2004 Annual Report Conference on Electrical Insulation and Dielectric Phenomena

Unconventional partial discharge measurement

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Abstract: The partial discharge measurement is a very well known possibility to assess the quality of an insulation system. The aim is the detection of destruction in the electrical insulation as a result of electrical stress. In the working field of technical diagnostics alternatives to the conventional partial discharge (PD) measuring techniques with the aim to evaluate the insulation condition of electrical equipment are looked for.

In a research project, a contribution in the area of optical partial discharge measurement technique and analysis was compiled. An optical partial discharge measuring system was developed, which gives the basis for investigations inside of electrical equipment.

Introduction

For the economic use of high voltage operational equipment, it is necessary to know the condition of the used components. If the condition is known, the most economic maintenance strategy can be realised. Inspections can be planned on a long-term basis and the components lifespan can be used fully. That is the reason why monitoring-, analysing- or diagnose systems become a fixed part in power generating, transmission and distribution systems. In this area partial discharge measurement is an important diagnostic tool.

The presence and the strength of partial discharges in electrical resources are criterions for its quality (insulation). Partial discharges have only a small short time influence on the electrical firmness of electrical resources. On the other side the long time influence shows a destructive effect predominantly on organic insulation systems, which degrade the electrical characteristics of the insulation or the insulation systems. This can lead to a breakdown and a failure of the concerning resource. That's the reason why different techniques of partial discharges measurements are regarded as important diagnostic tools for detection and location. Partial discharge measurements will be used as non-destructive checks for the insulation of high-voltage resources during quality tests in the factory and for resources being in service. A multiplicity of different partial discharge sources and their appearances shows different physical characteristics. For the measuring, physical effects, such like optical, electrical and acoustical appearances, will be used. Different measuring methods for the analyse of the PD behaviour are used. The conventional measuring technique after IEC 60270 finds the main application.

Basics

Partial discharges are local enhancements of the electric field in the area of inhomogenities, either in gaseous, liquid or solid media [1]. They can lead to another deterioration of the electrical characteristic up to a failure. Two basic kinds of detection methods can be distinguished: electrical and non-electrical methods (figure 1).

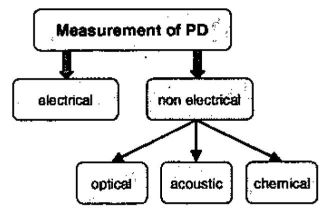

Figure 1: Types of partial discharge measurement

With the conventional electrical measuring method according to IEC 60270 partial discharge level can be proved, but with this method an exact location of the defect area in the equipment is hardly possible. So alternative non electrical measurements are used for it.

Electrical Methods

The electrical methods depend on the electrical and electromagnetic effects of partial discharges. These methods use for their detection currents, voltages and existing electromagnetic fields.

Conventional Measurement of Partial Discharges

The test set up consists of a high voltage source, a coupling capacitance and measurement impedance (quadrupoles). Each partial discharge causes a short high frequency signal which can be detected with the impedance. The following measurement system can be analysed the detected signal. The system can be build up as a narrow-, limited-wide- or a wide-band system.

UHF Measurement of Partial Discharges

Impulses of partial discharges in SF6-Systems are from very short duration (<nanoseconds), so that the spectrum of the electromagnetic waves, caused from

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the partial discharge, is very high frequency (GHz). In coaxial gas filled systems (e.g. GIS) this impulse releases transient waves. For this reason capacitive sensors, as like antennas, were developed, which can detect transient waves. Measurements can be made in the frequency range with narrow band procedures up to some MHz and in the time interval with a bandwidth up to 2 GHz.

HF Measurement of Partial Discharges

Partial discharges in polymer insulation systems causes impulses with duration of a few nanoseconds. A transformation of this signal in its frequencies shows that the spectrum is constant up to some 100 MHz.

If partial discharges cause travelling waves, for example in a VPE-cable, this waves spreads in two directions to the two ends of the cable. Inductive and capacitive sensors will execute the measurement of the waves.

Chemical Verification of Partial Discharges

PD decompose insulating oil and organic insulation. Analysing the existing gas in the oil, which is produced by discharges can give information of the energy of the discharges. So it is possible to evaluate the faults of the insulation system. If partial discharges appear in air, chemical reactions produce ozone. The determination of this ozone concentration can give information about the partial discharge activity.

Acoustic Measurement of Partial Discharges

Each partial discharge delivers energy, which can also be detected as sound. The propagation speed of the acoustic wave depends on the surrounding medium. Reflections, refraction and absorption influence the sound propagation, which must be considered during detection and interpretation. Microphones and piezoelectric transducer are used as sensors.

Optical Detection of Partial Discharges

Another alternative measurement possibility is to detect partial discharges optically. In this case the optical spectrum of the emitted light, caused by the partial discharge, must be considered. Directly in connection with the electrical discharge it comes to a radiation in the ultraviolet-, visible and infrared area. This appearance can be consulted for optical detection. The spectrum depends on the surrounding medium (air, SF6, oil) and must be considered by the selection of the optical detection system. Depending for the spectral region coronascope, night vision device and low-light enhancer as well as fibre-optic cables are 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 in Graz. One scientific project deals with the economic possibilities of the optical detection of partial discharge with fibre optic cable or fluorescent fibre-optic cables. At the same time a conventional measurement of the partial discharge activity is executed with the aim of a comparison between both measuring methods. Also an appropriate storage and processing of the measuring signals with the aim their visualization take place [2, 5].

Beyond the electromagnetic wave emissions, each partial discharge emits light. This emission transport information about the energy level of the discharges. At the same time an localisation of the defect is possible. The wavelength spectrum of the PD emitted light occurring in a gas near the surface of the insulation is dominated by the spectrum that is characteristic of the surrounding gas. PD`s in air produce light with an optical spectrum which is dominated by the spectrum of nitrogen. 90 % of the total energy in this discharge spectrum is emitted in the ultraviolet area between 250 and 400 nanometers [3]. The optical spectrum in SF6 is situated in the ultraviolet and in the visible blue-green area of light (main part between 350 and 500 nm). Transformer oil indicates a spectral region of 350 to 700 nm depending on the used type [4].

Air and SF6 are almost to 100 % transparency, and so the light can be detected from a larger distance. In liquids and fixed insulations a section or the whole emitted light will be absorbed and none detection is possible.

Investigation

The aim of investigations is to detect and locate partial discharges in different insulation media (air, oil) by using an optical fibre system. The optical fibre were used as a sensor. The concept shows figure 2.

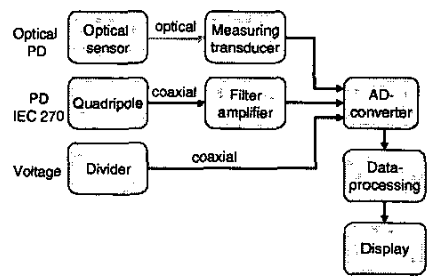

Figure 2: Concept of the optical PD measurement

As test setup a simple peak-plate arrangement is used for producing reproducibly partial discharge activitiy at the same place. The distance between the peak and the plate can be changed in an area from 1 to 20 cm, Voltage supply 0 -100 kV (figure 3).

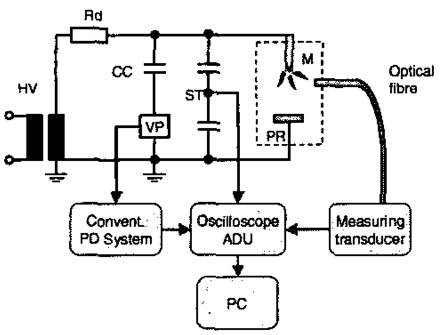

Figure 3: Measurement circuit
HV – high voltage supply; Rd – damping resistor
CC, VP, - conventional PD measuring system;
ST – voltage divider; M, PR – medium, test setup

A conventional partial discharge measuring system according to IEC 60270 is simultaneous used to the optical system with the aim to permit a comparison and correlation (optical PD characteristics) between the results of the two different measuring systems. For the optical system different optical components (optical sensors, different fibre-optic cables with and without lens) were used.

The emitted spectrum of the PD at the place of its origin will be used and is guided by a fibre-optic cable to an optical receiver. Different procedures of the light linking into the fibre-optic cable, as well as different geometrical arrangements to the source of partial discharges were analysed. One method is to use a lens system in front of the optical fibre. A further method is using a fluorescent optical fibre, whereby the light penetrates over its surface into the fibre (figure 6).

The light signal is coupled into the optical fibre and at the end of the fibre the signal is transmitted to the photodiode and/or photomultiplier and the amplifier circuit. The advantage of this application is the minimised electromagnetic influence, because the amplifier circuit is not arranged in the proximity of the high voltage set.

The measuring signals were digitised and sent to a data processing unit, with a program adapted software for the collection, analysis, storage and result presentation. The investigations under high voltage were executed using two important dielectrics, air and oil.

Test results

After preliminary investigations for the determination of the characteristics of the developed optical system (rise time, cut-off frequency), investigations under the use of a peak-plate arrangement as partial discharge source in the environment medium air and oil under normal atmospheric conditions (pressure) have been taken.

The effectiveness of the light linking was examined by a variation of geometrical arrangements. The following results show the measured output signal (voltage) from the optical measuring system. The preliminary investigations resulted in a distance from 5 cm (using a lens in the front of the fibre) to the partial discharge source as optimal for the light linking. As insulating medium at first air was used.

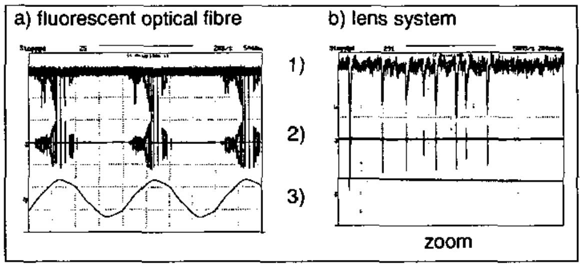

Figure 4: Confrontation of the signals
(1) Optical system – output signal
(2) Output signal of the conv. PD measurement
(3) Supply voltage

The partial discharge level varies into a range between 100 – 2000 pC (high peaks). Figure 4 show detail view of single pulse resolution (fluorescent fibre a) and lens with conventional optical fibre b)). There is a good correlation between the conventional measured PD signal and the output signal from the optical system.

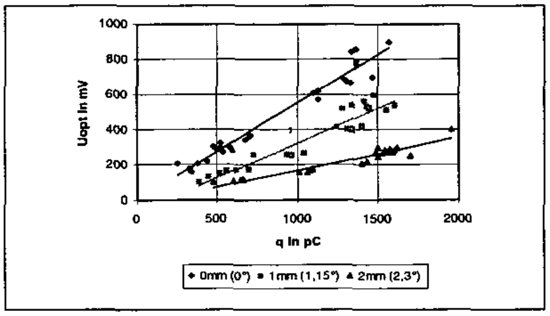

Figure 5: Output voltage of the optical system as a function of the apparent charge during angle (0° - 2,3°) dependent light linking (air, lens)

By varying the angle to the PD source between the peak and the sensor (lens + optical fibre), change in the peak value of the light pulse was observed as shown in figure 5.

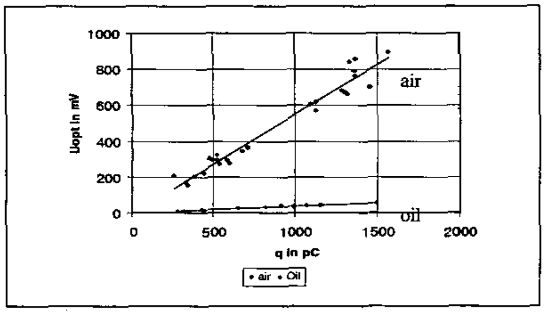

Figure 6: The relationship between the optical signal and the discharge level in air and in oil at the same arrangement

Both the air and the oil gap conditions were measured and the relationship between the electrical and optical signal is shown in figure 6.

To consider the circumstance is that in air and in oil different discharge behaviour, another optical absorption, as well as different spectral region of the radiated light are given. Thus also the characteristics of the optical system change, evidently by the large difference between the received output signals (figure 6).

Signal Processing

The measured signals are processed by software (LabView), with the aim of the automatic analysis of the optical detected signal. The main program control the individual program sections (figure 7) [5].

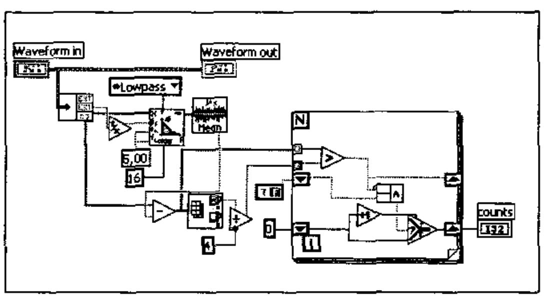

Figure 7: Graphic programming surface

The necessary data types are defined, and adjusted different options. Over a pulldown-menu the individual program sections can be called.

Summary

During the past investigations a good correlation between the results of the optical system and the conventional PD measurement is given. Starting from an apparent charge of approx. 35 pC in air (lens and photodiode) and 1 pC (lens and photomultiplier) an optical detection in air could be obtained. Also the phase affiliation is given. In oil it comes usually to brush discharges (many discharges in very short temporal succession), thus a direct connection between charge value and optical signal level is hardly possible.

It is also problematic to use a fluorescent optical fibre, because the absorption of the optical signal in the fluorescent optical fibre (opt. attenuation) is very high.

Conclusion

This contribution gives an short overview of the possibilities of partial discharge detection and localisation.

The measurement system can be used to detect and locate the optical signal of the partial discharge occurred in the transparent dielectrics. Some questions have been investigated based on a peak-plate arrangement and to typical insulation media. It has been found that the intensity of the optical signal corresponds with the level of the partial discharge. The optical detection possibilities seen to be an appropriate method for the future with the advantage of precise discharge location and immunity to EMV.

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