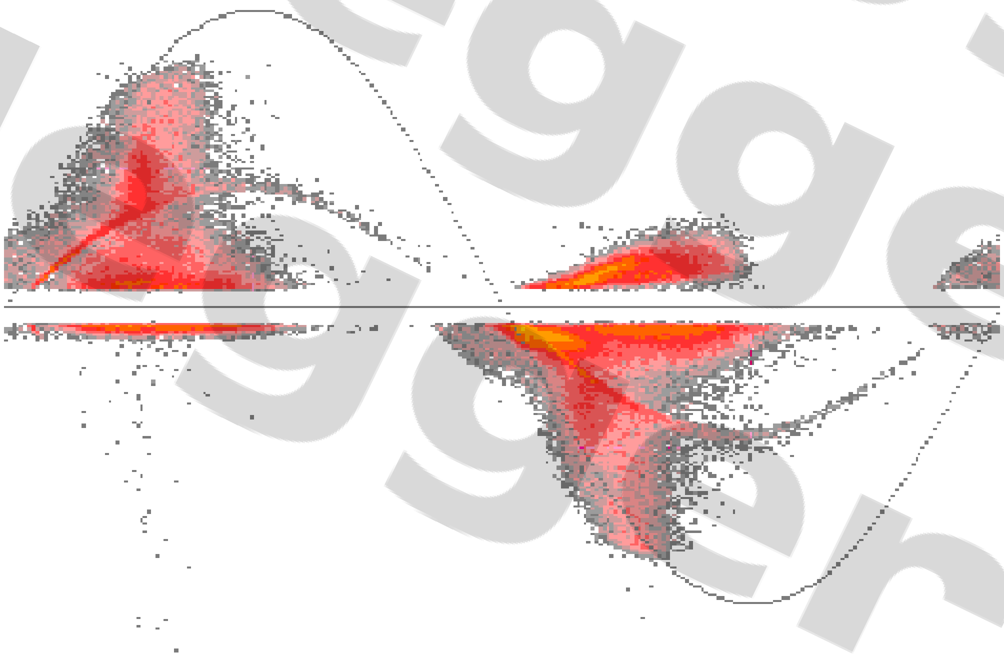
Quality control of HV products using the ICM*compact*

Ceren Gürbüz
Electrical Engineer
Power Diagnostix Systems
July 22, 2020

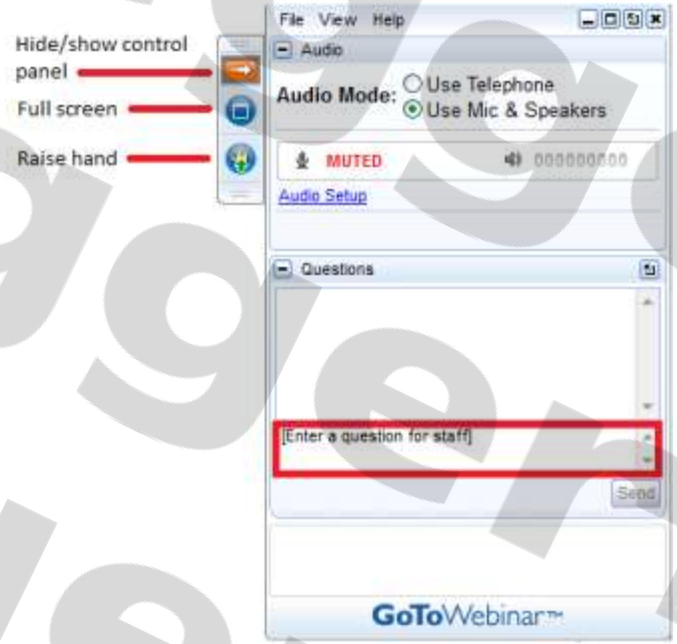


Moderator

- Daniel Hering
  - Power Diagnostix Development Engineer

Q&A

- Send us your questions and comments during the presentation



Megger

Todays Presenter & Panelist

- Presenter:
  - Ceren Gürbüz
    - Power Diagnostix Electrical Engineer
- Panelists:
  - Markus Fockenberg
    - Power Diagnostix Senior Development Engineer

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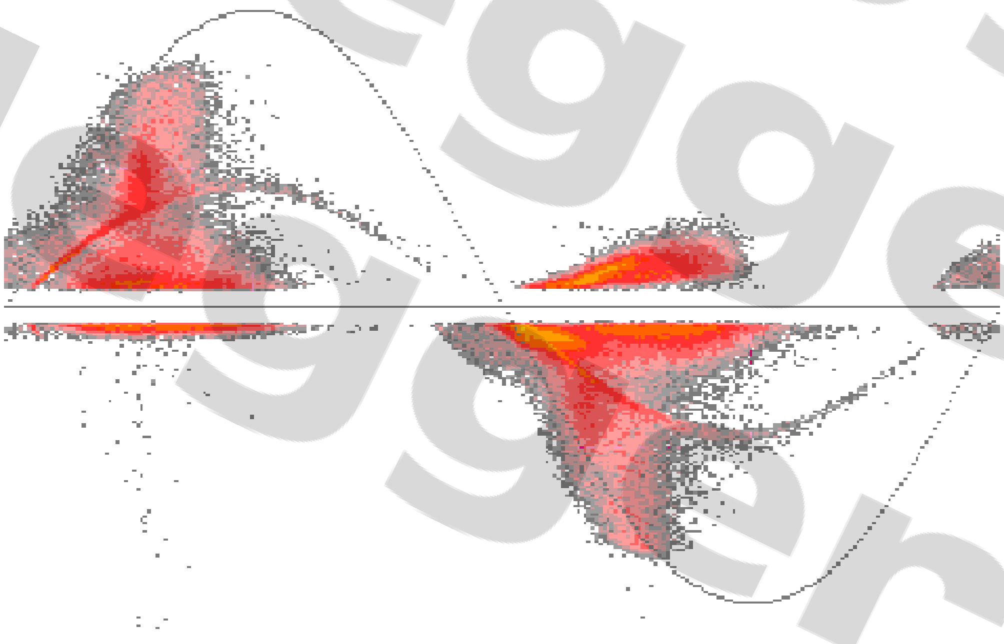
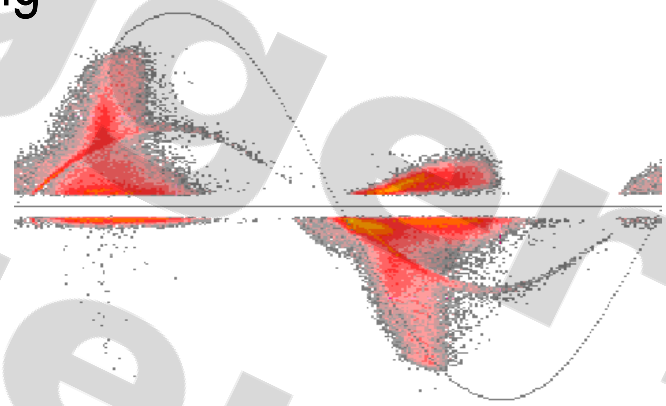


Quality control of HV products using the ICM*compact*

- Introduction – Why partial discharge testing
- Normative references
- Partial discharge theory
- The ICM*compact* & Software
- The common applications
- Automatic serial testing with HV*pilot* software



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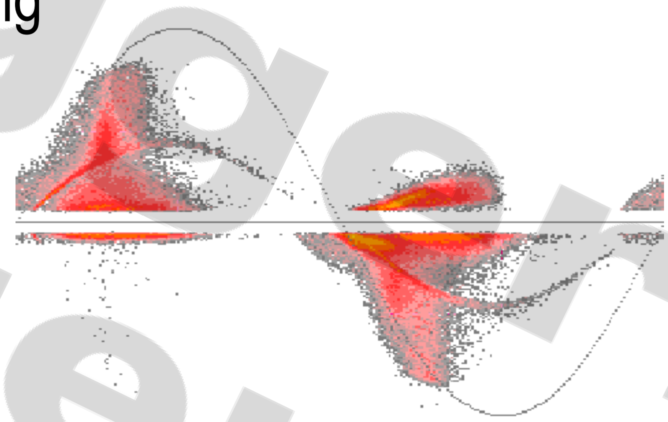
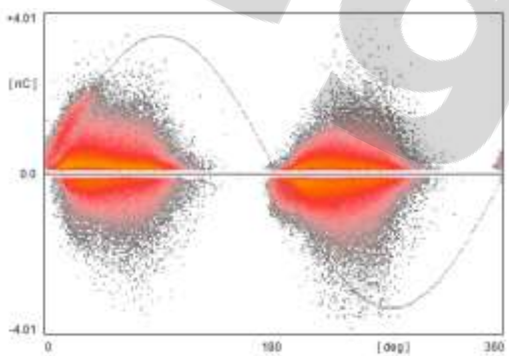


Quality control of HV products using the ICM*compact*

- Partial discharge measurements are vital for quality assessment of high voltage products
- Quality control test regimes can be self-defined or in accordance with the IEC60270
- High voltage products such as cables, bushings, GIS, instrument and power transformers and many others require factory acceptance testing (FAT)
- Several IEC and IEEE standards focus on testing of HV components
- Successful quality test reports in accordance with the standards are often requested

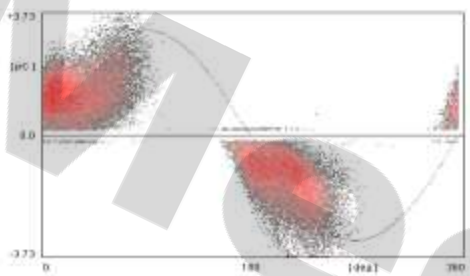
Problems can be detected early:

- Internal stress created by material contamination or gas inclusions (voids) weakens solid insulation.
- Breakdown in operation due to surface cracks
- Resulting PD pattern recorded during maintenance
- PD testing during manufacturing could have revealed problem early

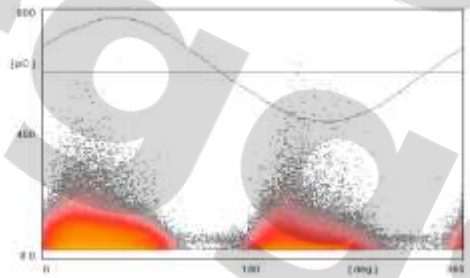


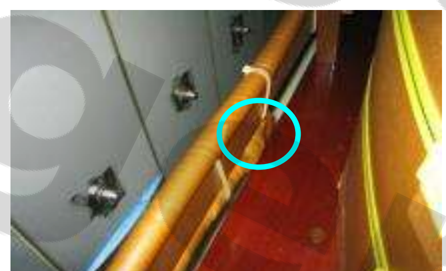
Introduction - Why PD testing

“Treeing” Superficial Cracks

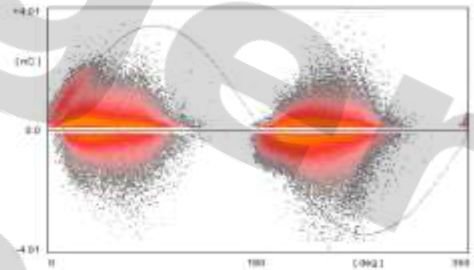


Sharpe Edge pointing to HV Coil



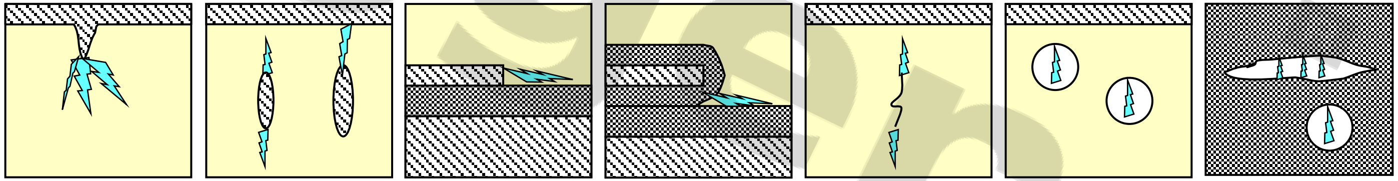


Surface Discharge



PD sources in transformers

- Sharp points and particles
- Surface and tracking discharge
- Fiber bridges in oil
- Gas inclusions
  - Voids (bubbles in oil and solid)
  - Delaminations (paper and solids)
- Humidity (indirect)



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- Partial discharge theory
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- The common applications
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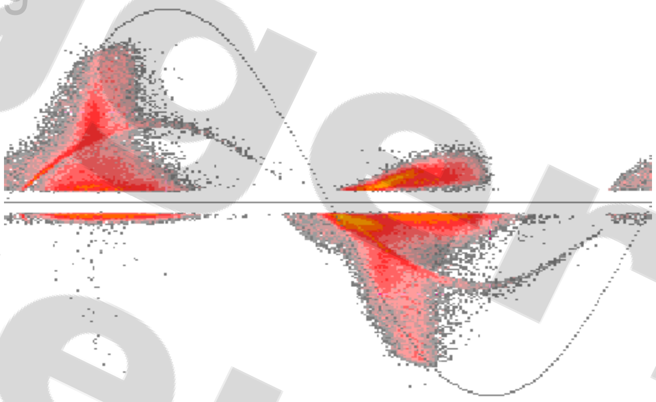
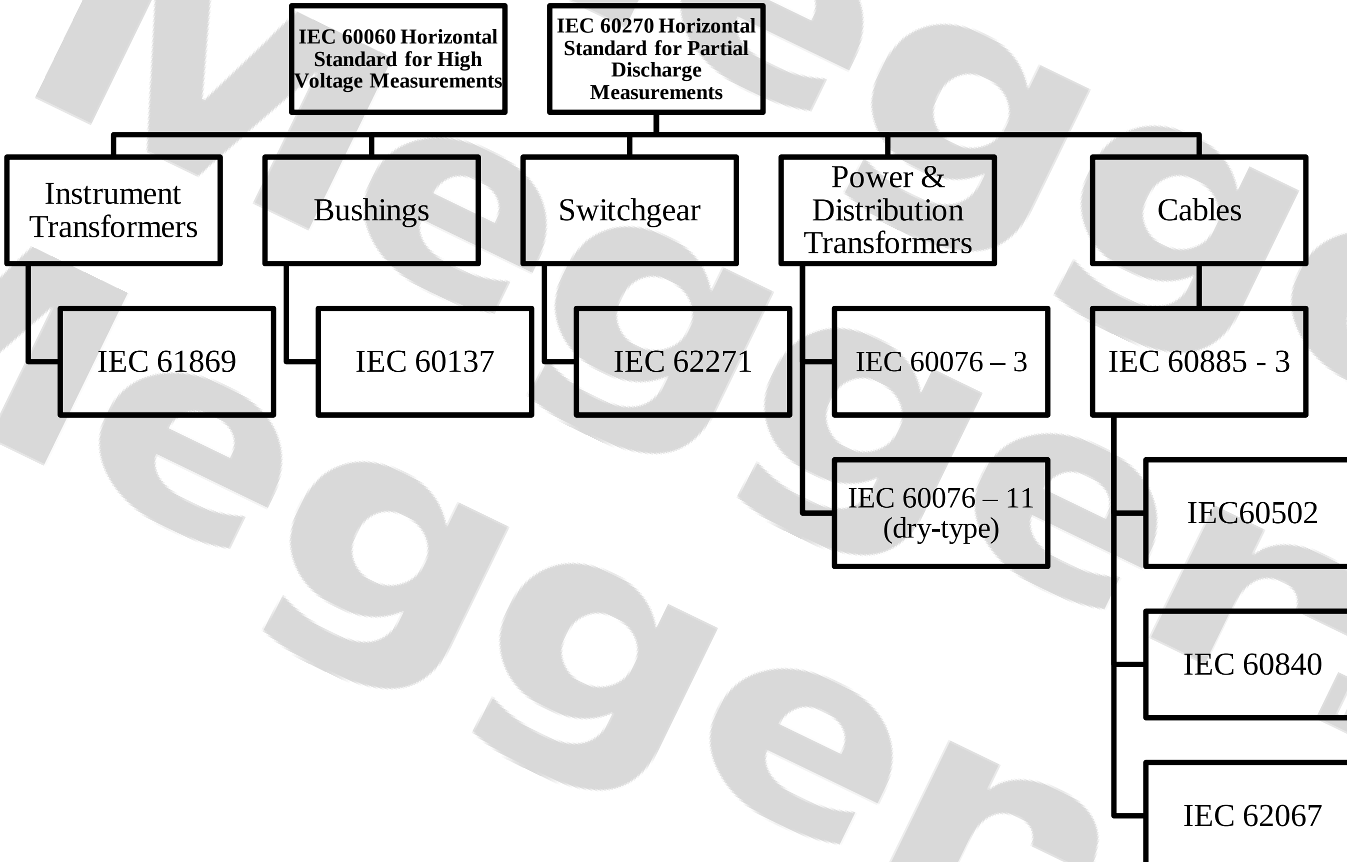


Normative references



Normative references

- Cables
  - IEEE 400: 2000
  - IEEE 400.2
  - IEEE 400.3
  - Cigre TB 728
- Power & Distribution Transformers
  - IEEE C.57-113
  - IEEE C.57.12.00
- RIV
  - NEMA 107-2016
  - CISPR 18-2
  - ANSI C.63.2

IEC 60270:2015 :

- Frequency bands:

- Wide-band	(100kHz ≤ Δf	≤ 900kHz)
Lower limit:	30kHz ≤ f_1	≤ 100kHz
Upper limit:	f_2	≤ 1MHz
- Narrow-band	(9kHz ≤ Δf	≤ 30kHz)
Center frequency:	50kHz ≤ Cf	≤ 1MHz

- Factory-acceptance testing of high voltage equipment has to be performed in the frequency range below 1 MHz.

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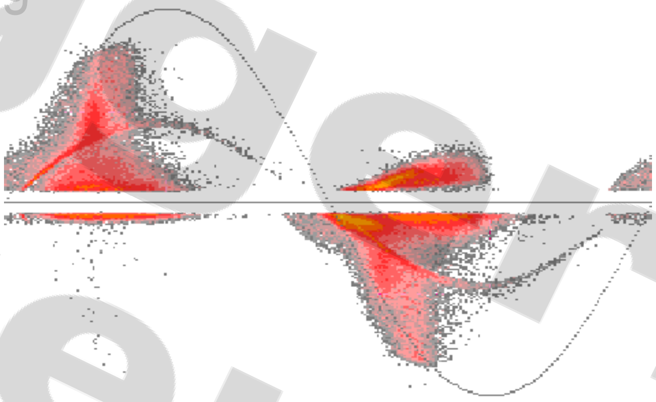
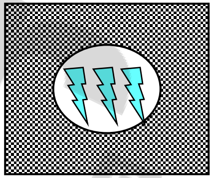


Occurrence of partial discharge

- For the occurrence of partial discharge two conditions must be met:
  - The local electric field must have reached the critical inception field ($E > E_{crit}$)
  - A free electron must be available to start the discharge avalanche
- Two main processes to derive this initial electron:
  - Ionization by photons
  - Field emission



- The statistical properties of these processes control the appearance of the PD pattern

Provision of starting electrons

- Plenty free electrons on metallic surface – immediate inception of partial discharge if $E > E_{crit}$
- Polymeric low energy surfaces (PE, PP, PTFE, etc.) offer literally no free electrons – ionization needed
- The sources of ambient radioactivity (cosmic photons, ^{222}Rn, soil, fallout) cause ~$2 \cdot 10^6$ free electrons per second and cubic meter – delayed inception

- Hence, it takes in average 15 minutes until a spherical void of 1mm diameter is hit and discharge starts
- Common testing times of epoxy molded equipment often too short e.g. dry-type transformers 3 minutes

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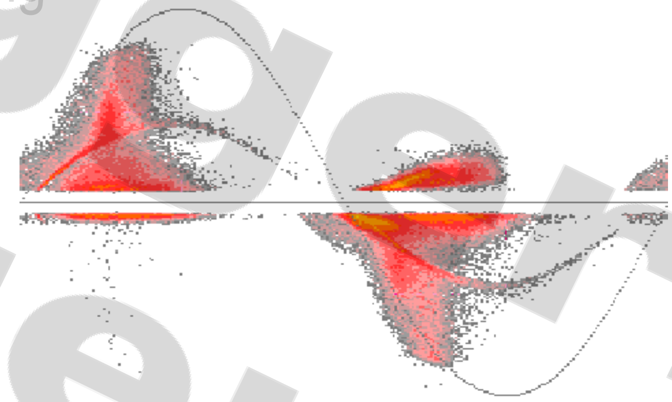


Technical details

- Multiplexer for measurements of multiple samples
- High voltage measurement
- Sync: VLF, 6 – 505Hz, DC
- Analog pulse gating
- Integrated cable fault location feature

  TDR display
- Time domain PD pulse acquisition 100MS (10ns)

Technical details

- Spectrum scan
- Frequency selective measurements for noisy environments
- RIV meter optional
- PD detection on specific frequencies between 10kHz and 10MHz
- Bandpass filter (9 kHz/300 kHz)
- Remote software
- Multiple housings available

The ICM*compact*

Decoupling

- Coupling capacitor
- Quadrupole
- Current transformer

Preamplifier

- <1MHz (IEC-60270) RPA1
- RPA for different frequency ranges or Acoustics on request

The instrument

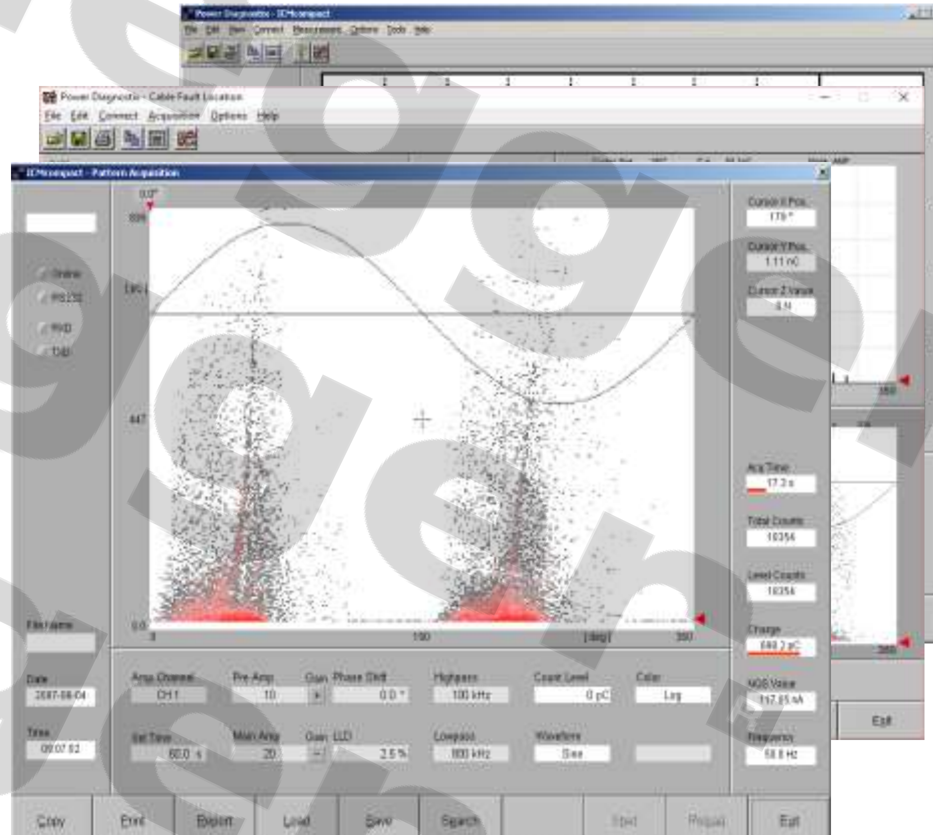
- Robust outdoor case
- Rack mountable version
- ½ 19inch ICM*compact*

The ICM*compact* accessories

- Coupling capacitors
- HV PD filters
- Quadrupoles
- Preamplifiers
- PD & RIV calibrators

ICM*compact* software

- Saving calibrations and measurements
- Screen shots
- Printing, exporting
- Records vs. time
- Test reports
- Interfaces to third party test systems
- High resolution TDR
- Colored PD pattern



PD by Megger®
Power Diagnostix Systems

- Calibration channel by channel – every test
- Record setup (once per test procedure)
- Multiplexed recording
  - Values per channel recorded
  - Delay between two channels set up before
  - Legend on the left for voltage and PD
- Data export functions

Date	Time	Amp In	Sync In	Qp Cur [pC]	Qp Mean [pC]	Qp Max [pC]	Qp Min [pC]	RIV [µV]	Urms [kV]	$U_p/\sqrt{2}$
12/09/2019	09:38:04	1	1	0,03	0,03	0,04	0,02	-1	0,07	
12/09/2019	09:38:09	2	1	0,30	0,06	0,30	0,00	-1	0,14	
12/09/2019	09:38:14	3	1	0,30	0,26	0,31	0,22	-1	0,15	
12/09/2019	09:38:19	1	1	0,32	0,30	0,36	0,24	-1	0,15	
12/09/2019	09:38:24	2	1	0,22	0,25	0,37	0,19	-1	0,15	
12/09/2019	09:38:29	3	1	0,29	0,29	0,34	0,25	-1	0,15	
12/09/2019	09:38:34	1	1	0,41	0,39	0,50	0,30	-1	0,16	
12/09/2019	09:38:39	2	1	0,37	0,38	0,45	0,31	-1	0,16	
12/09/2019	09:38:44	3	1	0,36	0,39	0,53	0,29	-1	0,16	
12/09/2019	09:38:49	1	1	0,48	0,47	0,53	0,43	-1	0,16	
12/09/2019	09:38:54	2	1	0,38	0,38	0,44	0,32	-1	0,16	
12/09/2019	09:38:59	3	1	0,43	0,39	0,45	0,33	-1	0,16	
12/09/2019	09:39:04	1	1	0,46	0,45	0,54	0,36	-1	0,16	
12/09/2019	09:39:09	2	1	0,38	0,36	0,47	0,31	-1	0,16	
12/09/2019	09:39:14	3	1	0,38	0,41	0,57	0,34	-1	0,16	
12/09/2019	09:39:19	1	1	0,46	0,44	0,50	0,37	-1	0,16	
12/09/2019	09:39:24	2	1	0,30	0,38	0,45	0,28	-1	0,16	
12/09/2019	09:39:29	3	1	0,44	0,41	0,46	0,35	-1	0,16	
12/09/2019	09:39:34	1	1	0,41	0,47	0,62	0,32	-1	0,16	
12/09/2019	09:39:39	2	1	0,41	0,38	0,47	0,30	-1	0,16	
12/09/2019	09:39:44	3	1	0,42	0,42	0,47	0,35	-1	0,16	
12/09/2019	09:39:49	1	1	0,44	0,43	0,49	0,35	-1	0,16	
12/09/2019	09:39:54	2	1	0,49	0,39	0,49	0,34	-1	0,16	
12/09/2019	09:39:59	3	1	0,38	0,38	0,41	0,31	-1	0,16	
12/09/2019	09:40:04	1	1	0,45	0,45	0,52	0,35	-1	0,16	
12/09/2019	09:40:09	2	1	0,43	0,39	0,47	0,33	-1	0,16	
12/09/2019	09:40:14	3	1	0,44	0,41	0,48	0,33	-1	0,16	
12/09/2019	09:40:19	1	1	0,48	0,47	0,51	0,40	-1	0,16	
12/09/2019	09:40:24	2	1	0,34	0,39	0,55	0,34	-1	0,16	
12/09/2019	09:40:29	3	1	0,39	0,39	0,45	0,33	-1	0,16	
12/09/2019	09:40:34	1	1	0,54	0,46	0,59	0,33	-1	0,16	
12/09/2019	09:40:39	2	1	0,36	0,38	0,46	0,30	-1	0,16	
12/09/2019	09:40:44	3	1	0,40	0,42	0,46	0,36	-1	0,16	

Tabelle1 Tabelle2 Tabelle3

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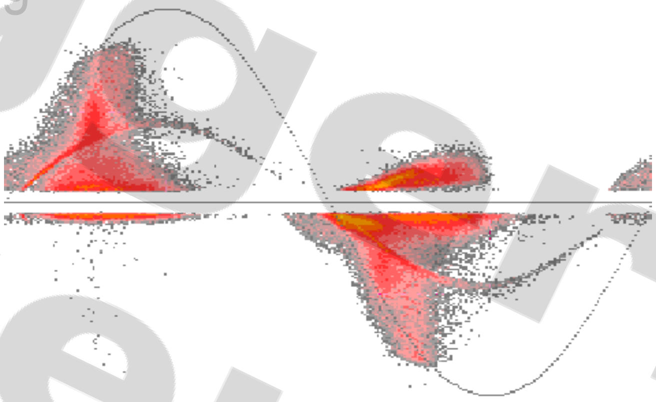
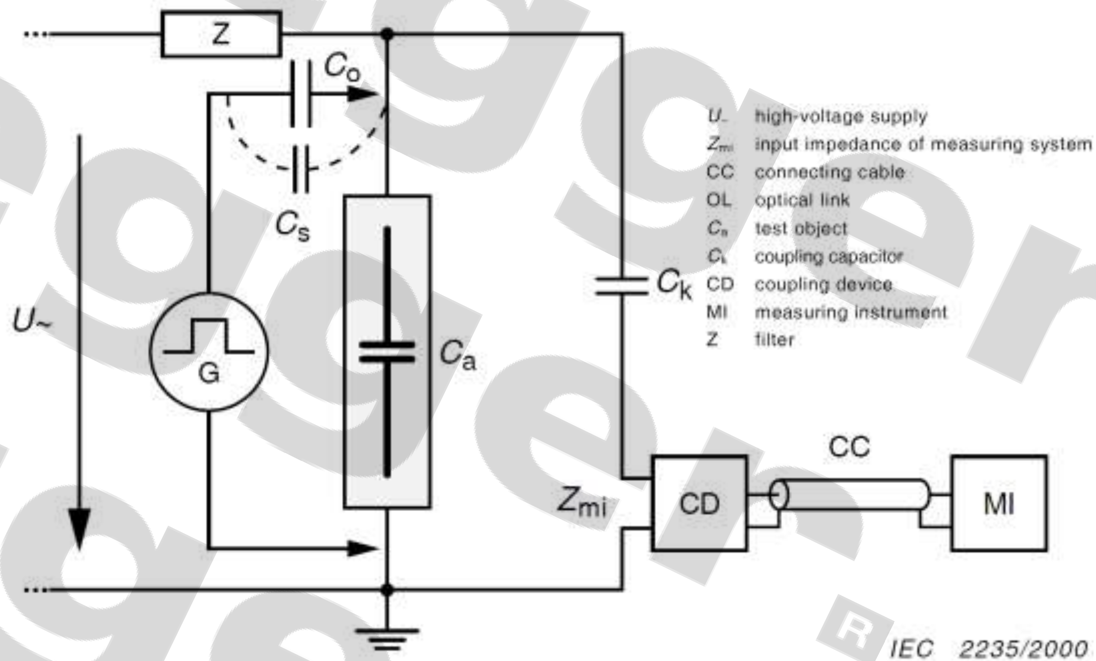


The common applications

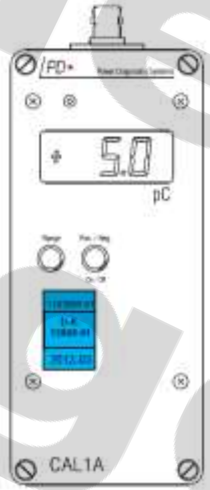
IEC60270 compliant calibration

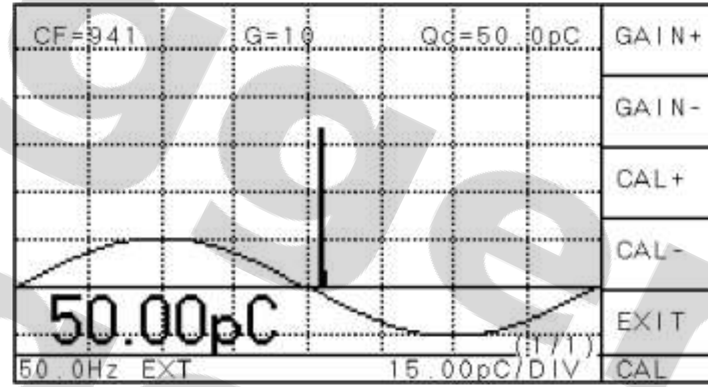
- PD measurements are relative
- Charge impulse is generated using a step voltage and an injection capacitor
- Charge impulse calibrator connected across the test object to simulate an equivalent discharge

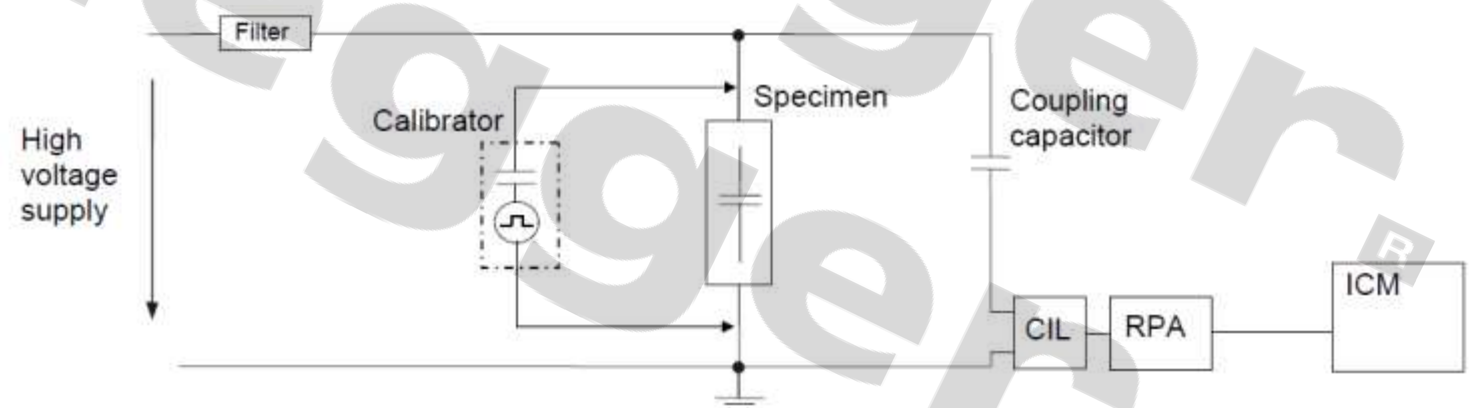


Calibration circuit diagram

- Overall attenuation
  - The entire signal path
  - Instrument properties
  - Filters



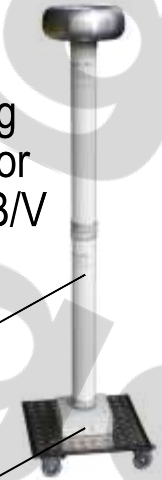




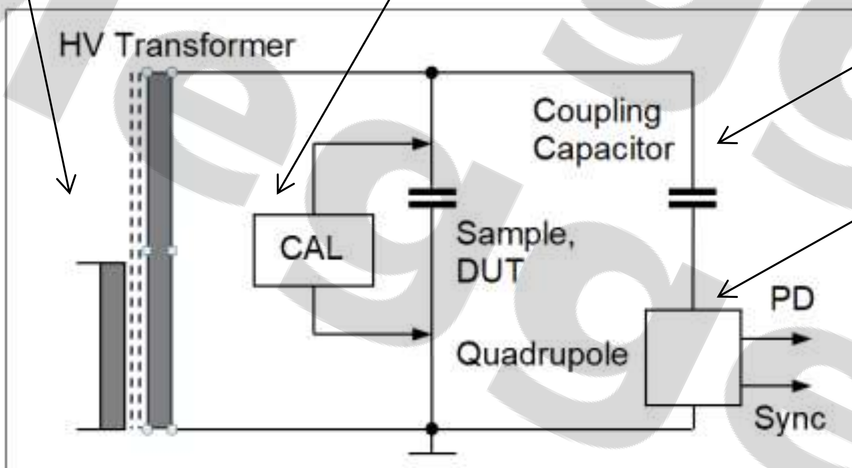
Example : Laboratory measurements

PD Calibrator
CAL1A

Coupling
Capacitor
CC200B/V



PD detector
ICM*compact*

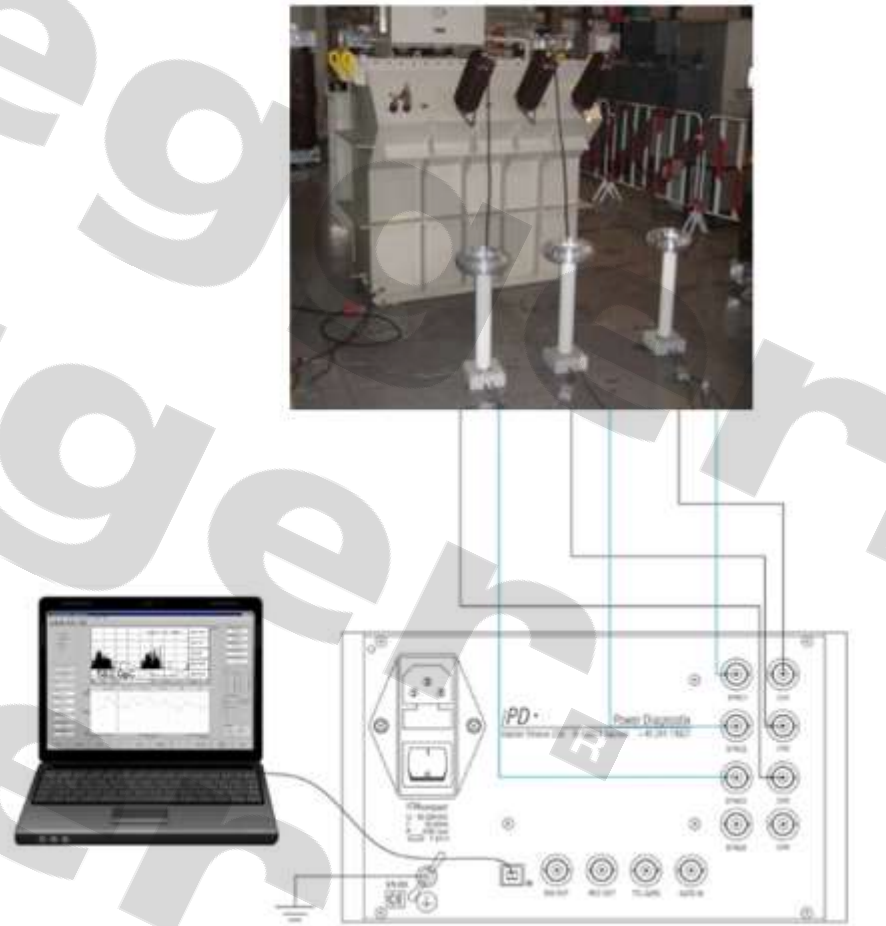


- Example test setup for measurements on a distribution transformer
- Decoupling: coupling capacitor with built-in quadrupole (e.g. CC35B/V)
- The decoupled PD signals are amplified by RPA1

PD by Megger
Power Diagnostix Systems

Testing of distribution transformers

- Example test setup for measurements on a distribution transformer
- Decoupling: coupling capacitor with built-in quadrupole (e.g. CC100B/V)
- The decoupled PD signals are amplified by RPA1



Configuration for distribution transformers

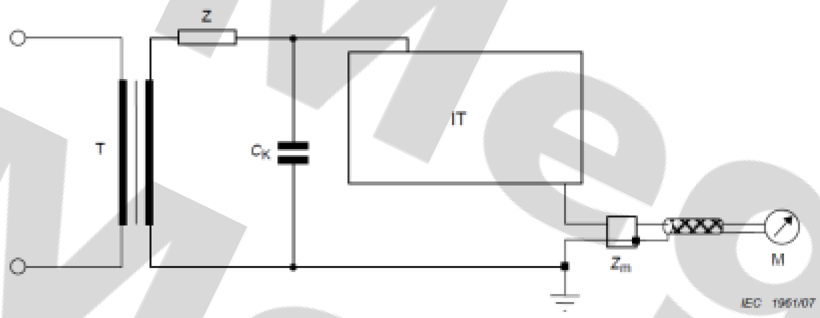
Minimum configuration:

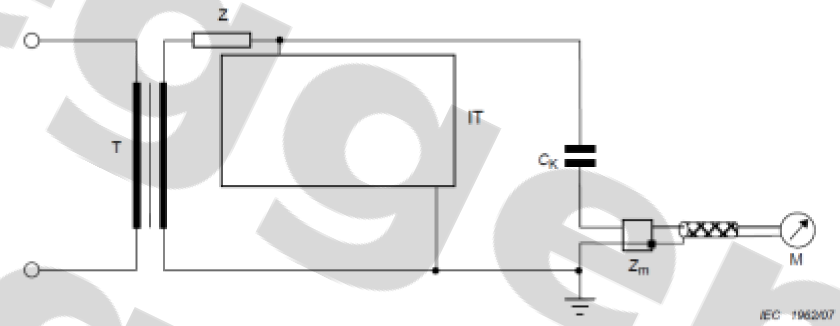
- The ICM*compact* acquisition unit with multiplexer (MUX4)
- The coupling capacitor e.g. CC100B/V
- 3 x preamplifier RPA1
- PD calibrator CAL1D
- The ICM*compact* Software

Full configuration:

- Spectrum and HVM
- Gating with current transformer e.g. CT1

The IEC 61869 compliant test circuits for PD Measurements





- The test circuit and the PD detector is in accordance with the IEC60270
- Prestressing is to be performed
- The PD test voltages are reached and corresponding PD levels are measured
- The measured PD levels should not exceed the defined limits

Example test setup

Configuration for instrument transformers

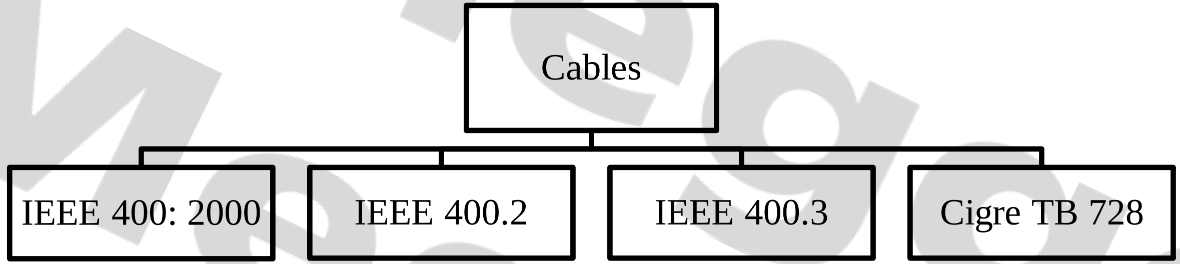
Minimum configuration:

- The ICM*compact* acquisition unit
- Coupling capacitor e.g. CC100B/V (5kV-100kV)
- 1 x preamplifier RPA1 or RPA1L
- PD calibrator CAL1A or CAL1D
- The ICM*compact* Software

Full configuration:

- Spectrum and HVM
- Gating with current transformer e.g. CT1

Normative references



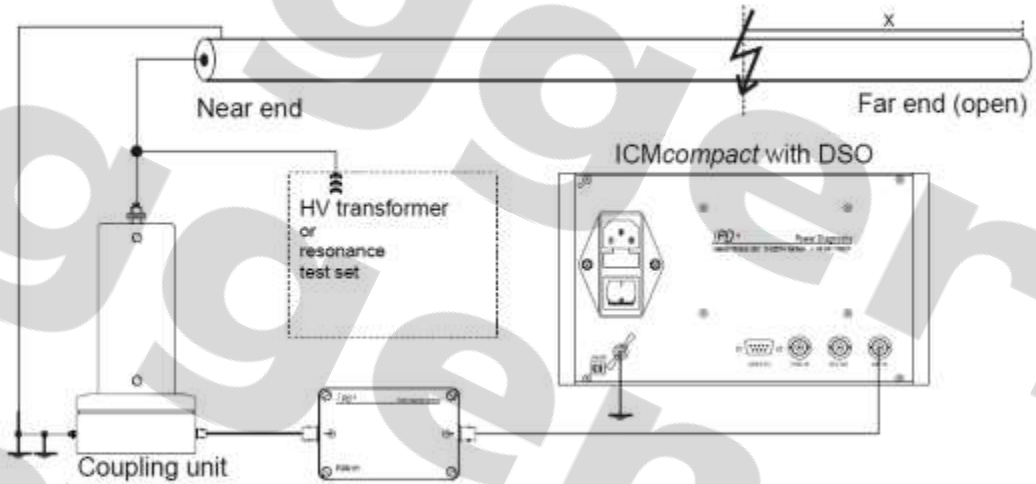
Acceptance Testing

Standard	Frequency	Voltage	PD Criteria
		1 kV < U < 40 kV	
IEC 60502	49-61 Hz	3.5 U / 5 min	1.73 U < 10 pC
		40 kV < U < 150 kV	
IEC 60840	49-61 Hz	2.5 U / 30 min	No PD up to 1.5 U
		150 kV < U < 500 kV	
IEC 62067	49-61 Hz	2.5 U / 30 min and 60 min	1.5 U < 10 pC

Example setup for cable fault location

The setup for acquisition of PD pulses in TDR:

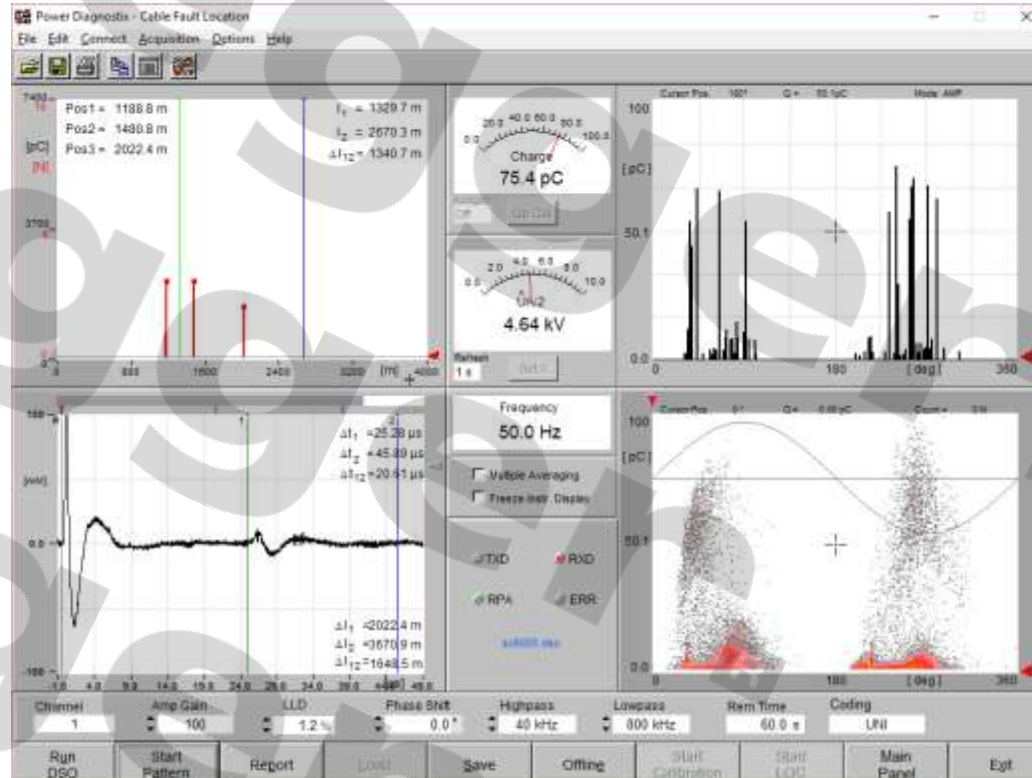
- The D.u.T must have an open end
- The cable sheath must be grounded
- All phases tested separately
- PD signals decoupled by the CC
- Amplified PD signals are digitized by the ICM*compact*



The optional software extension

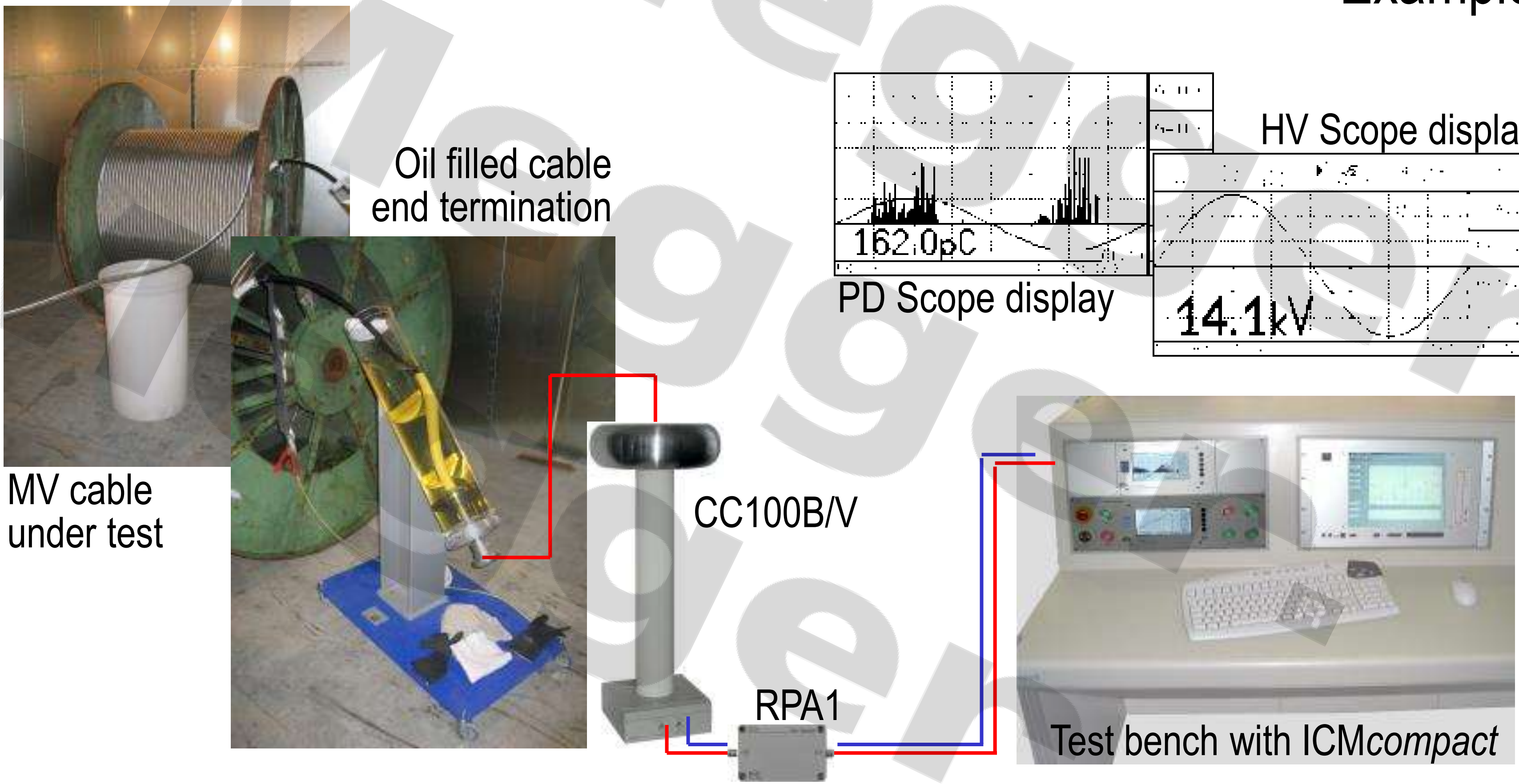
The software for CFL:

- Greatly simplifies the acquisition and analysis with the DSO board
- LOC display, DSO graph, an oscilloscope-like display and pulse-amplitude-phase-height distribution
- Calibration of the cable length
- The setup values e.g. range, gain, cable length, pulse velocity
- Online measurement or offline use for data evaluation



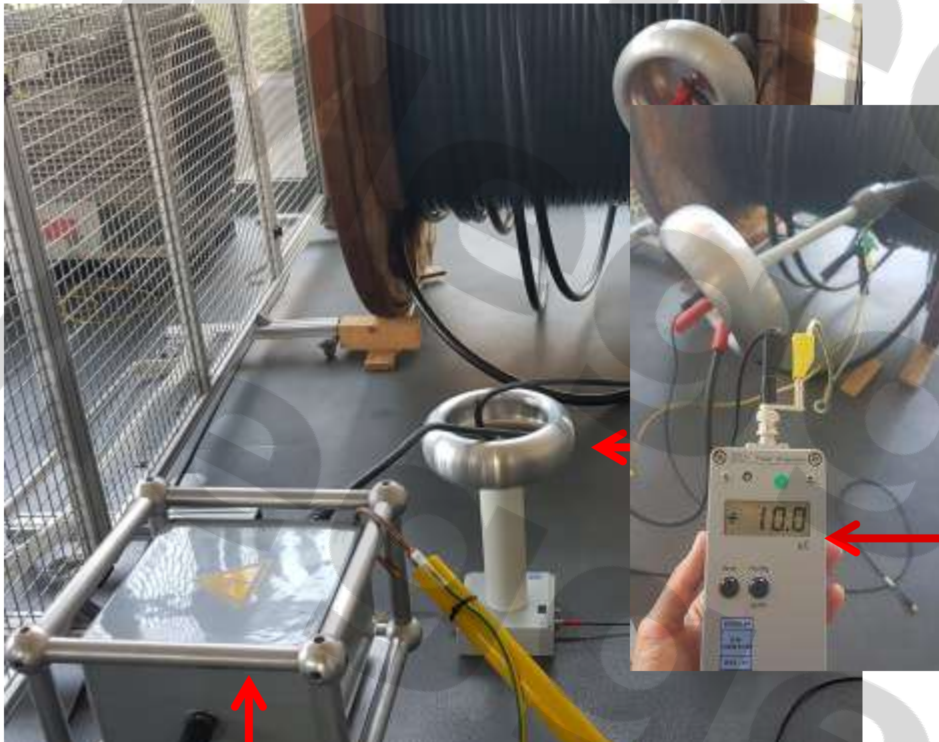
Testing of MV/HV cables

Example 1



Testing of MV/HV cables

Example 2



Configuration for MV/HV cables

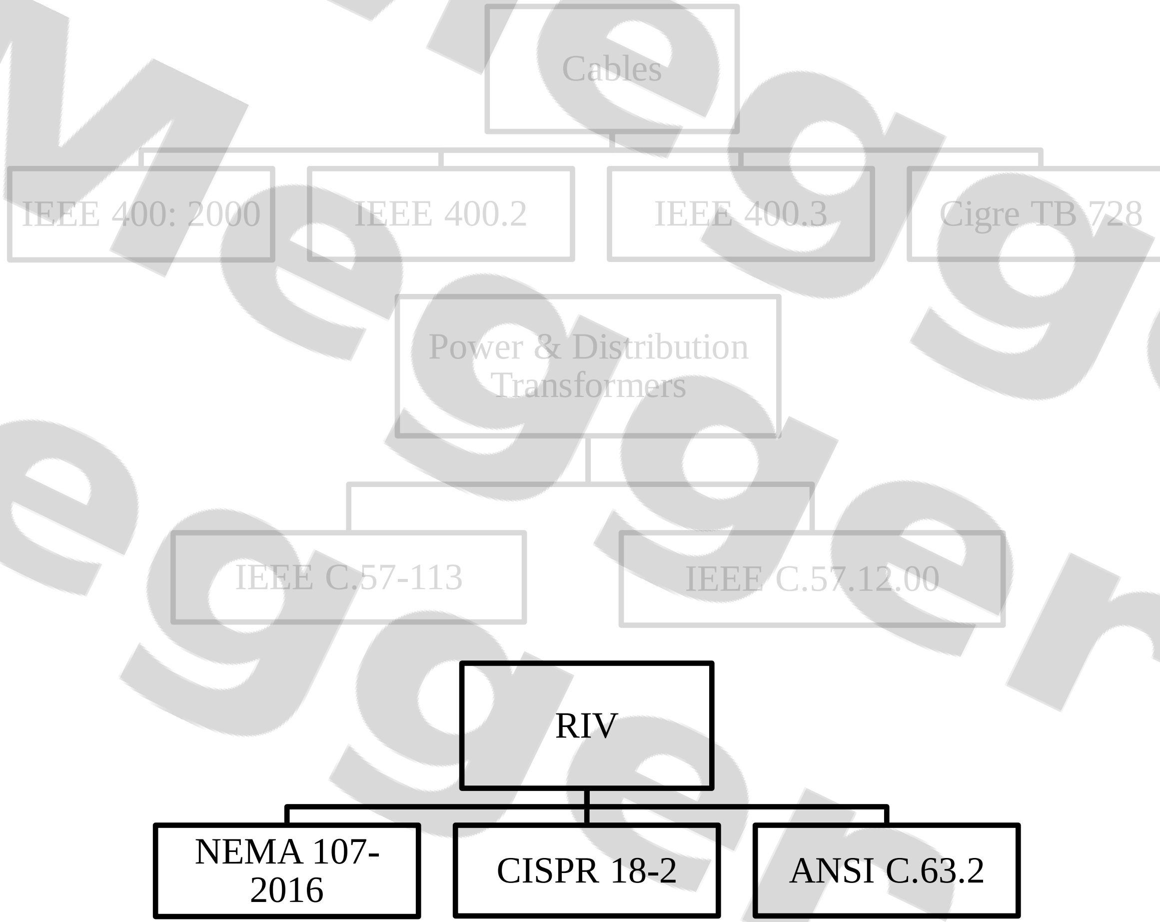
Minimum configuration:

- The ICM*compact* acquisition unit with DSO for CFL
- 1 x coupling capacitor CC100D/V or
- Quadrupole CIT4M/Vxxx (2-12µF)
- 1 x preamplifier RPA1L
- PD calibrator CAL1A or CAL1B
- The ICM*compact* Software

Full configuration:

- HVM (enabling VLF measurements)
- Spectrum and Gating options (for noise elimination)

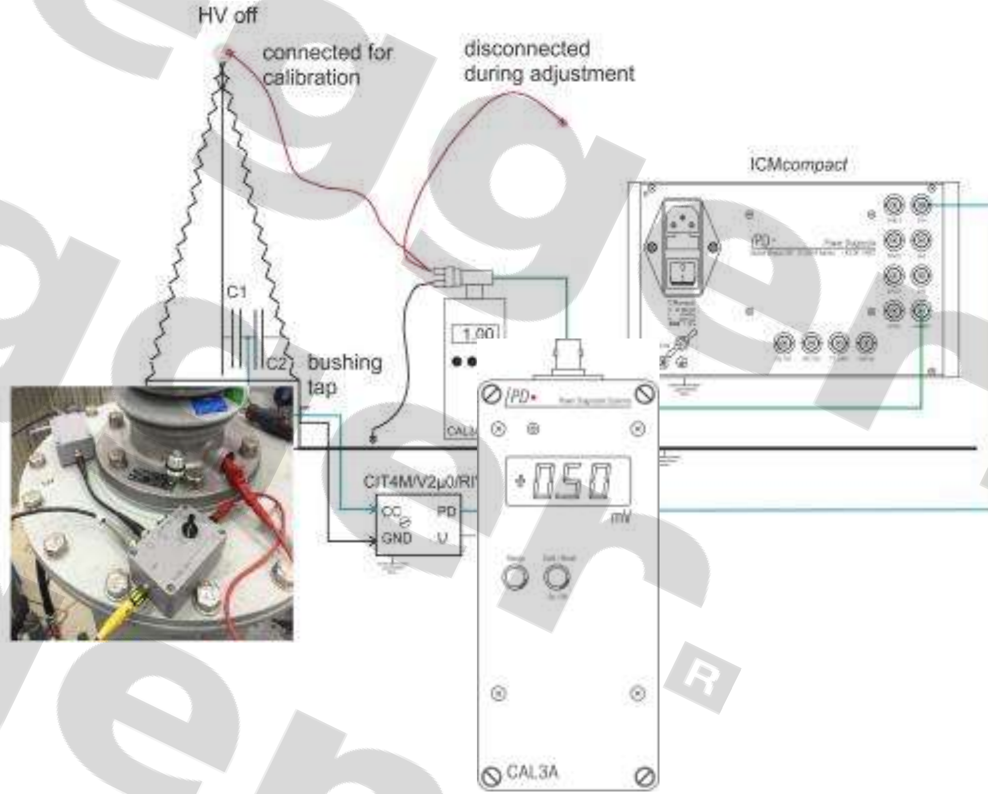
Normative references



RIV measurements

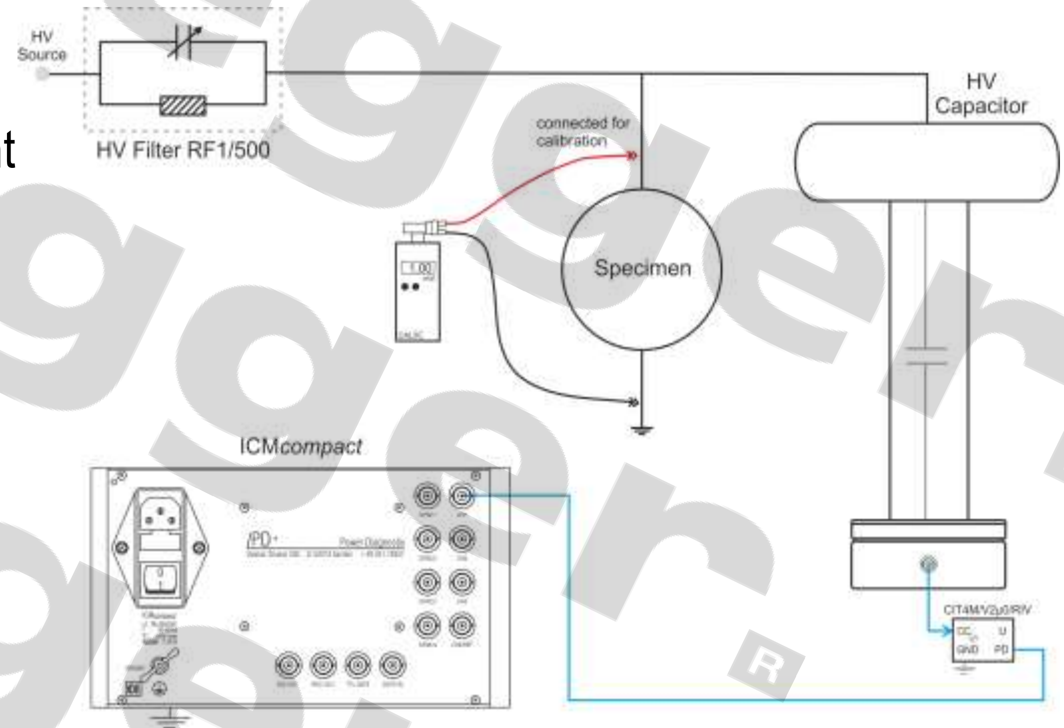
NEMA 107-1987 / 2016 compliant RIV calibration:

- Example setup on a transformer bushing
- The ICM*compact* automatically measures, calculates and stores the circuit RIV factor
- Adjustment and calibration with RIV calibrators e.g. CAL3A (50Ω output impedance)



CISPR 18-2 compliant RIV calibration:

- The RIV calibrator act as a current source causing a voltage drop across the 300 Ω resistor
- The HV source acting as RF bypass
- The IEC CISPR 18-2 requires determination of circuit attenuation and the network attenuation factor in dB.
- The ICM*compact* automatically calculates the combined correction factor



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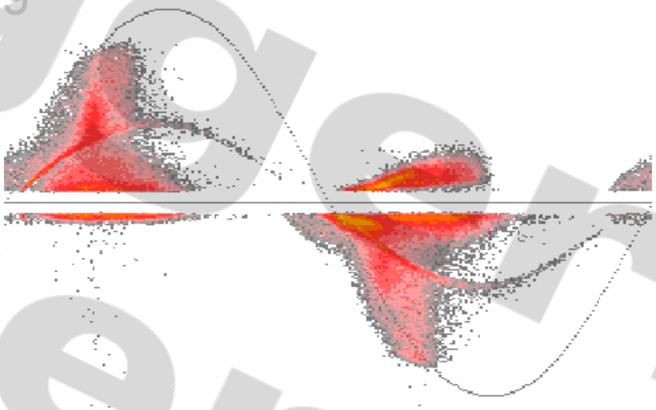
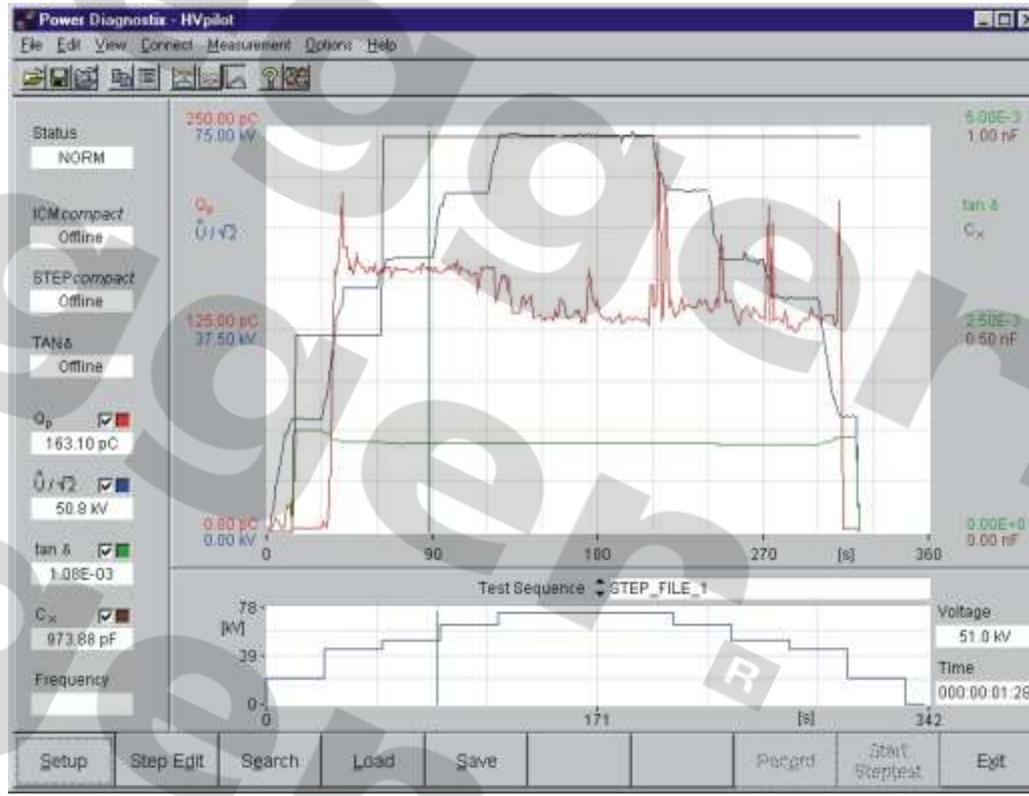
- The common applications
- **Automatic serial testing with HV*pilot* software**



The HV*pilot* software

Integration of the ICM*compact* into full test environment

- IEC61869 for CTs and VTs
- IEC60137 and IEEE C.57.19.00 for bushings
- The HV*pilot* software is connected to the PC with serial interface
- The HV*pilot* software reads out the data from different instruments
- It runs HV test steps automatically



Component testing

Testing of electronic components e.g. IGBTs, couplers, capacitors

- The serial PD testing of HV components in a test chamber
- PD recordings can be integrated into automated setups by using HV*control* and HV*pilot*
- Automatic or manual test sequences can be applied for series testing

Automated test bench for switchgear

- PD testing of switchgear components for quality assurance test procedures
- IEC 62271, High Voltage switchgear and controlgear
- IEC 60270, High voltage test techniques - PD measurements
- Analog gating option as well as the TTL gating to block switching pulses
- In combination with HV*control* and HV*pilot* SW the tests can be standardized and test reports generated automatically
- HV*pilot* SW supports preconfiguration of multiple setups, automatic voltage control and parallel recording

Configuration for gas-insulated switchgears

Minimum configuration:

- The ICM*compact* acquisition unit
- 1 x coupling capacitor CC100B/V or CC50B/V
- Quadrupole CIL4M/Vxxx (2-10µF)
- 1 x preamplifier RPA1 or 1 x RPA1L
- PD calibrator CAL1A or CAL1D
- The ICM*compact* Software

Options:

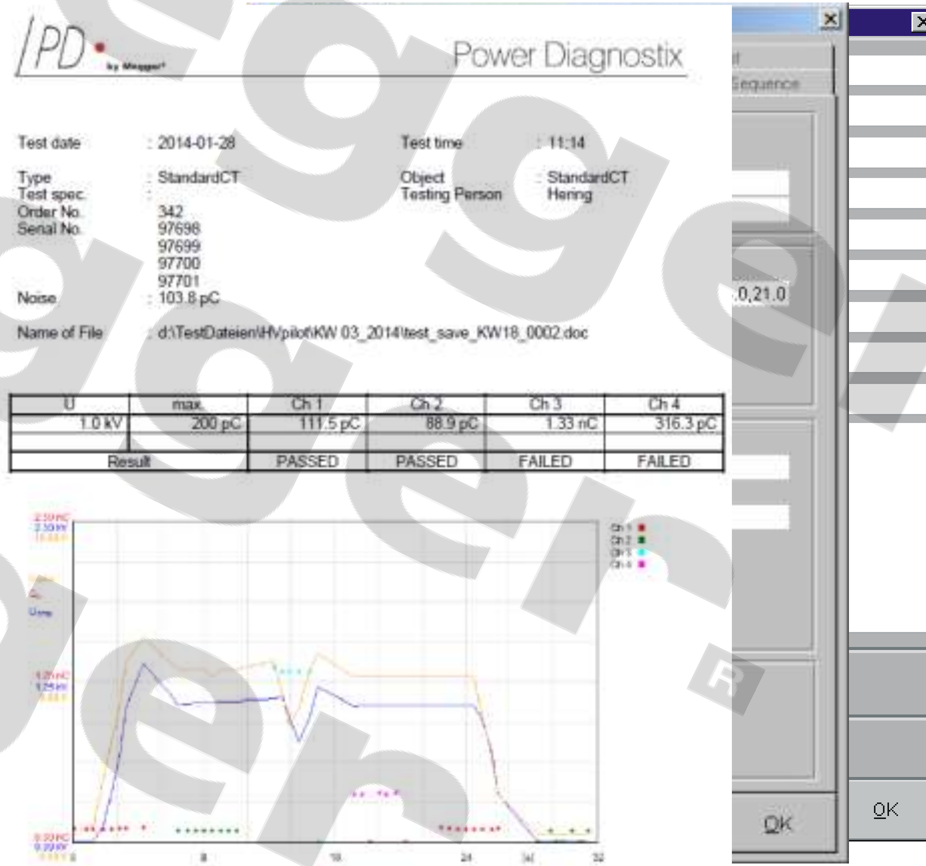
- MUX4
- Spectrum and HVM
- Gating with current transformer e.g. CT1

Automatic serial testing

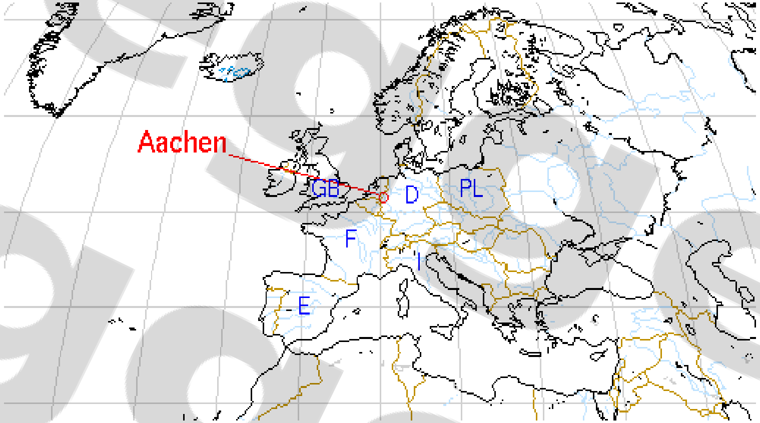
The HV*pilot* software

Software Features:

- Automatic test control
- Customizable reports
- Test templates created accordingly
- Tolerances for e.g. bushing tests are set for PD and tanδ
- Automatic report generation



Thank you for your attention!



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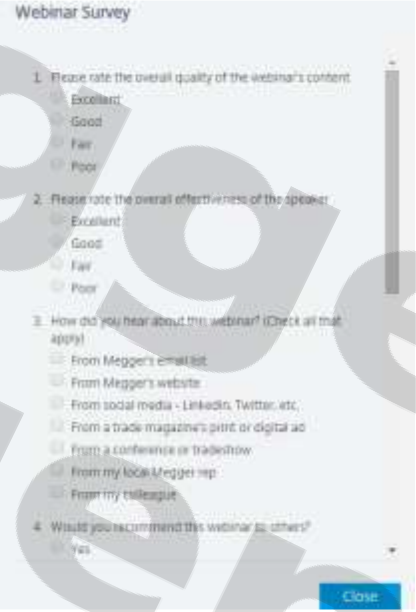

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- Date: September 16, 2020
- Presented by Stefan Seibel
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Questions?

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We can assist your acceptance, commissioning and maintenance testing for predictive, diagnostic or routine purposes. By working closely with electrical utilities, standards bodies and technical institutions, we contribute to the dependability and advancement of the electrical supply industry.