

Technical paper

A Guide for Partial Discharge Measurements on medium voltage (MV) and high voltage (HV) apparatus

Part 1 - Introduction

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1 What are partial discharges (PD)?

Partial discharge (PD) is a localized dielectric breakdown of a small portion of an insulation system under electrical stress. They can occur when the local electric field exceeds the local dielectric strength, at a given location, within or near an energized object. Even though there are some exceptions, most of electrical insulation systems used in medium voltage (MV) and high voltage (HV) apparatus are not resistant to PD. Therefore, a deterioration process will take place if the insulation system is exposed to PD activity. Overtime, it can lead to a complete dielectric breakdown of the insulation. The most common causes of PD are defects introduced during the manufacturing process or anomalies caused by different ageing mechanisms during an asset service life.

PD activity is usually present in the early stages of the insulation deterioration process. Therefore, an accurate PD measurement can help identify weak points within the insulation system before a complete insulation breakdown. For this reason, many international standards require or recommend PD measurements during the production of different MV and HV equipment. It is also increasingly recommended for commissioning and preventive maintenance of equipment during their service life.

2 Theory of partial discharges

The theory of partial discharges is very comprehensive, and a complete description is beyond the scope of this guide. However, a basic understanding of the phenomenon is provided.

As mentioned in section 1, PD can be initiated when the local electric field surpasses the local dielectric strength in a given insulation system. This high local electric field can be the results of different defects or anomalies within an insulation system. For example, figure 1a shows the simplified electric field distribution within a healthy solid insulation system located between two energized electrodes. Now, for this specific example, let's just assume that a void filled with air was introduced during the manufacturing process. Air has a lower relative permittivity than solid insulation and therefore, a higher electric field will result across the void as shown in figure 1b. If the electric field across that void exceeds a certain level, a localized discharge can occur.

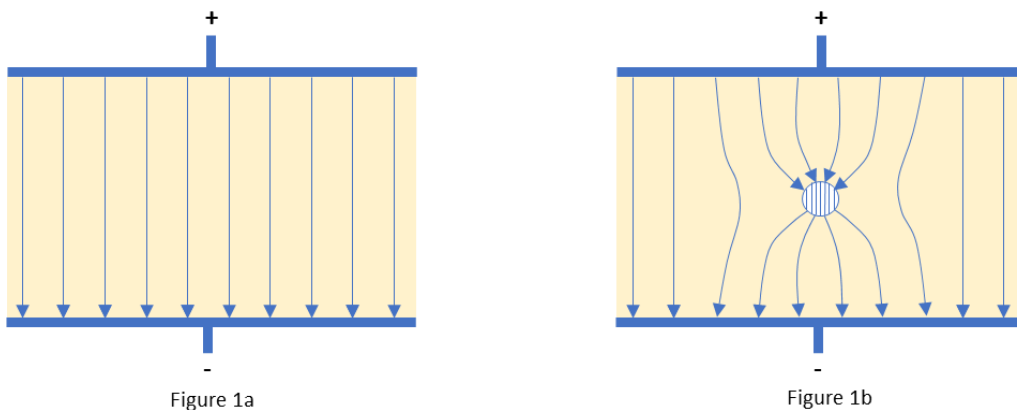


Figure 1 : a) simplified electric field distribution within a healthy solid insulation system and b) in a solid insulation system with one air-filled cavity.

When the electric field across the void surpasses its dielectric strength, a partial discharge can occur. The energy that is stored in the capacitance of the system will therefore migrate to the discharge site (recharging current). To simplify the process, each PD event generates a current pulse which circulates through the insulation as illustrated in Figure 2.

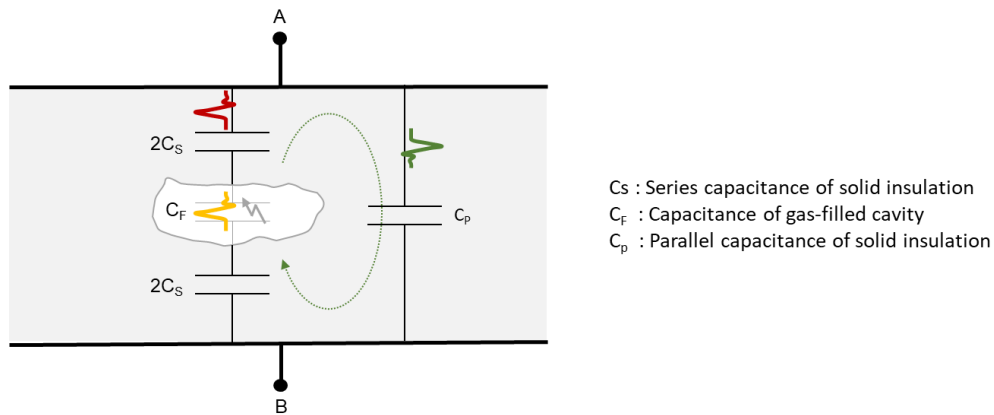


Figure 2 : Current pulse generated by a partial discharge

The discharge mechanism described above is only one example among the different types of partial discharges. In general, PD can be broken down into two different categories; a) internal partial discharge and b) external partial discharge (figure 3).

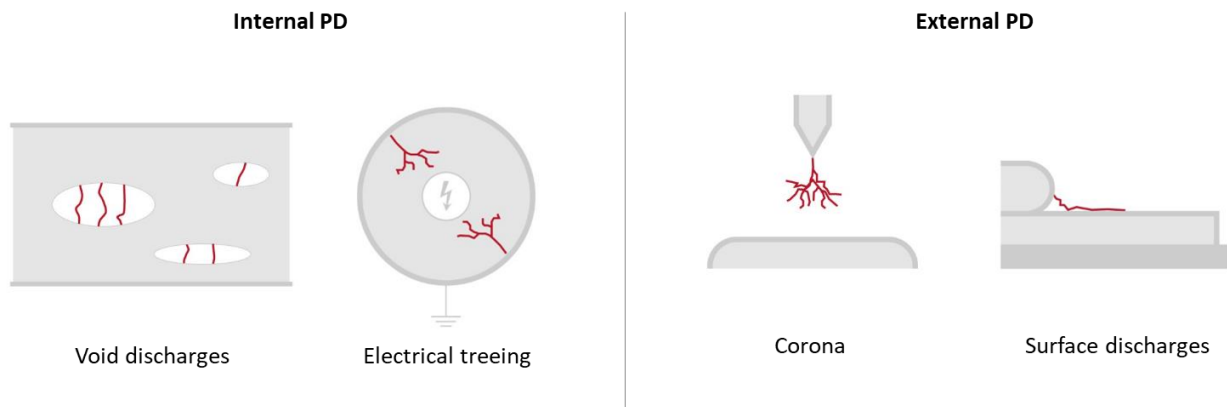


Figure 3 : Different types of partial discharges

Generally, internal discharges are the most dangerous types of PD activity inside an insulation system.

3 Methods for PD detection and measurements

As mentioned in the previous section, each PD event will generate a current pulse. At its origin, this pulse has a rise time of just a few nanoseconds and contains a constant broad frequency spectrum, from DC to up to several hundreds of megahertz (MHz). Partial discharges will also generate byproducts. The kind of byproducts mostly depends on the type of insulation material in which they are occurring. Part of the energy will also be converted in a sound wave or in light emission. Therefore, PD can be measured using different technologies.

This document will primarily be focused on the electrical measurement of partial discharges. However, a brief overview of other PD detection techniques is provided below.

a) Electrical measurement

The electrical measurement of PD measures part of the current pulse that is initiated by the discharge mechanism. Different measured quantities are used in the industry. However, the apparent charge, in coulombs (C), is the most widely accepted unit. The measured values are usually in the ranges of picocoulombs (pC) or nanocoulombs (nC).

b) Ultra-high frequency (UHF) detection

Partial discharges produce a wide frequency content. However, the highest frequencies tend to propagate by radiation in the surrounding insulation media. A fast breakdown mechanism, such as discharges in air or gas-insulated HV apparatus creates a signal with frequencies up to the gigahertz range. The UHF PD detection uses antenna to capture the radiated electromagnetic wave from PD activities. The measured frequencies are above 100 MHz and the sensors are inserted inside the device under test (DUT). The application is mostly used to perform PD detection on gas-insulated switchgear (GIS) and the results are expressed using millivolts (mV). Other applications include power transformers, HV cable terminations and rotating machines.

c) Acoustic detection

Partial discharges produce sound waves. Therefore, acoustic sensors can be used to detect PD activity. The available equipment is usually a hand-held device that acts as an antenna in the ultrasound frequency range. Piezo sensors are also available and are usually attached to the equipment enclosure. The results are usually expressed using decibels (dB) or millivolts (mV).

d) Ultraviolet (UV) light Camera

PD activity produces light waves in different frequency ranges. Corona and surface type PD can be detected using the naked eyes in a dark room. Nowadays, the use of UV camera has replaced the naked eye technique. The camera can often capture the UV light signal and superimpose it over a live video. The number of PD events during a predefined period is usually recorded.

e) Detection using by-products

When PD occur, the breakdown mechanism can generate different by-products depending of the insulation media. For example, it is now well established that PD activity in insulating mineral oil will generate hydrogen. Another example is the generation of ozone when PD activity occurs in air. Using respectively dissolve gas analysis and ozone measurement can be used to detect PD activity inside a given an asset. Those are usually expressed in terms of particles per million (ppm).

f) Indirect methods

Under specific circumstances, partial discharge activity can be indirectly detected using other electrical tests such as power factor measurement, using infrared cameras or using resistance temperature detectors (RTD) as an antenna.

4 Coupling methods for electrical PD measurements

As previously mentioned, PD generates current pulses that circulate through the insulation system as illustrated in figure 2. In a simplistic way, the electrical PD measurement consists of measuring part of this current pulse. There are many ways to acquire that signal and many sensors are available.

The most common ones are a) the coupling capacitor, and b) the high frequency current transformer (HFCT).

a) Coupling capacitor

The coupling capacitor is by far the most commonly used sensors. They usually consist of a high-voltage capacitor that is connected in parallel to the test object. When a PD event occur, the energy

stored in the coupling capacitor will supply part of the recharging current. The more energy that is stored in the capacitor, the higher the recharging current will be in case of a PD event. Therefore, a high capacitance value usually results in a higher sensitivity. Figure 4a shows a picture of a coupling capacitor and figure 4b demonstrates a simplified PD measurement circuit using a coupling capacitor.

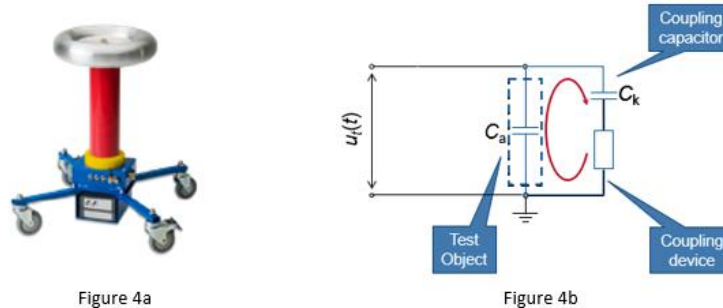


Figure 4 : a) picture of a 100kV coupling capacitor, and b) a simplified PD measurement circuit using a coupling capacitor

When using a coupling capacitor, it is common to be able to also obtain the waveform of the supply voltage. This is needed for a phase synchronized PD measurement. It is also possible to connect the measuring impedance in series with the test object.

When performing onsite measurement on HV apparatus, the size and cost of a coupling capacitor can become problematic. Therefore, there are some cases where it can be preferable to use alternative sensors.

b) High Frequency Current Transformers (HFCT)

PD causes electromagnetic signals. Therefore, inductive sensors can measure the electromagnetic content of the current pulse. HFCT are usually installed around an available ground conductor of a given DUT. Therefore, the measurement does not take place at high-voltage but rather at ground potential. This allows the sensors to be smaller and cheaper in comparison to a traditional coupling capacitor. Figure 5a shows a picture of an HFCT while figure 5b displays a simplified PD measurement circuit using an HFCT.

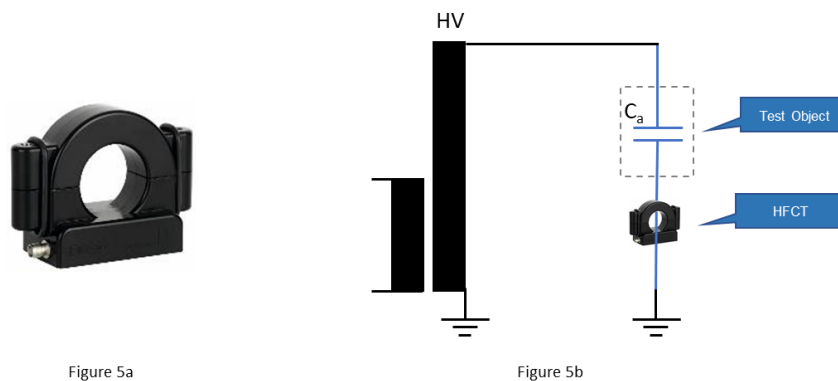


Figure 5 : a) picture of an HFCT, and b) a simplified PD measurement circuit using an HFCT

HFCT are often used to measure partial discharges on installed MV and HV cable systems. However, in theory, they can be applied to the ground connection of many apparatus.

In theory, you can perform electrical PD measurements using any type of capacitive sensors. However, there are some advantages and disadvantages of using specific sensors to decouple the signal. The use of international guidelines is recommended in order to perform consistent and repeatable electrical PD measurements. IEC60270 is one of the most frequently used standards for PD measurements performed in controlled environment. It covers what is called conventional PD measurements and specify the use of coupling capacitors as sensors. The next article will provide a guide to perform PD measurement according to IEC60270.

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