Transformer Health Management using Temporary On-Line Partial Discharge Monitoring

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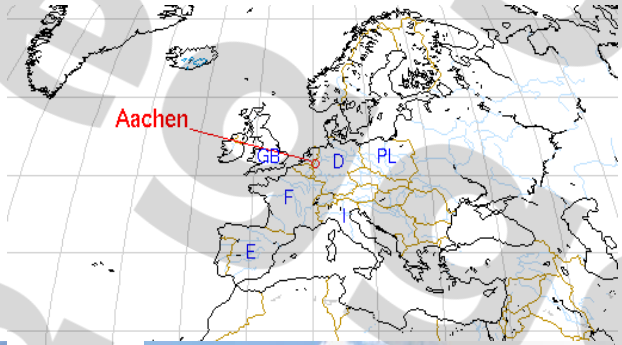
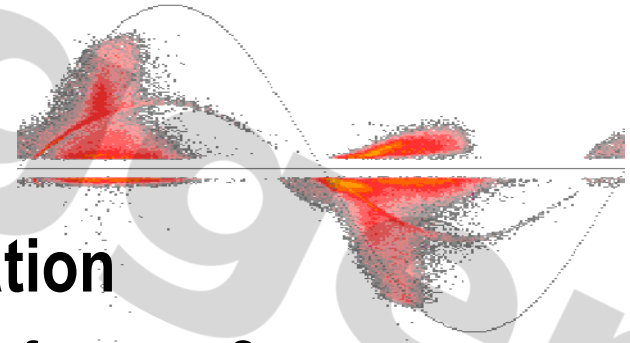


Temporary PD Monitoring of Power Transformers



- **PDIX by Megger Group Presentation**
- Why PD monitoring of Power Transformers?
- System technical details
- Remote Connectivity and Software
- On-site testing of Power Transformers

Megger Diagnostic Holding GmbH

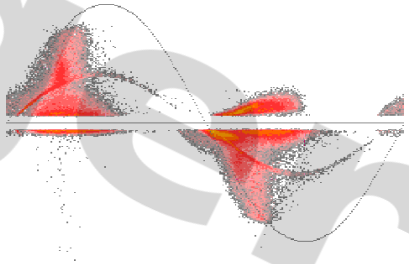
Power Diagnostix Systems GmbH
- Sales and Distribution

Power Diagnostix Service GmbH
- Measurement Services, Mobile Test Systems

Power Diagnostix Instruments GmbH
- Development and Production

Company Structure

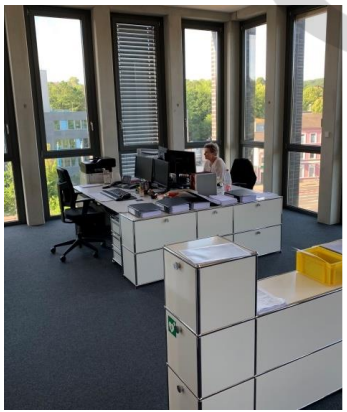
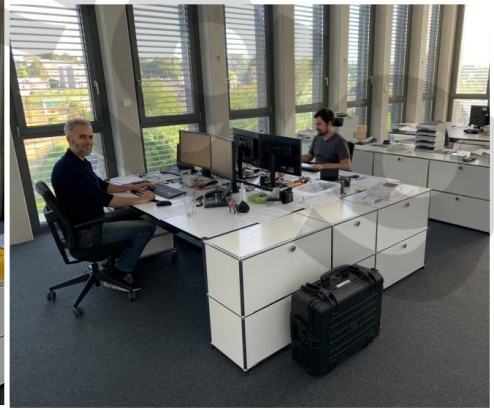
- Three Companies operated as a group
- Executive Board: Detlev Gross, Mihai Huzmezan, Markus Söller
- Running a very lean structure
- Employees having multiple roles within the Team
- ~50% of company staff are engineers
- German high level of in-house production & quality control
- We do everything in house:
  - Hardware (Analog & Digital) design, Software & Firmaware Programming, Project Management, Technical Sales, Back office, Services, Repairs, Development, QM & Calibration, Production



PD by Megger®
Power Diagnostix Systems

Company Impressions



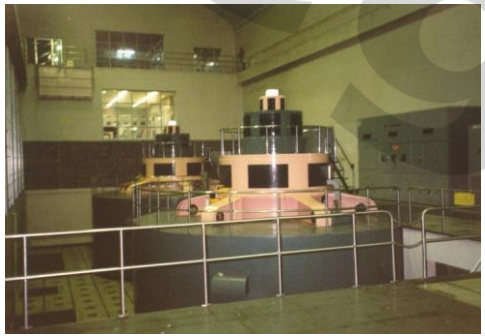
Product Overview 1/3

- Instruments for Partial Discharge and Loss Factor Measurement
- Control Systems for PD test benches
- PD Monitoring Systems
- DAkkS Calibration Laboratory
- Consulting, Service, Seminars, and Training

Product Overview 2/3

- Wide Range of Applications
- Measurement Tools for the whole Product Life-Cycle
- Applicable from below 1kV up to EHV (>1MV)
- Instruments made for tough Industrial Conditions

Generators and Motors



GIS/GIL

Product Overview 3/3

- PD/TD Acceptance Testing in the Laboratory
- Testing under AC and DC Voltages
- Non Conventional Test methods for Onsite Testing
- Research on Insulation Materials

Research

Transformers, Bushings

Power Cables, Joints, Terminations

Product Groups 1/3

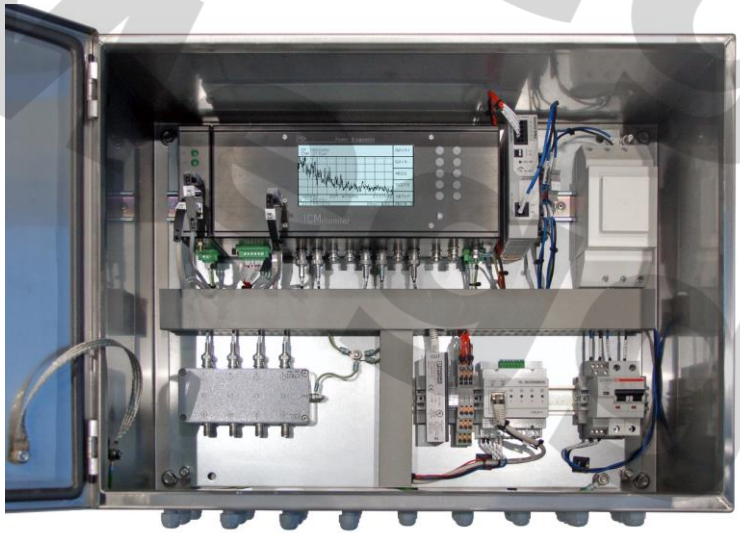
So called “Portable Products”

- ICM*system*
- ICM*compact*
- AIA*compact*
- ICM*flex*
- ICM*monitor* portable

Product Groups 2/3

PD Monitoring systems

- ICM*monitor*
- GIS*monitor*



Product Groups 3/3

Special devices and systems

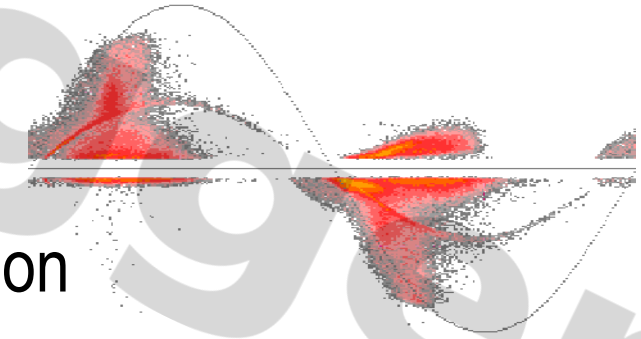
- TDA*compact*
- RIV*meter*
- ATT*analyzer*
- HV*control*, HV*compact*, STEP*compact*
- FO*system* (FOS1 – FOS4)

Certificates and Qualifications

- DAkkS calibration services; 1st accreditation in 2003
- 2018 reaccreditation according new ISO17025:2018
- ISO9001:2015 (quality) since 2016
- ISO14001:2015 (environment) since 2017
- Approved and preferred supplier for ABB, Siemens, GE, Koncar (Siemens), Air Liquide, MR, others
- Successful prequalification of PDM Systems for GIS (GIS*monitor*) with large utilities such as: DEWA (UAE), National Grid (KSA), Kahramaa (QA), PGCIL (India)

DAkkS
Deutsche
Akkreditierungsstelle
D-K-15068-01-00

Temporary PD Monitoring of Power Transformers



- PDIX by Megger Group Presentation
- **Why PD monitoring of Power Transformers?**
- System technical details
- Remote Connectivity and Software
- On-site testing of Power Transformers

PD Monitoring of Power Transformers

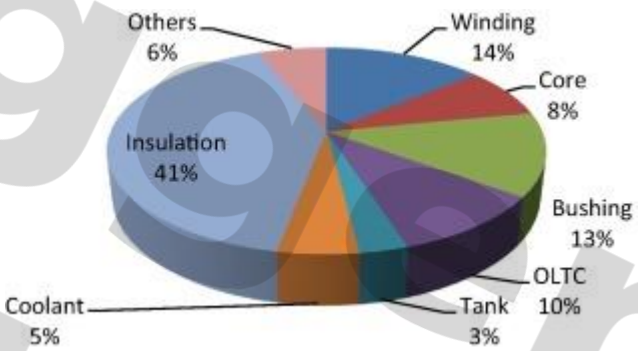
Transformer Failure is costly and can be Disastrous...

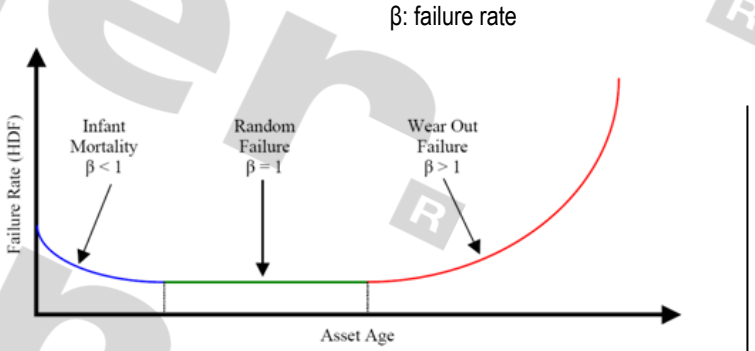
PD Monitoring and Testing of Power Transformers

- Increased population of aged substation equipment worldwide
  - In the past, no extended transformer maintenance programs
  - “No need for specific maintenance of static grid assets”
  - Delayed or cancelled investments by deregulations
  - Uncertainty on the condition of numerous transformers
- Possible consequences
  - Increased failure rate and risk
  - Unexpected outages long down times
  - Associated safety and environmental risks
  - Tremendous repair and transportation costs
- Transformer maintenance today
  - Different asset management approach
  - New maintenance strategies (predictive)
  - Cost & time saving solutions
  - Priority : condition assessment

Why PD Monitoring on PTs?

- High percentage of failures related to insulation problems
- Bushing and Winding problems can be detected by PD monitoring
- Early failures due to improper FAT, transportation, onsite commissioning
- Random failures caused by special stress (e.g. high load, lightning or switching impulses or ambient cond.)
- End of life failures due to aging of insulation materials





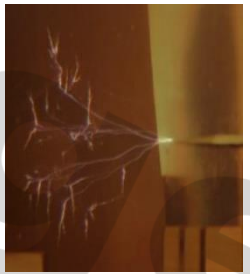
Why PD Monitoring on PTs?

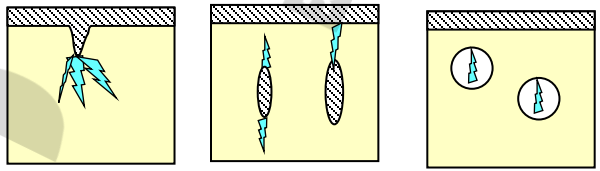
- General Root Causes of PD in transformers
  - Inferior quality of insulation materials
  - Fundamental design related problems
  - Incomplete or improper processing
  - Assembling related problems
  - Humidity in oil

- Impact of Partial Discharges on transformer insulation systems
  - Severity depends on the nature of the PD and location in the main tank
  - Accelerated degradation of Insulation materials
  - Reduced life expectancy of the grid system
  - Worst case scenario: unexpected breakdown → black outs

Why PD Monitoring on PTs?

- Most common root causes:
  - Inadequate vacuum stage prior to impregnation
  - Insufficient drying of the active part before oil impregnation
  - Remaining (conductive) particles in the oil
  - Increased water content in the oil
    → reduced breakdown strength
  - Missing electrical connections
    (e.g. floating static shields)
  - Poor contacting of tap leads towards at OLTC
  - Drops of casein glue in areas with elevated electrical fields





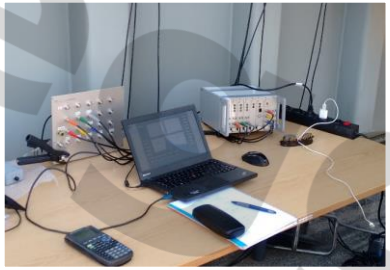
Why PD Monitoring on PTs?

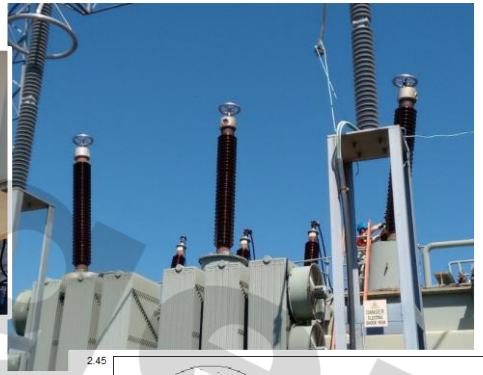
- PD Monitoring to assess insulation health of Power Transformers and Transformer Accessories
- PD Trending and Changing PD Patterns indicate incipient failure
- PD Pattern Analysis assists with failure Investigations (Root Cause Analysis)
- Added value if PD Monitoring is combined with DGA, Voltage, TD, Temperature and Load Monitoring

Foto: First PDM installation on a 400kV grid transformer (RWE) 1998

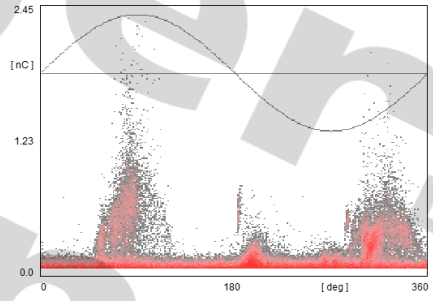
Temporary On-Line PD-measurements on PTs

- Why/When ?
  - Budget constraints
  - After poor DGA-results
  - No immediate long outage possible
  - No fast availability of a mobile test system



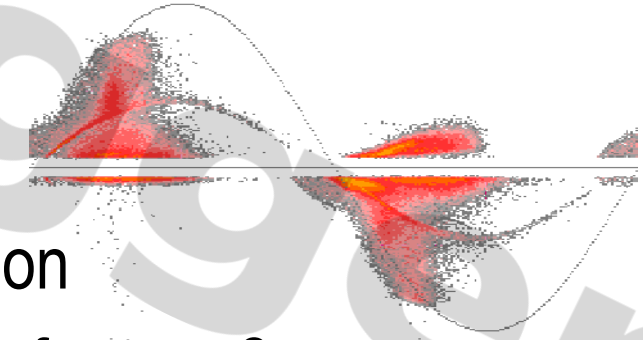


- How?
  - Using permanently installed bushing adapters and BCU´s
  - Temporary installation of quadrupoles, HFCT´s, UHF-antenna
  - PD-test equipment
  - Minor setup modifications → installation of corona rings



- Notes:
  - Grid systems > 132 kV generally produces high repetitive external corona
  - A more limited coverage compared to off-line testing → elevated detection bandwidths
  - Acoustic PD-location attempts are generally more successful with an external power supply
  - Data interpretation requires an operator with decent knowledge level

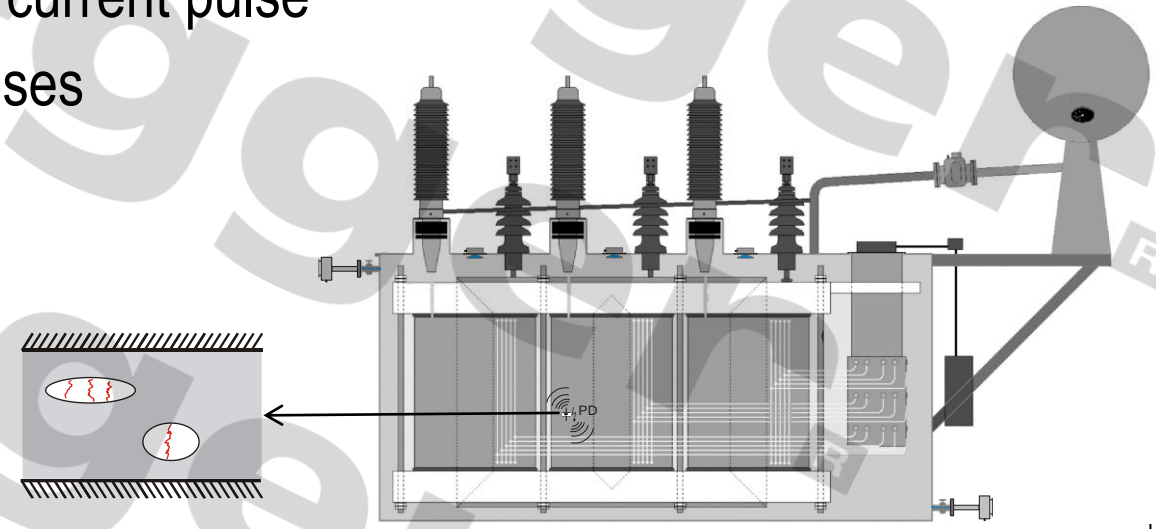
Temporary PD Monitoring of Power Transformers



- PDIX by Megger Group Presentation
- Why PD monitoring of Power Transformers?
- **Technical details**
- Features and benefits
- On-site testing of Power Transformers

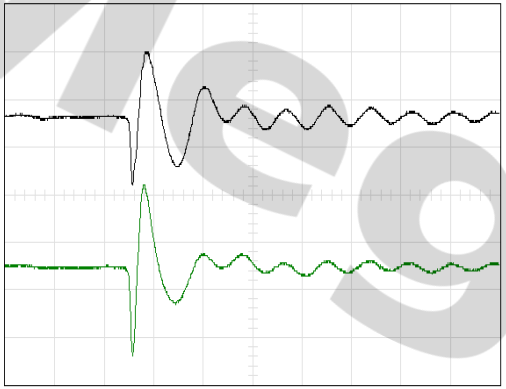
Technical details

- Partial Discharge is a breakdown of a small area of the overall insulation
- Each PD pulse generates different measurable electrical signals:
  1. Local displacement current pulse
  2. Electromagnetic pulses
  3. Acoustic pulse



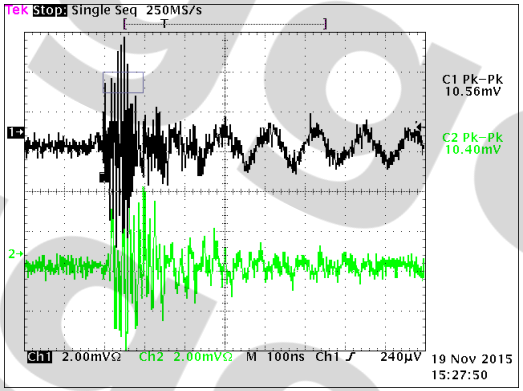
Technical details

Electric PD Pulse taken from the test tap of a bushing

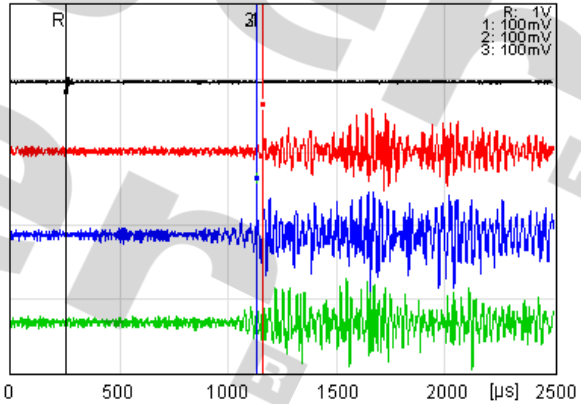


X Scale 10.00 µs / DIV | Y Scale CH1 1.00 V / DIV | Y Position CH1 1.72 DIV | Y Scale CH2 1.00 V / DIV | Y Position CH2 -1.56 DIV

UHF PD Pulse taken from UHF antenna via oil valve



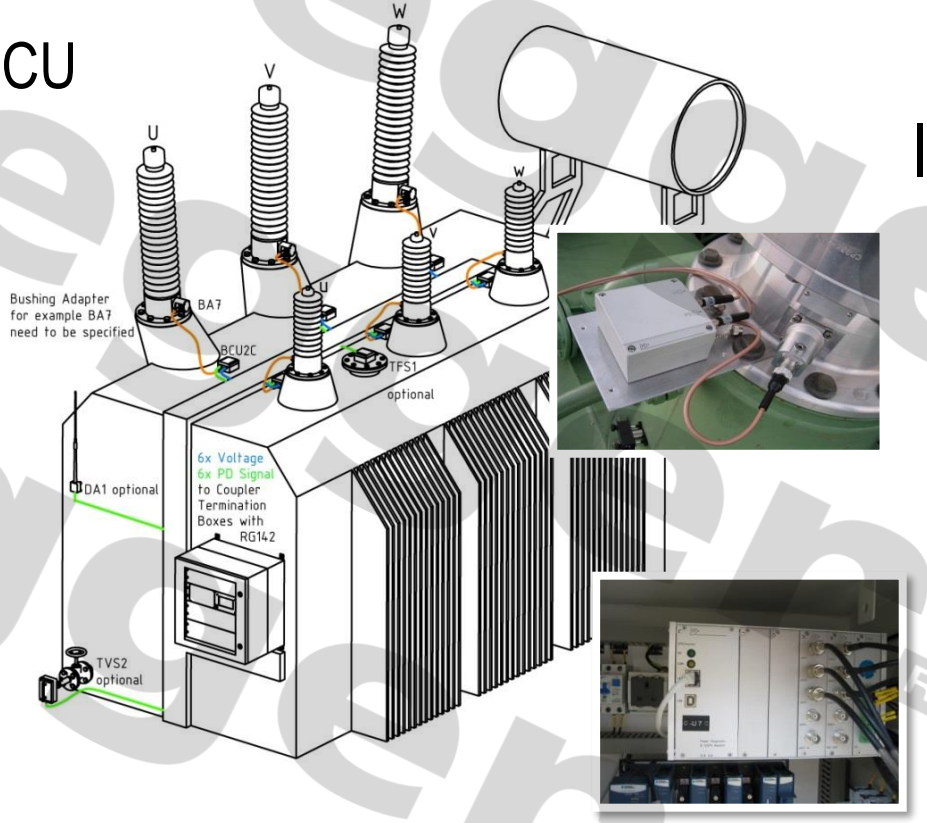
Acoustic Signal measured on the tank wall



Technical details

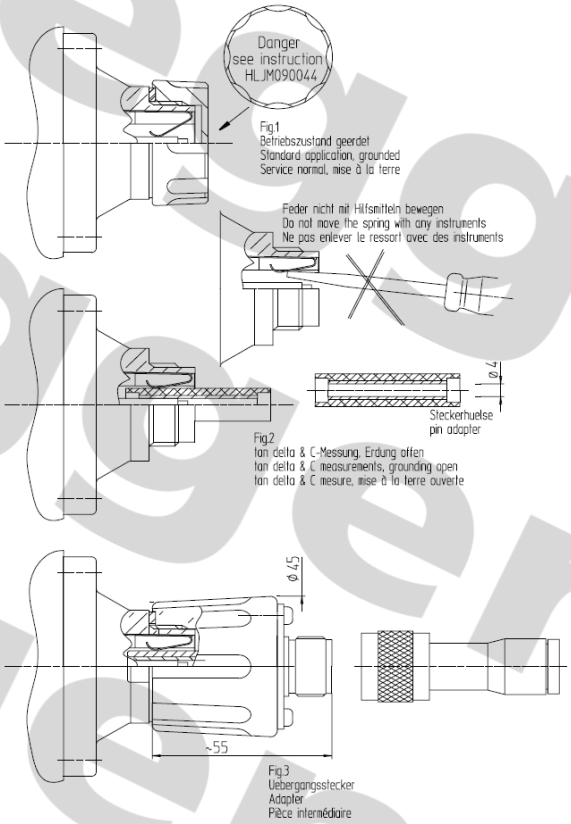
- PD and Sync from BCU to Input Multiplexer
- HF or UHF Sensors
- Noise Gating (DA1)
- Spectrum Scan
- PD Pattern & Trend
- OEM Solutions for Koncar and others...

Overview ICM*monitor*



Hardware - *Bushing Adapter BAxy*

- Multiple Types and Designs
- Aluminum Enclosure
- Two 600Vdc Surge Arrestor
- Output Connector: N Type
- Protection Class: IP65
- Temp. Range: -40°...+90°C
- Stainless Steel Enclosures (available on request)

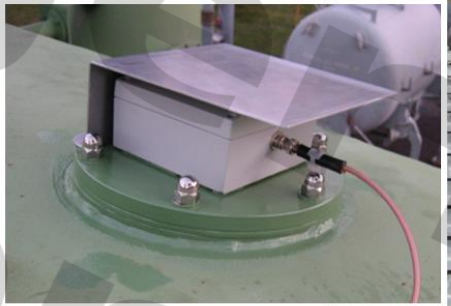


Hardware - *Bushing Coupling Unit BCU2C or BCU2D*

- PD Decoupling Circuit:
  HFCT or Quadrupole (switchable)
- Voltage Output via Capacitive Divider
- Two Output Connectors of N Type
- Protection Class: IP65
- Temperature Range: -40°C to 75°C
- Stainless Steel housing
  (available on request)

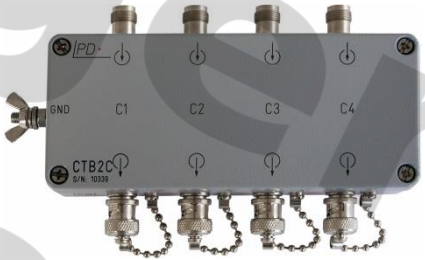
Hardware - *UHF Sensors TVS2 and TFS1*

- Sensor for Noisy Site Conditions
- Transformer Valve Sensor
  (DN40 - DN50 and DN100 flanges
- Hatch sensor (various diameters)
- Built-in logarithmic UHF signal converter
- Frequency Range: 300MHz – 1GHz
- TNC Output Connector
- Oil-tight Design



Hardware - Signal Cabling

- Cables suited for extreme site temperatures and heavy weather conditions
- High Quality PTFE Teflon Coaxial Cable RG142, 50Ohm
- Recommended Distance (BCU to ICM*monitor*) up to 20m
- CTB2C provides protective ground
- Both Cable Ends grounded and fitted with clamp-on ferrite cores

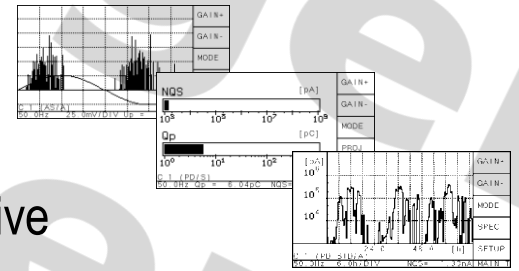


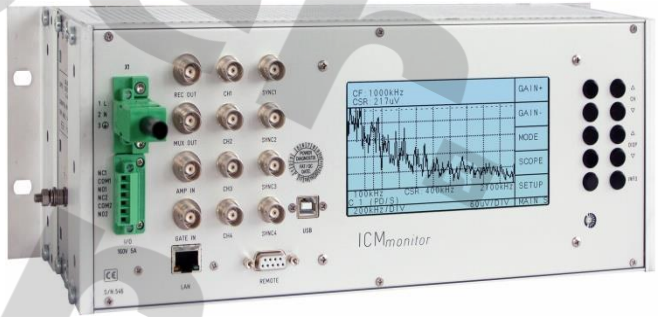
Hardware - Noise Gating Tools

- Disturbance Antenna DA1 picks up Noise Pulses radiated by Corona for instance
- High Frequency Current Transformers CT1 or CT100 pick up Disturbance Pulses from shields of signal cables or from ground connections
- Instrument interrupts PD Measurement for the duration (in µs) of Disturbance Pulses, (we call this Gating)

Hardware - *Acquisition Unit ICMmonitor*

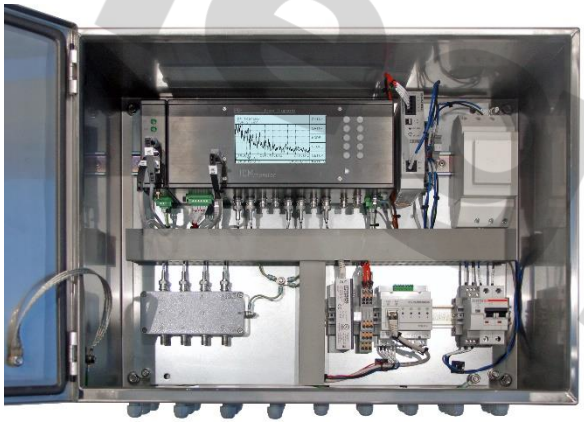
- 4, 8 or 12 Multiplexed PD Input Channels
- Separate Sync and Gating Inputs
- LAN and USB Interface
- 12-26Vdc Supply, 20VA max
- Customized Design for Hat-Rail Mounting
- Opt. 240x128px LC Display for Onsite Configuration and Inspection
- Commissioning and Monitoring Mode Frequency Selective Measurement
- Wide Band and Narrow Band Filter
- Spectrum Analysis
- UHF Measurement
- Dry Alarm Contacts
- IEC61850 (HW or SW)



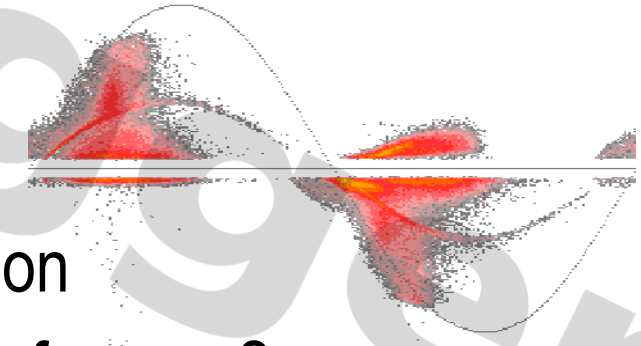


Temporary and Permanent Enclosures - *PDMAR500*

- Stainless steel cabinet
- ICM*monitor*, CTB, Network Interface, IOs, Main Switch,…built-in
- Compact design(s)



Temporary PD Monitoring of Power Transformers



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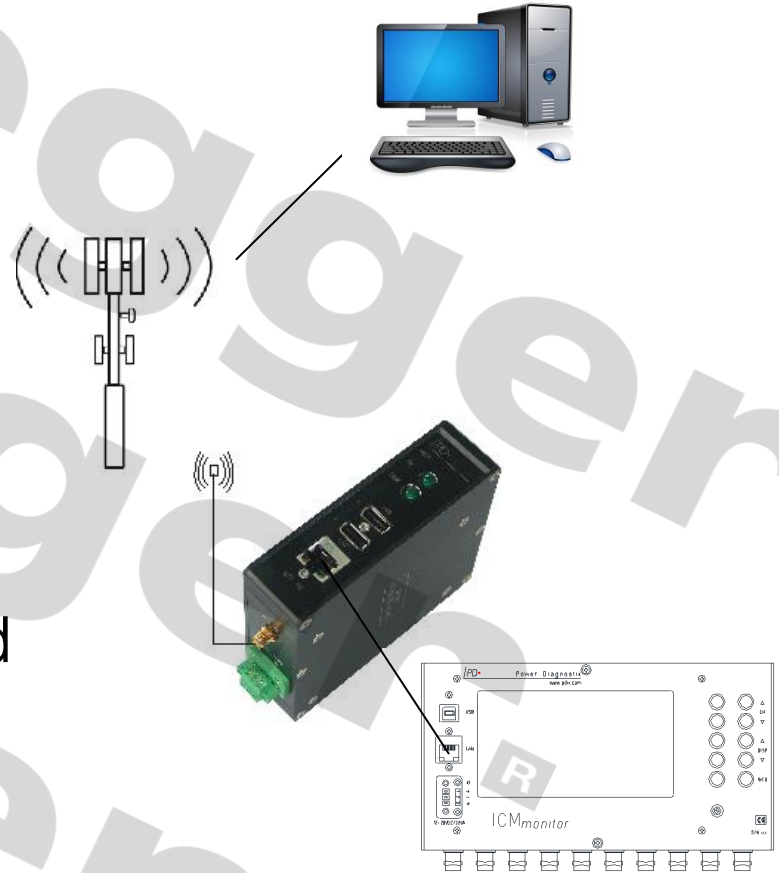
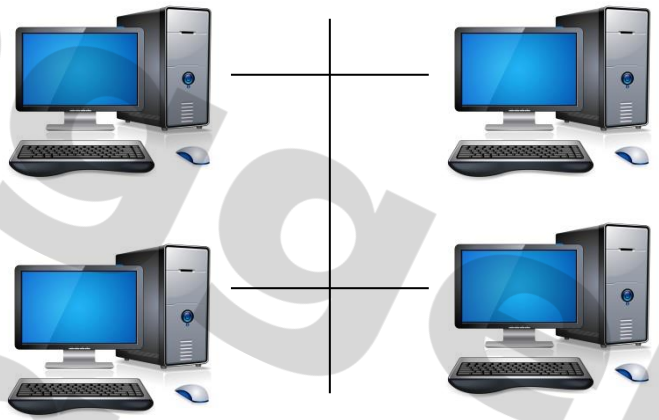
Remote Connectivity - *Mobile Communication*

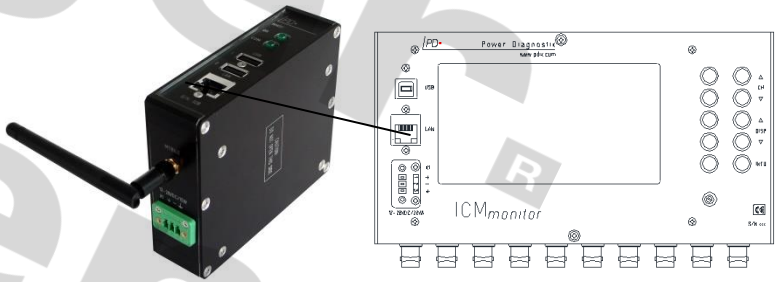
- ICM*monitor* SW connects via ***pdmon.com*** Cloud-Server to the instrument at site
- Direct Access via virtual IP address
- No network cabling
- Variety of options (VPN etc.)
- UMTS provider with local SIM required



Remote Connectivity - *Mobile Web Server MWS1*

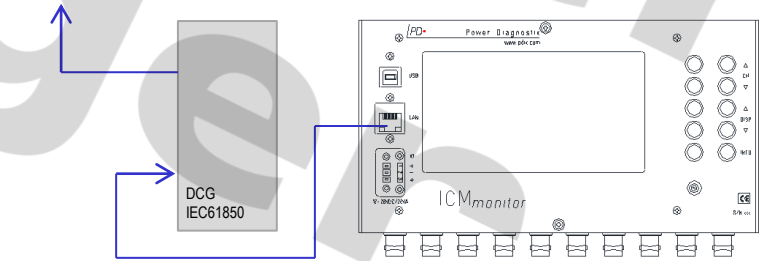
- OS independent
- Direct Access via local IP address
- Full Description of API
- Access to specified Data Sets provided by the instrument
- Remote connectivity for Maintenance / Assessment during temporary testing





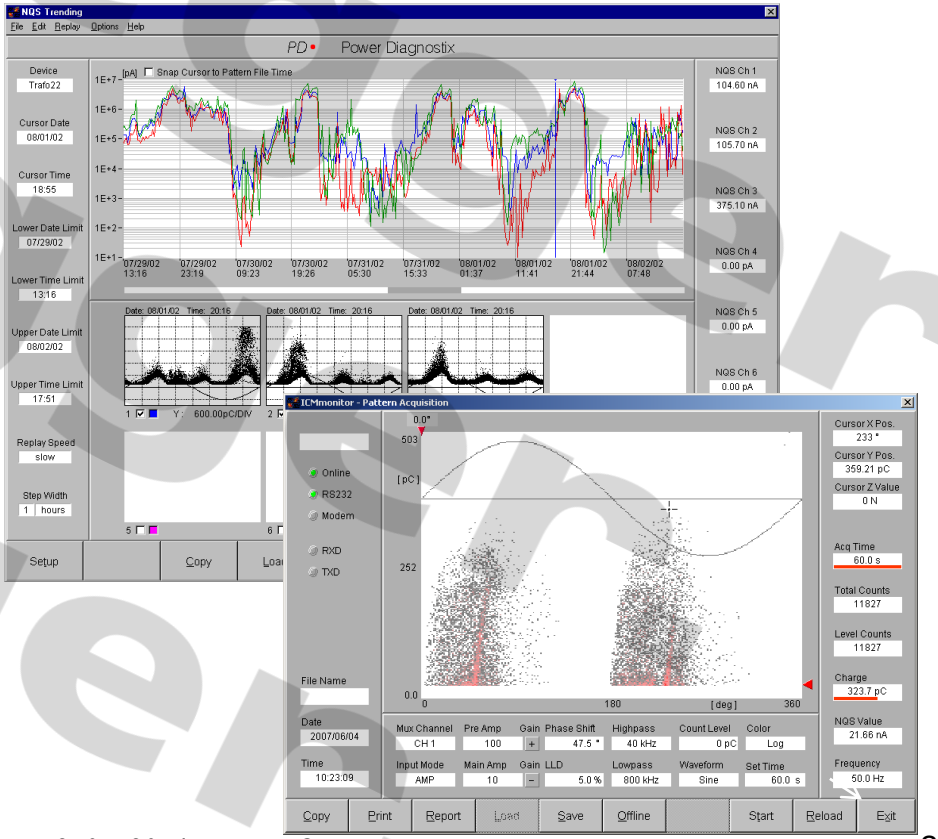
Alarming and Essential Data via the *IEC61850 HW Interface*

- Additional Hardware based **D**evice **C**ommunication **G**ateway
- OS independent
- Provision of ICDs
- Full Description of all Data Sets and 61850 relevant documents
- Provided Data Sets such as: Current Readings of NQS, Qp, Alarm Status per Channel



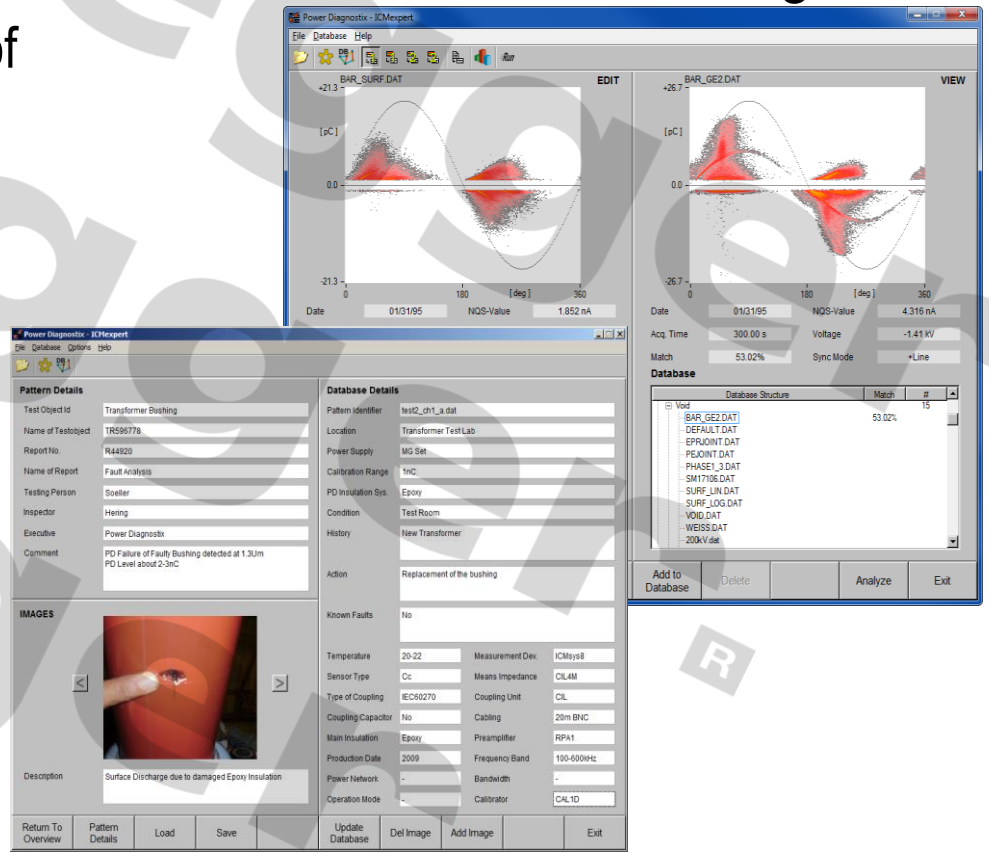
Windows SW: ICM*monitor*

- Remote Access to Multiple Monitoring Instruments
- Long Term Trending, History Structure
- Alarm Handling
- Colored PD Pattern Acquisition
- Automated Data Acquisition
- Connects via USB or LAN

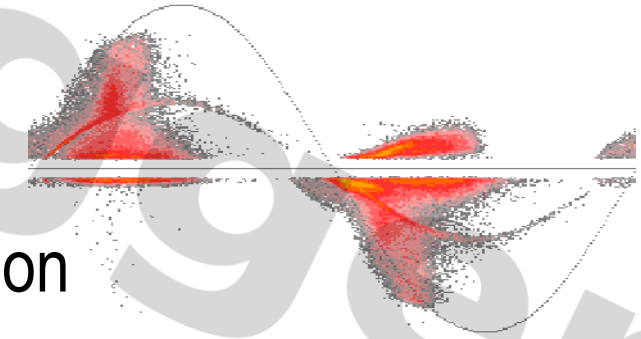


Advanced Data Management

- Database-Supported Handling of all Measurement Files and Supplementary Information
- PD Pattern Comparison
- PD Pattern Classification
- Storage of Photos, Comments, and all Instrument Settings with each Data Set
- Add On Tool for all Products



On Line PD Monitoring on Power Transformers



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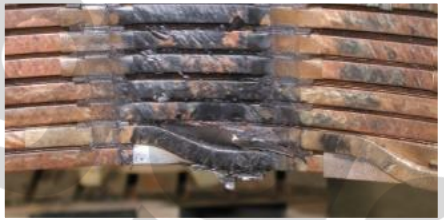
- **On-site testing of Power Transformers**

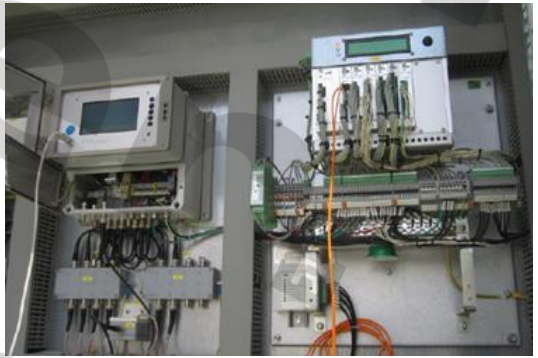
On-site testing of Power Transformers

- Once problems are spotted we can “move the factory testing to site”
  - Reducing down times
  - Active part repairs or coil exchanges
  - Power rating upgrades
  - Oil treatments and re-generation



- Increasing demand for on-site high voltage testing incl. PD-measurements
  - After site repairs and component replacements
  - In the commissioning stage
  - Verification of dissolved gas analysis (DGA) results
  - Confirmation of Bucholz or PD-monitor alarm events

- Requirement for compact mobile test systems
  - Light weighted test gear
  - Compact electronic power supply (converter-based)
  - Advanced multi-channel PD-detection system and accessories



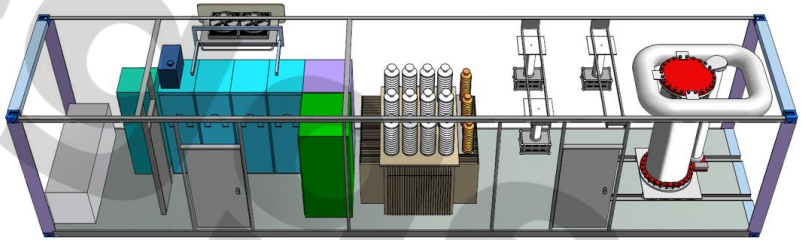
ICM*monitor* (PDIX) with ABB TEC system

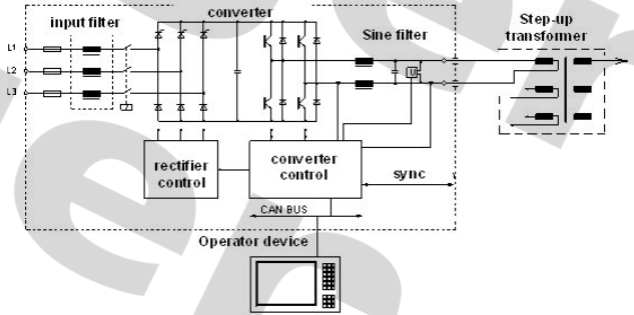
1,3 MVA AC Mobile Test System

- 40 ft. High cube container ~ 38 tons
- Action radius : Europe ~ 1500km around Aachen
- Main application : Testing of Power Transformers (80% of the mobilizations)
- Others : Power cable (66kV - 155kV – 220kV) after installation testing

1,3 MVA AC Mobile Test System

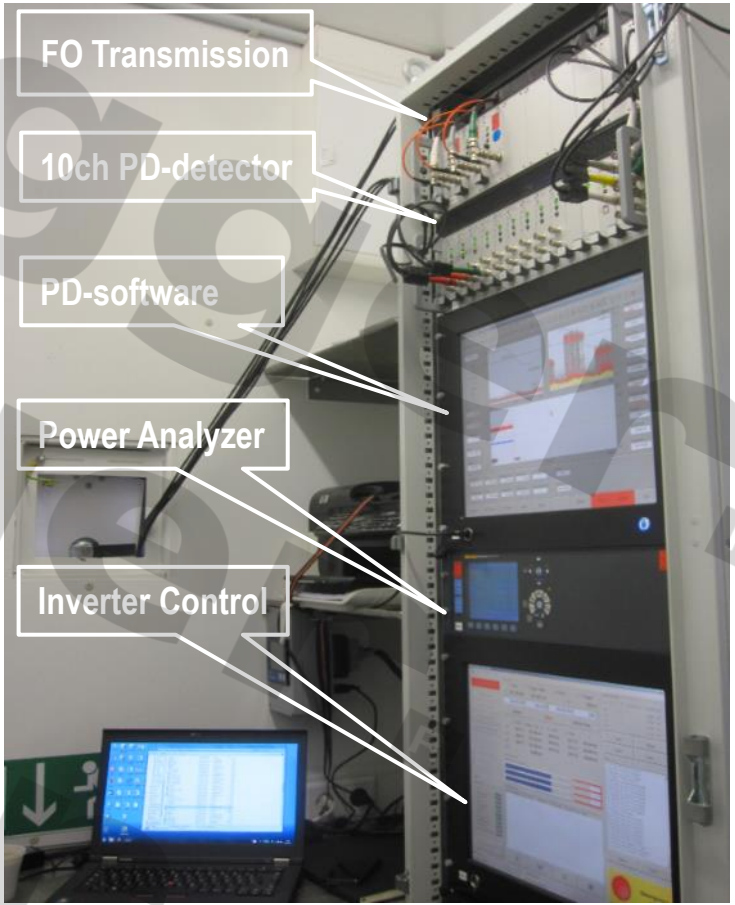
- 1,3 MVA -Three phases induced voltage source
- 3 x 450 kVA inverter sets (15-200Hz)
- 2 MVA step-up or matching transformer
- 500 kV series resonant reactor (4A-15min)
- Embedded L/C compensation
- Advanced HF-noise filtering
- 400V power intake (diesel-generator)





- Control room with embedded advanced PDIX test equipment
  - Electrical and acoustic PD-measurements (multi-channel)
  - Norma 5000 power analyzer

1,3 MVA AC Mobile Test System

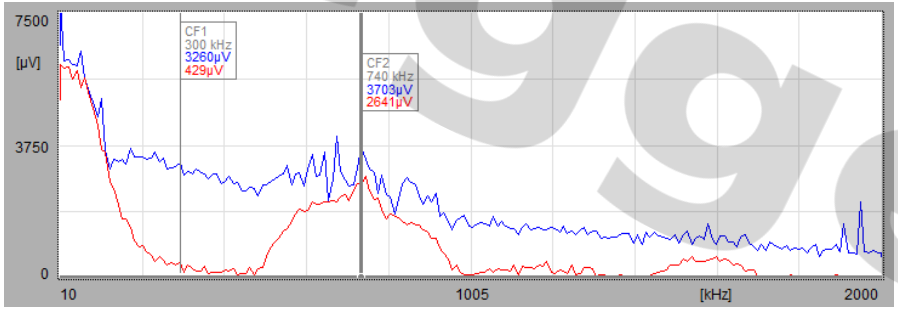


Off-line assessments with the Mobile Test System

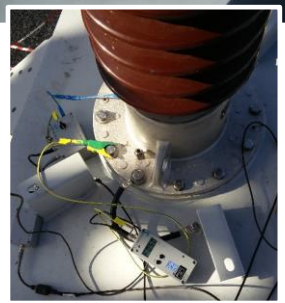
- Site acceptance testing (SAT) and diagnostic testing under induced and applied voltage
- Separate source AC-withstand tests up to 500kV with series resonant reactor (4A max – 15min)
- Three phases induced voltage tests up to 90kV (ph-ph) acc. to IEC 600076-3 (up to 1,3 MVA)
- Single phase induced voltage testing up to 70 kV– (up to 1,3 MVA)
- Single phase induced voltage testing up to 104 kV with symmetrical excitation – (up to 900 kVA)
- No load loss measurements (~ 500kW)
- Load losses or impedance voltage tests (achievable level to be calculated in advance)
- Electrical PD-measurements and Acoustic PD-location

Installing “the shielded test room” onsite

- Shielded MV-power cables
- Corona shields
- PD-free connections
- Gating sensors
- HF-Line Filters
- Advanced spectrum analysis

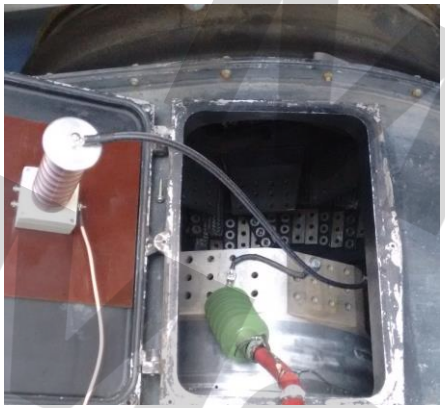


Standard (FAT) test circuit

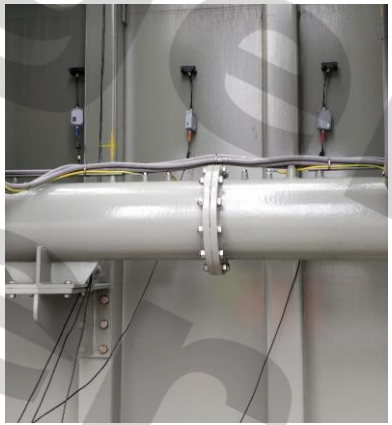


- Matched quadrupole (e.g. CIL4M, CIL5M, …) → capacitive test tap
- At HV, MV and optionally on the Neutral
- DIN-bushings (LV) & Dry type units → coupling capacitors (CC100B/V)
- Wideband preamplifier (RPA1L) & CAL1D/CAL1B

Additional decoupling methods for PD-testing

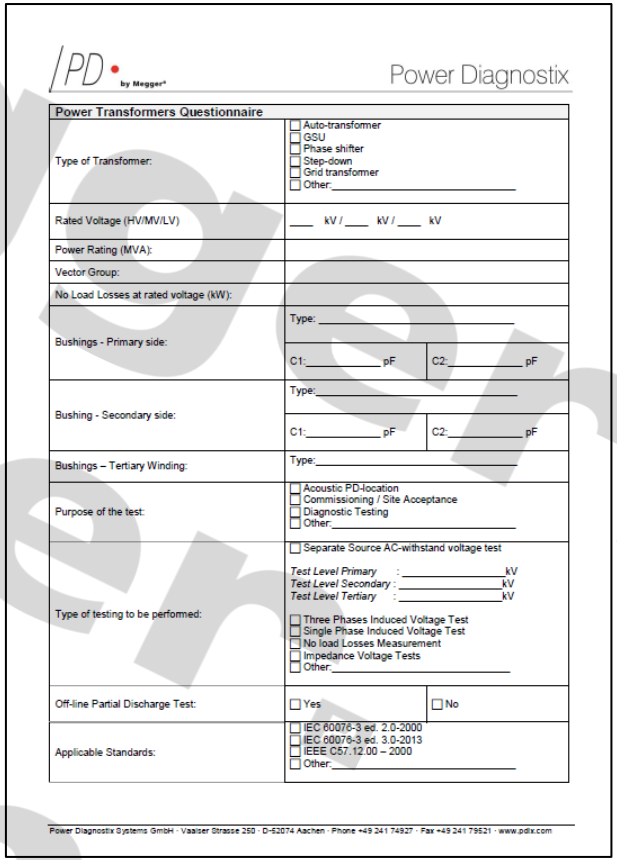


- High frequency current transformers (HFCT´s)
- Various coupling capacitors
- UHF drain valve & flange sensors
- Acoustics
- Disturbance antenna´s



Required technical information

- Reference ► application teaser questionnaire!
- First line key questions:
  - Reason for the test ? site acceptance or diagnostic?
  - Type of required tests and measurements
  - Transformer rating plate
  - No load losses at rated voltage
  - Bushings details (HV, MV, LV)
  - For condenser bushings (C1 & C2 values)
  - If available, FAT test report
  - In case of a PD-location attempt
    - Outline drawings
    - Internal images of the active part
    - Design drawings



PD by Megger® Power Diagnostix

Power Transformers Questionnaire

Type of Transformer:	☐ Auto-transformer ☐ GSU ☐ Phase shifter ☐ Step-down ☐ Grid transformer ☐ Other:_____
Rated Voltage (HV/MV/LV)	___ kV / ___ kV / ___ kV
Power Rating (MVA):	
Vector Group:	
No Load Losses at rated voltage (kW):	
Bushings - Primary side:	Type: _____ C1:_____ pF C2:_____ pF
Bushing - Secondary side:	Type:_____ C1:_____ pF C2:_____ pF
Bushings – Tertiary Winding:	Type:_____
Purpose of the test:	☐ Acoustic PD-location ☐ Commissioning / Site Acceptance ☐ Diagnostic Testing ☐ Other:_____
Type of testing to be performed:	☐ Separate Source AC-withstand voltage test *Test Level Primary* : _____kV *Test Level Secondary* : _____kV *Test Level Tertiary* : _____kV ☐ Three Phases Induced Voltage Test ☐ Single Phase Induced Voltage Test ☐ No load Losses Measurement ☐ Impedance Voltage Tests ☐ Other:_____
Off-line Partial Discharge Test:	☐ Yes ☐ No
Applicable Standards:	☐ IEC 60076-3 ed. 2.0-2000 ☐ IEC 60076-3 ed. 3.0-2013 ☐ IEEE C57.12.00 – 2000 ☐ Other:_____

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Available Information Material

- Questionnaire for PDM on PT
- Spec sheets and manuals
- BCU, BA design specification
- TVS, TFS data sheets

Questions & Discussions

At Power Diagnostics Systems (PDIX) by Megger, we understand that keeping the power on is essential for the success of our customers and our business, hence we are dedicated to creating, designing and manufacturing safe, reliable, easy-to-use Partial Discharge monitoring and testing equipment backed by world-leading support and expertise.

Everyday we assist our customers with monitoring, acceptance, commissioning, testing and maintenance 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.