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Technical paper

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

Part 2 – Measurement according to IEC60270

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September 2020

Version 1.1

1 IEC 60270 – A Normative Reference

IEC 60270 – High-voltage test techniques – Partial discharge measurements is a general standard that defines the broad lines of partial discharge (PD) measurement in electrical apparatus. It is applicable for electrical measurements of PD using alternating voltages up to 400 Hz and direct voltage. The standard defines several parameters such as the test circuit, measured quantities, calibration requirements and guidance on test procedures.

Throughout the years, this document has become one of the most commonly used standards for PD measurements and has established itself as a normative reference for many other standards. IEC 60270 is quite comprehensive and includes more information than it can be covered by this document. The present article will introduce and summarize some of the most important parameters to perform a PD measurement according to IEC 60270.

2 Test circuits

2.1 Test circuit for alternating voltages

Several test circuits can be used for PD measurements according to IEC 60270. The standard provides five examples of accepted test circuits. However, they can all be summarized into one schematic which is illustrated in figure 1.

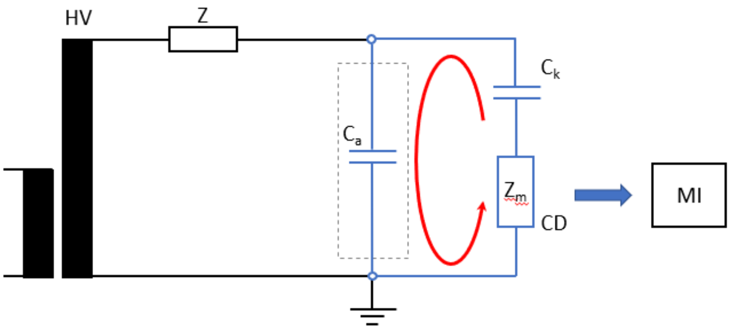


Figure 1 : PD measurement circuit according to IEC60270

where,

HV	high-voltage supply
Z	high-voltage filter (optional)
C_a	test object
C_k	coupling capacitor
Z_m	measuring impedance
CD	coupling device
MI	PD measuring instrument

In theory, an optimal sensitivity is achieved when $C_k >> C_a$. However, this condition is not convenient for most applications. This is mainly due to the additional load that would need to be supplied by the high-voltage source. IEC 60270 thus recommend using a value of C_k of 1nF or higher.

Every component in the test circuit must exhibit a sufficiently low level of background noise. This background noise is referred as signals detected during the PD measurement, which do not originate from the test object. In some cases, a high-voltage (HV) filter can help to attenuate unwanted signals circulating from the HV supply. In addition, the filter also prevents PD pulses from circulating through the HV transformer and thus, increases the sensitivity of the test circuit.

Some variations of the test circuit of figure 1 can also be used. For example, the test object and the coupling capacitor can be exchanged so that the measuring impedance is series connected with the test object. Another accepted test circuit is the use of a bushing capacitance C_1 to replace the coupling capacitor. The coupling device is therefore connected to the bushing tap.

The coupling device is usually a four-terminal network that is often referred to as quadripole. It converts to PD current pulse into an output voltage. Additionally, it often includes fast overvoltage protection and some filtering features that separate the test voltage to allow for synchronization.

2.2 Test circuit for direct voltage

The test circuit used during tests using direct voltage is very similar to the test circuit used for alternating voltage (figure 1). However, the coupling capacitor cannot be used to obtain the voltage information. If a voltage reference is needed, an additional DC voltage divider is required.

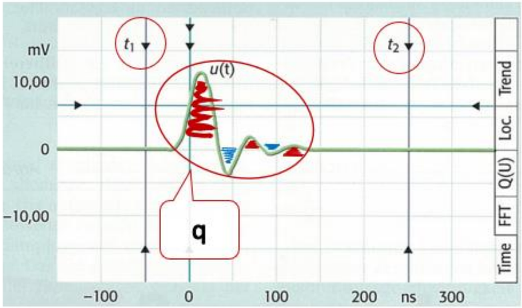
The measured quantities and evaluation criteria are also different than the ones used under alternating voltage. There is no polarity reversal in the voltage waveform. Thus, the discharge pulse repetition rate will be highly dependent on the insulation relaxation characteristics. The present document focuses on alternating voltage measurement. Additional information regarding PD measurement under direct voltage can be found in clause 11 of IEC 60270.

3 Apparent charge

At its origin, a PD generates a unipolar current pulse that includes a constant and broad frequency content (from DC to several hundreds of megahertz). However, this pulse is distorted when it travels from its origin to the sensor. For this reason, the amount of charge locally involved at the site of the discharge cannot be measured directly.

They are many measured quantities that can be derived from a PD measurement. IEC 60270 recommends the use of the apparent charge wherever possible. The apparent charge of a PD pulse is defined as the charge, if injected within a very short time between the terminals of the test object in a specified test circuit, would give the same reading on the measuring instrument as the PD current pulse itself.

The apparent charge is expressed in picocoulombs (pC). For a single theoretical PD event, the value is calculated by integrating the current over time as shown in figure 2. The data acquisition unit detects the voltage drop across a measuring impedance in the test circuit and converts it to a current.



$$q = \int_{t1}^{t2} i(t)dt = \frac{1}{R}\int_{t1}^{t2} u(t)dt$$

Figure 2: Time domain integration of a PD pulse

However, under alternating voltage, PD hardly ever occur as isolated single events. A defect which results in PD usually generates a pulse train of stochastically scattered charge values. Because of this, IEC 60270 recommends using what is called the largest repeatedly occurring PD magnitude and a weighting process, which is described in clause 4.3.3 of IEC 60270. The calculated values are usually automatically displayed by the PD instrument.

As mentioned before, PD pulses contain a constant and broad frequency content and therefore, can be measured at different frequencies. The effect of different frequency ranges is beyond the scope of this publication. However, IEC 60270 has the following requirements for PD measurement using wide-band PD instruments:

$$30 \text{ kHz} \leq f_1 \leq 100 \text{ kHz}$$
$$f_2 \leq 1 \text{ MHz}$$
$$100 \text{ kHz} \leq \Delta f \leq 900 \text{ kHz}$$

where,

f_1	lower limit frequencies
f_2	upper limit frequencies
Δf	total bandwidth

4 Calibration

The purpose of the calibration is to verify that the measuring system will be able to measure the specified PD magnitude correctly.

As discussed previously, when a PD occur, a current pulse which contains a broad frequency range will be generated. Only a portion of the energy content of each PD pulse reaches the coupling capacitor. Some of the content circulates through the stray capacitance of the system as illustrated in figure 3, and therefore, is not available at the sensor.

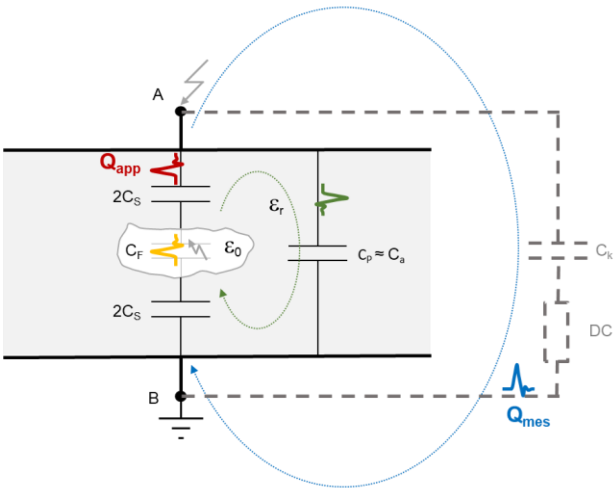


Figure 3: Schematic of the propagation of a PD pulse

The calibration process is carried out before the actual PD measurement and is done by injecting short-duration current pulses of known charge magnitude, across the terminals of the test object. A scale/calibration factor, also called k factor, is therefore calculated by the software of the PD instrument. This k-factor is simply the ratio of the known injected charge magnitude over the measured charge magnitude. It is only valid for a specific test object for a specific frequency range, a specific test setup and PD instrument. If any of those parameters are modified, the calibration process must be repeated. Figure 4 shows a simplified schematic of a setup used for calibration.

The instrument which is used to inject the artificial PD pulses is called a calibrator. During the calibration process, it must be connected as close as possible to the terminals of the test object. The magnitude of the injected pulses must be between 50% and 200% of the specified PD magnitude expected during the PD test (acceptance criteria).

It is also recommended that the magnitude of the injected pulses be at least twice the background noise level, as illustrated in figure 5.

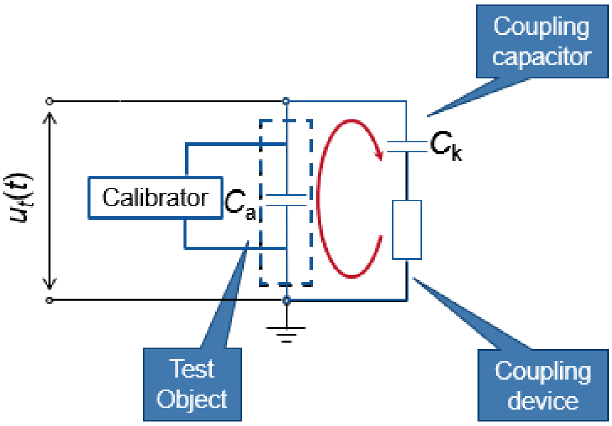


Figure 4 : Circuit schematic of a calibration

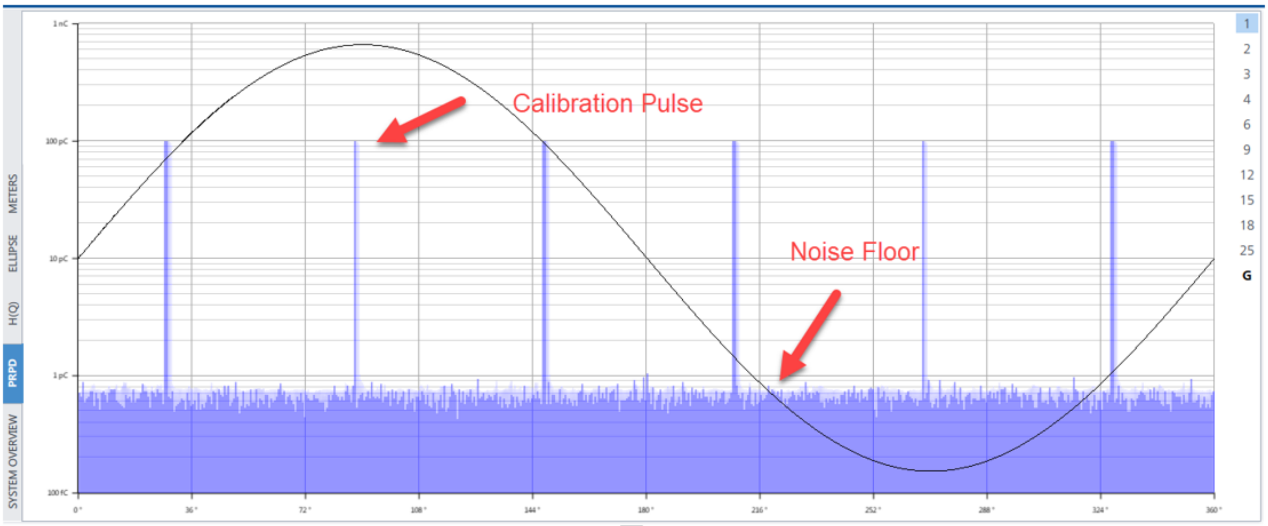


Figure 5: PRPD diagram of calibration pulses in comparison to the background noise

Note: *The calibration process of the test circuit should not be confused with the calibration of an instrument. The latter must be done periodically on the calibrator or PD acquisition itself to verify if the device is performing correctly under the required accuracy and specifications.*

5 Typical test procedure

IEC 60270 does not provide any specific test procedure. They are usually provided by the testing specifications or by the relevant technical committee for a specific test object.

A typical test procedure defines the test voltage levels and frequency, the sequence and duration of voltage applications and the pass/fail criteria. Those criteria can include the determination of the partial discharge inception voltage and extinction voltage.

The inception voltage is the lowest voltage at which PD is first observed following an increase of the voltage from a level that no PD are observed. The extinction voltage is the applied voltage at which PD cease to occur when the applied voltage is decreased from a higher value at which PD is observed.

Usually, the applied voltage is raised to a specified level which exceeds the partial discharge test voltage for a specific duration. This is called pre-stressing. The applied voltage is then decreased to the specified partial discharge test voltage and maintained for a specified time. The PD quantity is then measured at fixed intervals or at the end of this time.

As an example, figure 6 shows a typical test sequence with pre-stressing.

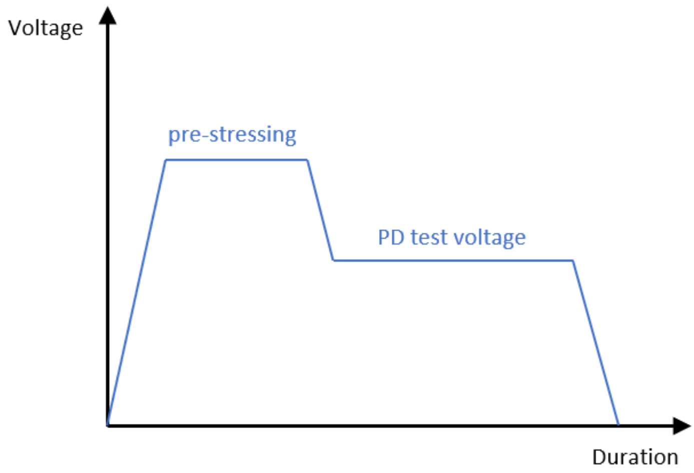


Figure 6: Typical test sequence with pre-stressing

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