Partial Discharge Impulse Characteristics of Different Detection Systems

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***Abstract* — The partial discharge measurement is a very well known possibility to assess the quality of an insulation system of high voltage equipments. It is an important method in the area of non destructive insulation diagnostic.**

In the working field of technical diagnostics alternatives to the conventional partial discharge (PD) measuring techniques are looked for, with the aim to evaluate the insulation condition of electrical equipment and the detection of a beginning destruction in the electrical insulation as a result of electrical stress.

***Index Terms* — Electrical, optical PD measurement, partial discharge, impulse behaviour.**

I. INTRODUCTION

Insulation monitoring and diagnostic systems are the basis for condition based maintenance and an economic use of high voltage equipment.

Depending on the internal structure of the insulation system, different electric field distributions occur. At local inhomogenities in the insulation discharges in small areas can appear. This discharge - called partial discharge (PD) - shows different physical and electrical characteristics as a result of the multiplicity of different PD sources and appearances.

PD activity can be detected by different techniques. Electrical, acoustical, optical und chemical measuring techniques are in use. The PD measurement is a sensitive and effective way to detect the beginning of destruction in electrical insulation or insulation failures as a result of electrical stress.

Arising PDs in an insulation system are characterized by a kind of non-periodic impulses with duration of 10^{-9} – 10^{-7} s. The frequency spectrum of this discharge is very large, being up to GHz, but traditional PD measuring systems measure and analyse PD in the range of 1 MHz. So the traditional measurement can not achieve the complete partial discharge characteristics of the different insulation systems.

For the electrical measurement of the apparent charge different systems are possible, which are predominantly different upon the bandwidth of the used PD measuring system.

Advancements on the area of the applicable sensors, signal collection, powerful data processing and analysis make the employment of new technologies for PD detection possible. New noise suppressor systems permit the increasing use of ultra wide band detection systems.

In a research project, a contribution in the area of optical partial discharge measurement technique and analysis was developed. A comparison between the optical and the conventional electrical measurement system (with different band width) will be carried out for a peak-plate arrangement at different insulation medium and voltage supplies (AC, DC, and Impulse voltage).

II. BASICS

Partial discharges are small electrical pulse caused by a electrical breakdown in a defect in the insulation system. This discharge at local inhomogenities emits a spectrum of electromagnetic waves or radiation and transmits information about the energy level of the discharges. For the measuring physical effects like optical, electrical and acoustical appearances are used.

The conventional electrical methods are primary used for the detection of inhomogenities. The unconventional methods for example the acoustical or the optical detection are used for the exact localisation of the PD.

For the conventional partial discharge measuring technique the measuring circuit according to guidelines of IEC 60270 is used. Each PD in the test specimen causes a short high frequency current pulse in the measuring circuit. The available measurement systems can detect the apparent charge and also the phase location to the supply voltage. Furthermore the number of discharges over a given time interval will be recorded.

Different sensors for the detection of the PD impulse are used. In the simplest case a resistor converts the PD impulse current to a voltage signal. The characteristic of the detector (RLC detection impedance - quadrupole) can be manipulated to integrate the PD signal to obtain the apparent charge of each discharge.

For the conventional electrical measurement especially narrow band and wide-band system detectors are in use. Narrow band detectors have a band pass filter/integrator with a bandwidth of about 10 kHz or so, while wideband detectors have a band pass filter/integrator with a bandwidth of several 100 kHz.

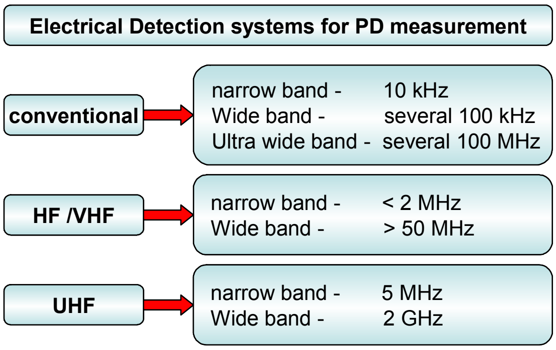

Fig. 1: Electrical PD detection systems

New systems have a tendency to use sensors and detectors with a bandwidth up to several 100 MHz. Higher bandwidth implies that the apparent charge may not be directly produced (displayed) by the detector, since the current is not directly integrated [1].

Partial discharge in polymeric insulations shows a duration of several nanoseconds and so the frequency spectrum pass to the range of 100 MHz. For the High Frequency/Very High Frequency (HF/VHF) PD measurement inductive and capacitive sensors are in use The bandwidth of the system can be differ between a bandwidth up to 2 MHz (narrow band method) as well as bandwidth over 50 MHz (wide band method).

Partial discharge impulses of very short duration (< ns), for example in GIS, produce electromagnetic waves, whose spectrum reaches up to the GHz range. In the area of ultra high frequency (UHF) detection systems also two types of PD measurement can be termed. These are the narrow band technique with a measurement bandwidth of only a few MHz, and the wide band method typically up to 2 GHz.

The acoustic partial discharge measurement uses the fact, that an acoustic signal is emitted (mechanical vibration) as a result of the pressure build-up caused by the generated spark in the insulation medium. Because of the short duration of the PD-impulses, the resulting compressional wave has frequencies far in excess of the audible band of sound. The frequency spectrum lies in the range between 10 Hz up to 300 kHz (1 MHz) and will be measured with appropriate ranges of the detection system.

The optical partial discharge detection is based on the detection of the light produced as a result of various ionization, excitation and recombination processes during the discharge. The amount of the emitted light and its wavelength depend on the insulation medium (gaseous, liquid or solid) and by different parameters (temperature, pressure …). The spectrum of the emitted light of partial discharges depends on the surrounding medium. The optical spectrum reaches from the ultraviolet to the infrared range [2]. The optical signal of a PD impulse has a very short rise time, thereby different measuring system with a bandwidth up to GHz can be used.

The partial discharge measuring technique as a part of the insulation diagnose is object of investigations at the Institute of High Voltage Engineering and System Management at the University of Technology in Graz. A scientific project deals with the economic possibilities of the optical detection of partial discharge with fibre optic and/or fluorescent fibre-optic cables.

III. INVESTIGATIONS

An optical system for PD detection consisting of a special fibre-optic cable, a photomultiplier for converting the light into electricals signal and a detection unit was developed. The usage of an photomultiplier allows the measurement of very low light level and has a very fast rise time. Due to this fact, the application of an ultra wide band amplifier is possible, with the advantage to achieve a high dissolution of the impulse.

As test setup a simple peak-plate arrangement is used for the PD measurement. Investigation with two different conventional detection systems (different bandwidth of the system) in comparison to the optical system are carried out (Fig. 2). The PD pulses were observed simultaneously by the used systems.

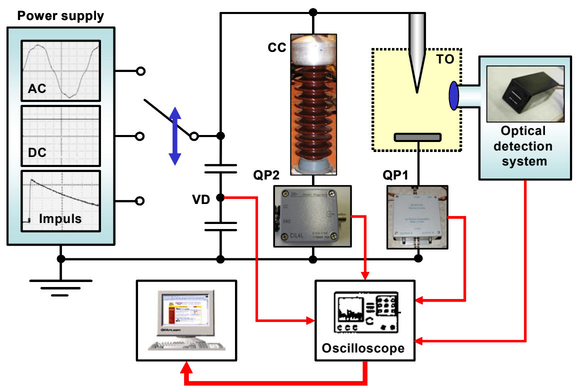

Fig. 2: Concept of the conventional and optical PD measurement

TO … test setup (peak-plate in air or oil)
CC … coupling capacity
VD … voltage divider
QP1 …Quadripole – 20 MHz
QP2 … Ouadripole – 800 kHz
Optical detection system – 70 MHz

Further investigations about the partial discharge impulse behaviour at different voltage supply were made. The voltage supply (AC, DC, Impulse) can be vary up to 100 kV. The distance between the peak –

plate could be changed in a range from 1 to 20 cm. Air or oil (transformer oil) under normal pressure conditions is used as insolating medium.

IV. Test Results

For the measurement two different conventional measuring systems and a optical system, were used:

- (1) optical system – band width 70 MHz
- (2) conventional system – band width 800 kHz
- (3) conventional system – band width 20 MHz

A. Partial discharge under AC

In the following picture a PD impulse in air is shown, which was measured by conventional and the optical measurement systems.

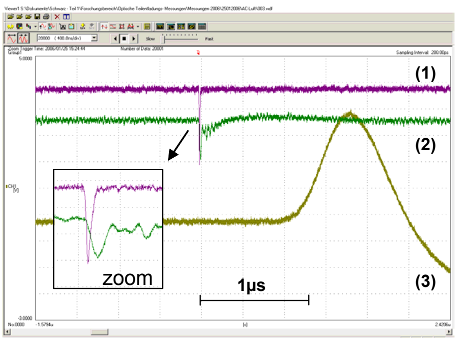

Fig. 3: Comparison of the optical (1) and conventional (2), (3) detected single impulse PD signal in air

Due to the signal processing of the used conventional system (3) a time delay about 1 µs results (Fig 3.). Also the limited bandwidth of this system causes a signal extension (2,5 µs). This system has a rise time of 400 ns rise time in the comparison to the optical system (1) with a rise time of approx. 5 ns and an impulse time of approx. 20 ns. The second wide band conventional system (2) has a rise time of 10 ns and a pulse time of 300 ns. The time delay is missing.

The rapid rise time of the PD event is detected by the conventional limited bandwidth measuring system in the form of a single integrated apparent charge impulse.

For example in oil, the detected discharges are scattered in amplitude and shape. Positive and negative streamers have different transient behaviour. Positive streamers are a superposition of fast pulses and the negative streamers are composed by a burst of fast pulses of growing intensity with a very fast rise time. With the limited bandwidth of the measuring technique, the conventional PD system (3) can not correct represent the fast impulses in oil,. The pulse represented the single response to a PD pulse burst involving a number of pulses in oil. By increasing the time interval between the fast single impulses within a burst, the resultant charge integrating pulse of the output of the limited PD measuring system assumes a protracted shape with more secondary pulse peaks (Fig. 4).

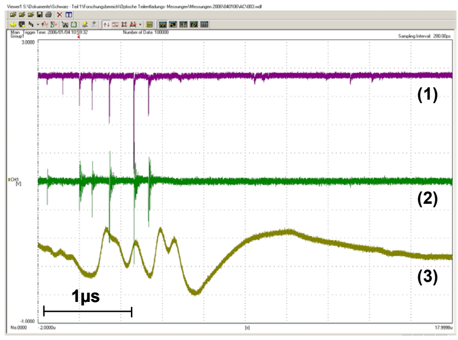

Fig. 4: Comparison of the optical (1) and conventional (2), (3) detected single impulse PD signal in oil

In contrast the second wide band conventional system (2) shows good impulse dissolution.

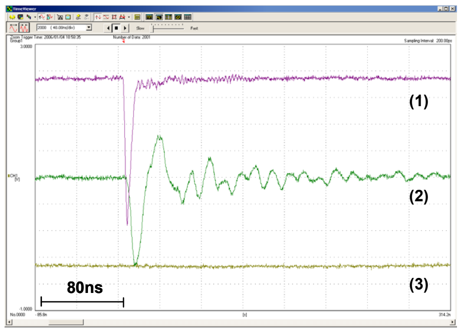

Fig. 5: Comparison of a single impulse in oil - optical (1) and wide band conventional (2) system (negative half-wave)

B. Partial discharge under DC

The impulse behaviour is depending on the polarity of the supply voltage. The impulse at negative voltage is smaller than the positive impulse, and the repetition rate is higher in comparison to the positive voltage. There is also a different in the rise time between both discharge impulses.

In the following two pictures PD impulses in air are shown at different polarity of the test voltage.

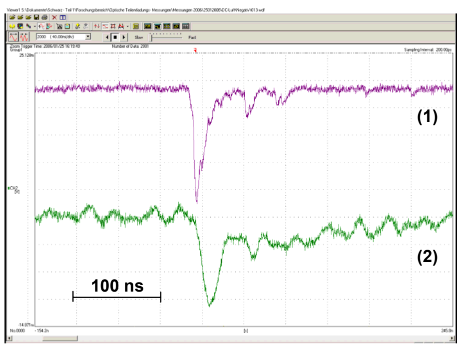

Fig. 6: Comparison of a single impulse in air - optical (1) and wide band conventional (2) system (negative DC, 8kV)

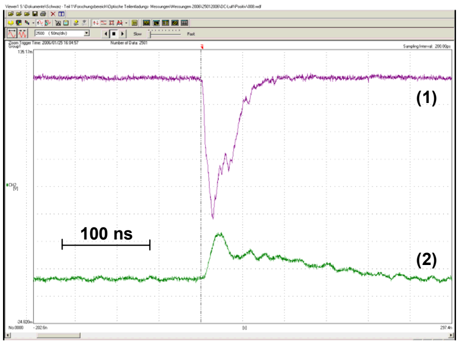

Fig. 7: Comparison of a single impulse in air - optical (1) and wide band conventional (2) system (positive DC, 8kV)

The rise time for positive pulses was higher than those for negative. Fig. 6 shows the impulse with neg. polarity with a rise time approx. 5 ns and the impulse width approx. 20 ns and Fig. 7 shows the impulse with pos. polarity with a rise time approx. 10 ns and the impulse width approx. 60 ns in case of the optical detection system. The conventional (wide band) measured signal has a larger rise time and a longer pulse width.

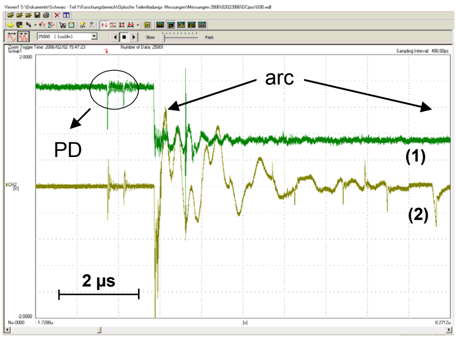

Fig. 8: Comparison of a discharge in oil - optical (1) and wide band conventional (2) system (DC, 40kV).

Fig. 8 shows the optical and the conventional measured signal PD signal in oil under positive DC. Two discharges occur in the front of the following arc - with its intensive light channel (optical system overload (1)) and the transient current process (2).

C. Partial discharge under Impulse voltage

In Fig. 9 the PD impulses by using impulse voltage in air is shown.

During the accomplished measurements the rise time of the optical signal (1) is thereby approx. 5 ns and the pulse time about 50 ns. The electrical detected signal (1) is affected by strong disturbances and with the assigned measuring system, so an interpretation of the signal is not possible. Curve (3) shows the impulse voltage.

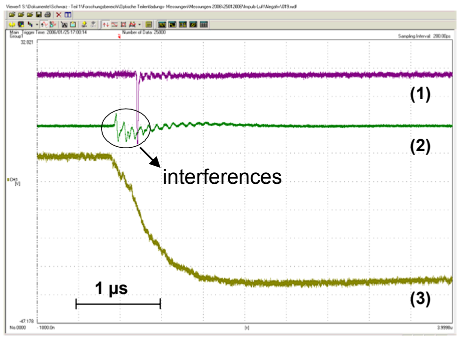

Fig. 9: Comparison of PD impulse in air - optical (1) and wide band conventional (2) system during negative impulse voltage (3).

V. CONCLUSION

In the last years new sensor technologies, cheaper electronics, new software tools and memory make the application of ultra wide-band detection systems possible. The advantage of the usage of a wide-band detection system is the higher time resolution of the impulse, fast rise time and polarity information of the impulse. The trend to higher bandwidths enables also the use of improved noise suppression and facilitates PD location.

For example the burst of partial discharges with fast rise times, which are characteristics of partial discharge process in oil (insulating liquids) are detected by conventional band limited detection system in form of integrated apparent charge impulse. These systems accomplish an integrative character and if many PD impulses arise in a short time interval, an exact statement about the single pulses, their number and magnitude cannot be made. So the limited measuring method cannot express the complete PD impulse characteristics of the insulating system.

Using ultra-wideband PD detection technique, the specific characteristic of PD can be observed and understood better for exact investigations of the damage process and aging behaviour of the insulation.

An additional method to the conventional measurement is the optical detection with the advantage of the galvanic separation, the insensitive to interference (EMC), and the possibility to use systems with high bandwidth to analyse the PD impulse behaviour.

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