

Electrical and acoustical PD measurement on a 300 MVA Transformer

21st Conference on High Voltage Insulation Diagnostics, Sopron, Hungary, May 4th, 2023

▶ Case Study – Power Transformer

▶ History

- ▶ Transformer was bought as a used unit
 - ▶ no evidence of a defect
- ▶ Bushings removed for transport
- ▶ PD measurement should confirm proper onsite installation and ensure that no air bubbles are trapped in the bushing dome



▶ Power Transformer – Offline MPD 800 Test Setup

▶ Power Transformer

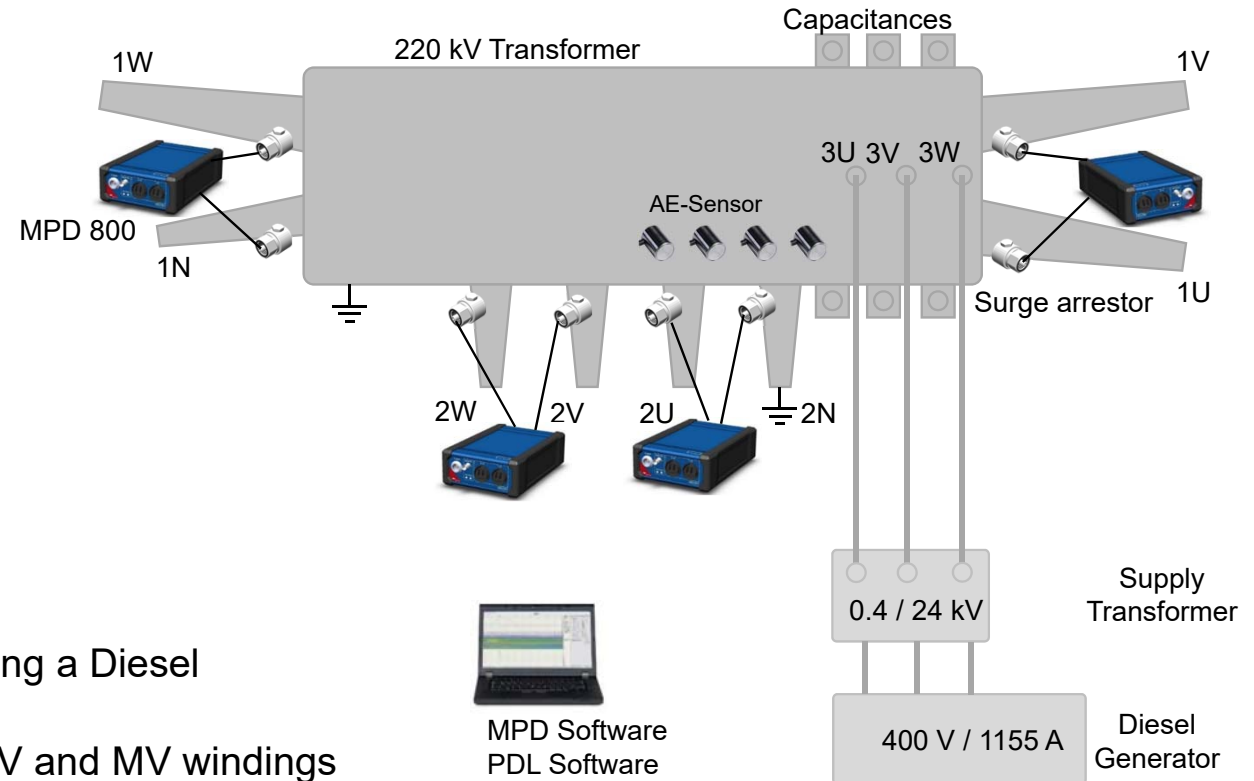
- ▶ 220 / 110 / 21 kV
- ▶ 300 MVA
- ▶ YNyn0d5
- ▶ Manufacturing year: 1993

▶ Location

- ▶ Austria

▶ Test Setup

- ▶ Induced voltage test via tertiary winding using a Diesel generator and a step-up transformer
- ▶ PD signals measured at bushing taps on HV and MV windings
- ▶ Setup using 4 x MPD 800 units (8 measurement channels)

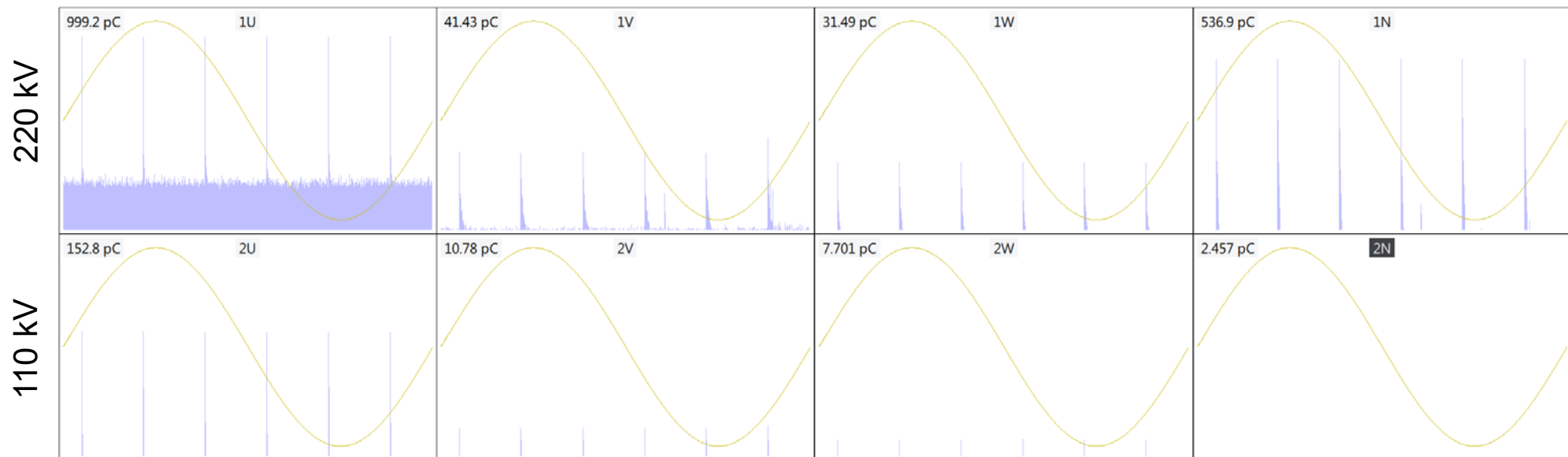


Power Transformer – Calibration

- ▶ Measurement frequency according IEC 60270
 - ▶ $f_c = 400 \text{ kHz}$, $\Delta f = 600 \text{ kHz}$
- ▶ PD Calibration matrix
- ▶ Voltage calibration
 - ▶ Sufficient to enter bushing C1 capacitance to compute test voltage level

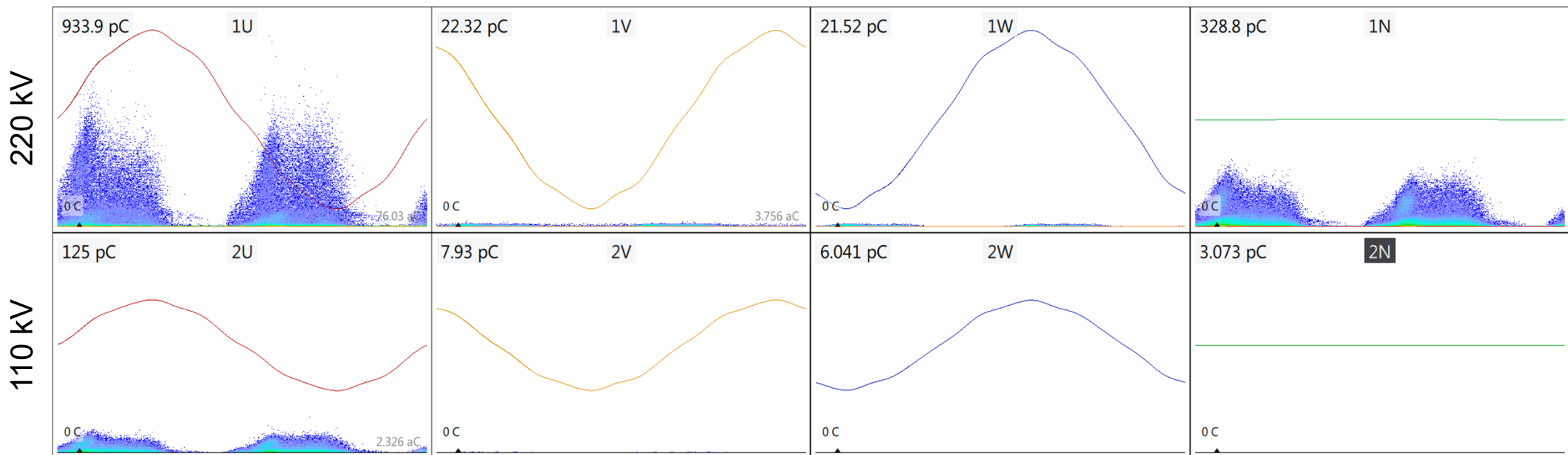
	1U	1V	1W	1N	2U	2V	2W
1U	1000	42	32	537	153	11	7,8
1V	34	1005	28	510	8	142	7
1W	31	30	1003	503	7,3	9,1	153
1N	82	83	76	1042	21	24	19,4
2U	243	14	12	223	1000	30	10
2V	12,3	250	12,3	232	17,4	996	16,4
2W	11,2	13	263	216	8,6	17,7	1000

Calibration Matrix



▶ Test Voltage of $0.72 \times U_n$ (91 kV)

- ▶ First PD activity at a test voltage of $0.72 \times U_n$ (91 kV)
 - ▶ 1 nC discharge at phase 1U and cross talk to other measuring points
 - ▶ Indications of floating voids with surface discharges (compare e.g. Cigre 676)

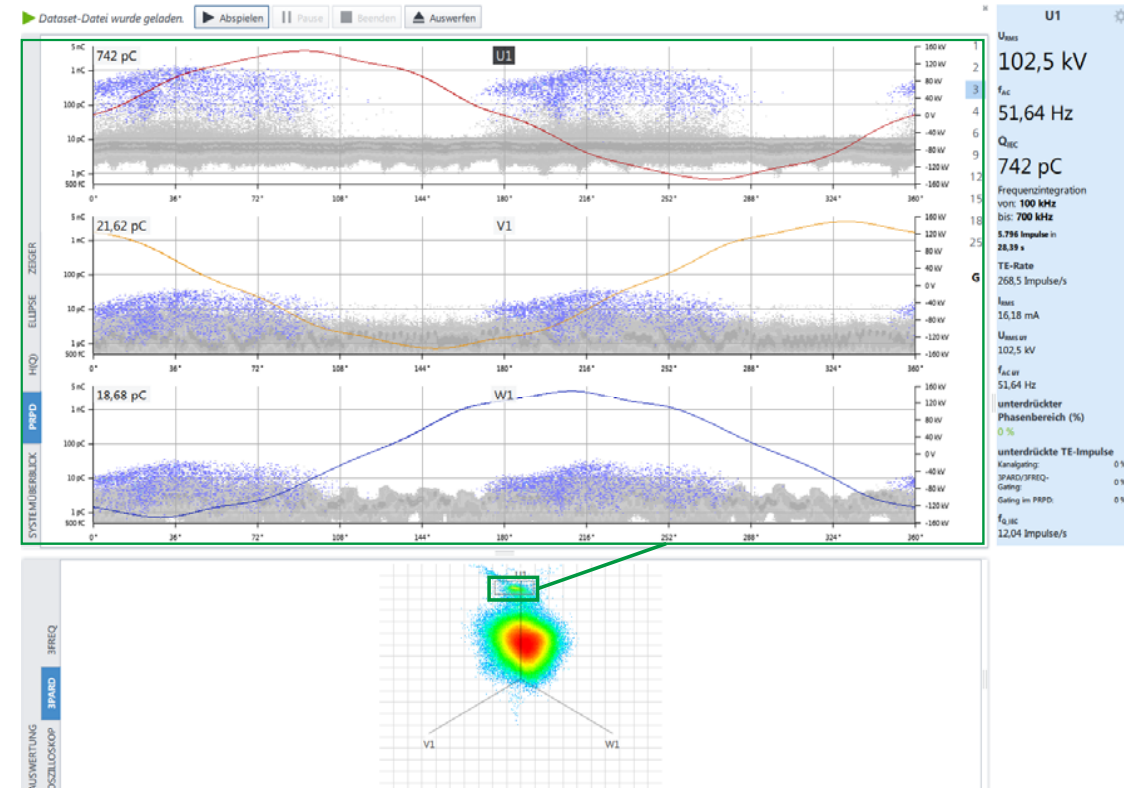


Assessment of PD Activity

- ▶ Time and frequency signal show high similarities to CAL signal
- ▶ Cross-coupling of real PD and CAL signal injected directly at the measuring tap are very similar

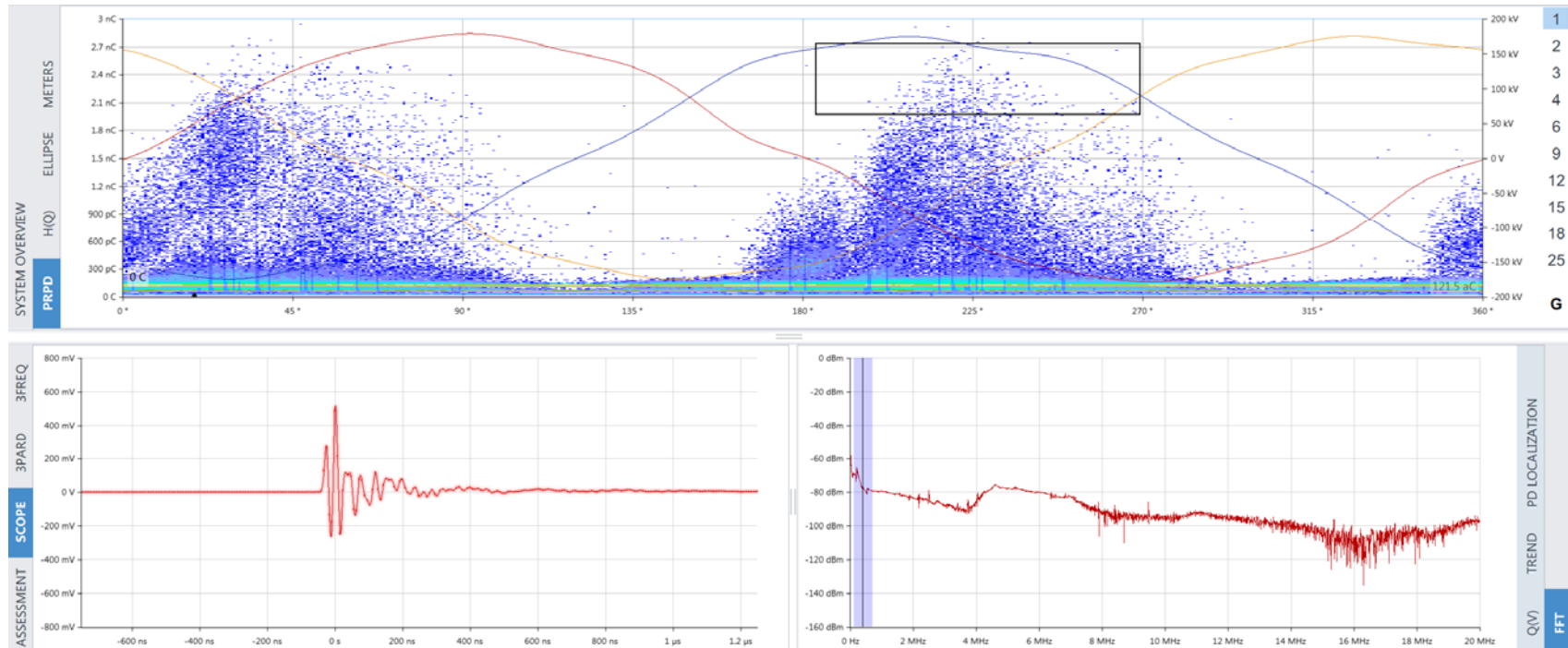
	1U	1V	1W	1N	2U	2V
PD 1U [%] @ 100 kV	100	3,33	2,31	44,03	16,29	0,87
PD 1U [%] @ 100 kV	100	5,05	2,56	56,68	19,42	1,03
PD 1U [%] @ 83 kV	100	4,61	4,38	48,04	14,81	1,12
PD 1U [%] @ 83 kV	100	4,62	4,90	45,94	13,87	1,23
Average PD 1U [%]	100	4,61	3,47	46,99	15,55	1,08
CAL Impulse 1U [%]	100	4,20	3,20	53,70	15,30	1,10

- ▶ **Conclusion:** PD source is close to measurement location



Assessment of PD Activity – Time Domain Signal

- ▶ Select single PD impulses via *Window Trigger*
- ▶ Analysis of impulse shape and frequency spectrum

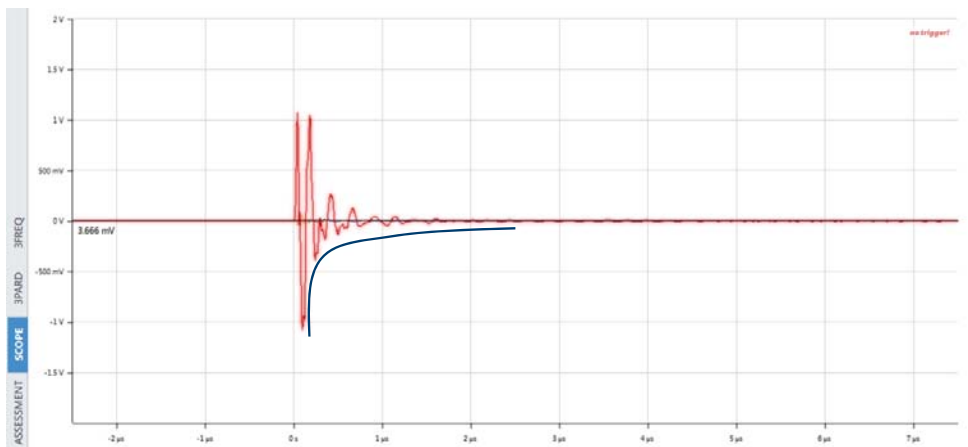


Window-Trigger with corresponding time- and frequency domain signal

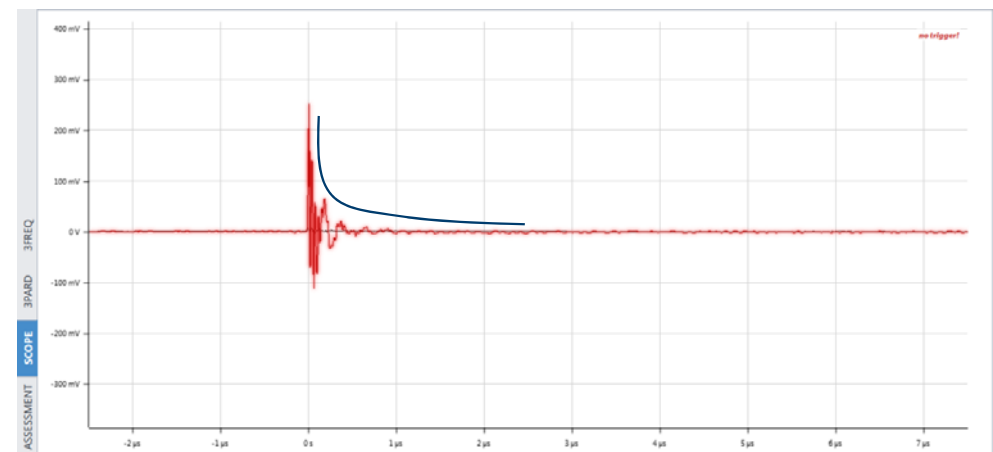
► Assessment of PD Activity – Time Domain Signal

- Comparison of calibrator and PD impulse on phase 1U
- High-frequency impulse with little oscillations
- Indication for short propagation path
- **Conclusion:** PD source close measurement system, e.g. bushing.
- **Next step:** Acoustical PD localization

CAL at Channel 1U



PD at Channel 1U



Comparison of calibrator and PD impulse

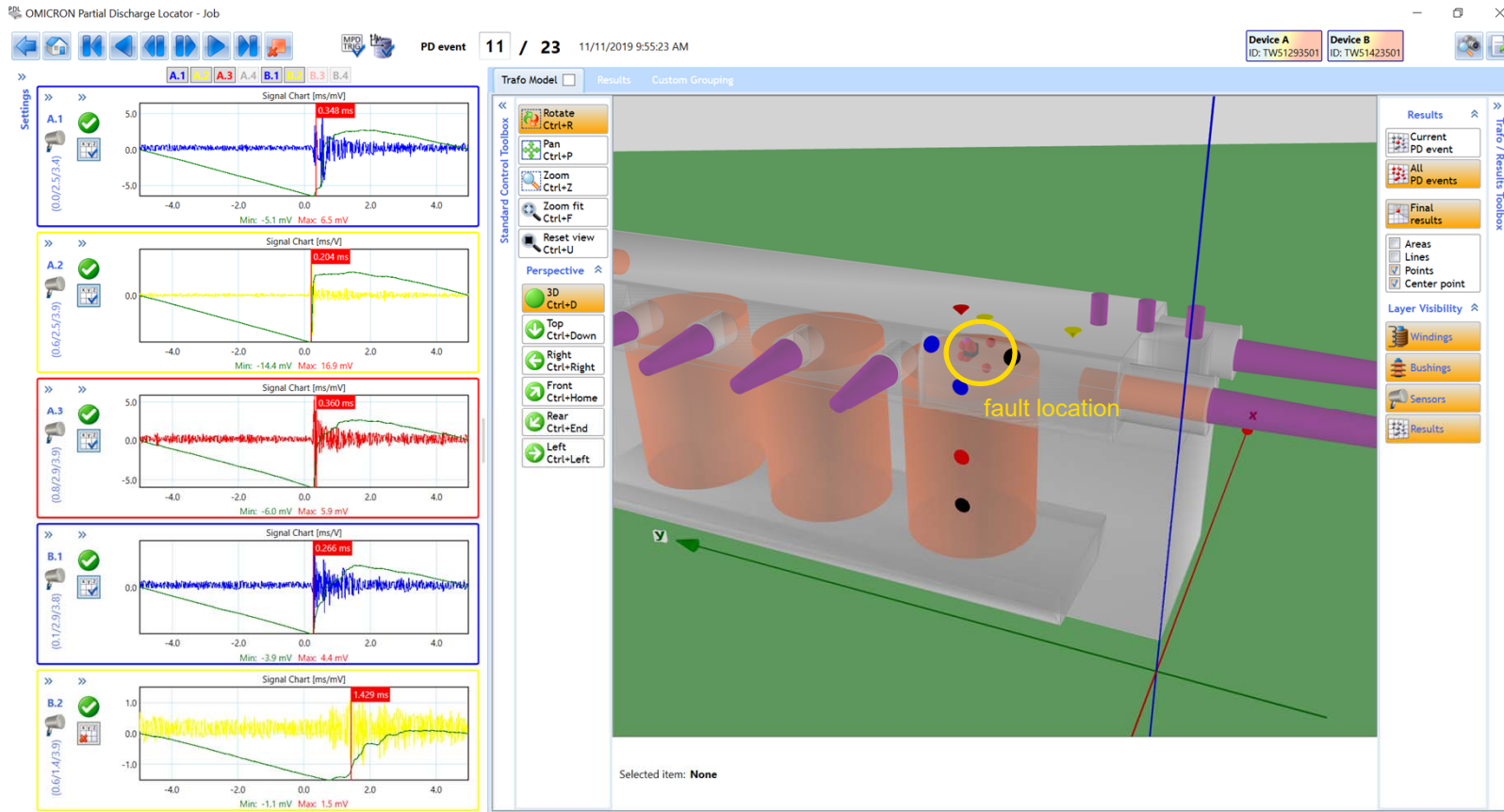
▶ Power Transformer – Acoustic PD Localization

- ▶ Two PDL 650 systems
 - ▶ 8 acoustic sensors/microphones
- ▶ Sensor position based on results of electrical PD measurement
- ▶ Sensitivity check via pencil tip
- ▶ Trigger
 - ▶ Electrical (using window trigger)
 - ▶ Acoustical



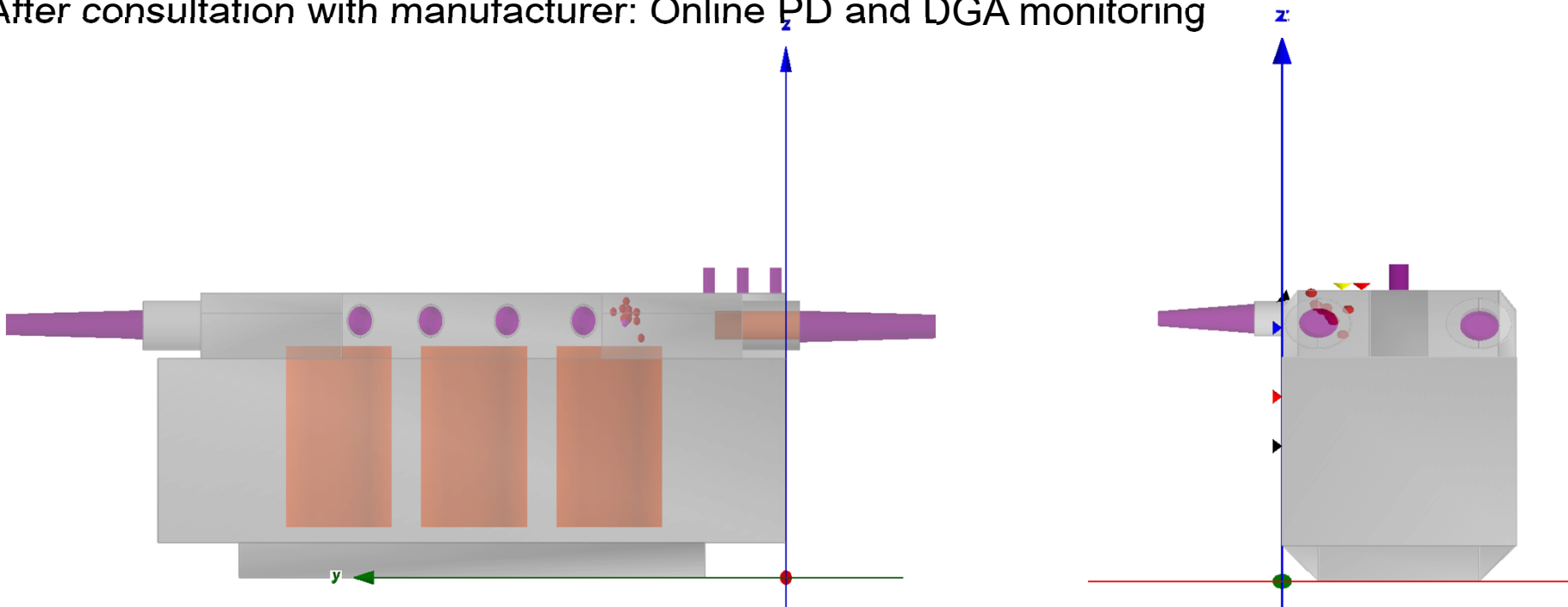
▶ Power Transformer – Acoustic PD Localization

▶ Transformer model, sensor position and acoustic signals (A1, A2, A3, B1, B2)



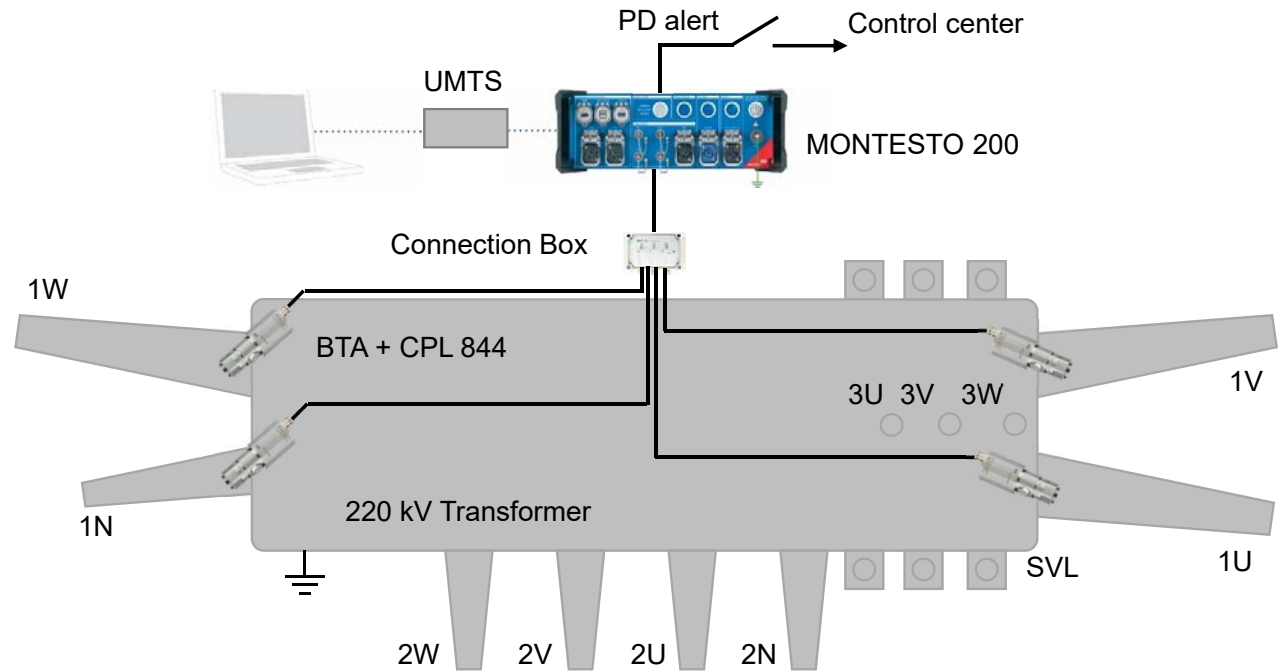
▶ Power Transformer – Acoustic PD Localization

- ▶ PD source close to winding connector of phase 1U
- ▶ Bushing seems not be affected
- ▶ On-site repair not feasible, transport to workshop too cost intensive
- ▶ After consultation with manufacturer: Online PD and DGA monitoring



▶ Power Transformer – PD Trending Test Setup

- ▶ Measuring system **MONTESTO 200** with integrated IPC and 4 PD input channels is installed next to the connection box.
- ▶ Measuring impedance and bushing tap adapters are permanently installed at all 220 kV bushing taps (1U, 1V, 1W, 1N)
- ▶ Customized Solution:
 - ▶ UMTS modem for remote control
 - ▶ Automatic alert in control room by switching a contact in case of PD rule violation



Temporary PD Monitoring System



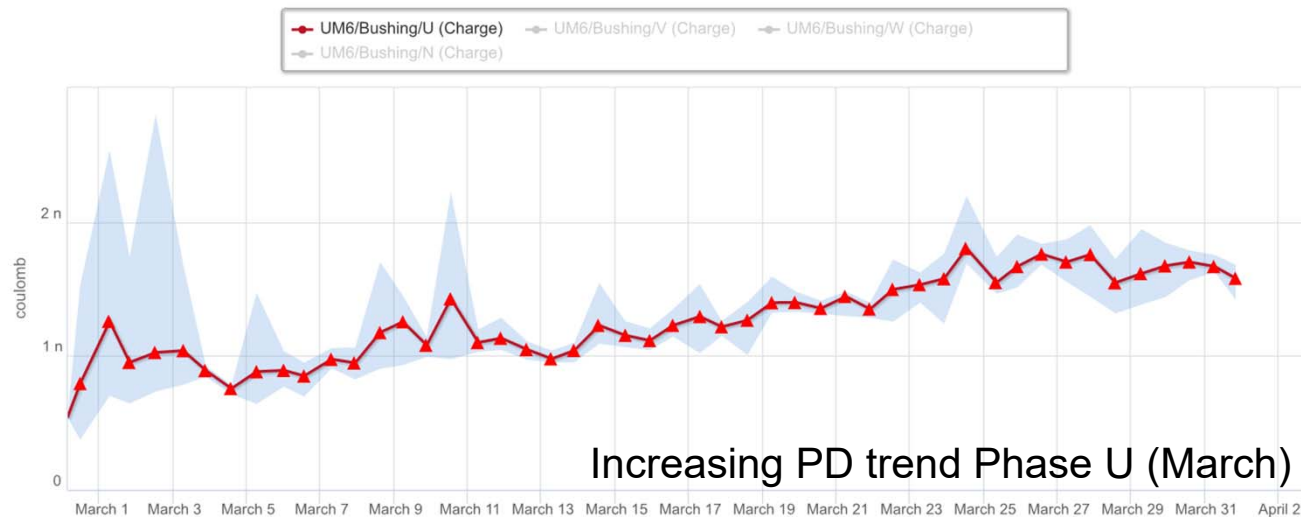
MONTESTO 200

Connection Box

UMTS Modem and contacts for PD alert

▶ Power Transformer – PD Trending

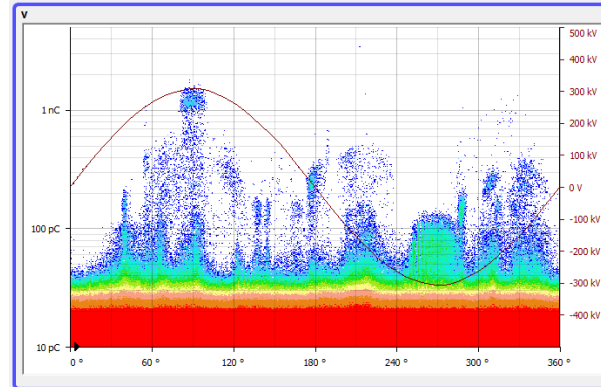
- ▶ Stable PD trend for the first two month (January / February)
 - ▷ approx. 500 pC on Phase U
- ▶ Increasing PD trend on Phase U over the period of 1 month (March)
 - ▷ afterwards the level stabilized ~ 1500 pC
- ▶ New PD source on Phase V after 4 month of operation
 - ▷ increasing trend for 3 month
 - ▷ afterwards the level stabilized at ~ 2000 pC



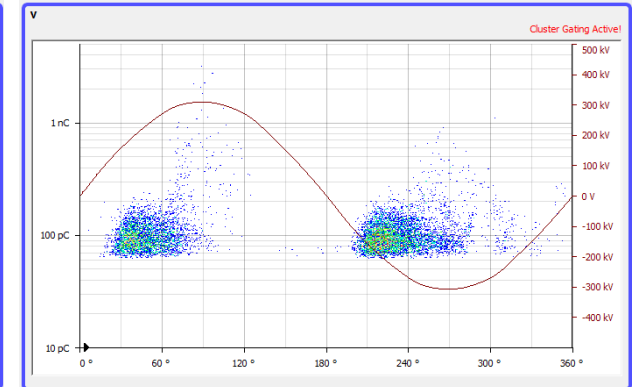
▶ Power Transformer – PD Trending

▶ Development of PD at Phase V

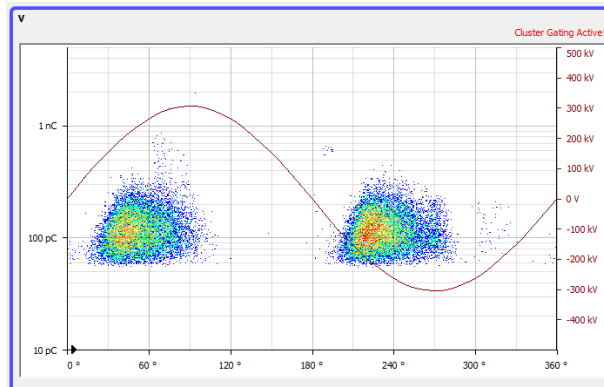
- ▶ First discharges end of March with 100 pC
- ▶ Increasing trend up to 2000 pC
- ▶ Stabilized after 3 months



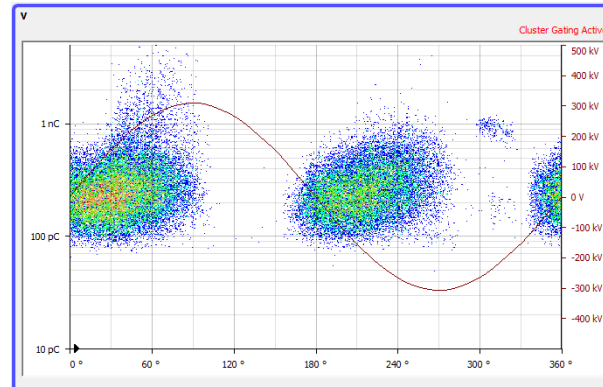
29. February
(unfiltered, noise only)



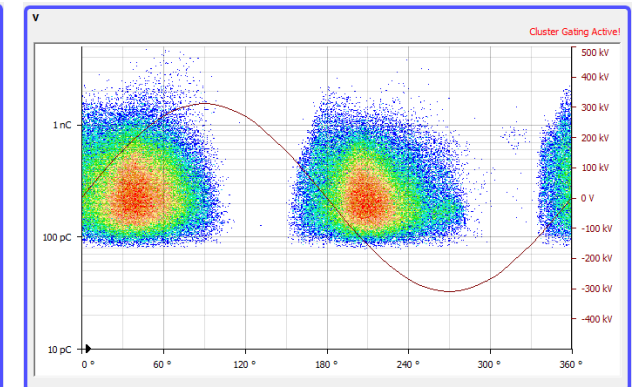
27. March



21. April



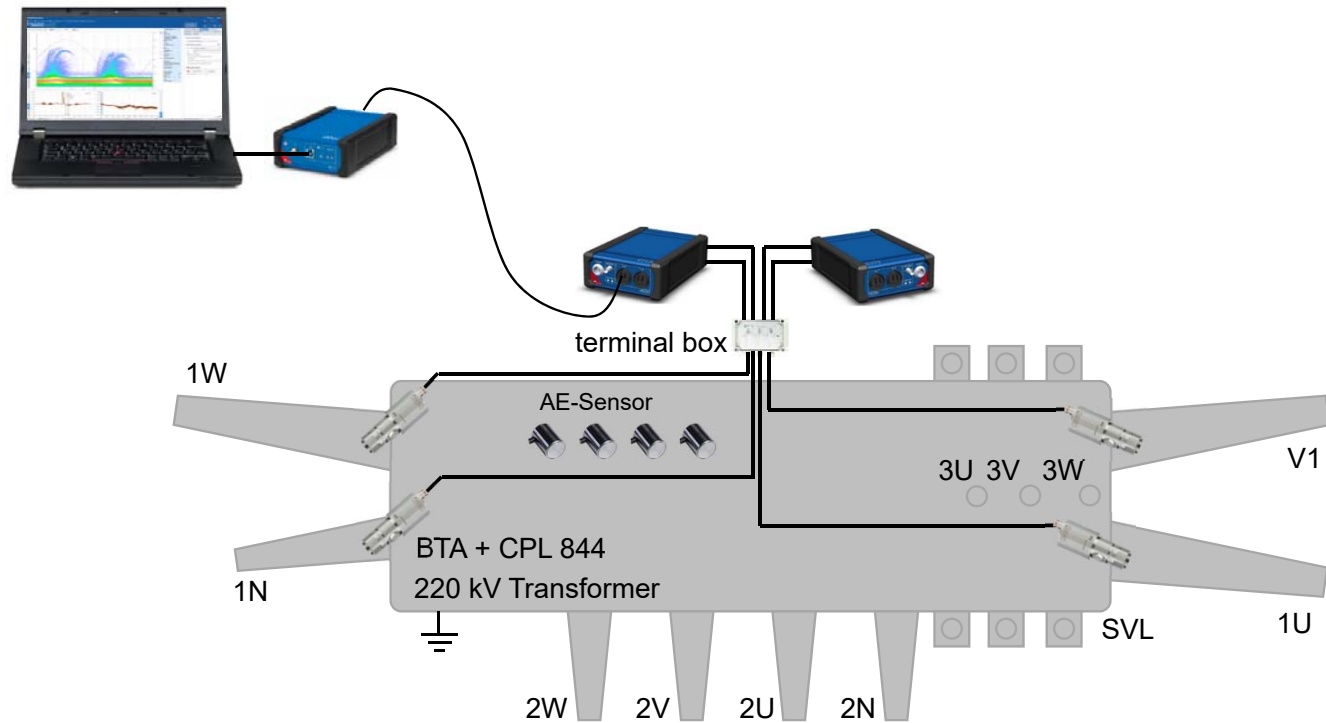
08. May



03. June

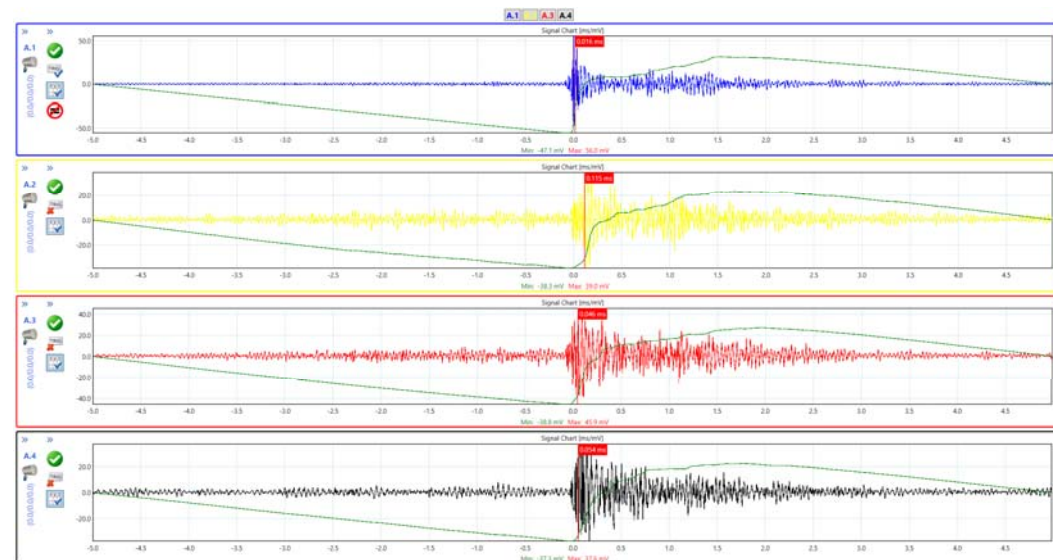
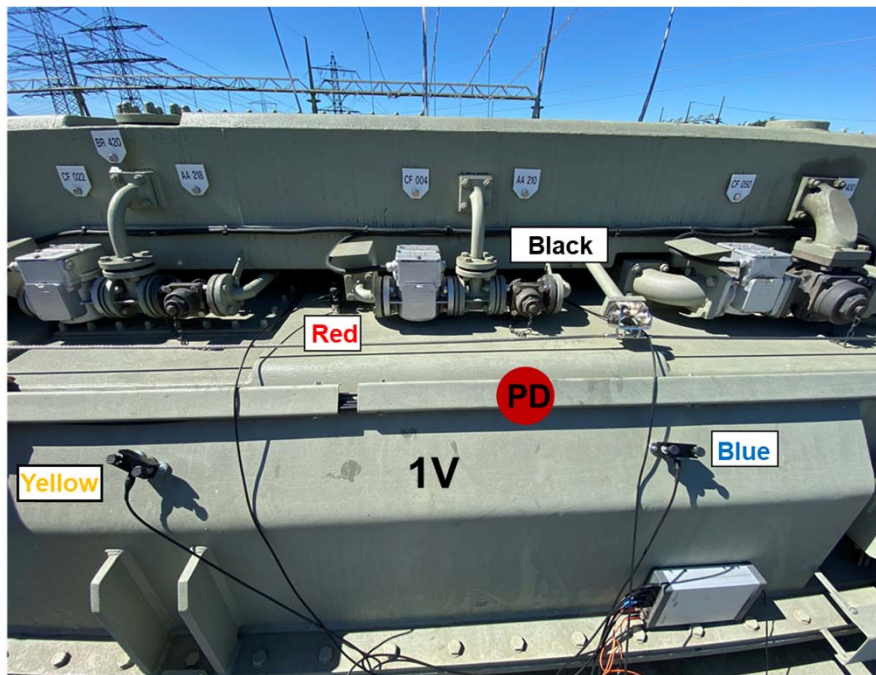
▶ Power Transformer – Online MPD 800 Test Setup

- ▶ Analysis and localization of the new developed PD pattern at Phase V using the MPD 800 - online
- ▶ Transformer can remain online for installation
- ▶ MPD 800 System directly connected to the pre-installed terminal box of the MONTESTO 200.
- ▶ PDL 650 used to pinpoint the acoustic signals.



▶ Power Transformer – Online MPD 800 / PDL 650 Test

- ▶ PRPD Pattern at 1U and 1V look the same
- ▶ Time- and frequency domain signals of discharges at 1U and 1V show similarities
- ▶ PDL 650 detected acoustical signals at the exit lead of 1V
- ▶ **Conclusion:** It is very likely that PD happens at the same point at different windings!



▶ Summary

- ▶ Combination of offline PD measurement, acoustical localization and PD trending
- ▶ Early detection of incipient PD activity
- ▶ Three channel measurement used for separating PD sources
- ▶ Successful acoustical localization using electrical trigger
- ▶ On-site repair of transformer not feasible
- ▶ Temporary PD trending and DGA monitoring allowed operator to keep transformer in service until replacement of unit



Thank you very much for your attention!

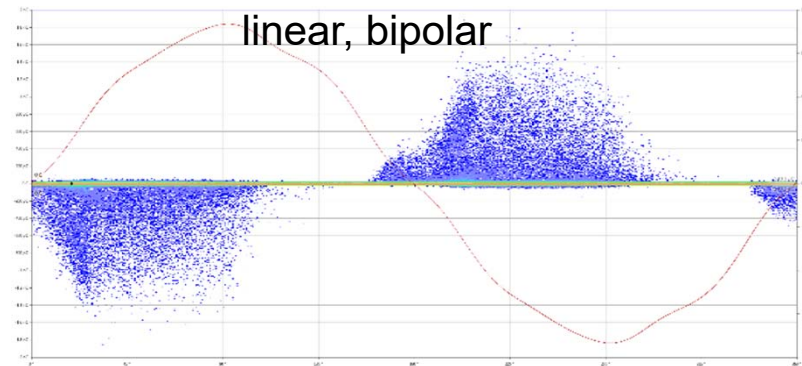
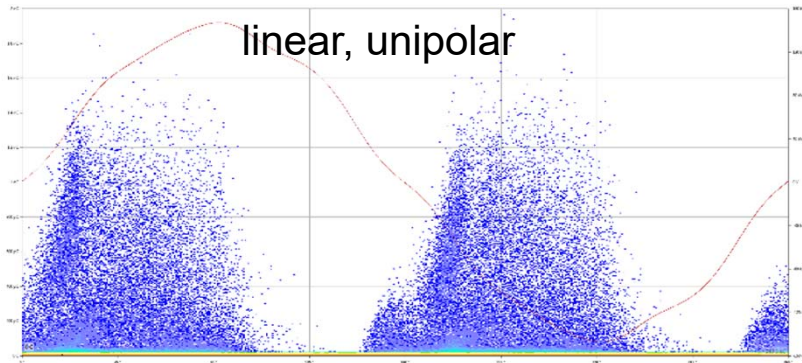
Emotions are energy. Our energy moves.



► Identification of PD Type

► PD at 1U at 0.72 x Un (91 kV)

► Comparison of measured PRPD pattern with “CIGRE Guide 676 – Partial Discharges in Transformers”



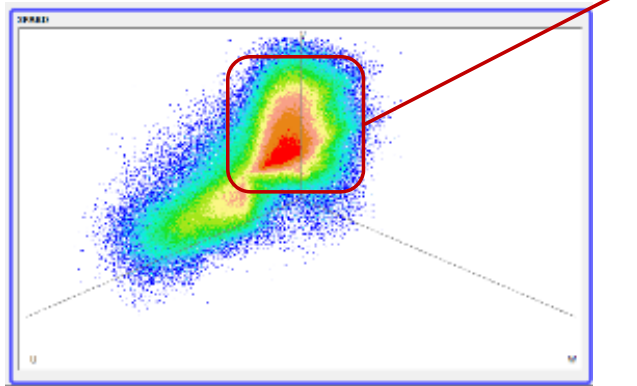
PARTIAL DISCHARGES IN TRANSFORMERS

FLOATING VOID WITH INTERACTION AT THE SURFACE OF THE INSULATING MATERIAL

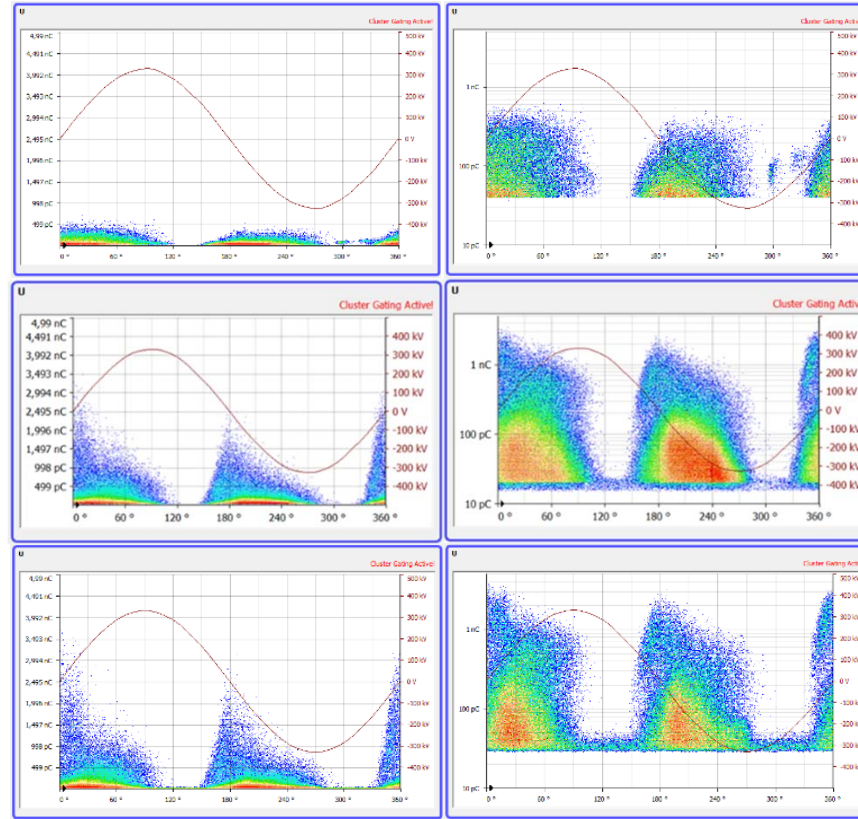
PD source	PD pattern	Remarks
		Voids with surface discharge
		Voids with surface discharge

▶ Power Transformer – PD Trending

- ▶ Development of PD at Phase U
 - ▶ Started with 500 pC
 - ▶ Increase during a period of 1 month
 - ▶ Since then, it stabilized at 1500 pC



3PARD



PRPD Linear

PRPD Log

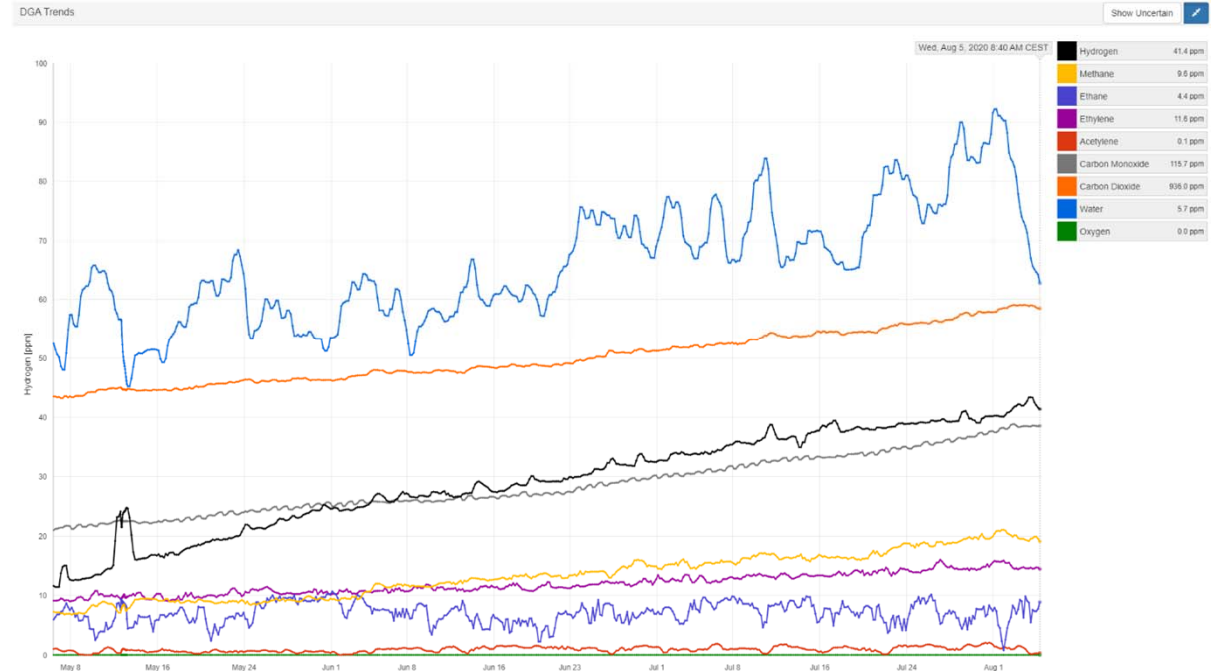
29. February

27. March

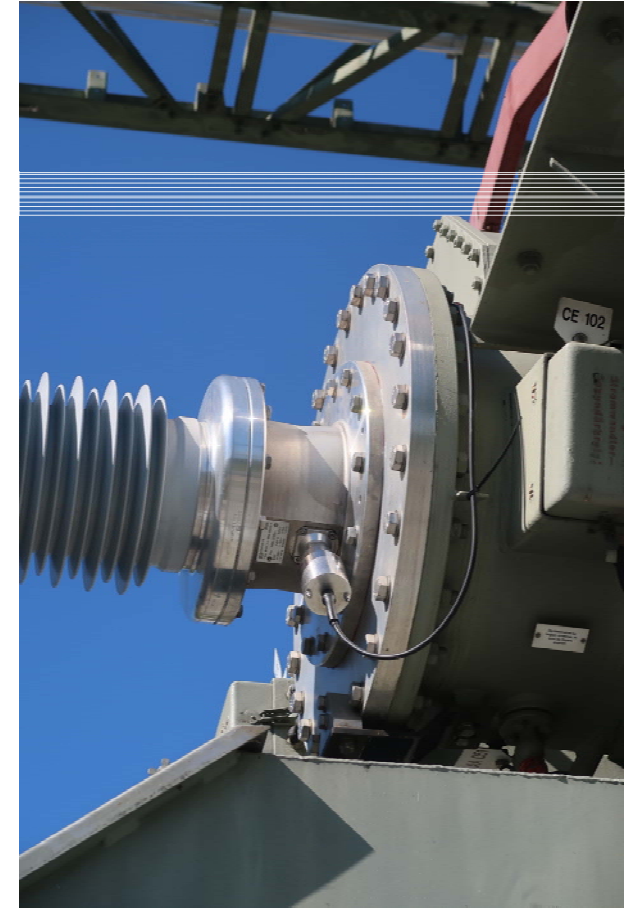
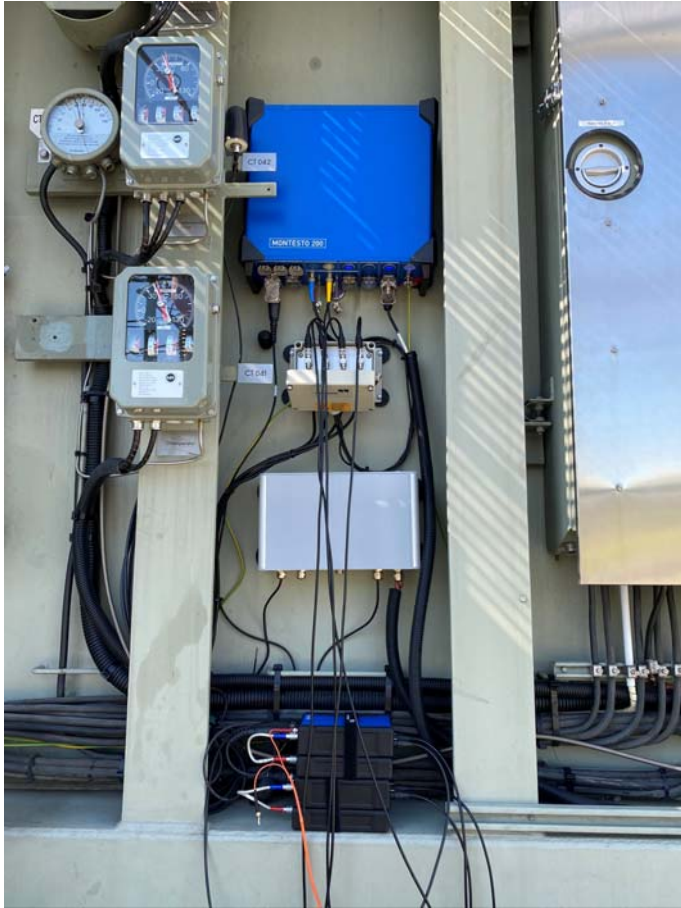
03. June

▶ Power Transformer – Dissolved Gas Analysis (DGA)

- ▶ DGA Monitoring of CAMLIN
- ▶ DGA results before and after transportation did not indicate any failure nor PD activity
- ▶ Hydrogen slightly increased during operation, but the overall amount of dissolved gases are below typical values, thus no reliable assessment can be performed according IEC 60599.
- ▶ A local defect inside a solid insulation part doesn't necessarily lead to an increase of dissolved gases.
- ▶ Electrical PD measurement and trending can be more sensitive and instantaneous compared to DGA



► Power Transformer – Online MPD 800 Test Setup



▶ Power Transformer – Bushing Installation 220 kV



► Power Transformer – Offline MPD 800 Test Setup



Power Transformer – Offline MPD 800 Test Setup

