Technical paper

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

Part 3 – Noise mitigation

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1 Introduction

Partial discharge (PD) measurement is a very sensitive test which requires measuring very small signals. As an example, for factory acceptance tests, the pass/fail criteria of most apparatus are in the picocoulomb (pC) range. Therefore, test results can be easily affected by interferences.

According to IEC60270, interferences are referred as signals detected during PD measurements, which do not originate from the test object. The terms interference, disturbance and noise are commonly used interchangeably and therefore, they all have the same meaning in this article.

There are different types of interferences, which can be coupled into the test circuit through either a radiated propagation path or a conduction path. Examples of interferences are radiated electromagnetic interferences (EMI), sparking (e.g. gas discharge lights or welding machines), electromagnetic waves from corona type PD in nearby equipment and switching from power electronics. Figure 1 shows an example of different sources of interferences frequently encountered.

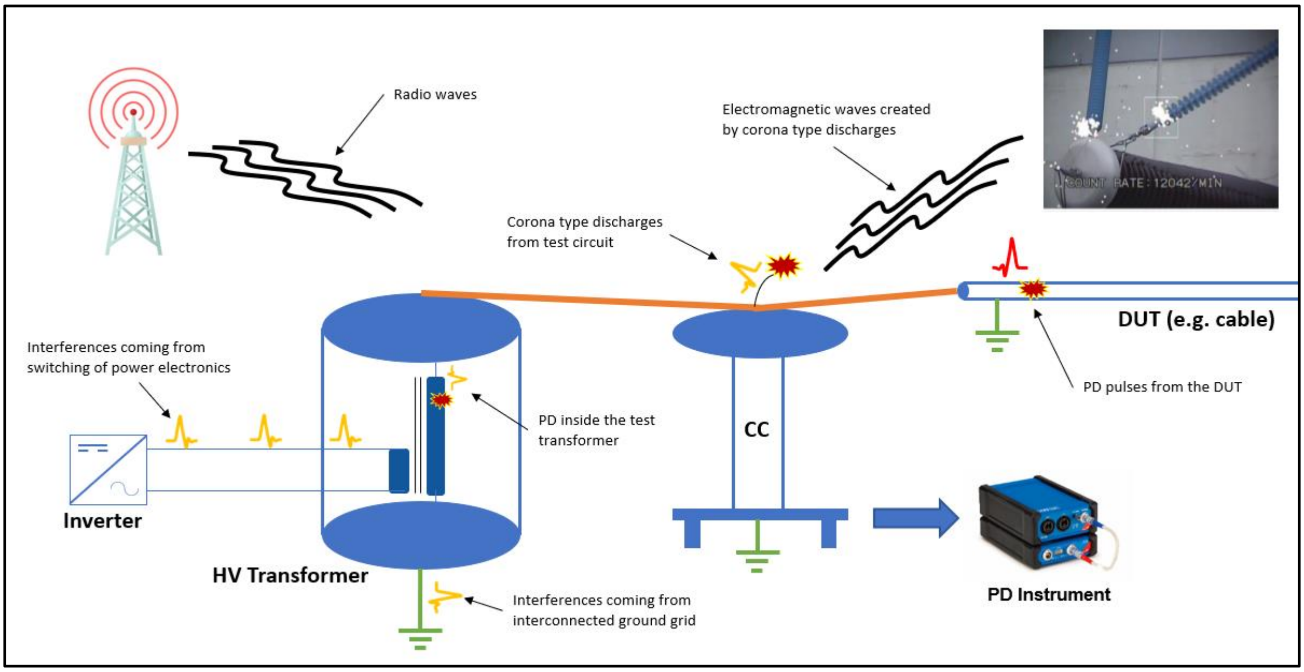

Figure 1: Examples of interferences

Interferences can affect the results of PD measurements in different ways. For example, they can:

- Decrease the sensitivity;
- Increase the complexity of data interpretation;
- Superimpose to the actual PD pulses resulting in distorted magnitudes.

It is not feasible to completely suppress interferences. Even in well-controlled laboratories, a given background noise level is usually observable. However, using efficient grounding design, Faraday cage and PD-free apparatus, it is common to reach a sensitivity level of 1pC or below.

PD measurements are not always performed in such environment. Interferences can be measured in laboratories, in factories and are prominently encountered during onsite PD measurements (offline & online). In addition, EMI are present in most environments and are usually prominent in the allowable conventional frequency range of IEC60270. The present chapter will provide a quick summary of different hardware or software techniques for noise mitigation.

2 Noise mitigation techniques

The best noise mitigation technique usually focuses on eliminating the interferences at the source. However, it might not always be possible nor practical to execute the required corrective actions. This section will explain different hardware and software noise mitigation techniques that can be used to reduce interferences or to separate them from the actual PD pulses.

2.1 Hardware PD filter

When dealing with disturbances that travel through the conduction path, a PD filter can be used to attenuate those signals. These filters can be made of a single reactor (often called blocking impedance) or from a combination of passive elements such as capacitors, reactors and/or resistors. They can be used as a low-pass filter, which attenuates part of the high frequency signals coming from the network or the HV supply. Filters can be installed on the low voltage (line filter) or high-voltage side (HV filter) of the test transformer. Figure 2 shows a picture of a HV filter and a typical equivalent schematic of a test circuit with the use of a HV filter.

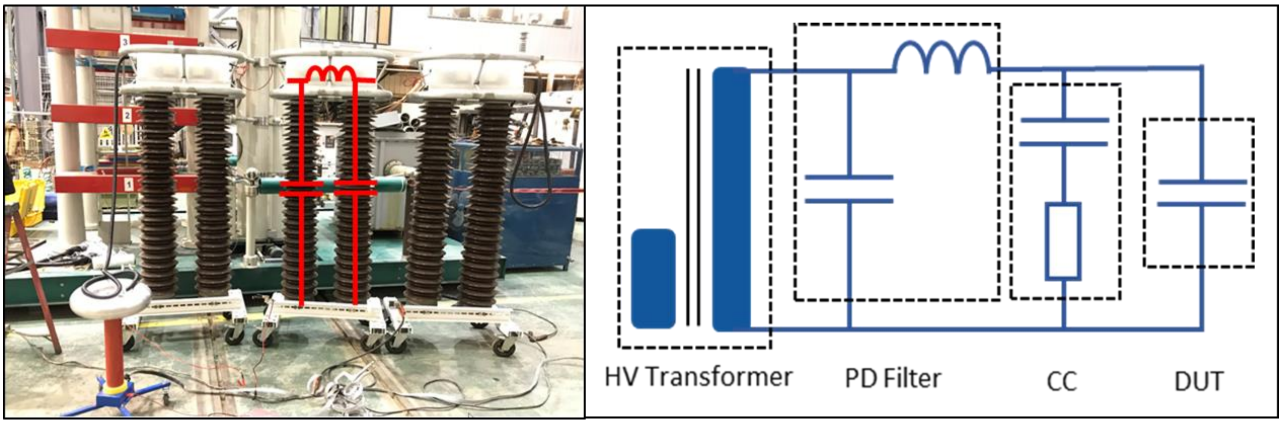

Figure 2 : left) Picture of high-voltage filters and right) typical test circuit including a HV filter

2.2 Gating

External disturbances that are visible in the PRPD diagram can be masked using the window gating function. Interferences that are fixed in position with the test voltage frequency can be easily removed using this gating function. These events will not be considered for the charge calculation. Figure 3 shows an example of the application of manual gating.

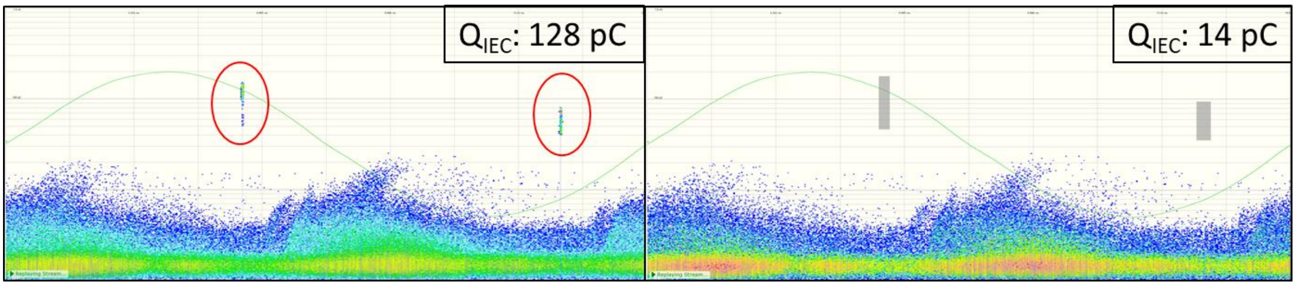

Figure 3 : left) without manual gating and right) with manual gating

Another available method is the channel gating or antenna gating technique. It uses a second sensor and a second PD input channel to measure interferences and remove them from the original measurement. This is particularly useful when the external disturbances are not stable with the test voltage frequency. For example, a high-frequency current transformer (HFCT) can be installed around the grounding cable of a nearby equipment that is known to cause interferences. Figure 4 shows the results of an actual measurement, respectively without and with channel gating.

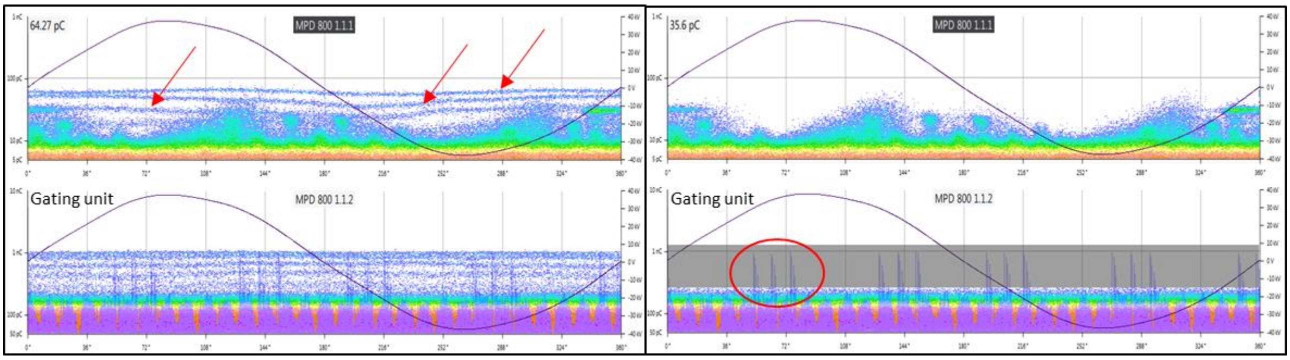

Figure 4 : left) without channel gating and right) with channel gating

If a conventional PD measurement is required, IEC60270 allows the use of signal gating to hide part of the PRPD diagram for up to 10% of each test voltage period under certain conditions. For more information, please refer to clause 10 of IEC60270.

2.3 Differential PD measurements

The differential technique, which is described in IEC60270, is based on a PD measurement in two different branches using two measuring impedances, a differential processing unit and one PD input channel. It is especially efficient to mitigate common mode noise that is coupled into the test circuit. Figure 5 shows an example of a test circuit using the differential PD measurement technique.

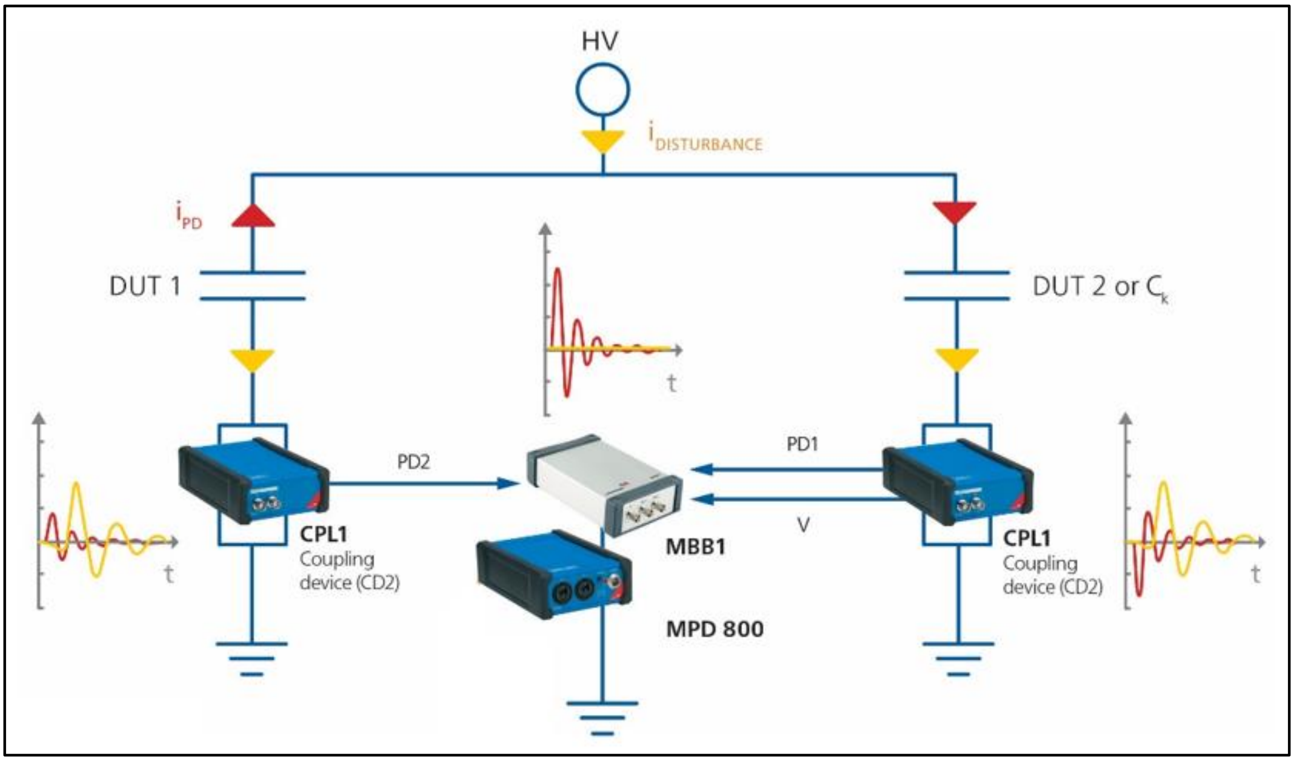

Figure 5 : Test circuit using the differential PD measurement technique

One measuring impedance is connected in series with the test object (DUT 1) while the second measuring impedance is connected in series with the sensor (C_k), or with a second test object (DUT 2) which has a similar impedance as DUT 1. The common mode elimination is based on the principle that PD signals and common mode disturbance signals show different polarities when measured in two different branches as described in figure 5. When signals are captured by the measuring impedances, the differential processing unit (MBB1 in figure 5) will display the difference between the two measured signals. If common mode noise signals (yellow pulses in figure 5) are coupled into the test circuit and that both branches are balanced, the signals will theoretically be measured with the same magnitude and polarity by the measuring impedances and therefore, will cancel each other out. However, if PD is occurring in DUT 1 (red pulses in figure 5), then the measured signals will be of opposite polarity and therefore, will be displayed with higher signal-to-noise ratio by the measuring instrument. Figure 6 shows the PRPD pattern of a PD calibration on a HV bushing without and with using the differential PD measurement.

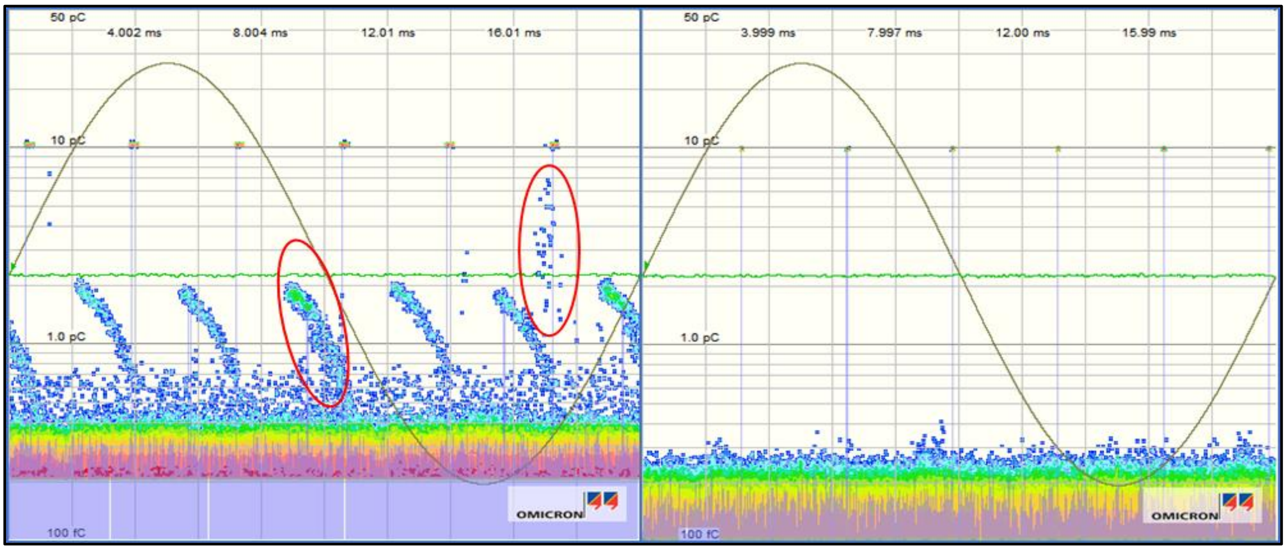

Figure 6 : left) without differential measurements and right) with differential measurements

3 Noise mitigation and source separation techniques

3.1 3-Phase-Amplitude-Relation-Diagram (3PARD)

3PARD, also known as synchronous multi-channel PD measurement, uses 3 PD input channels (and three sensors) and is usually applicable for three-phase test objects, even though it is sometimes used in specific single-phase applications. As the name implies, PD events are measured by three synchronously connected PD inputs, generally one input per phase. Simplified, the magnitude of each PD event from one channel is compared to the magnitude of the events recorded by the two other channels. Because of inductive and capacitive cross-coupling, a PD occurring on one phase can often be measured at the other two phases. The measured magnitude is a function of several factors, including the construction of the test object, the location of the PD event and its propagation path to the sensor. This comparison is then plotted on a diagram, where separate clusters are created based on vector summation over many cycles. When selecting a specific cluster, it is possible to isolate a PD source or interferences, and back transform them into PRPD patterns. Figure 7 shows a simplified theoretical schematic of a single pulse being measured by all three sensors while Figure 8, 9 and 10 show a practical example of the application of 3PARD on a power transformer.

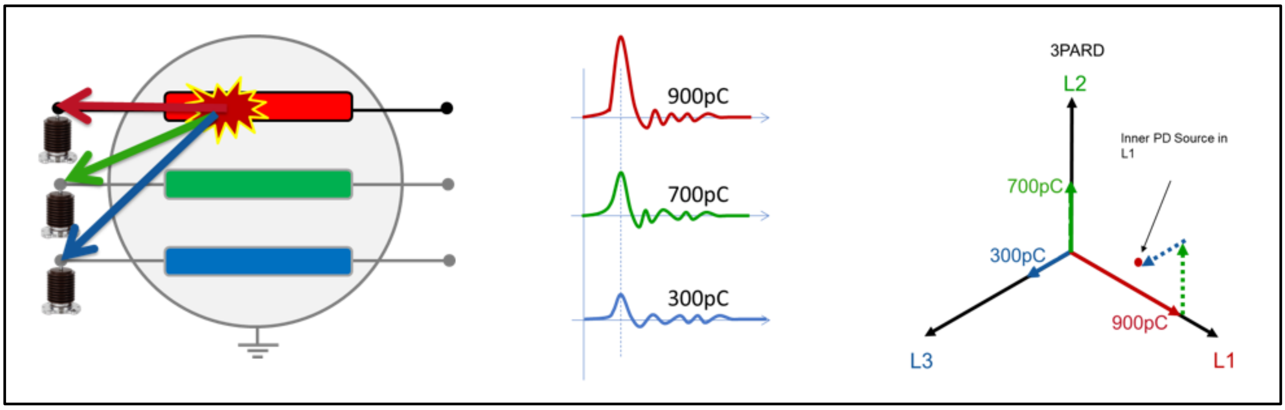

Figure 7 : Simplified theoretical schematic of 3PARD for one single PD event

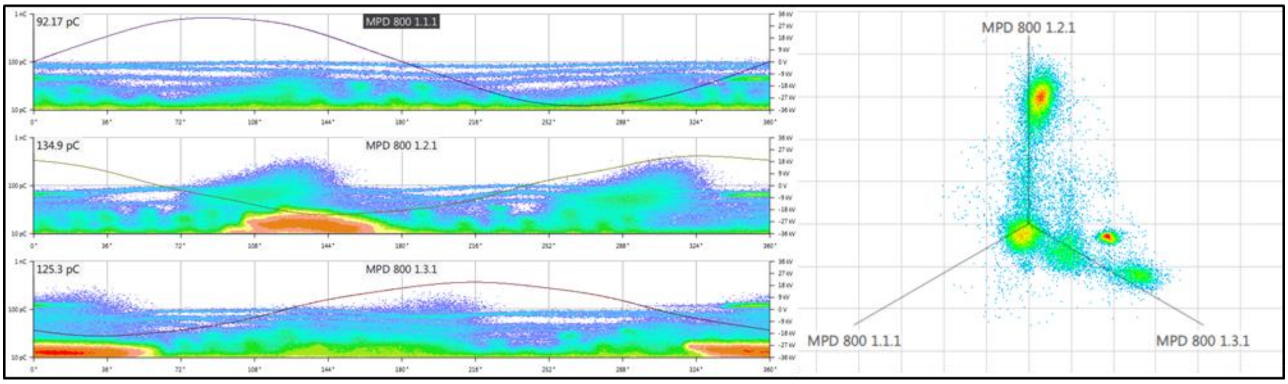

Figure 8 : Without 3PARD

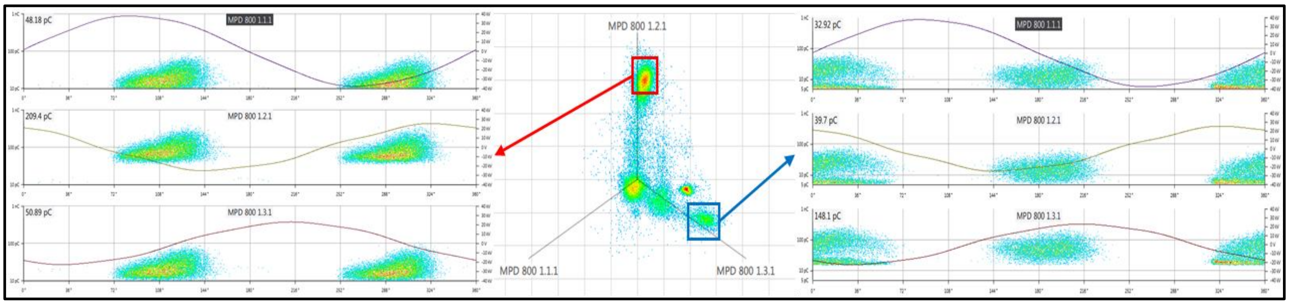

Figure 9 : left) PD occurring on phase B and right) external interferences

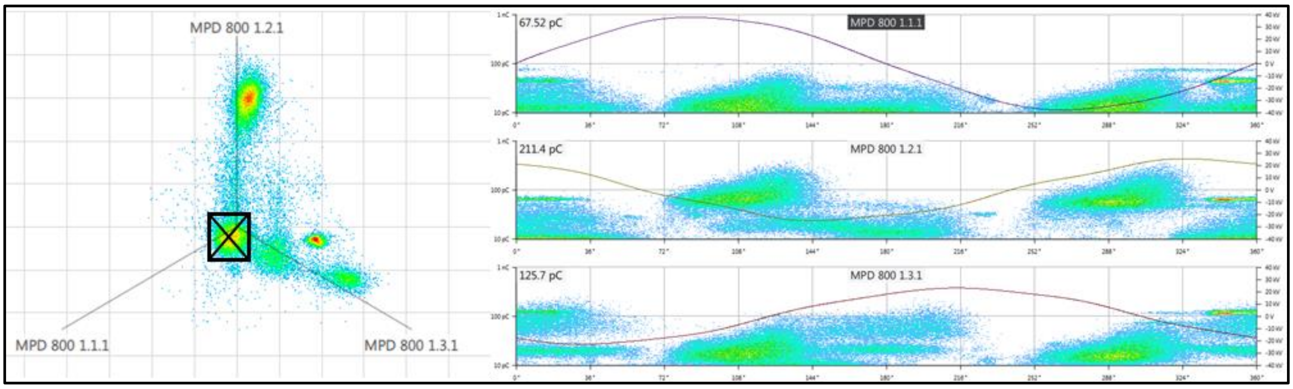

Figure 10 : 3-PARD inverse gating function to remove one specific cluster (external interferences)

3.2 3-Center-Frequencies-Relation-Diagram (3CFRD)

The 3CFRD technique is based on a single-channel PD measurement while simultaneously applying three different frequency filters to every measured PD event. Each filter uses the same bandwidth, but their center frequency can be configured freely and independently.

The recorded frequency content of the measured pulses can be influenced by several factors, including the type of anomalies, the location, the traveling path, the insulation material and the sensors. Their distinctive characteristics can therefore be measured and processed by different bandpass filters.

The visualization is done using a star diagram like the one used in 3PARD. The correlation between the PD magnitude obtained from each frequency filter is plotted on a diagram where separate clusters are created over many cycles. When selecting a specific cluster, it can be possible to isolate a PD source or other external interferences. Figure 11 shows a simplified theoretical schematic of 3CFRD, Figure 12, 13 and 14 show a practical example of the application of 3CFRD on a potential transformer (PT).

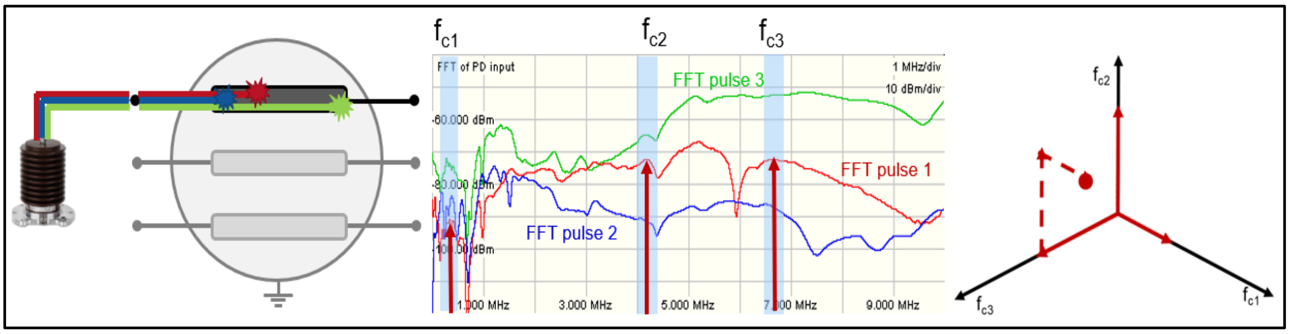

Figure 11 : Simplified theoretical schematic of 3CFRD

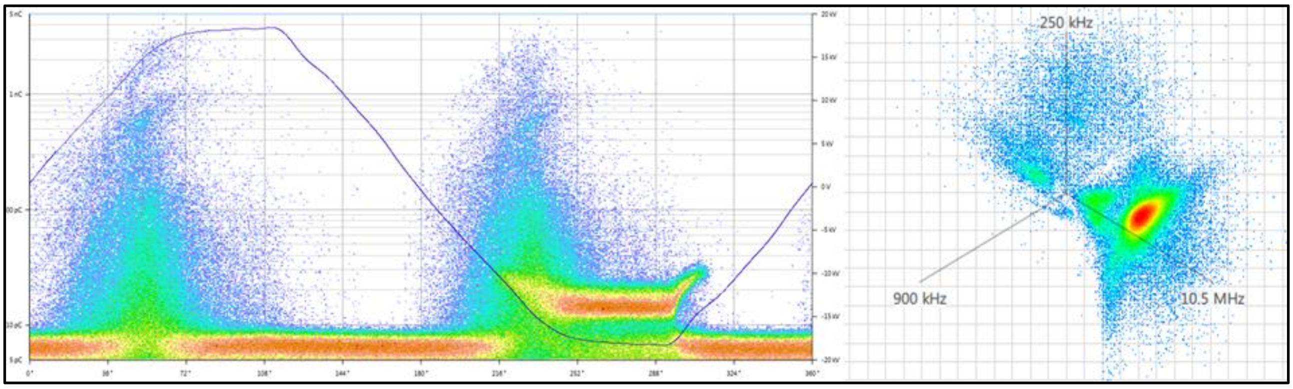

Figure 12 : Without 3CFRD

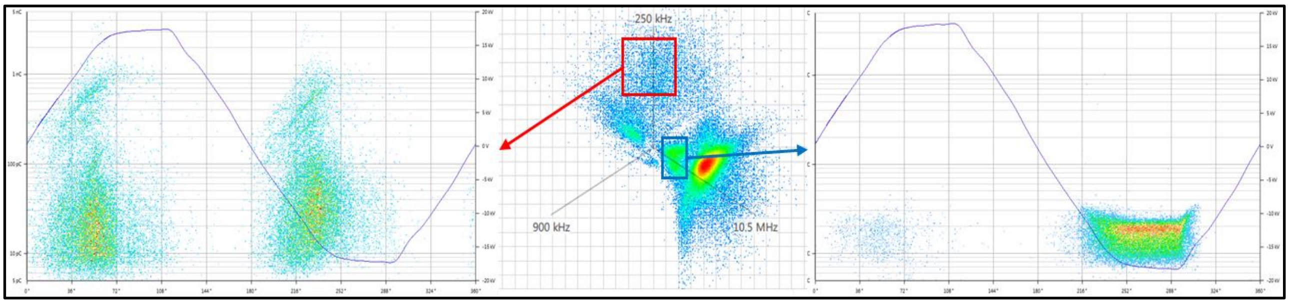

Figure 13 : left) inner PD and right) Corona type PD

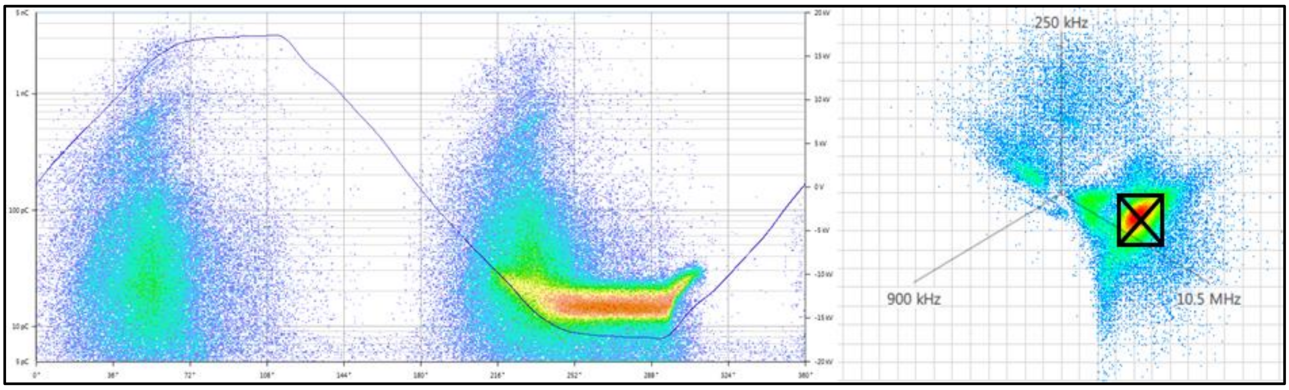

Figure 14 : 3CFRD inverse gating function to remove one specific cluster (ambient noise level / noise floor)

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