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Dipl.-Ing. Thomas Linn,
Qualitrol Corp., Schweiz

Since 3/2013
Senior Technical Application Specialist cable, transformer, bushings and GIS for Partial Discharge Monitoring Systems; Qualitrol
8/2011 – 2/2
Head of strategic initiative 2015/ strategic project management and project portfolio management within the 'Bushing' profit center (ABB Switzerland Ltd)
1/2007 – 7/2011
ABB Switzerland Ltd, Micafil
Production Manager HV- Bushings
4/2003 – 1/2007
ABB Switzerland Ltd, Micafil;
Head of High Voltage test laboratories bushings
6/1998 – 3/2003
ABB High Voltage Technologies/ ABB Switzerland Ltd;
Quality insurance for gas insulated switchgear (GIS), HV on-site testing and on-site measurements, technical support, technical responsibility for factory testing
4/1992 – 5/1998
Bauprojekt Nord GmbH Rostock (Germany);
Electrical engineering and project management

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Online Partial Discharge Monitoring and discharge localization on transformers by means of UHF method

Transformer Life Management Tagung 2014, Neuss

Presented By: Thomas Linn Qualitrol LLC

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Agenda

1. Overview
2. UHF PD measurement principle
3. UHF magnitude to pC conversion and discussion
4. PD source localization by means of the UHF method
5. Conclusions
6. Q & A

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Economical environment - Challenges

- **Smart Grid technologies and alternative electrical energy generation**
  - Energy generation more and more decentralized
  - Energy generation far away from load centers – needs to be transported over long distances
  - Long bureaucratic processes to build transmission lines – importance of key equipment is shifting
  - Offshore energy generation – difficult to access, n-1 availability can not be achieved
- **Deregulated energy markets**
  - Cost and price pressure on industry is increasing
  - Often maintenance is outsourced
  - Equipment needs to operate until it reached its real end of life
- **Developed markets (like Central Europe, US, Japan) are facing an aged fleet of key components**
  - Cost pressure are forcing utilities to keep the equipment running as long as possible
  - Real life time of equipment is not know (e.g. oldest GIS installation built in 1967 – 45 years “only”)
- **Increasing demand on new installations in especially India and China**

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Economical environment - Solutions

- **Condition base maintenance principles are more and more part of maintenance strategy**
- **Implementation of condition monitoring is increasing (especially also in terms of comprehensive monitoring)**
  - In the earlier years monitoring meant the presentation of measured data without any integrated analyses
  - As state of the art today, analyzing tools and expert systems are integrated and comprehensive, scalable platform solutions
  - For some parameters also simulation and forecasting is available (for network operations)
- **Different approaches or combination of different approaches will be used (according to the needs):**
  - Condition monitoring to gain economical benefit
  - Condition monitoring to prevent failure
  - Condition monitoring to increase maintenance intervals

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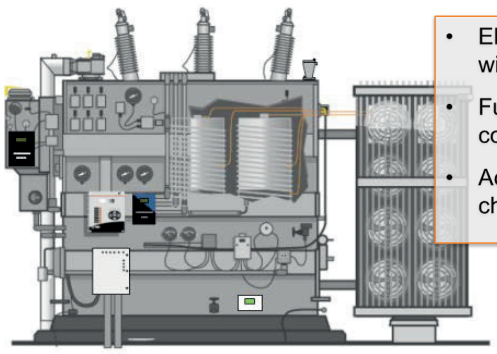
PD Monitoring on Transformers



- Electrical PD monitoring on bushing Tap is wildly used technique today
- Function principle is using Bushing as coupling capacitor according IEC 60270
- Acoustic PD detection is used for periodic checks and localization purpose

Monitoring Challenges of conventional methods:

- Electrical PD signals measured on bushing Tap, origin is difficult determine (Tank? Overhead line? …..)
- Sensitivity is limited (low capacitance and outside disturbances)
- Acoustic measurement influenced by outside disturbances (e.g. rain/ dust/ pressure leakages/ work close by …)
- Acoustic measurements have limits to detect PD inside winding and insulation

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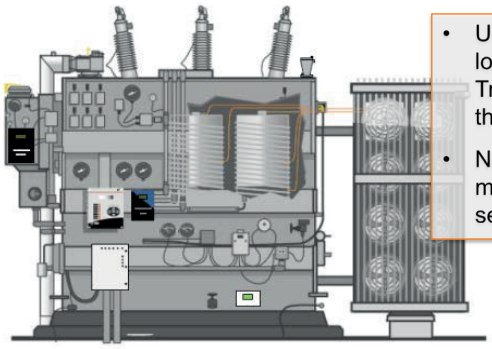
UHF PD measurement



- UHF Partial Discharge detection and localization are more and more established in Transformer diagnostics and monitoring over the last years.
- New Transformers are increasingly manufactured with more then one UHF sensor installed.

Challenges:

- **Calibration of UHF measurement in terms of pC is not possible**
- Sensors are difficult to retrofit
- Experience level is low compared with conventional PD measurement (e.g. bushing Tap)

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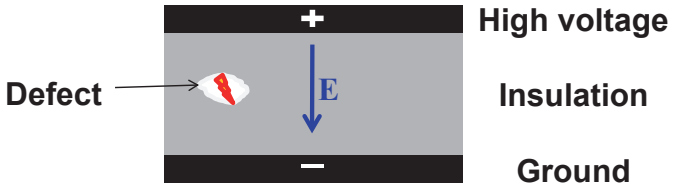
Partial Discharge

- **Partial discharge** (PD) is a local dielectric breakdown of a small portion of the electrical insulation system under a high voltage stress.
- PD can occur at any point in the insulation system, where the electric field is disturbed by irregularities.



- The electrical impulses caused by PD, have risetimes on the order of less then 100 picoseconds and thus produce RF signal extending to several gigahertz.

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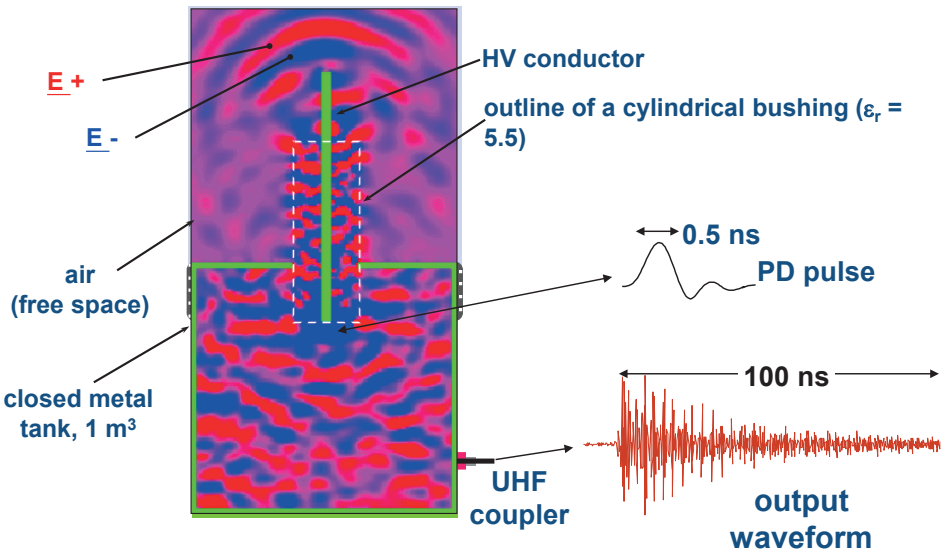
Physics of UHF PD Detection



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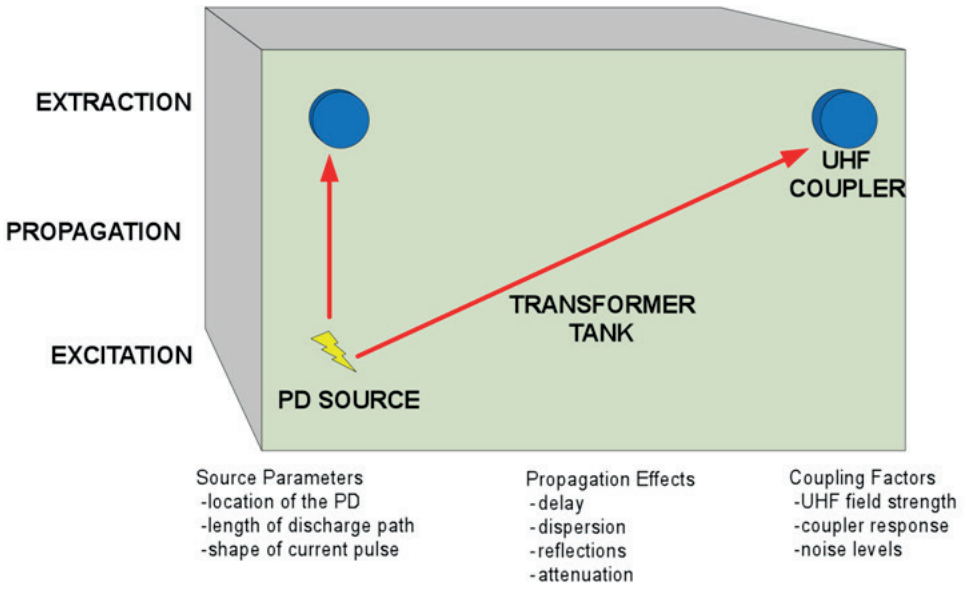
References



Source Parameters
-location of the PD
-length of discharge path
-shape of current pulse

Propagation Effects
-delay
-dispersion
-reflections
-attenuation

Coupling Factors
-UHF field strength
-coupler response
-noise levels

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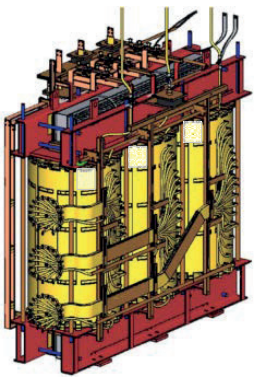
Basic consideration

- Sharp point causing void.
- Sharp point embedded in insulator.
- Punctured paper increasing stress.
- Loose paper causing void.
- Winding movement.
- Conductor to conductor discharge.
- Surface discharge.
- Void adjacent to insulator.
- Void on conductor surface.
- Corona gas discharge



Source: Partial Discharges in Transformer Insulation; TF 15.01.04, CIGRE Session 2000

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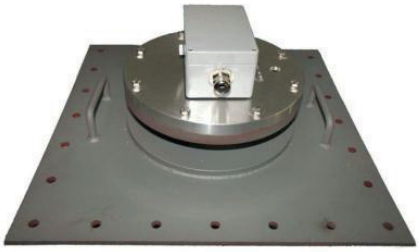
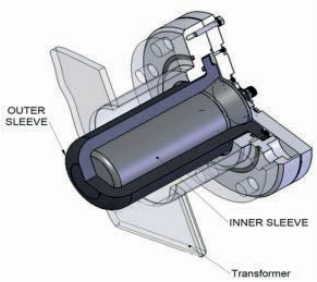
UHF Sensors





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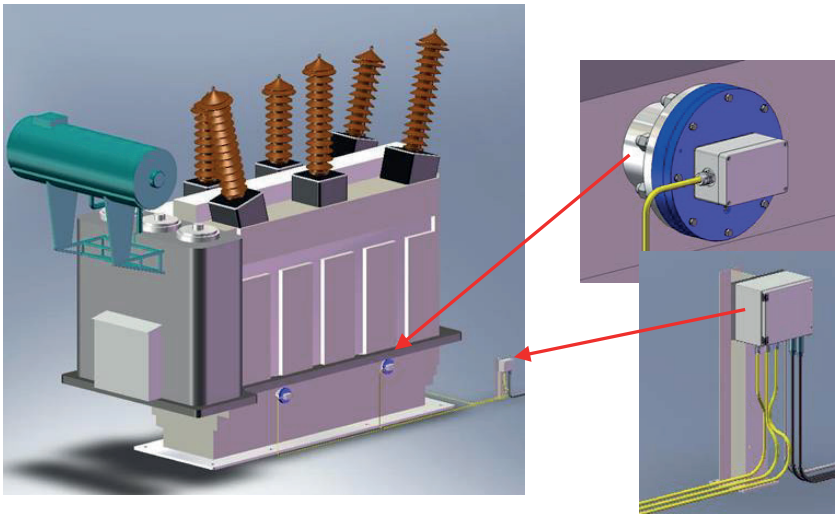
Transformer with UHF Sensors



Sensors fitted to tank and connected to a monitoring unit

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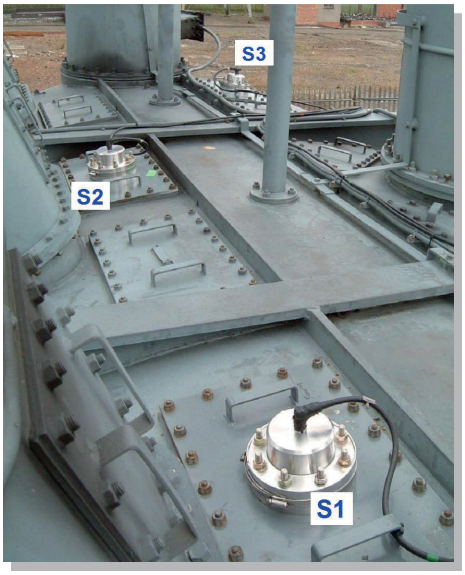
Transformer Retrofit with UHF Sensors



- Replacement hatch covers were prepared before the installation
- Sensors fitted on top of tank to the replacement hatch covers
- Oil was only drained to a few cm below the hatch level
- Outage time was kept to a minimum

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Risk Assessment for Transformer faults according PD level

- Poo… regnation caused discharges of about 1,000-2,000 pC. Large (3-5 mm in dia… …as bubbles in oil resulted in discharges ranging in magnitude from 1…
- …00 pC (in paper) and over 10,000 pC (in oil) may be
- Mecha… …for defect-free and defective insulation:
  - Defect free 10-…
  - Normal deterioration <…
  - Questionable 500-1000 pC
  - Defective condition 1000-2500 pC
  - Faulty (Irreversible) >2500 pC
  - Critical >100,000-1,000,000 pC

How to assess with UHF PD monitoring?

Source: CIGRE WG A2.18, Life Management Techniques for Power Transformers, CIGRE (Paris) Technical Brochure 227, 2003

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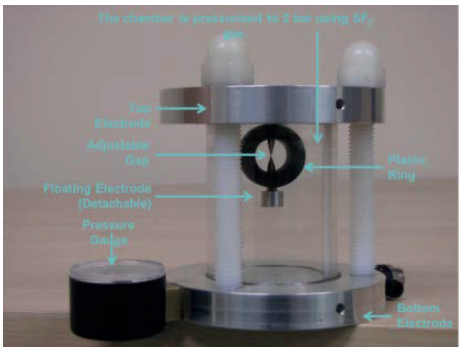
UHF Propagation inside Transformer Tank



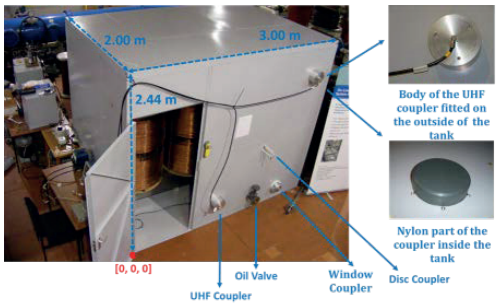
PD test cell with adjustable gap

Gap Size / mm	PD Inception Voltage / kV
0.05	4.8
0.10	7.3
0.15	8.8
0.20	10.9

PD propagation paths and displayed value

PD Data Acquisition Point	Position Coordinate - (x, y, z) / m
Positon 1	(1.15, 0.65, 0.55)

	S 1	S 2	S 3	S 4
Position 1	21.7%	29.3%	21.9%	28.9%



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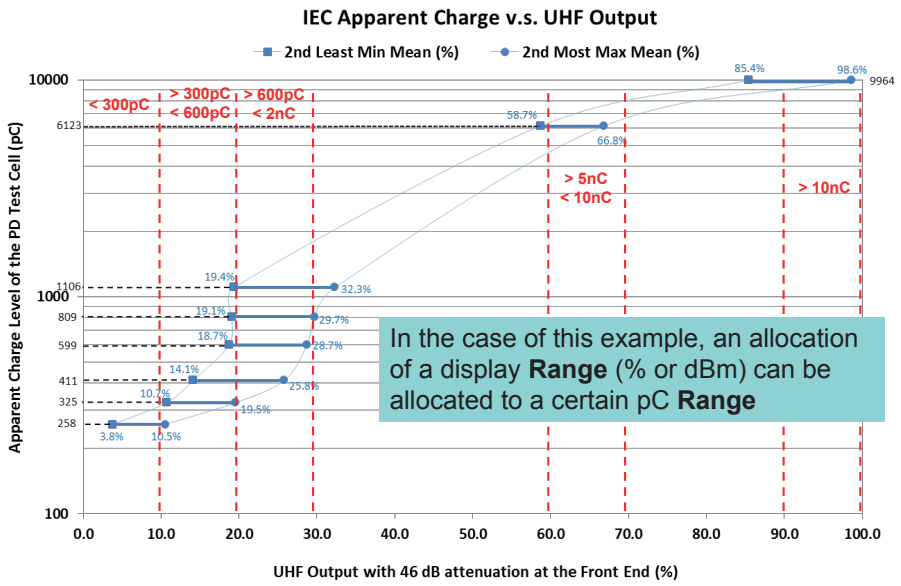
pC vs. dBm Comparison



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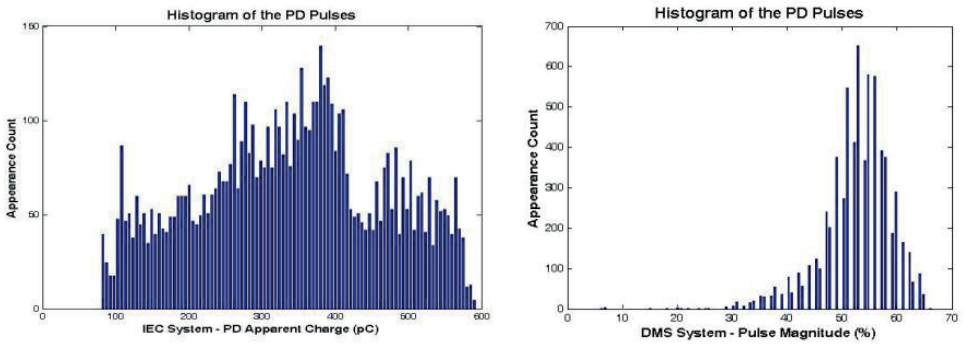
PD pulse distribution (test tank)



PD generation: Test cell gap 0.05mm recorded in parallel with IEC 60270 system and UHF system (measured in an empty test tank /1.0 x 1.0 x 1.0m/ with PD created by the PD test cell)

Repetition accuracy:

The histograms above show the repeatability for the same propagation path.

Furthermore it can be seen that the fluctuation of the measured apparent charge (measured according to IEC 60270) is between 100 and 600 pC for different discharge pulse from the same discharge source.

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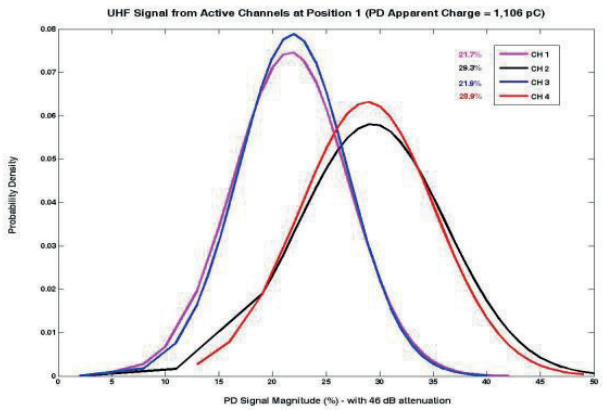
PD pulse distribution (transformer model)



Magnitude distribution recorded with transformer model:

The magnitude distribution on the more realistic transformer model basically shows the same behavior as for the empty test cell.

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dBm vs. pC Discussion

Converting a dBm or percentage **Range** to a pC **Range** according to the understanding of IEC 60270 might be possible under the following condition:

- Location of discharge source is known
- A sensitivity verification (in a sense of CIGRE recommendation for GIS is carried out)
- The defect type is known
- The propagation path between discharge source and sensor is known

The pC range information might be accurate enough to be able to assess the risk according to CIGRE recommendation.

- Localization of PD source by using UHF techniques is well known.
- Procedure for sensitivity/ amplitude verification needs to be established
- Defect type detection is possible by PD pattern analyses and localizing of PD source
- Propagation path (once the PD source is localized) is known by design information

➢ **Key for Transformer PD Assessment: Localization of PD source**

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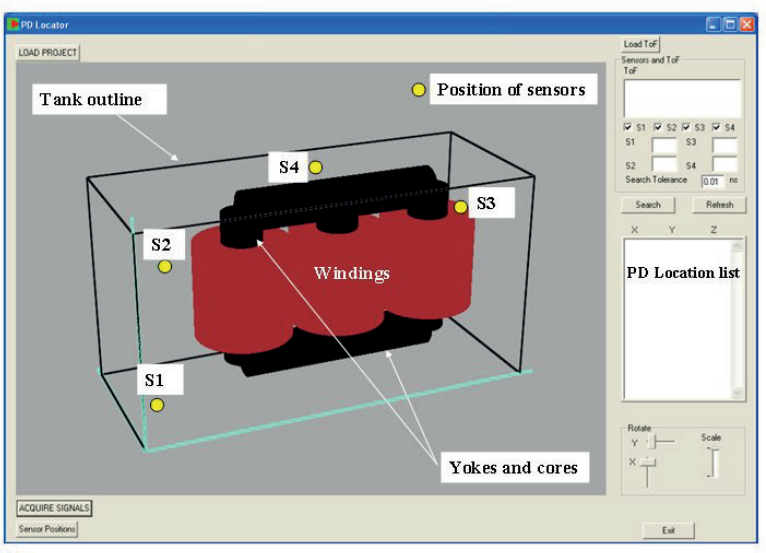
Test tank with 4 UHF sensors



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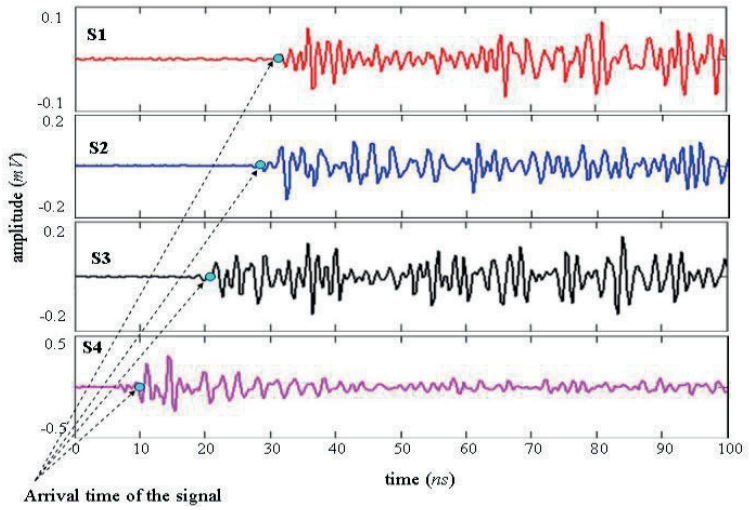
PD signal Time of Flight delays between sensors on model



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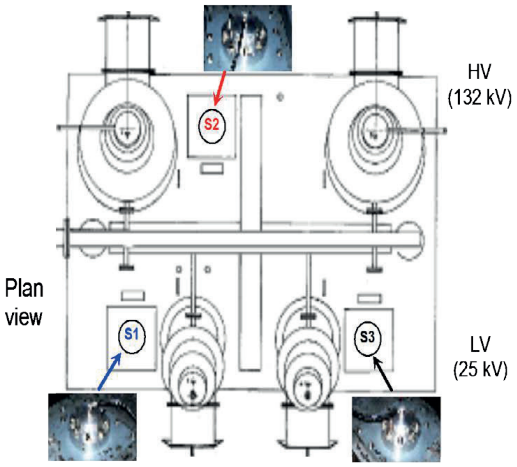
Case study - 18 MVA Transformer 132/ 25 kV with 3 UHF couplers

Side view



Plan view

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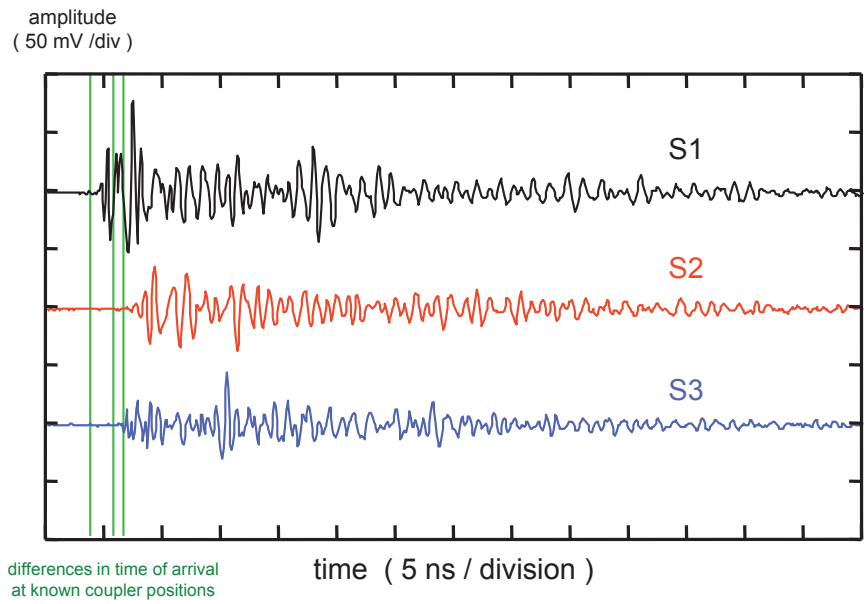
Case History: Set of UHF signals from a single PD pulse



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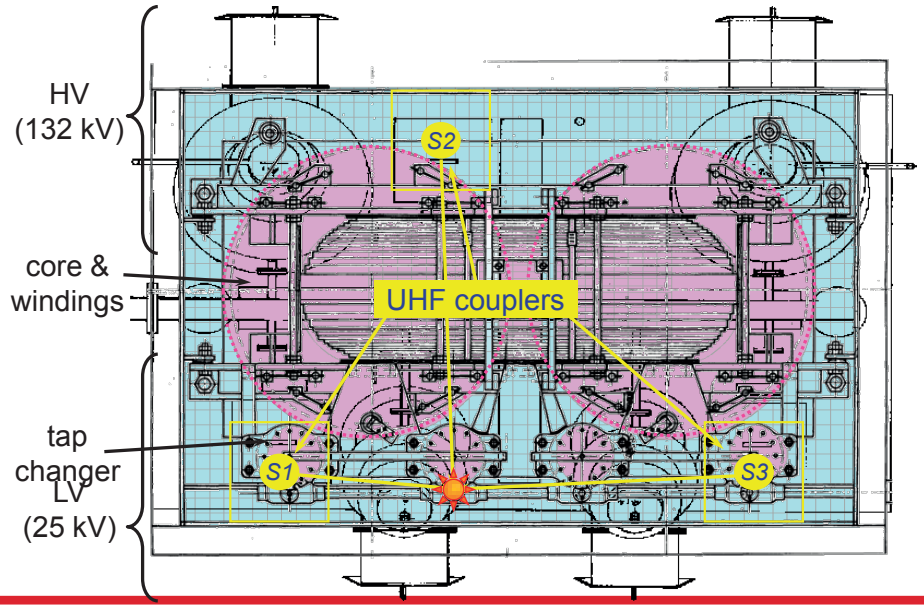
Case History: Transformer model location calculation



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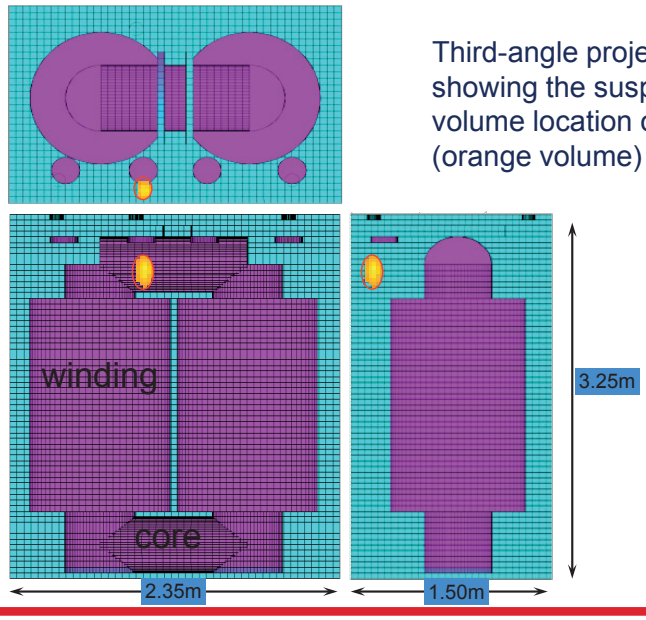
Case History: 3D location of PD source



Third-angle projection showing the suspect volume location of PD (orange volume)

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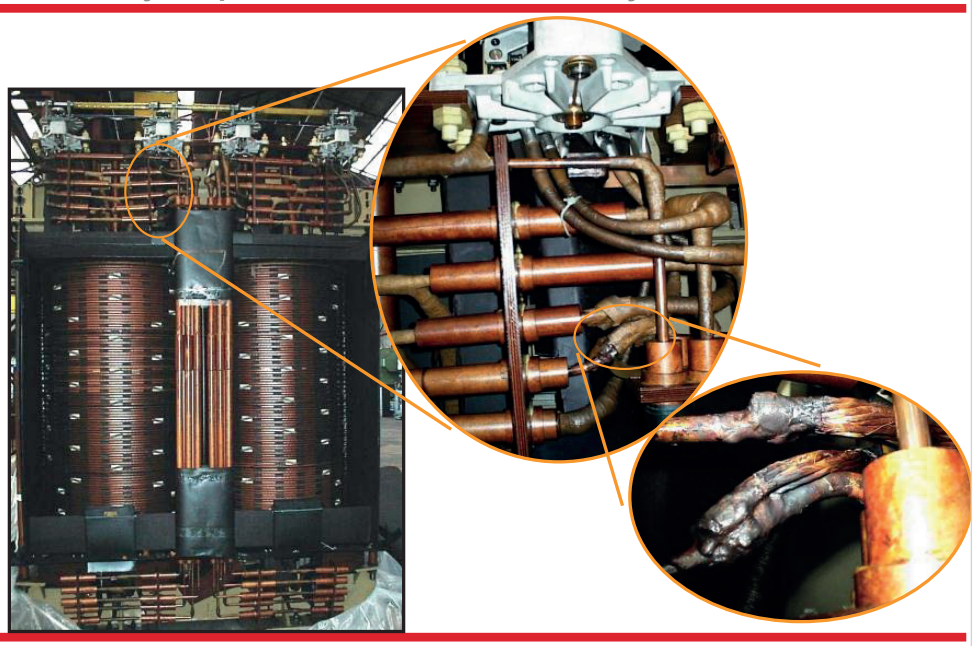
Case History: Inspection of de-tanked assembly



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General Conclusions

- UHF technique effective for PD detection and localization in transformers
- Installation of UHF couplers is simple on new transformers
- Retrofit normally requires outage and possibly lowering of oil level
- 4 or 6 couplers are ideal for accurate location to
- For amplitude/ sensitivity verification purpose, further discussion and investigations (also on real transformers) throughout the industry is necessary
- New CIGRE joined working group (JWG A2/D1.51); kick- off during CIGRE Paris 2014 → "*Improvement to Partial Discharge Measurements for Factory and Site Acceptance Tests of Power Transformers*" → will focus on alternative PD techniques, especially UHF

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Q & A

Thank you for your time

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