

Sensitivity of UHF PD Measurement

S. Coenen^{1*}, S. Tenbohlen¹
Universität Stuttgart
Sebastian.Coenen@ieh.uni-
stuttgart.de
Germany

S.M. Markalous², T. Strehl²
LDIC GmbH
markalous@ldic.de
Germany

KURZFASSUNG

Zur Überprüfung und Diagnose der Isolationsqualität hochspannungstechnischer Geräte wird die Messung von Teilentladungen (TE) durchgeführt. Bei Anwendung der konventionellen Teilentladungsmessung nach IEC60270 kann das Messergebnis durch den hohen Störpegel im Feld nur beschränkt aussagekräftig oder unter Umständen gar nicht brauchbar sein. Die Entwicklung einer unkonventionellen Messmethode auf Basis elektromagnetischer Sensoren wird vorgestellt. Diese Sensoren werden über einen normalerweise zur Ölbefüllung benutzten Flachkeilschieber bei laufendem Betrieb in den Transformator eingeführt. Durch die Schirmungseigenschaften des Transformatorkessels sind externe elektromagnetische Störungen minimiert und ermöglichen Messungen mit hohem Störabstand.

Bisher war es nicht möglich, den installierten Sensor auf seine Funktionalität zu überprüfen. Das vorgestellte Design eines am Institut für Energieübertragung und Hochspannungstechnik (IEH) entwickelten Sensors ermöglicht diesen sogenannten Performance Check. Untersuchungen zur mechanischen Belastbarkeit des Sensors belegen seine Tauglichkeit für eine permanenten Montage für Online Monitoring Systeme.

Ein Nachteil der UHF Messmethode ist die fehlende Möglichkeit zur Kalibrierung, oder ein Nachweis ihrer Empfindlichkeit in Bezug zur IEC konformen Messung. Die im Beitrag vorgestellten Ergebnisse zur Bestimmung der Empfindlichkeit lassen sich wie folgt zusammenfassen:

- Die Abstrahlung von elektromagnetischen UHF Wellen ist nicht nur von der TE Quelle abhängig. Die Abstrahlung wird ebenfalls durch die Struktur bestimmt, die sich zwischen der Hochspannungsquelle und der TE Quelle befindet.
- UHF Signale erfahren eine Dämpfung, die vom Ausbreitungsweg der Signale durch den Aktivteil abhängig ist.
- Für konstante Ausbreitungswege existiert eine lineare Korrelation zwischen der UHF Signalamplitude und der scheinbaren Ladung einer TE in pC.
- Es erscheint nicht möglich, durch die alleinige Messung der UHF Signale, die Intensität einer TE in pC abzuschätzen.
- Der vorgestellte Sensitivity Check ermöglicht unter Umständen eine Worst-Case Abschätzung der Empfindlichkeit der UHF Messmethode.

1 INTRODUCTION

The reliability of electrical energy networks depends on the quality and availability of electrical equipment like power transformers. Examining the existing insulation quality of oil/paper-isolated transformers during full operation or at least in field gets more and more important because of the increasing number of transformers reaching their technical life expectancy. Local failures inside their insulation may lead to catastrophic breakdowns and might cause high outage and penalty costs. To prevent these destroying events power transformers are e.g. tested on PD activity before commissioning and currently also during service. The so called conventional PD measurement according to IEC60270 might show certain drawbacks for online measurements.

PD under oil are very fast electrical processes and radiate electromagnetic waves with frequencies up to the ultrahigh range (UHF: 300 – 3000 MHz). The current contribution deals with the electromagnetic method, also known as the UHF-Method (Ultra High Frequency). Electromagnetic waves are detectable with UHF probes, e. g. seen in Fig. 1.



Fig. 1: UHF PD probe for standard oil valve

The probes can be inserted into the transformer during full operation using the oil filling valve. As a result of shielding characteristics of the transformer tank against external electromagnetic waves, normally a clear decision can be made concerning the PD activity of the test object. Precondition is the moderately attenuated propagation of UHF waves inside the transformer tank. This was shown in laboratory research in [1] and is investigated continuative in this paper. Because of a missing calibration possibility of the UHF measuring method it is necessary to examine the installed probes for its function with the so-called Performance Check. Therefore probes with new design are presented.

For the verification of sensitivity, the relation between unconventionally measured UHF quantities to the PD apparent charge level in pC is aim of current research. The following questions are important:

- What exactly is the source of the emitted UHF waves? Does the PD source itself radiate? Or is actually the high-frequency PD current the origin of emitted UHF waves, while flowing through the surrounding high voltage structure?
- Can UHF signals be measured everywhere inside the transformer tank with the same sensitivity? How strong is the signal amplitude or signal energy dependent on the measuring location? Regarding the attenuation of UHF signals inside and through the internal structure of the transformer, is there a constant attenuation factor and what is the range of the attenuation? When measuring inside another transformer with different tank size and/or internal structure, is the attenuation factor in a comparable range?
- Can an e.g. linear correlation be found between measured UHF quantities like the signal amplitude to the PD apparent charge level in pC according to IEC60270? Is it possible to extract a correlation for single impulses or are only impulse repetition rates or phase correlation comparable? Is the correlation constant for one transformer, or even for transformers of the same tank size or similar internal structure?
- Is it possible to perform a so called Sensitivity Check to verify the quantity of a PD in terms of apparent charge (pC) by only measuring UHF signals, at least in a “worst-case way”? Is this dependent on the location of PD inside the transformer, e.g. if there is a PD inside the winding?

The following chapters provide some answers to the questions above by outlining some experimental research work.

2 UHF PD PROBE DESIGN

An essential component for the detection of PD originated electromagnetic waves propagating through transformer tanks are the decoupling devices called UHF probes. Experiences made during measurements in field and in laboratory lead to newly developed probes. Focus is the improvement of the measuring performance, enhanced handling as well as the mechanical properties. First aim was the development of a so called Performance Check to proof the functionality of the UHF probe and therewith the whole measuring setup. Second aim was the improvement of the mechanical properties of the UHF probe regarding thermal and mechanical stresses.

2.1 Electrical Improvements

Using an UHF probe with just receiving capability leads to the problem of considering its functionality. Therefore the new design of the UHF probe includes an insulated monopole, see Fig. 2, which allows a so called Performance Check with the general procedure like mentioned in the following.

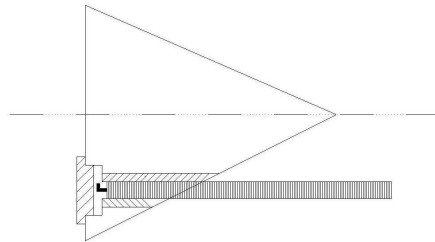


Fig. 2: Conical probe head with integrated insulated monopole for injecting artificial UHF impulses

The injection of an artificial UHF-impulse (see Fig. 3 left)) caused a coupling of the UHF signal to the probe head. Therefore two parallel lines inside the probe frame for transmitting and receiving are necessary. Precondition of a correct Performance Check is the prevention of direct cross-coupling of signals from the transmitting to the receiving line. The line lengths are used for an approximation of the signal propagation time of 6 ns in case of solely coupling from the integrated monopole to the probe head. The theoretically estimated propagation time was proofed in a separate laboratory test, i.e. there is no direct cross-coupling of signals.

Another precondition for a successful Performance Check is the recognition of an inaccurate probe application. One fault might be the galvanic contact of the probe head within the oil valve or the transformer tank due to incorrect mounting and the resulting grounding. In worst case, no high frequency signals may be detectable due to that. During a reference measurement the UHF probe with integrated monopole laying on a wooden table is punctually grounded. The detectable signal has a frequency spectrum without significant high frequency fractions. (see Fig. 3 right)), grounded probe).

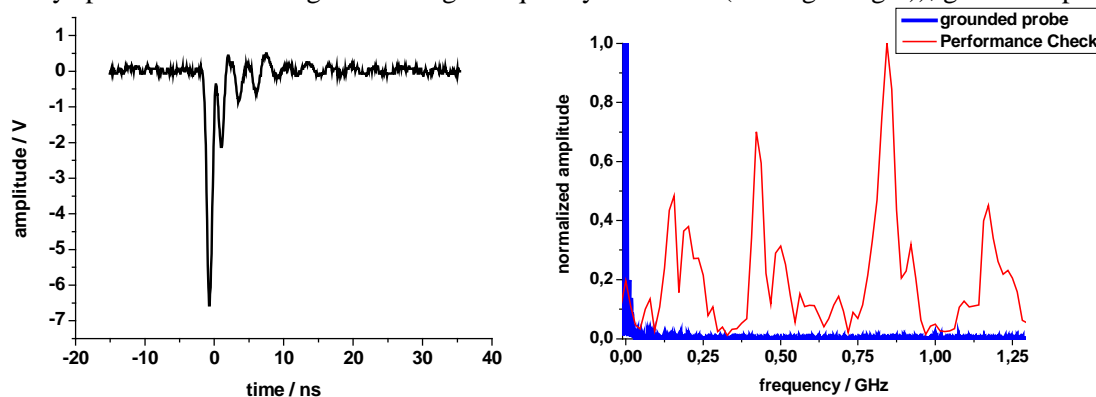


Fig. 3: left) Time signal of artificial UHF impulse, right) Spectrum of the grounded probe (thick blue line) in the comparison to the error free probe in the transformer tank (thin red line) using same injected signal

The method of the Performance Check is investigated finally on a test transformer tank inside laboratory. The shown UHF signal is injected and the received UHF signal was measured with a transient recorder with the analogue bandwidth of 2 GHz. After injecting the artificial UHF impulse the signal with the corresponding frequency spectrum (see Fig. 3 right), thin red line) was detectable.

High frequency components up to 1.25 GHz are clearly recognizable. Hence it could be obviously measured that the complete receiving path from the UHF probe to the PD acquisition unit is correctly installed. The Performance Check fulfils its task to check whether the UHF probe and the UHF measuring system are correctly installed and ready to capture PD UHF signals from within the transformer.

Further investigations will focus on the gain or effective height of the probe head. The gain characterises the transformation of the electromagnetic waves (far field conditions assumed) to the conducted UHF signals in the measuring line. Therefore a set up using a giga hertz transverse electromagnetic cell (GTEM cell) might be necessary offering defined electromagnetic waves and standardised analyses for high frequency antennas.

2.2 Mechanical Development

Oil flanges of power transformers may in worst-case be located at the top of the transformer tank. According to the IEC60354 "Loading Guide" [2], the maximum oil temperature at the top of the transformer tank may reach 115 °C regarding local hotspots of maximum 160 °C. In addition to the resulting thermal stress the inserted UHF probe has to withstand mechanical stresses caused by the oil pressure. Most transformers do not get above the height of about 10 m (or the conservator respectively), consequently the oil pressure occurring in power transformers will be below 1 bar (also due to the fact that the density of insulation oil is lower than that of water). For a leakage test a safety factor of 5 might be sufficient. Summarizing these aspects of stresses, a type test for the UHF probe is performed with a pressure of 5 bar at a temperature of 120 °C. The UHF probe developed at the Institut für Energieübertragung und Hochspannungstechnik (IEH) is intended for the installation at oil valves with a normalized flange, as mentioned above. For the examination of the oil tightness a test vessel was designed that corresponds to a standard oil valve flange. The probe mounted at the appropriate flange side of the test vessel can be seen in Fig. 4 on the left side.



Fig. 4: Picture of leakage test; left) UHF PD probe attached to a test vessel, right) Measured temperature and pressure

The bleeder screws existing at the probe are used for the subsequent oil filling. At room ambient temperature oil is pumped into the test vessel with an appropriate oil pump. Existing air in the vessel is released over the second bleeder screw. Finally, the oil filled test vessel with the attached UHF probe is brought into a furnace.

With the help of the attached pump a pressure of 5 bar is generated and held. The following heating lead to an expansion of the oil and the pressure equalization is reached manually with an expansion container. The furnace reached quickly the necessary temperature of 120 °C and heated up the test container with the oil inside. With closed valves the heating caused a constantly increasing pressure. With manual opening of the valve to the expansion container, the pressure can be kept constant at approximately 5 bar. The necessary monitoring of the pressure allows a check of the completely heated oil volume with a constant pressure and the detection for an arising leakage by a sudden decrease of pressure. After heating the oil volume the pressure remained apparently constant during the tests. The optical control of the whole UHF probe during the pressure and heat test resulted in no evidence of a leakage. The developed UHF PD probe might be installed at every located oil valve and will withstand every occurring thermal and pressure caused stresses.

3 RADIATION BEHAVIOUR OF PD SOURCES

PD under oil emit electromagnetic waves in the lower UHF range. I.e. occurring wave lengths inside power transformers are between 10 and 70 cm. Regarding antenna theory, an emitting antenna might have the minimum dimension of half the occurring wavelengths to work best, i.e. in the range of 10 cm. That leads to the question, what is the antenna for the PD originated electromagnetic waves? The PD source itself seems to be ranges too small. But PD phenomena causes high frequency currents. Possibly parts of the high voltage structure in the galvanic circuit surrounding the PD source act as an antenna, while high frequency current is flowing through them?

The following setup was used to examine that question. The so called 2-path-arrangement, see Fig. 5, offers the possibility to measure independently two UHF signals of one and the same PD impulse.

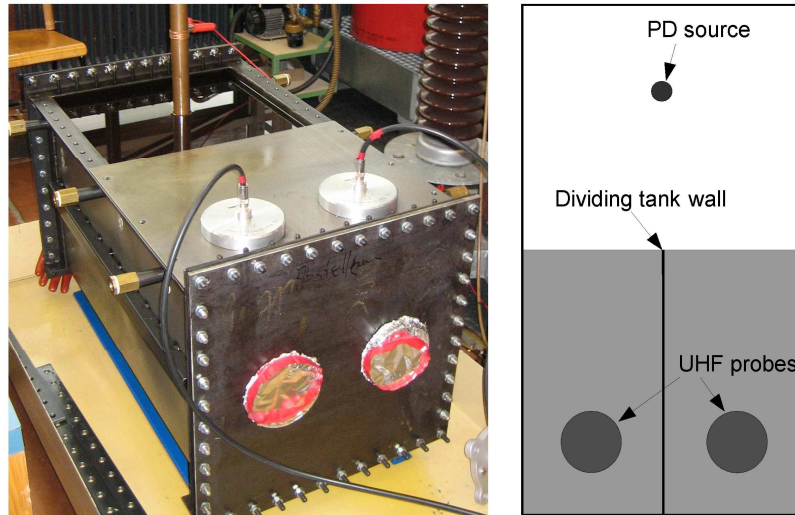


Fig. 5: 2-path-arrangement

By a metal wall, two UHF probes are electromagnetically decoupled. The needle sphere PD source inside the 2-path-arrangement was energized with high voltage. In the feeding electrode of the PD source a bow of copper was introduced, see Fig. 6. The high-frequency PD current has to flow through the bow into the PD source.

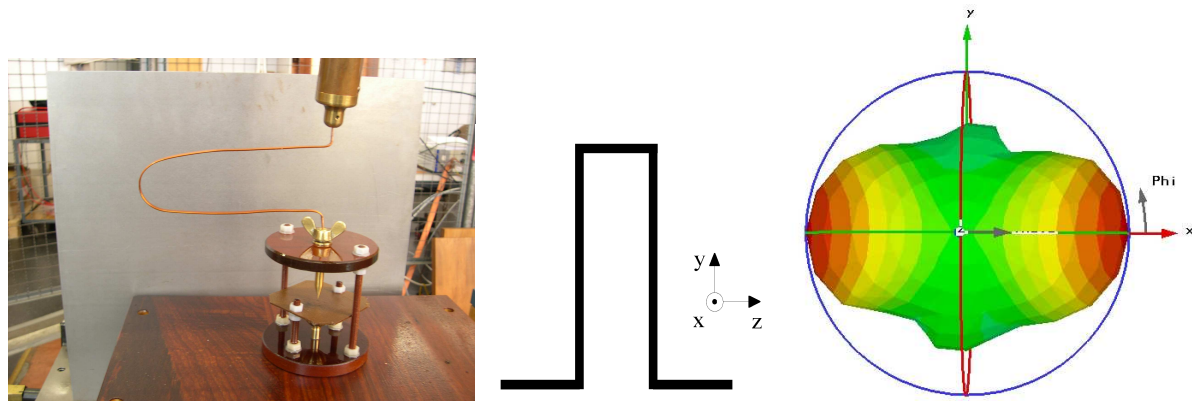


Fig 6 : Radiation behaviour; left) Bow of copper, middle) simulated model, right) simulated radiation

The horizontal dimension of the bow is about 20 cm which leads to a resonance frequency of about 500 MHz in oil. The two UHF probes have the same range of resonance frequency and measure sensitively the emitted UHF waves. By changing the orientation of the bow, see Fig. 7, the qualitative radiation behaviour can be analysed. For each PD phenomena/pulse, the signal energy of the two UHF signals were computed, i.e. E_{left} and E_{right} , see Fig. 7. By building the ratio of the two signals energies, the influence of the bow of copper can be estimated. In case of symmetrical paths, the ratio should be 1. In case only the PD source is somehow responsible for the emitted UHF waves (and deviations from slightly changing discharge channels are insignificant), the ratio should remain 1, also in case if changing the orientation of the bow.

In the following the bow was orientated in different positions, see Fig. 7.

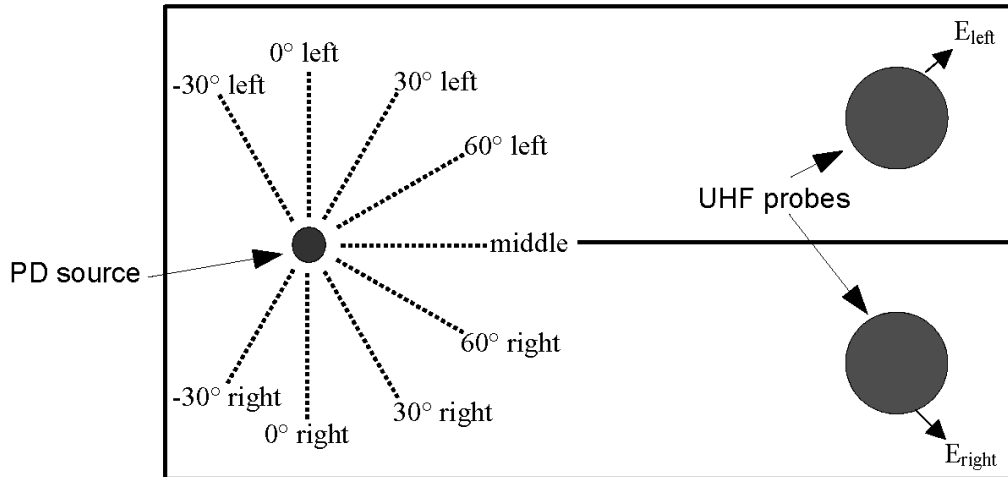


Fig. 7: Different orientations of the bow of copper in the feeding electrode of the PD source

The PD source was energized with high voltage and produces PD phenomena of 50-100 pC. For each position of the bow, 10 UHF signals for both UHF probes were recorded with a 2 GHz analogue bandwidth transient recorder. Building the ratio of the signal energies between the probe on the left and right side and averaging the ratios leads to the bar diagram in Fig. 8.

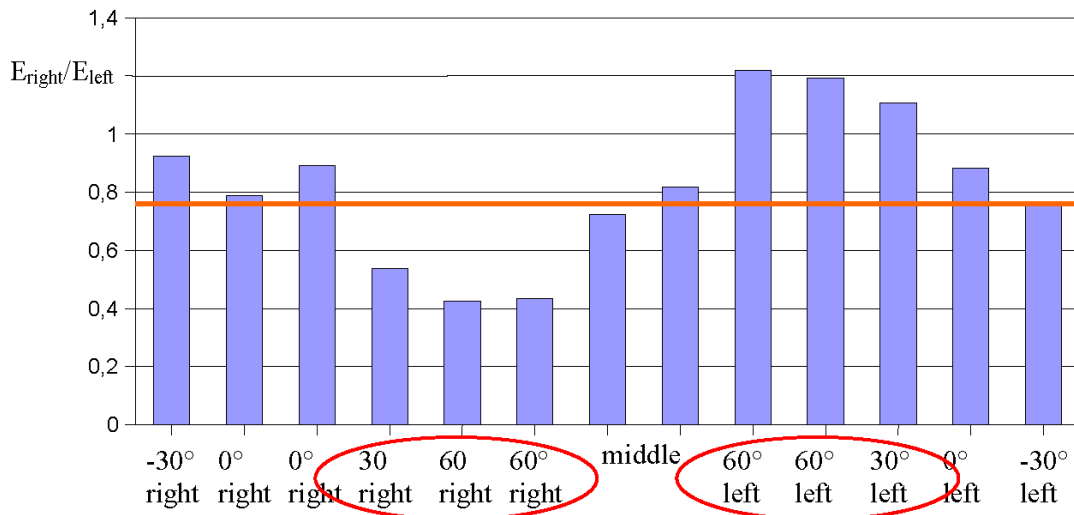


Fig. 8: Ratio between measured UHF signal energies with different bow orientations, one bar represents 10 measurements, standard deviation less than 6 %

The orientation of the bow of copper has an influence on the measurable UHF signals. Regarding e.g. position 30°right shows, that the energy E_{right} must be smaller than the energy E_{left} . That leads to the conclusion, that the bow of copper radiates UHF waves normal to its stretching area, i.e. the diagonal UHF sensor receive more energy than the other. Taking some experiments more than once and changing the orientation of the bow to the opposite side proof this radiation behaviour. The standard deviation during all measurements was below 6 %.

The qualitative results of the experiment were proofed in a second step with an simulation tool for high-frequency signals. As could be seen in Fig. 6, the bow of copper was modelled with the same dimension as in the measurements. It was energized by a high-frequency current flow (gaussian impulse). The radiation diagram simulated by the software (see Fig. 6 right)) shows the most radiation in normal direction (x-direction) to the stretched area of the bow.

The radiation behaviour of UHF PD sources depends as well on the structure between the high voltage source and the PD source.

4 ATTENUATION OF UHF SIGNALS IN 220 MVA AUTOTRANSFORMER

PD signals might be measured and quantified with regards to a sensitivity check in apparent charge (pC) within large power transformers with an UHF sensor, when electromagnetic waves emitted by a PD can be measured everywhere in the transformer without or at least with known loss of UHF signal power. For optimal measuring results, there should be no significant influence of the internal structure on the propagation of UHF signals.

For analysing this characteristic of the UHF propagation inside power transformers, two 220 MVA single-phase autotransformers of the same type intended for scrapping were prepared for some experiments. The transformers were oil free but with intact tank, which acted as a faraday cage for external disturbances. More important, the transformers included their complete active parts. To get several different location for injecting and receiving electromagnetic waves through the transformer a lot of boreholes were drilled in the tank wall at various positions around the transformer tank. This is exemplarily shown for the front side view of one transformer in Fig. 9.

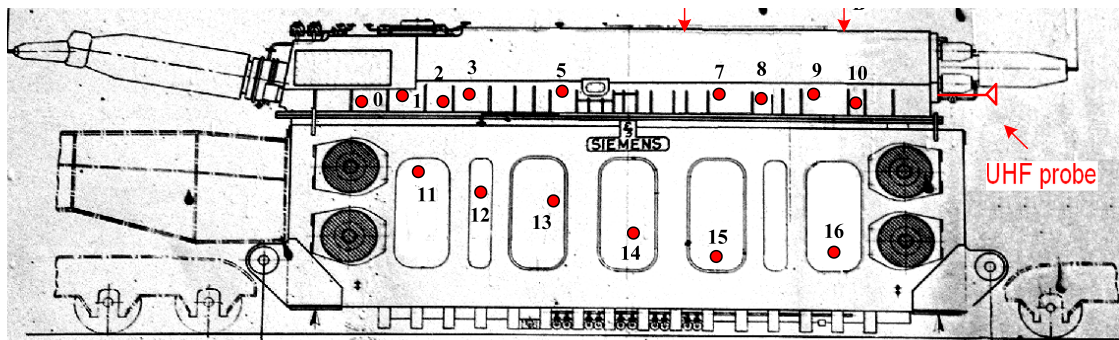


Fig. 9: Positions of boreholes into the front side of one transformer (other boreholes were at the back of the transformer, e.g. No. 17 – 27)

At least two 10 cm long monopoles (see Fig. 10) can be shifted into the transformer through the boreholes. The attenuation of different propagation paths through the transformer can be investigated by feeding one of the monopoles by an UHF impulse generator and measuring at the other monopole the received UHF waves. Additionally an UHF probe was installed for reference measurements at an oil-filling valve. The feeding signal had an amplitude of 60 V with signal rise times of less than 100 ps and a corresponding frequency spectrum up to 2.5 GHz [3].

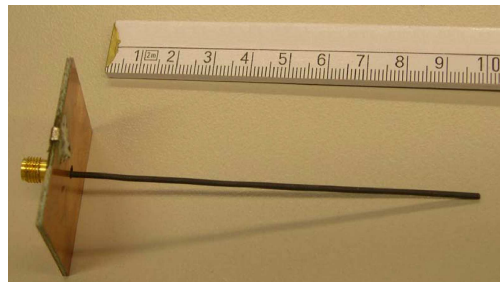


Fig. 10: Monopole for emitting and receiving electromagnetic waves

With the impulse generator repetition rate of 100 Hz, many non-amplified single signals could be received and analysed independently. Fig. 11 shows e.g. the maximum amplitude of the received UHF signals at different positions characterized by the number of the borehole, as defined in Fig. 9. The UHF signal source (the emitting monopole) was held on constant location, e.g. here at a borehole on top of the transformer tank.

Immediately recognizable is the clear difference of signal amplitude depending on the position of the receiving antenna. Regarding the antenna position 9 as a reference, the damping factors to the other antenna locations could be calculated.

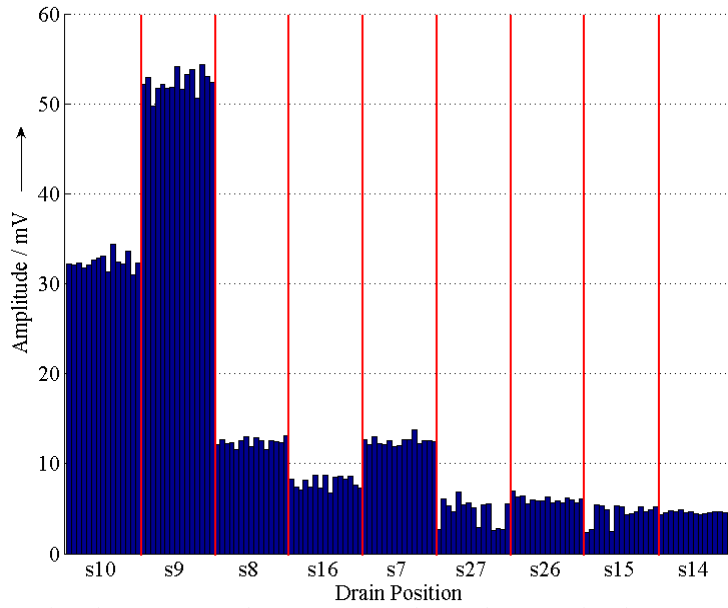


Fig. 11: Maximum amplitude of received UHF waves depending on the drain position (source position constant)

Fig. 12 summarizes an example of one fix UHF source location and different receiving antenna locations by plotting the calculated attenuation factors in dezibel (dB), see left axis. By knowing the transformer tank dimensions, the corresponding source-receiver antenna distances are calculated and included in the diagram. This results in general attenuation factors of the UHF signals inside the transformer with the unit dB/m, see right axis in Fig. 12.

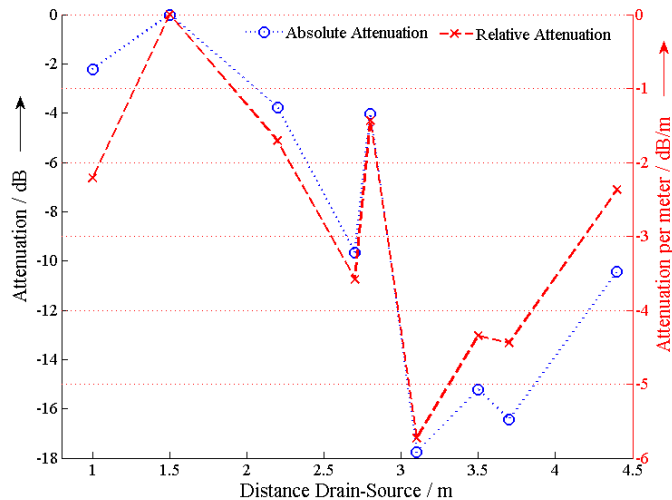


Fig. 12: Attenuation of UHF signals measured in time domain

The attenuation of UHF signals relating to the distance is not linear correlated to increasing distance. Depending on the internal structure of the transformer, some antenna locations might be better for receiving UHF signals than other locations. The showed way of analysing the attenuation was done for many different measurements with different drain and source locations. Summarizing, the attenuation of UHF signals within the transformer varies between 5 and 13 dB/m, depending on the location and therewith the propagation path of the UHF signals. The maximal measured attenuation was 33 dB at a distance of nearly 6 m. Compared to the state-of-the-art amplification of about 30 dB for UHF signals, the high UHF signal-to-noise ratios and regarding the strong amplitudes, the measured attenuation do not undermine the sensitivity of the UHF method in general.

Comparing the attenuation factors of complete active part arrangements from above (e.g. propagation path through complete HV/LV-windings etc.) to results for single, generic structures as e.g. part of a disc-winding (attenuation around 2 dB) or a 0.5 cm gap in a metal plate of (attenuation around 3 dB) [1, 4], shows comparable ranges.

Active parts of transformers have strong influence to UHF signals and the caused attenuation is not linear to the distance. More experiments like the mentioned above with different transformers will show, if the attenuation is within same range or even predictable for identical transformer types. Because of the showed attenuation, it might be impossible to examine the quantity of a PD originated UHF source (in terms of apparent charge) without knowing its location and therewith the possible span of experienced attenuation of the UHF waves on the propagation path to the UHF probe.

5 CORRELATION BETWEEN UHF – IEC60270

The so-called Sensitivity Check for UHF measurements on power transformers might be comparable to the procedure suggested for the UHF method at gas isolated switchgear (GIS) [5, 6]. An approximation of the measured UHF PD quantity comparable to the quantity of the apparent charge in pico Coulomb (pC), determined with the measurement according to IEC60270 (IEC), should be achieved.

First step is an investigation about the correlation between the apparent charge pC and the measured UHF signals. Therefore the IEC measuring method was done simultaneous with the UHF measuring method, see setup in Fig. 13. The UHF signal and the voltage signal of the IEC measuring impedance were recorded at the same time.

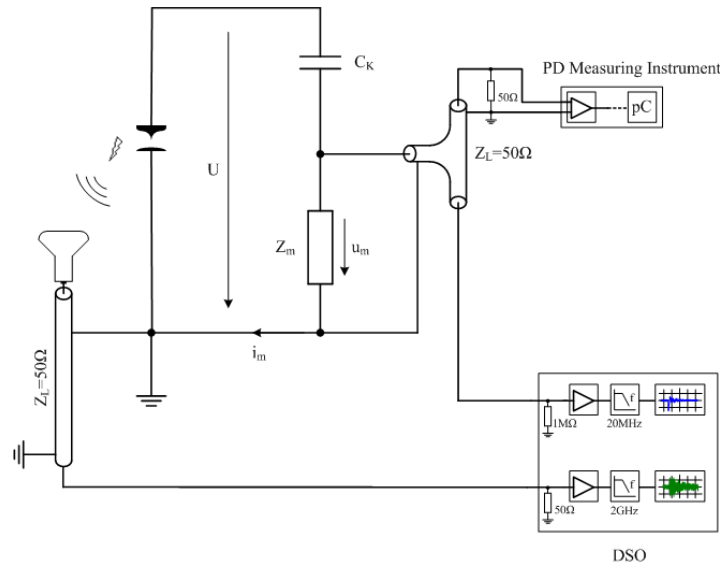


Fig. 13: Combination of UHF and IEC60270 measurement

Additionally a PD measuring system measured directly the apparent charge level Q_{IEC} serving for reference measurement and voltage measurement. After calibrating the IEC measuring method, the scope measures the apparent charge and the UHF effects of one and the same PD pulse. While recording e.g. more than 30 signals the natural deviation of PD defects helps to find a relation between UHF signal amplitude and apparent charge.

Two different sources of PD are shown in Fig. 14. The first source of PD consists of a glass ampoule with an air cavity between a rod-plane PD source under oil. The second PD source consists of another rod-plane arrangement which uses the same oil volume as the transformer. The high voltage was applied by a coaxial cable (RG214), which is PD-free up to a voltage of approximately 12kV. PD inception voltage of the sources was about 5-10kV.

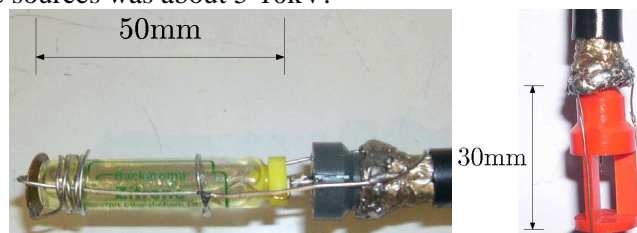


Fig. 14: Rod-plane PD sources, 50-300 pC, 5-10 kV

The PD sources were brought into a 10 kV/380 V 200 kVA distribution transformer. Through an available oil filling valve an UHF probe was slid into the transformer, receiving the emitted UHF waves from inside the transformer tank. Because of the not completely closed top cover, the location of the PD sources, mounted on a stick, can be changed to 20 different positions, defined in Fig. 15.

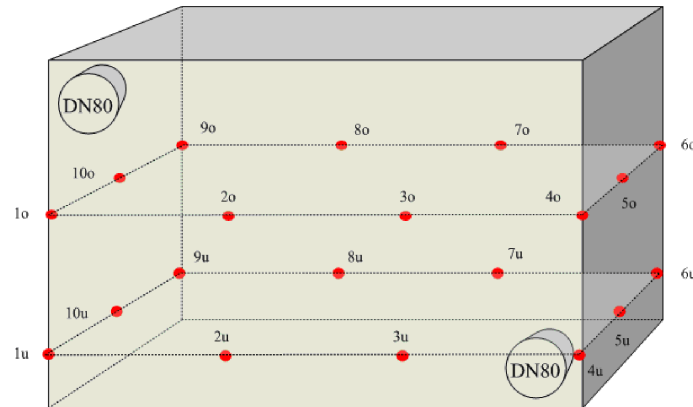


Fig. 15: Measuring positions in transformer tank, 10 kV/380 V, 200 kVA

During the measurements the transformer with the included active part was oil-filled and an aluminium foil closed the cover to simulate a closed tank. In the exemplary results shown in this paper, the UHF probe was installed at the upper oil filling valve and the PD source with the glass ampoule was used. The applied voltage was adapted so that PD with an intensity of 50 to 150 pC occurred. For each measured UHF signal, the amplitude and the apparent charge of the corresponding PD were determined. In Fig. 16 the measured UHF amplitude over the apparent charge Q_{IEC} is shown.

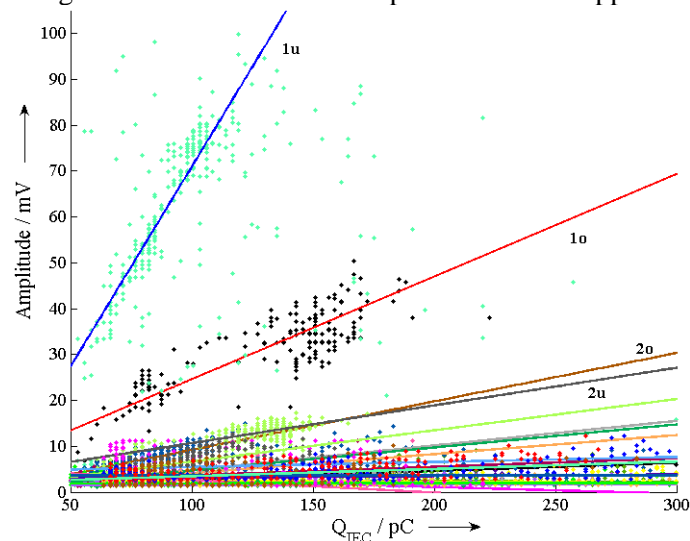


Fig. 16: PD Source “glass ampoule”: Correlation between UHF amplitude and apparent charge Q_{IEC}

All measurements (points) of the 20 locations are coded with a clear colour. Different clusters of points with the same colour are remarkable. These points show a linear correlation between the apparent charge and the measured amplitude of the UHF signal. In order to examine this correlation quantitatively, for the measured values regression lines were computed according to the method of the smallest error squares, see Fig. 16. The following observations can be made:

- The regression analysis shows a linear correlation between the apparent charge and the measured UHF signal amplitude.
- The correlation is constant for a fixed position of PD source. The correlation factor depends on the position of PD source and thus of the distance between PD source and UHF probe.
- The signal/noise ratio decreases with increasing distance between PD source and UHF probe.
- The PD sources show - even with constant apparent charge level - a large dispersion regarding the UHF signal amplitude. From this it can be stated that different kinds of PD have likewise different characteristics concerning the relation between measured apparent charge and emitted electromagnetic waves.

6 SENSITIVITY CHECK

The idea for the so-called Sensitivity Check for the UHF measuring method on power transformers is based on the procedure suggested for the UHF measuring method at GIS [6]. Therefore a well known real PD has to be placed into a transformer tank in laboratory. The same probe reading from the measured real PD will be simulated in a second step with an UHF signal generator with variable output power using a second transmitting probe. With an excitation voltage of e.g. 10 V this will lead to a ratio of the feeding amplitude to the apparent charge of 0,1 V/pC. Installing the whole measuring system at an identical transformer with two oil filling valves may then allow a sensitivity verification for 100 pC, i.e. the UHF method is able to detect PD effects with at least 100 pC.

Aim of the following investigation is to find the above mentioned relation between the feeding signal and the according apparent charge.

All measured UHF signals are measured with an UHF sensor, installed at the upper DN 80 oil-filling valve. First step is activating the PD source at position "7u" (see Fig. 15) with an apparent charge of 100 pC. The UHF sensor detects an UHF signal with an amplitude of 5 mV. In the second step, the monopole antenna (Fig. 2) held at position "7u" was fed by the UHF signal generator with an amplitude of 4.0 V for simulating the same measurable effects as the original PD. I.e. the relation of 0.04 V/pC can be used for the Sensitivity Check.

Comparing the relation of 0.04 V/pC to results in [7], which stated a relation between 0.2 V/pC and 1.5 V/pC, the big discrepancy might be explained by:

- different sensitivity of the UHF coupler or used amplification
- different transformer tank sizes
- different internal structures
- different types of PD

Investigations in future may allow comparable results when defining some standards for the Sensitivity Check procedure in laboratory first.

For analysing, if the artificial impulse of 4.0 V leads to the same quantitative result as in the chapter 5, the transmitting antenna was located successively at the 20 different defined positions in the transformer and the UHF probe signal was recorded.

The following Fig. 17 compares the measured UHF amplitudes using the 4.0 V impulses with the UHF impulses caused by the original PD of 100 pC at each location. Position "7u" is the reference point of the Sensitivity Check where the UHF signal amplitude of the original 100 pC PD has the same value as from the artificial impulse of 4.0 V.

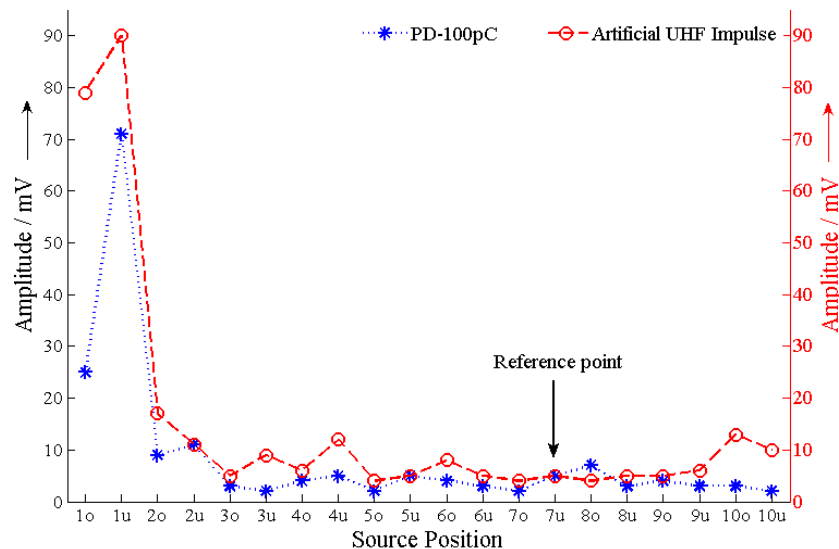


Fig. 17: Sensitivity Check with original 100 pC PD source and artificial UHF impulse with 4.0 V

The measured values strongly support the preliminary investigation results, that the attenuation of the UHF signals depends on the internal structure and the propagation path, because measured values of the same origin (100 pC PD and 4.0 V artificial impulses) varies between 3 and 90 mV. With the exception of point "1o", the artificial UHF impulses show similar UHF measuring results to the

original PD sources. The procedure makes an evaluation possible whether PD of certain intensity at the tested positions are detectable, i.e. it might only be a worst case estimation of the sensitivity for this transformer.

Generally the Sensitivity Check for UHF measurements does not allow an estimation of the apparent charge, because of not predictable UHF attenuations according to the location of the PD and the resulting propagation path of UHF signals. The procedure might be a worst case estimation of the sensitivity. But defining a general procedure for the immense number of different types of transformers might be difficult.

7 CONCLUSION

The detection of PD during full operation of power transformers is possible with the shown UHF probes. The probes withstand all occurring mechanical and thermal stresses and can be used as a permanently installed measuring device for online monitoring systems. Improvements of electrical properties of the UHF probes allow a significant functionality test of the probes and the whole measuring equipment including measuring lines and the PD acquisition unit.

For the verification of the sensitivity of the UHF method, the results of the presented research can be concluded as followed:

- Radiation of UHF waves depends as well on the structure between the high voltage source and the PD source.
- UHF signals experience propagation-path-dependent attenuation while propagating through the internal structure of the active part of the transformer.
- For fixed propagation paths there is a linear relation between the UHF amplitude and the apparent charge pC of PD.
- It seems not reasonable to solely calculate the pC-intensity of an PD according to IEC60270 with UHF measurement on a basis of a Sensitivity Check.

Near-future research will consist of the presented procedure in chapter 5 and 6 of the Sensitivity Check at transformers planned for scrapping to find some additional information.

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