Why partial discharge testing makes good sense

PD measurement and analysis have proven to be reliable for detecting defects in the insulation system of electrical assets before major damage or a breakdown occurs.

Introduction

The constant availability of medium- and high-voltage electrical assets used in the generation, transmission and distribution is important for a reliable power supply at both utilities and also industrial plants. These assets include generators and motors, instrument and power transformers, switchgear and power cables.

Insulation breakdown can lead to dangerous situations, severe damage and ultimately huge economic costs. Therefore, it is crucial that insulation condition be verified throughout an asset's lifecycle.

Partial discharge (PD) is considered to be one of the major contributors to the degradation and failure of insulation systems in electrical assets.

This white paper aims to familiarize you with the basics about partial discharge, including its consequences, how it is measured, and which criteria are important for selecting a PD measurement device. If you currently measure and analyze PD in your electrical assets, you are then already familiar with its importance to ensure asset availability.

Regardless of your experience level with PD testing, having the right PD measurement device is key to accurate detection in all types of testing environments. This white paper provides you with eight beneficial reasons why hundreds of electrical equipment manufacturers, test engineers at utilities and industrial plants, as well as service providers all over the world have chosen the MPD 600 for their PD testing needs.

What is partial discharge?

According to the IEC 60270 standard, partial discharges are "localized electrical discharges that only partially bridge the insulation between conductors and which can or cannot occur adjacent to a conductor. Partial discharges are in general a consequence of local electrical stress concentrations in the insulation or on the surface of the insulation."

PD can occur in gaseous, liquid and solid insulating mediums used in assets that are subjected to high electrical fields. It can be initiated by voids, cracks, or inclusions within a solid dielectric, at interfaces within solid or liquid dielectrics, in bubbles within liquid dielectrics, or along the boundary of different insulation materials.

PD can cause progressive and irreversible damage to liquid and solid insulation systems. With time, PD activity becomes more intense and dangerous. The process of deterioration can propagate and develop until the insulation is unable to withstand the electrical stress, leading to a flashover.

Why measure PD?

PD measurement is a reliable and non-intrusive method that can be used anytime to diagnose the insulation condition of an electrical asset.

Compared with other dielectric diagnostic methods, PD measurement provides you with very sensitive information to help you effectively detect localized weak points in the insulation system.

Because PD activity is often present well in advance of insulation failure, asset managers can assess it over time and make informed strategic decisions regarding the timely repair or replacement of the equipment before an unexpected outage occurs. PD detection is therefore essential to ensure the reliable, long-term operation of your electrical equipment.

When should PD be measured?

The integrity of the insulation in MV and HV equipment should be confirmed with PD measurement and analysis during the development, manufacturing, commissioning and, depending on the asset type, the service life of electrical equipment, so that it stays in good condition and is safe to operate.

The high amount of manual work at the manufacturing stage of an asset increases the likelihood of production errors that can lead to its premature failure. There is a disproportionately high percentage of insulation failures being observed within the first one to three years of service compared to the rest of an asset's working life. PD testing is therefore initially used for routine and factory acceptance testing after production to identify quality issues.

> "It is important for us to identify any developing PD defects early on, so that we can take the necessary corrective action."
>
> James Hill, Chief Test Engineer
> Seabank Power Station, UK

After the asset leaves the manufacturer, improper handling during transport and installation can lead to internal mechanical damage. An on-line PD measurement is then often used to commission new equipment on-site as a final quality control check.

Once in the asset is in service, strategic decisions about maintenance must be made to ensure maximum availability. Periodic PD measurement and analysis provide you with the required data to develop an overall test plan that ensures focus on the right assets and minimizes unnecessary maintenance outages and costs.

The frequency of PD testing for in-service equipment is determined by the type and importance of the equipment and prior service experience.

The integrity of the insulation should be confirmed with PD measurement and analysis at all stages of an asset's lifetime.

How is PD measured?

The tests and test set-ups are determined by the type of asset being measured and by the standard to which the PD measurements are performed. For example, the IEC 60270 standard specifies how to perform an off-line PD measurement on electrical equipment using a separate voltage source, the PD measurement device, a coupling capacitor and measuring impedances.

For three-phase assets, PD measurements can either be performed off-line, by energizing each phase successively during standstill, or on-line during regular load service operation. You can perform single-phase measurements with the other phases grounded, or three-phase measurements to identify phase-to-phase activity. PD pulses are of short duration and have rise times in the nanosecond range. The most important criteria for evaluating PD are:

- Charge level expressed in picocoulombs (pC) or nanocoulombs (nC). In RIV measurements, the charge level is expressed in militvolts (mV)
- PD inception and PD extinction voltage
- PD pulse repetition rate
- Phase-Resolved Partial Discharge (PRPD) diagrams

Should any of these criteria increase, so does the risk of insulation breakdown. PD limit values for electrical assets are defined in various international standards.

PD intensity is often displayed versus phase angle of the applied test voltage in a Phase-Resolved Partial Discharge (PRPD) Diagram.

In environments with high levels of interference, modern noise suppression techniques may also be used to separate PD from noise.

PD testing is performed on electrical assets to:

- Check the insulation state
- Detect the smallest defects up to critical defects
- Demonstrate the need for timely maintenance and repair
- Assess risks and the need for continuous PD monitoring

What are the measurement challenges?

Since signals emitted from PD activity may be of low magnitude, it is crucial to use highly sensitive PD measurement equipment. This, however, results in a higher susceptibility to interference from electronic noise. These conditions can render the detection and location of PD signals difficult or even impossible. The elimination of this interference where possible is therefore critical for successful PD detection.

Additionally, while some partial discharges can be extremely dangerous to the health of the insulation system, other types of PD may have a slower degradation effect. In rotating electrical machines (motors and generators), for example, several different PD sources are present and active within the stator winding insulation at the same time.

Therefore, an important function of modern digital PD testing systems is to separate overlapping PD signal sources and to filter out noise. This capability is necessary for successful PD diagnostic testing to be able to differentiate any damaging or elevated PD levels from normal PD activity without interference.

What type of PD testing device do you need?

The measurement system used for PD measurement must be able to provide reliable measurement results even under the most difficult conditions.

The measurement challenges described in the previous section can be overcome when the testing system can measure PD with high sensitivity, identify external sources of interference and filter or separate them when possible.

Lastly, since each type of electrical asset has its own PD measurement requirements, such as for signal decoupling, the chosen PD measurement system should allow you to easily add components tailored to the asset and testing environment.

Eight reasons why the MPD 600 system enhances PD testing

With its fully digital data processing and its advanced measurement and analysis tools, OMICRON's MPD 600 separates even the smallest PD pulses from interference for the highest measurement accuracy. It ensures reliable and repeatable IEC 60270-compliant PD measurements in both test laboratories and in the field.

The MPD 600 PD measurement and analysis systems is already in use worldwide in the following areas:

- For type testing and quality control at well-known manufacturers of cables, transformers, generators and motors, converters, switchboards and electrical components
- For the regular maintenance of equipment in utilities and industrial plants
- For research at laboratories and universities

Here are eight good reasons why:

MPD 600 – Modular, plug-and-play design

1 Modular design for easy setup

The modular plug-and-play MPD 600 system enables fast and flexible setup for a variety of PD measurement applications. The system consists of a PD data acquisition unit, a USB controller and measurement and analysis software. You can easily add a variety of our PD measurement accessories to support diverse PD testing on various electrical assets, such as application-specific charge calibrators, measurement impedances and high-frequency PD sensors (HFCTs).

In addition, one MPD 600 acquisition unit can be effortlessly combined with multiple other MPD 600 acquisition units for synchronous multi-channel PD measurements. It is currently the only system worldwide that simultaneously records and analyzes the signals of all connected acquisition units.

2 Long battery life for uninterrupted testing

Each MPD 600 acquisition unit is powered by a rechargeable battery. Due to the low power consumption of the acquisition unit, an uninterrupted battery operation is ensured for more than 20 hours. This enables you to cover a complete day of testing without having to recharge the battery.

3 Fiber optics for improved safety & sensitivity

Fiber optic connections are used for the communication between each MPD 600 data acquisition unit and the PC or laptop controller to provide you with complete galvanic isolation. This not only protects you from high-voltage hazards, it also minimizes ground loops and therefore interference to achieve greater measurement system sensitivity through an improved signal-to-noise ratio.

4 Adjustable frequencies for noise suppression

The MPD 600 PD measurement and analysis system offers several methods of electrical noise suppression in challenging on-site conditions. With freely-selectable filtering options, the center frequency and bandwidth can be adjusted to achieve a high signal-to-noise ratio and a low level of background noise for reliable PD measurement and analysis.

Numerous gating methods are available to effectively eliminate the effect of disturbances, such as:

- **Amplitude-phase gating:** Signals with certain amplitude and fixed phase position are suppressed.
- **Antenna gating:** Disturbance effects are eliminated by comparing measured events between an external gating unit (e.g. additional MPD 600) and the measurement unit.

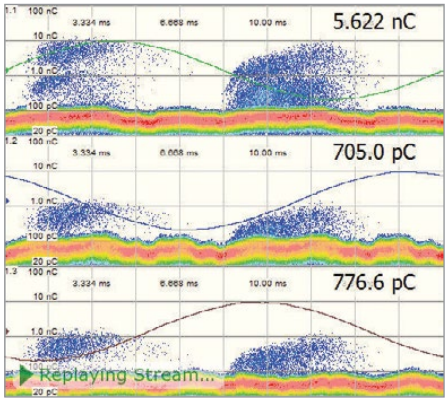
> "The MPD 600 represents the third generation of our market-proven PD measuring technology based on years of customer experience in various industries."
>
> Ole Kessler, MPD 600 product manager
> OMICRON, Germany

5 Synchronous multi-channel measurement for accurate PD source separation

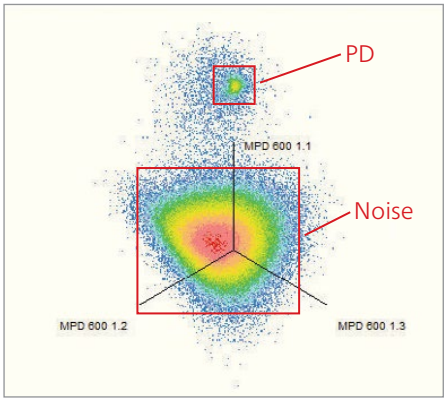
When using three or more acquisition units, the MPD 600 ensures a fully digital, synchronous multi-channel PD measurement. This not only minimizes the time for which the test voltage has to be applied and speeds up measurement time, it also enables you to take advantage of our unique separation tools, such as 3PARD (3-Phase Amplitude Relation Diagram), to simplify the differentiation of various PD sources and interferences.

PD signals originating from sources of different type and/or location appear in different parts of the 3PARD and can be analyzed separately in real-time. This enables an effective de-noising as well as an easy separation of overlapping PD signals in the corresponding Phase Resolved Partial Discharge (PRPD) diagram.

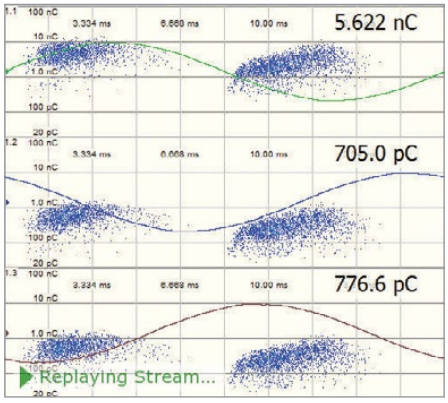
If you are using only one measurement channel, the multi-spectral PD measurement, called the 3-Center Frequency Relation Diagram (3CFRD), can be used to separate different PD sources.



Three-phase PRPD diagram with noise signals and PD (not separated)



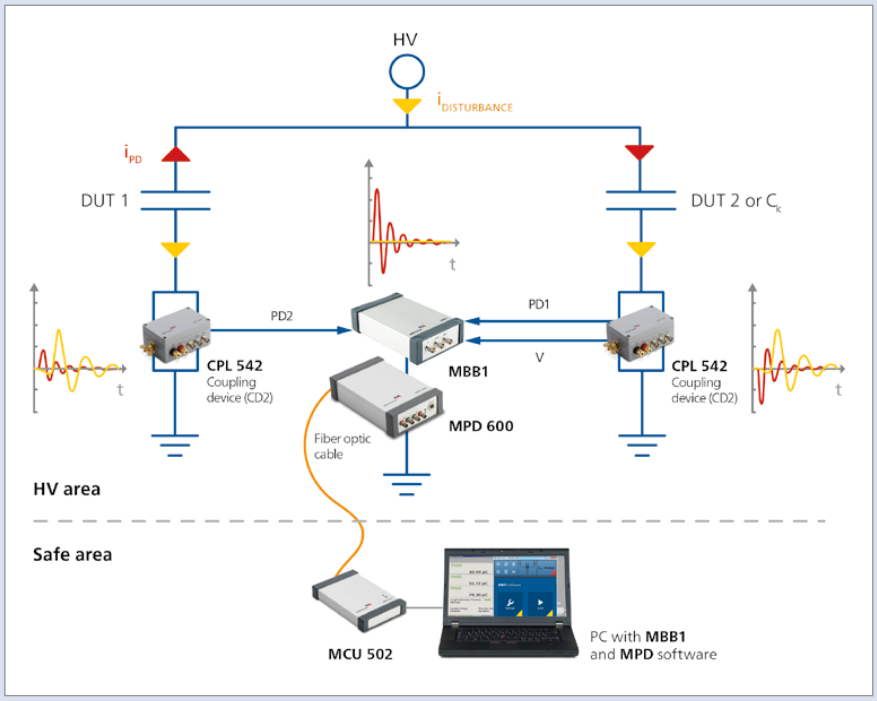
3-Phase Amplitude Relation Diagram (3PARD)



Separated PD source

"The MPD 600's synchronous, multi-channel measurement capability reliably separates internal PD sources from each other and from outer noise signals common in industrial environments."

Zsolt Gaal, Managing Director
Gaal Umwelttechnik, Germany



MBB1 measurement bridge

For added noise signal reduction in high-voltage laboratories with high interference, the MPD 600 can be used with OMICRON's MBB1 measurement balanced bridge. This accessory can be used to perform differential PD measurements during single-phase AC and DC PD testing. This method provides you with an improved signal-to-noise-ratio and a significant reduction of noise.

Single-phase PD test setup with CPL 542 measurement impedances, MBB1 and the MPD 600 PD measurement system

6 Measures up to the UHF range

The MPD 600 measurement range can be easily expanded up to the ultra-high frequency (UHF) range in combination with a variety of UHF sensors and a special bandwidth converter. This unconventional UHF measurement method ensures a more sensitive detection of PD in environments with high interference levels. It can be used for commissioning tests as well as off-line and on-line diagnostics, especially on power transformers, gas-insulated switchgear (GIS) and high-voltage cables.

7 Recording and flexible post analysis of measurement data

The MPD 600 can capture and store PD events as a data stream with a very high PD acquisition rate during the test. In addition, the test voltages and all other relevant system settings are stored, which can be used as reference for the interpretation of future measurement results. The measured data is stored as unprocessed raw data, so that it can be reworked at any time during the analysis. The full set of analysis functions, like 3PARD, can be applied to this data without having to repeat the measurement.

Recorded data streams can be individually cut to focus on relevant PD events. The playback speed can also be freely selected, enabling sections of data to be played back more slowly and analyzed in greater detail. Should questions arise during analysis, you can send recorded data streams to PD experts for interpretation and advice.

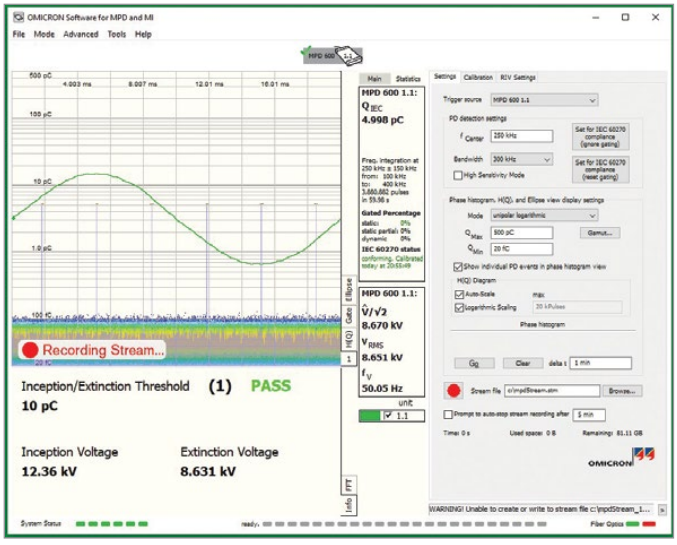
8 Integrated reporting

Using the integrated report function in the MPD 600 software, you can easily create reports with measurement values and screenshots in .xml format and save them as PDF files. With the optional .COM interface, PD data can also be integrated into other applications.

Hands-on PD training is available from OMICRON Academy, where you can learn how to use the MPD 600 PD measurement and analysis system on a variety of electrical assets.

"The biggest advantage of the MPD 600 is that you can record a stream of partial discharge data and analyze it later as you are playing it back."

Michael Jay, Chief of Test for Power Transformers
GE Grid Solutions, UK



Single-phase PRPD diagram with displayed test voltage and charge value as well as PD inception and PD extinction voltage (MPD 600 Basic Mode)

More information about the MPD 600 is available at:
www.omicronenergy.com/mpd600

OMICRON is an international company serving the electrical power industry with innovative testing and diagnostic solutions. The application of OMICRON products allows users to assess the condition of the primary and secondary equipment on their systems with complete confidence. Services offered in the area of consulting, commissioning, testing, diagnosis and training make the product range complete.

Customers in more than 150 countries rely on the company's ability to supply leading edge technology of excellent quality. Service centers on all continents provide a broad base of knowledge and extraordinary customer support. All of this together with our strong network of sales partners is what has made our company a market leader in the electrical power industry.