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Universal Data Acquisition and Monitoring System for insulation condition monitoring of high voltage machines

UDL-8000 V5

Application Manual

Partial Discharge Monitoring

(PD & M8019 or PD+ & M8019)

Revision 9 – March 2025

This publication supersedes all earlier versions, Specifications subject to change.

16.PD_PD+.304.201 Rev 9

Revision History

Rev No	Description	Date	Autor/Approval
0	Initial Release	December 2022	RH/FK
1	New alarm configuration updated	February 2023	RH/FK
2	Auto naming Unit added	July 2023	RH/FK
3	Details of Calculation parameters added Sample PRPD catalogue added	Sept. 2023	RH/FK
4	New Configuration Layout added	February 2024	RH/FK
5	Auto Gain information added	May 2024	RH/FK
6	Minor updates to newest software release	July 2024	RH/FK
7	Updates for UDL-DataClient	August 2024	RH/FK
8	Update to latest Version	Sept. 2024	RH/FK
9	Qm / Qr / Qiec descriptions changed/added PDBAS renamed to “PD” PDSTD renamed to “PD+”	March 2025	RH/FK

Table of Contents

List of Figures

List of Tables

List of Abbreviations

PD	Partial Discharge
A/D	Analogue to Digital Converter
D/A	Digital to Analogue Converter
PRPD	Phase Resolved Partial Discharge Pattern
UTC	Coordinated Universal Time

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1 Read This First!

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1.1 Warranty and Product Support

It is recommended that you thoroughly inspect the contents of the UDL-8000 Monitoring System packaging immediately upon receipt. Compare the contents to the packing list/invoice shipped with the instrument. Unless is notified promptly of any missing or damaged item, we cannot accept responsibility for its replacement. Contact your nearest Customer Service Center or national distributor immediately.

We warrants the UDL-8000 products for normal use and operation within specifications for a period of two years from the date of shipment. Spares, replacement parts and repairs are warranted for 90 days. The instrument’s firmware has been thoroughly tested and is thought to be functional, but is supplied without warranty of any kind covering detailed performance.

Products not made by Manufacturer are covered solely by the warranty of the original equipment manufacturer. Under the warranty, the supplier will repair or, at its option, replace any product returned within the warranty period to a authorized service center. However, this will be done only if the product is determined after examination by the manufacturer to be defective due to workmanship or materials, and not to have been caused by misuse, neglect or accident, or by abnormal conditions or operation.

NOTE: This warranty replaces all other warranties, expressed or implied, including but not limited to any implied warranty of merchantability, fitness, or adequacy for any particular purpose or use. The Manufacturer shall not be liable for any special, incidental, or consequential damages, whether in contract or otherwise. The client will be responsible for the transportation and insurance charges for the return of products to the service facility.

For Further Technical Information and application information of the device, please read the Knowledgebase at the end of this document or to the available/applicable IEC / EN Standards.

1.2 About this Manual

This manual is an extension to the main manual and describes the specific features and functions of the RF partial discharge monitoring. The partial discharge (PD/PD+) acquisition module is specifically designed for RF partial discharge monitoring of high voltage equipment

This manual is built up as follows

- Chapter 2
  Introduction of the partial discharge monitoring
- Chapter 3
  Application Description
- Chapter 4
  Hardware and Software requirements
- Chapter 5
  Hardware Module M8019
- Chapter 6
  Acquisition Module Configuration
- Chapter 7
  Acquisition Module Data Presentation

2 Introduction

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The RF partial discharge monitoring is used to monitor the insulation condition of high voltage equipment as stator windings of MV motors and Generators, Busbars, Switch-gears and MV cables.

My measuring the RF partial discharge activity of the high voltage equipment, the insulation condition can be determined while the equipment is under service.

For the partial discharge monitoring, 2 different acquisition modules are available:

- PD is used for simple partial discharge trending with basic analysis function
- PD+ is used for partial discharge trending and the high resolution PRPD patterns can be used for in deep analysis of the insulation condition

For the data acquisition, various M8019 modules with different number of input channels are available in order to provide a system to the customers requirement. The M8019 is available with 1, 3, 6, 12, 18 or 24 input channels. Depending on the number of input channels, the size of the enclosure varies, form 42TE, up to 80TE.

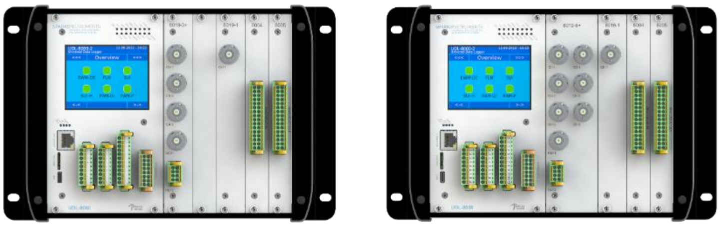


Figure 1: UDL-8000 System pd monitoring with 3 and 6 RF input channels

Figure 2: UDL-8000 System pd monitoring with 12 and 18 RF input channels

Optionally, the RF pd monitoring system can be equipped with a noise gating channel, as shown under Figure 1.

The PD Monitoring system is also available as a Dual CPU multiparameter monitoring system with other monitoring parameters as Endwinding Vibration, Rotor Flux Monitoring, Shaft Voltage / Current and many more.

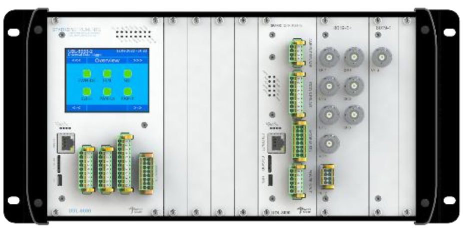


Figure 3: UDL-8000 Dual CPU Multiparameter Monitoring System

The PD Monitoring system is also available as a “All-in-one” solution. The UDL-8000 Pro includes additionally a windows touch panel PC with integrated UDL-DataServer for long term data storage in a SQL database

Figure 4: UDL-8000 Pro - Dual CPU Multiparameter Monitoring System

For periodic measurements, the system is also available as a portable device, either integrated in a plastic carrying case or as a desktop 2/3 19’’ Enclosure

Figure 5: UDL-8000 Case – Portable Partial Discharge Analyzer

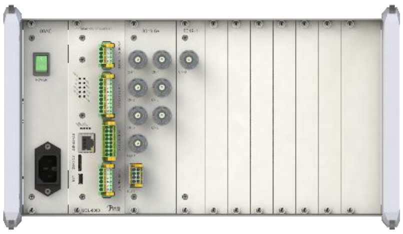
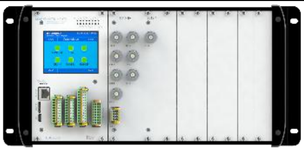
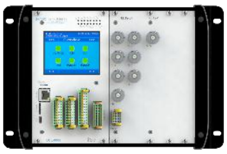
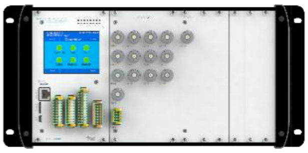
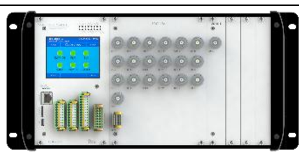
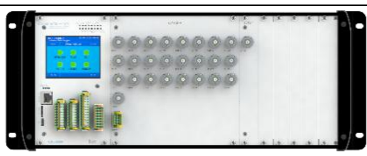
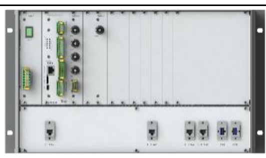


Figure 6: UDL-8000 Case – Portable Partial Discharge Analyzer

2.1 Standard Products

The Following table lists the available standard products.

2.2 Single Function Monitoring Systems

Description	Type
UDL-8000 3-Channel RF Partial Discharge Monitoring System (2 Slots) Type: P1042-PD3G0-A2	
UDL-8000 3-Channel RF Partial Discharge Monitoring System (6 Slots) Type: P1063-PD3G0-A6	
UDL-8000 6-Channel RF Partial Discharge Monitoring System (2 Slots) Type: P1042-PD6G0-A2	
UDL-8000 6-Channel RF Partial Discharge Monitoring System (6 Slots) Type: P1063-PD6G0-A6	
UDL-8000 12-Channel RF Partial Discharge Monitoring System (1 Slots) Type: P1042-PD12-A1	
UDL-8000 12-Channel RF Partial Discharge Monitoring System (5 Slots) Type: P1063-PD12G0-A5	
UDL-8000 18-Channel RF Partial Discharge Monitoring System (3 Slots) Type: P1063-PD18G0-A3	
UDL-8000 24-Channel RF Partial Discharge Monitoring System (5 Slots) Type: P1080-PD24G0-A5	
UDL-8000 Pro – All-in-one 3-Channel RF Partial Discharge Monitoring System (6 Slots) with Integrated 10” Touch Panel PC Type: RP2084-AC-PD3G0-A6	

UDL-8000 Pro – All-in-one 6-Channel RF Partial Discharge Monitoring System (6 Slots) with Integrated 10" Touch Panel PC Type: RP2084-AC-PD6G0-A6	
UDL-8000 Pro – All-in-one 12-Channel RF Partial Discharge Monitoring System (5 Slots) with Integrated 10" Touch Panel PC Type: RP2084-AC-PD12G0-A5	

Table 1: Single Function PD Monitoring Systems

2.3 Dual CPU Multiparameter Monitoring Systems

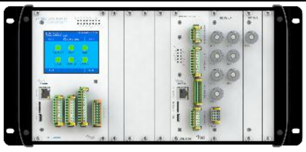
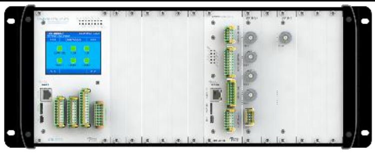
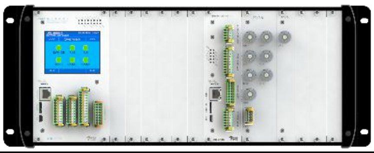
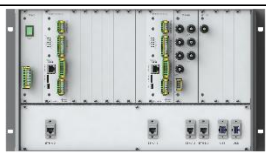
Description	Type
UDL-8000 Dual CPU Multiparameter Monitoring System (4 Slots) with 3 RF Partial Discharge Channels Type: P1263-A4-PD3G0-B0	
UDL-8000 Dual CPU Multiparameter Monitoring System (4 Slots) with 6 RF Partial Discharge Channels Type: P1263-A4-PD6G0-B0	
UDL-8000 Dual CPU Multiparameter Monitoring System (6 Slots) with 3 RF Partial Discharge Channels (3 Slots) Type: P1280-A6-PD3G0-B3	
UDL-8000 Dual CPU Multiparameter Monitoring System (6 Slots) with 6 RF Partial Discharge Channels (3 Slots) Type: P1280-A6-PD6G0-B3	
UDL-8000 Pro – All-in-one Dual CPU Multiparameter Monitoring System (7 Slots) with 6 RF Partial Discharge Channels (2 Slot) and Integrated 10" Touch Panel PC Type: RP2284-AC-A7-PD6G0-B2	
UDL-8000 Pro – All-in-one Dual CPU Multiparameter Monitoring System (5 Slots) with 4 Enhanced RF Partial Discharge Channels (1 Slot) and Integrated 10" Touch Panel PC Type: RP2284-AC-A5-PDSIM4G0-B1	

Table 2: Dual CPU Multiparameter PD Monitoring Systems

2.4 Portable Partial Discharge Monitoring System

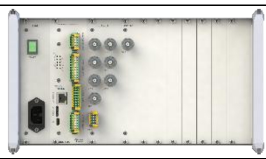
Description	Type
UDL-8000 Case - Portable 3-Channel RF Partial Discharge Acquisition System (4 Slots) for online and offline with Compartment for Accessories Type: C2050-AC-PD+3G0-A4	
UDL-8000 Case - Portable 3-Channel RF Partial Discharge Acquisition System (4 Slots) for online and offline with Compartment for 1x PPG-0010 & 1x PDC17.5-1000 Type: CA2050-AC-PD+3G0-A4	
UDL-8000 Case - Portable 6-Channel RF Partial Discharge Acquisition System (4 Slots) with Compartment for Accessories Type: C2050-AC-PD+6G0-A4	
UDL-8000 Case - Portable 12-Channel RF Partial Discharge Acquisition System (2 Slots) with Compartment for Accessories Type: C2050-AC-PD+12G0-A2	
UDL-8000 Portable Rack - Portable 6-Channel RF Partial Discharge Acquisition System (6 Slots) Type: PR2063-AC-PD6G0-A6	

Table 3: Portable Partial Discharge acquisition system

3 Application Description

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As there are many different high voltage equipment where partial discharges can be monitored the installation and type of the sensors might be different from application to application. In the following chapters, the most common installations are described, for applications not described within this document, please contact sparks instruments for further information.

3.1 Acquisition principle

The PD and PD+ acquisition module handle the acquisition of the RF partial discharges sequentially, means each channel is measured one after the other, this reduces the costs of the system greatly and as the partial discharges typically representing an aging effect over a long period of several months or years, it is acceptable to measure the results sequentially.

For customers who require simultaneous acquisition over the 3 phases, a separate acquisition module PDSIM is available and is documented in a separate manual. The enhanced simultaneous pd acquisition offers additional information in regards to the pulse activity between the channels / phases.

3.2 Sensor Compatibility

The RF inputs of the M8019 module do have 2 types of impedances, the RF impedance is 50Ohms, while the LF impedance is 20kOhm.

Basically, every known RF sensor can be connected to the system, from coupling capacitors with integrated or external quadrupoles, RF CT's, Rogowski Coils, UHF RF converters etc.

3.3 Installation Layouts

3.3.1 General

In order that PRPD patterns can be recorded, a reference voltage, with the power frequency and a stable phase to the high voltage equipment must be provided.

Generally coupling capacitors provide beside the RF partial discharge signal an overlaid AC voltage, which can be used as a phase reference. While the M8019 input card is calibrated for the PDC coupling capacitors series, the phase reference taken from 3rd party coupling capacitors must be measured or calculated depending on the type of quadrupole used. For coupling capacitors with integrated AC reference voltage, the M8019 provides an internal signal splitter for every RF channel, allowing to assign the reference voltage from any connected PD channel.

For coupling capacitors providing the reference voltage by a second output, the Ref1 BNC input can be used to provide the signal. The same BNC input can be used, whenever Rogowski coils are used to provide a reference voltage to the system. This is typically required whenever partial discharge measurements are performed on power cables by using RT CT's or PD measurements are performed at a location, where no AC reference is available.

Alternatively, two AC voltage inputs (30Vrms / 300Vrms) are available to provide the reference voltage from an AC supply, a voltage transformer or any possible reference source.

The UDL-8000 is also available with an additional AC power Supply module. For such configurations, the AC voltage from the AC supply can also be selected by the software.

3.3.2 Turbo Generators

Generally, for turbo generators, 3 partial discharge coupling capacitors are installed at each phase terminal. On larger generators or upon customer request, a 4th coupler at the neutral point is installed.

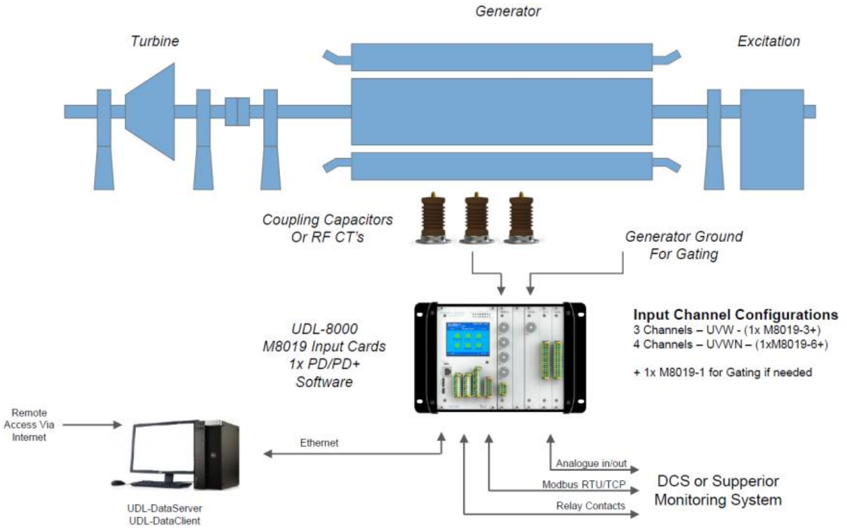


Figure 7: UDL-8000 System for standard PD monitoring on turbo generators

For machines >~30MW, or machines with a thyristor-based excitation system it is recommended to use the additional gating channel on order to remove the unwanted disturbances from the excitation system.

For customers who want to have additionally coupling capacitors on the busduct or near the transformer (as usually named system couplers) in total 6 couplers are installed. The M8019-6+ can be used for such a configuration. In case the customer requires the 6 couplers and an additional coupling capacitor on the neutral point, the Module M8019-12+ (12 input channels) is required.

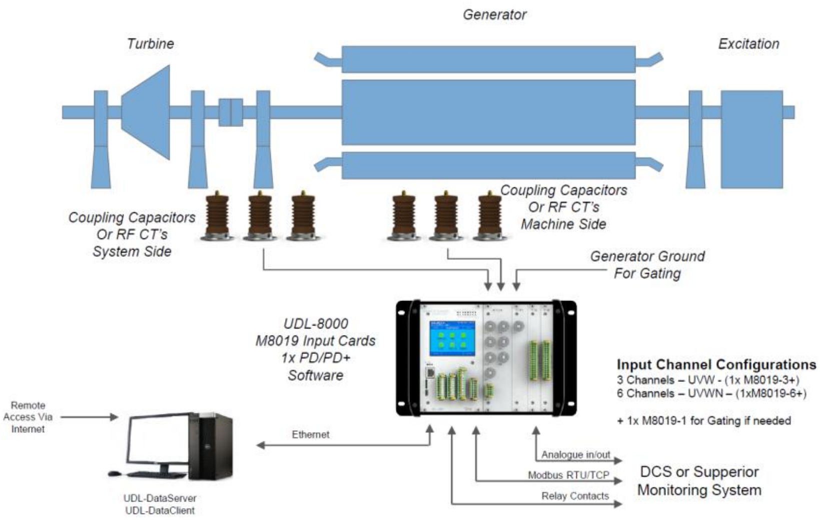


Figure 8: UDL-8000 System for 6 CH. PD monitoring on turbo generators

3.3.3 Hydro Generators

For the partial discharge monitoring on hydro generators, minimum 3 coupling capacitors are installed near the generator terminals. For machines with a thyristor-based excitation system, an additional single channel M8019 card is recommended for the noise cancelling function.

For customers who require an additional coupling capacitor on the neutral point, the 6-channel input module M8019-6+ is required.

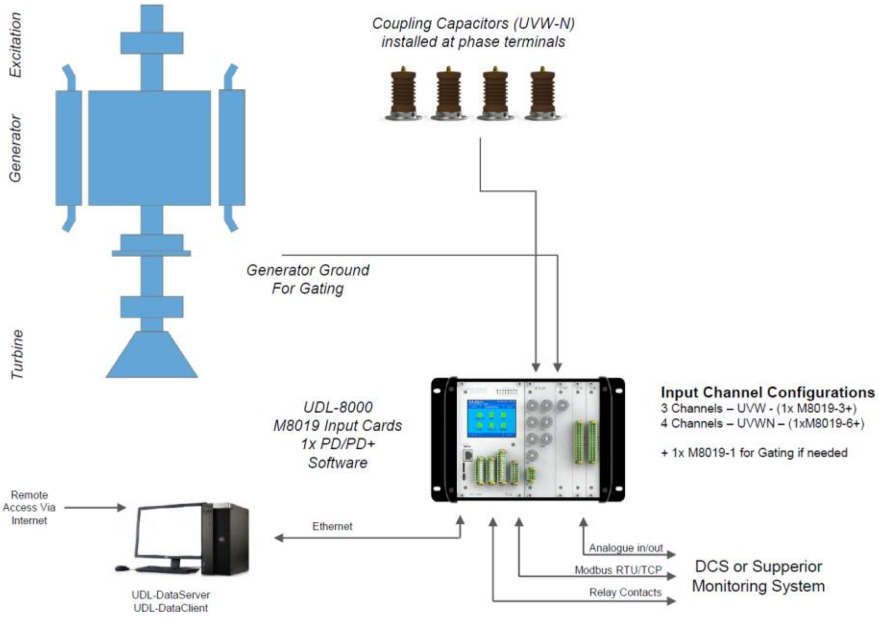


Figure 9: UDL-8000 System for 3/4 CH. PD monitoring on hydro generators

For customers who require coupling capacitors installed within the generator winding, typically for each parallel circuit, 6, 12, 18 or 24 channel input modules can be selected.

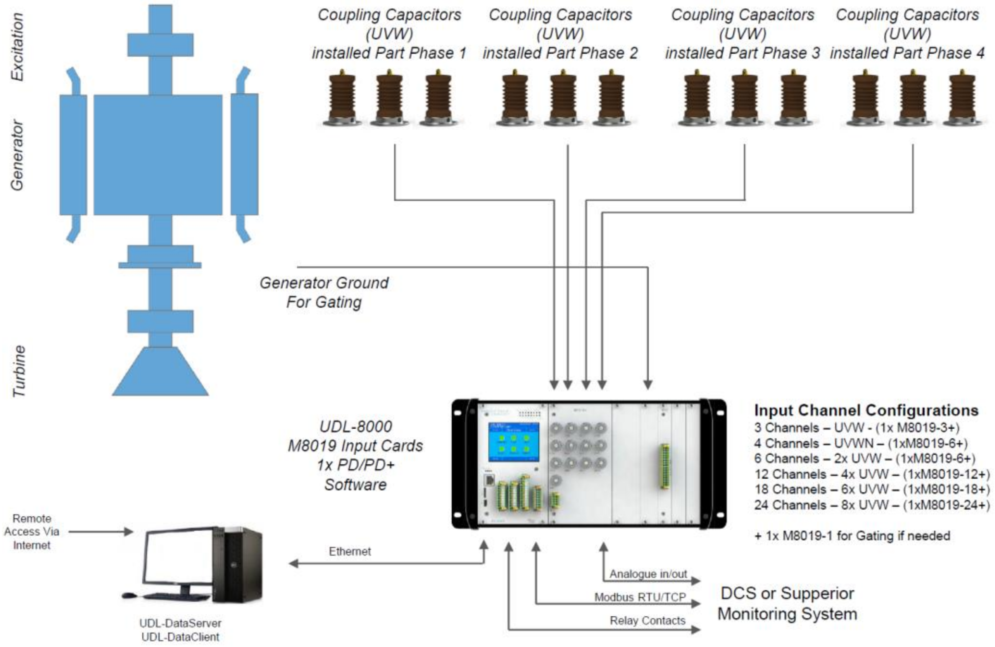


Figure 10: UDL-8000 System for 12 CH. PD monitoring on hydro generators

3.3.4 MV Motors

Standard motors can be handled the same as generators, and a noise canceling channel is generally not needed.

While some of the motors are powered by power cables instead of busbars, the terminal box is often too small in order to install coupling capacitors. Under such conditions, RF CT’s can be installed around the ground lead of the power cable, while using the cable capacitance as a decoupling unit.

For machines powered by 3 phase power cables, only one shield is available, therefore only 1 sensor can be used. PD monitoring is still possible, but it is impossible to make an assignment to the individual phase.

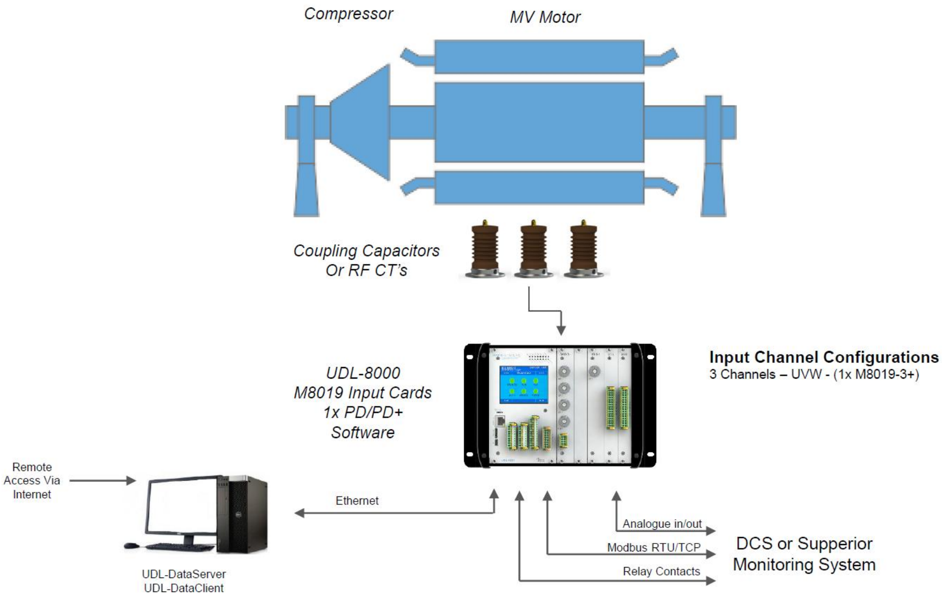


Figure 11: UDL-8000 System for 3 CH. PD monitoring on MV Motors

As often multiple motors are installed at the same location, it is also possible to use the multi-channel input cards and monitor multiple motors with a single device.

3.3.5 MV VSD Motors

VSD Drives, or also called variable speed drives do use a gearbox to change the rotation speed between the motor and the compressor or other loads. As the motor is powered by standard line frequency, the same approach than for standard motors can be used.

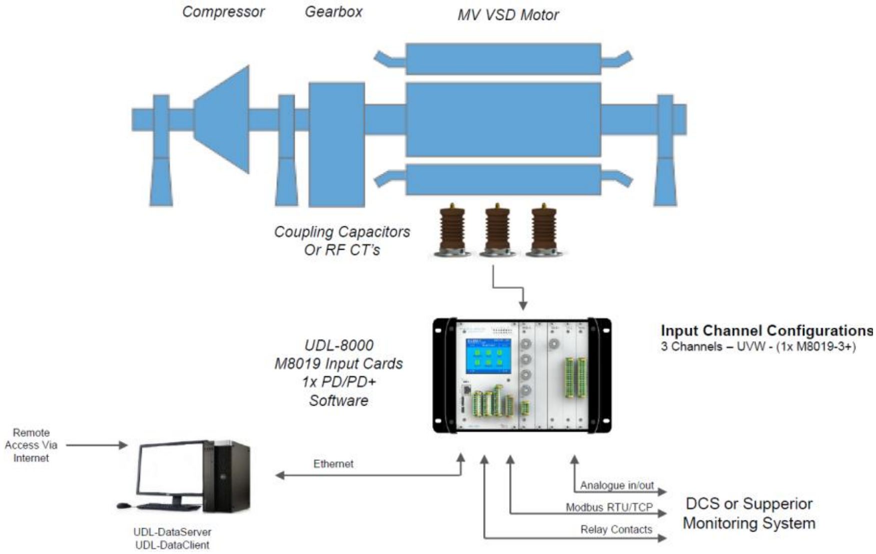


Figure 12: UDL-8000 System for 3 CH. PD monitoring on MV VSD Motors

3.3.6 MV VFD Motors

VFD Drives, or also called variable frequency drive are using a power frequency converter to power the motor. Such types of motors are especially subjected to stator insulation failures as the high du/dt signal from the power frequency converter are especially stressing the stator insulation system

Such motors are generally very difficult to monitor the stator insulation condition with the partial discharge measurement technology, as the high du/dt transients from the frequency converter can impact the RF PD Measurement. Another challenge is the measurement of the reference voltage, which is mandatory for the analysis of the partial discharge PRPD patterns. The reference voltage shall be provided by the frequency converter as a proper sinewave signal, or alternatively, it is possible to use a low frequency current transformer around one of the power cables to pick up the reference frequency. This approach provides a much better reference signal to the PRPD detector as the current from the frequency converter is regulated with much more steps than the voltage signal.

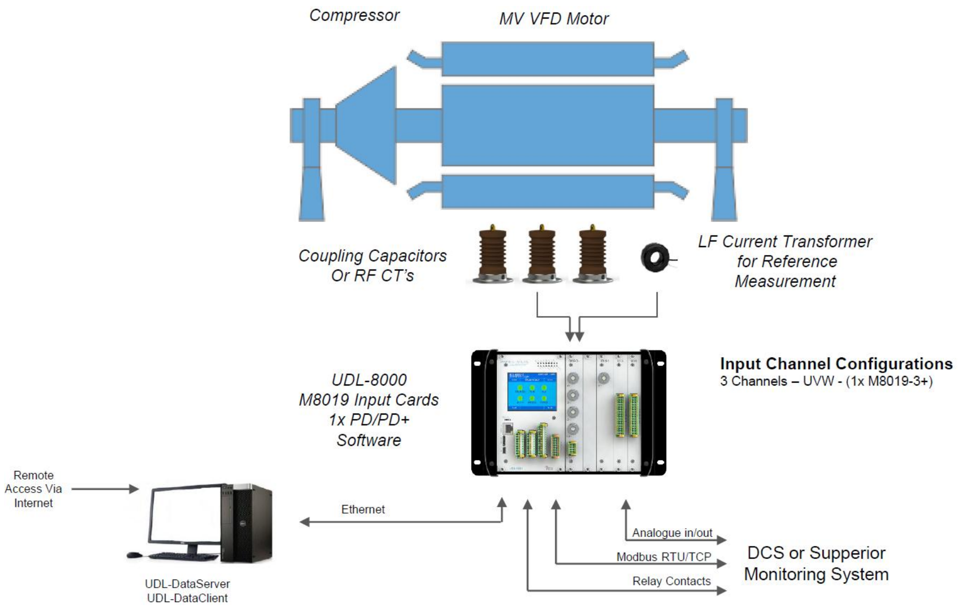


Figure 13: UDL-8000 System for 3 CH. PD monitoring on MV VFD Motors

The M8019-3+ input module does have an additional BNC reference voltage input, which can be used in order to directly connect a current transformer (Rogowski-coil-type).

Whenever multiple motors shall be monitored with the same system, it must be understood, that for each VFD motor, an M8019-3+ module is required, as every motor might run at a different frequency.

3.3.7 MV Air Insulated Switchgears

For the PD monitoring on air insulated switchgears, coupling capacitors can be used, but for higher voltages (e.g. 33kV) there is often not enough space to install coupling capacitors. Alternatively, so called TEV probes (Transient earth voltage) are installed at the AIS's wall, which will pick up any EMI created inside of a defect and will be absorbed by the ground. Alternatively a much better solution is to use UHF antenna's, but in order to reduce the costs of the UHF signal conditioning, UHF-RF converter modules are used, so a standard RF partial discharge detector can be used.

As shown on the next illustration, the partial discharge activity is measured by UHF-RF converters and additionally the temperature of the conductors and the ambient temperature and humidity is monitored as a whole AIS monitoring solution. Alternatively, switch status, voltages and current can be collected by the control system to round up the monitoring solution.

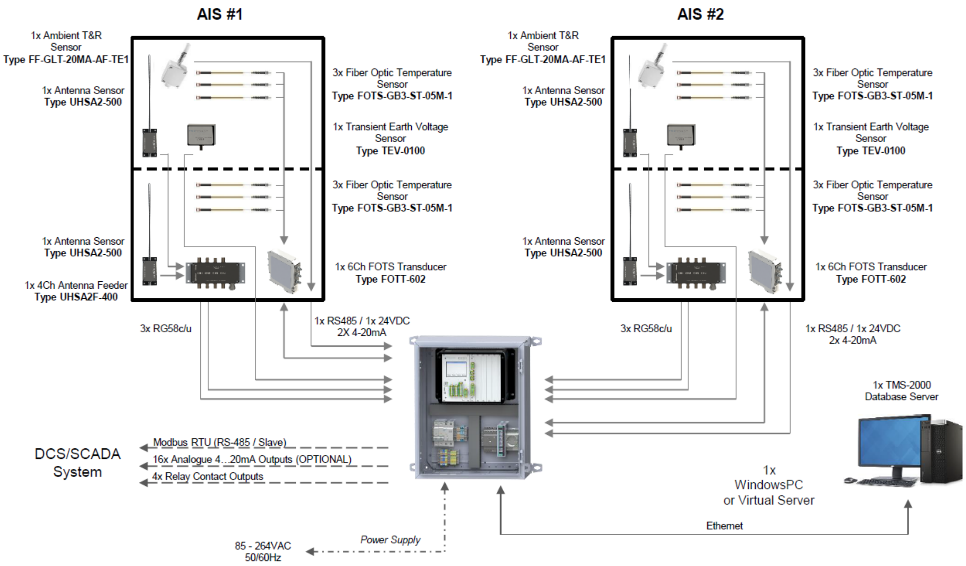


Figure 14: UDL-8000 System for 2 AIS with 2 separate chambers

3.3.8 MV / HV Cables with AIS

As most of the AIS are connected with MV cables, also the MV cables can be monitored with the RF PD monitoring solution. Depending on the size of the AIS, the type and number of the power cables an entire AIS can be monitored with 1 or 2 systems as illustrated in the below graphic.

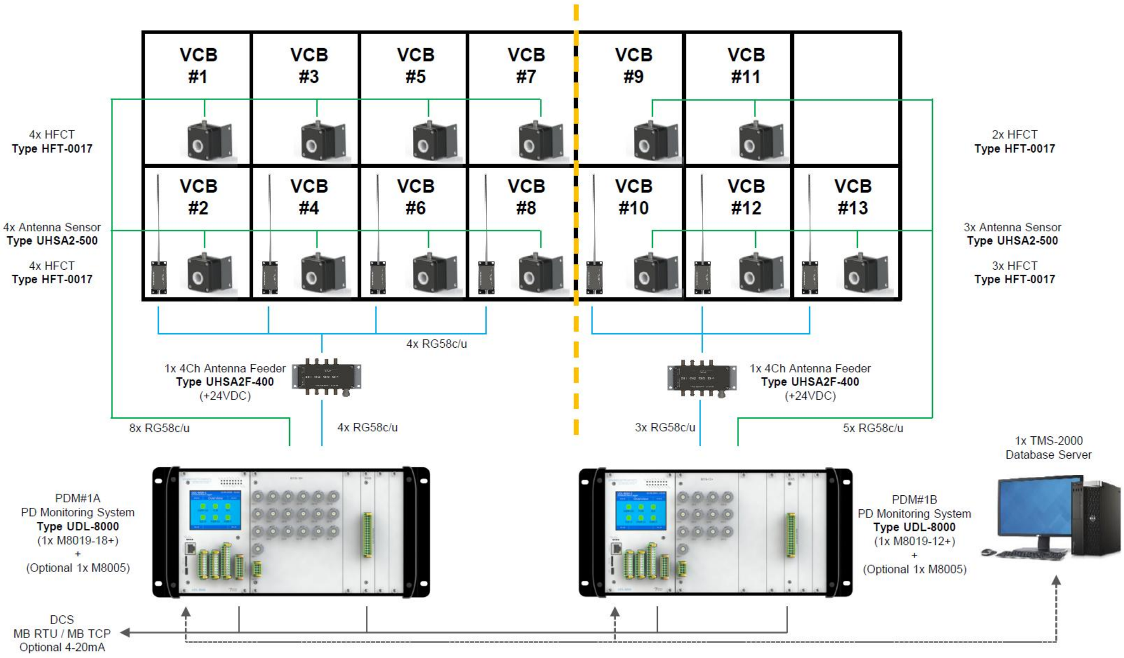


Figure 15: UDL-8000 System for Multiple AIS with UHF/RF and MV Cable monitoring.

As the UHF/RF signal can only be measured unipolar, the PD on the MV power cables shall be measured bipolar in order to be able to distinguish the origin of the PD source.

3.4 Measurement and Analysis of the partial discharge signal

The input of the PD Inputs includes several low frequency and high frequency over voltage protections (OVP) in order to protect the system from incoming transients. Every channel includes the overvoltage protection, a signal attenuator and the reference voltage splitter.

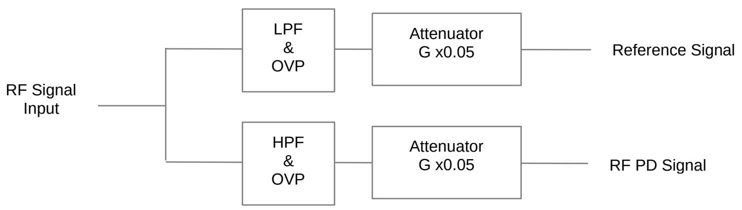


Figure 16: Principle of the partial discharge input

The standard RF input range is 2.5V .. 0.125V and can be extended with the input attenuator from 50V .. 2.5V. Each input is then multiplexed and connected to a preamplifier with a gain selection of 1 or 10, offering an increased sensitivity from 12.5mV to 250mV.

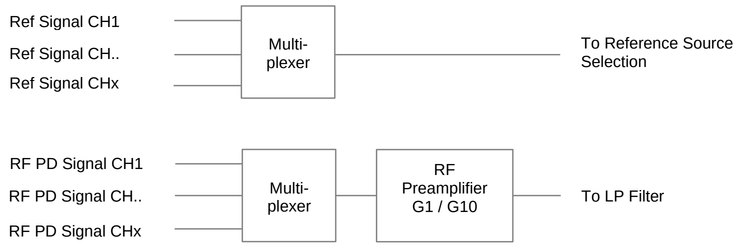


Figure 17: Input Range selection of the partial discharge input

The variable analogue high and low pass filters allow to set the best signal to noise ratio of the pd signal. A variable amplifier is further available to change to different measurement ranges in order to adapt the system to the actual signal amplitude.

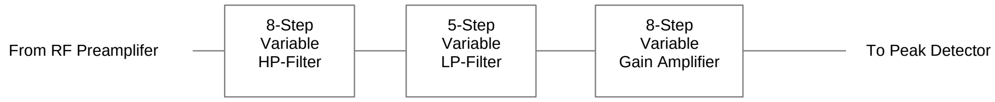


Figure 18: Filtering and amplification of the partial discharge input

An analogue bipolar peak detector is used to pick the peak of the partial discharge pulse controlled by a trigger level to define the threshold of the pd signal. By default, the system is configured for a detection of the pulse polarity by edge detection. Alternatively, the system can be configured so that the maximum of the positive or negative pulse magnitude is selected. The peak value of the PD pulse is converted by the analogue-digital converter, and the trigger is reset, making the system ready for the next pulse detection.

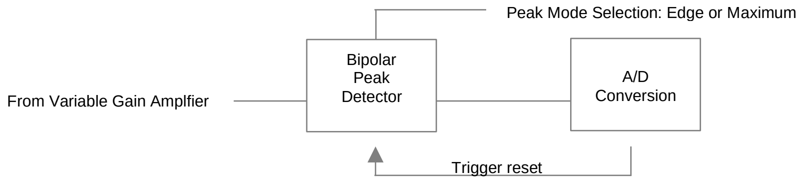


Figure 19: Peak Detection and A/D Conversion

By default, the system measured the partial discharge activity in mV. The system can be normalized by using a pd pulse generator with a known discharge level and can provide further the results in pC or nC.

The partial discharges are continuously recorded during a typical acquisition time of 30s without any loss of data, this allows the system to detect also partial discharge activities with very low repetition rates as it is often seen on surface discharges.

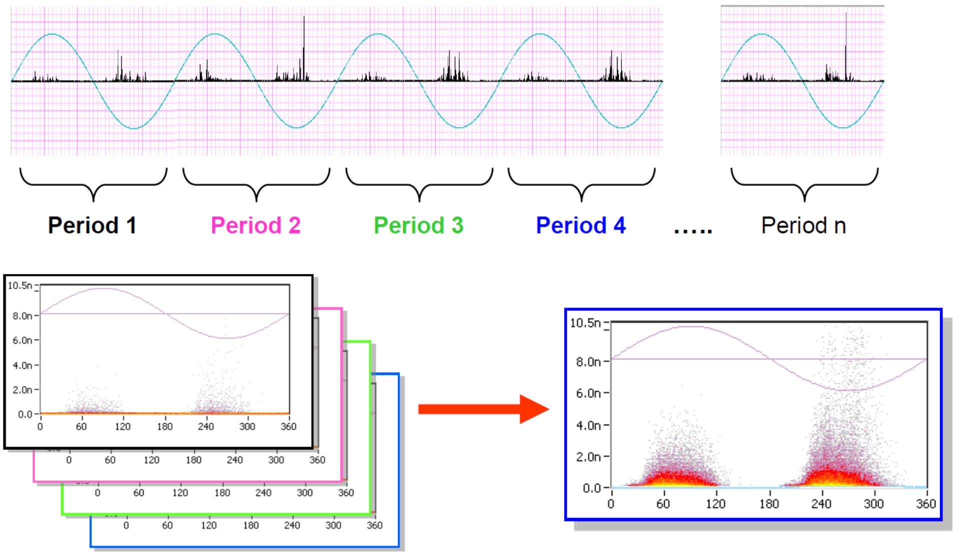
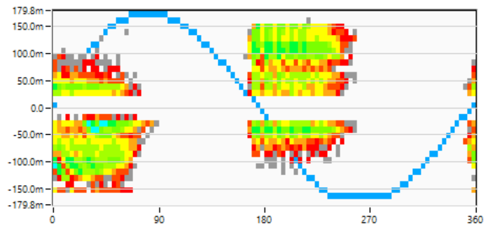
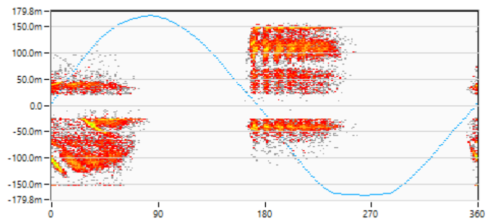


Figure 20: Continuous partial discharge data acquisition

Depending of the used acquisition module, the recorded data is shown with a lower or higher data resolution

- PD
  The PD acquisition module is mainly used for trending only, offering 2x4bit data results (16 Amplitude windows for each polarity and 100 windows for the phase). The low resolution PRPD patterns provide the operator if there is a partial discharge activity and is used during the commissioning for the configuration.
  
  Figure 21: PRPD Patterns with 32 Amplitude and 100 Phase windows.
- PD+
  The PD+ acquisition module provides the same parameter results with an increased resolution in order to provide high resolution PRPD pattens as e.g. shown in the IEC standards. With the high resolution PRPD patterns, multiple partial discharges can be identified with a single measurement.
  
  Figure 22: High Resolution PRPD Patterns with 256 Amplitude & Phase windows

The PRPD patterns are created by placing the pulse peak value at the specific amplitude location and phase angle, and as partial discharge pulses can occur at the same amplitude and phase within the acquisition time, a colour coding is used to show the occurrences of the PD pulses and for better visualisation, a logarithmic colour scale is used.

Additionally, the partial discharge activity is shown as a pulse height distribution showing the measured PD pulse magnitude over the pulse repetition rate (occurrence divided by acquisition time)

Based on the 30s recorded dataset, parameters are calculated for trending an alarming.

3.5 Channels and acquisition module assignment

As per design of the UDL-8000 platform, every acquisition module can handle up to 8 channels. For the partial discharge measurement with PD or PD+, the channels are assigned as

Channel 1: Reference Voltage
Channel 2: PD Input Channel 1 (e.g. Phase U)
Channel 3: PD Input Channel 2 (e.g. Phase V)
Channel 4: PD Input Channel 3 (e.g. Phase W)
Channel 5: PD Input Channel 4 (e.g. Phase U)
Channel 6: PD Input Channel 5 (e.g. Phase V)
Channel 7: PD Input Channel 6 (e.g. Phase W)
Channel 8: Gating Channel

For the Input module M8019-12+ with 12 input channels, a second acquisition module must be configured, covering the PD input channels 7-12. For the M8019-18+ with 18 input channels, a third acquisition module must be added for the input channels 13-18 and for the M8019-24+ with 24input channels, a total of 4 acquisition modules are required

The following Illustration shows the assignment of the multichannel input module to the specific acquisition module.

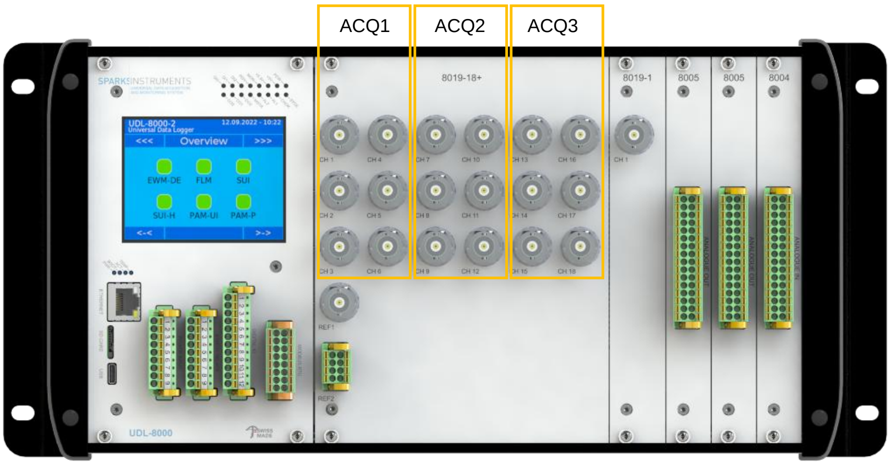


Figure 23: Multichannel assignment to acquisition Module

For each acquisition module, the acquisition mode must be the same (gating function, Pulse Acquisition mode, Unipolar/Bipolar PRPD etc.) and if different modes are required, an additional acquisition module must be added.

3.6 Parameter Calculation

Within the acquisition module configuration, the type of parameters to be calculated for each PD channel must also be defined.

Even the system is measuring the partial discharge signals bipolar, the parameters are calculated based on a unipolar pattern, unless otherwise noted.

Calculation parameters Set 0 – typically in nC unit

Parameter	Description
0	PPS1 (Qr1) – Charge Level at cumulated Pulse Repetition Rate 1Hz
1	PPS5 (Qr5) – Charge Level at cumulated Pulse Repetition Rate 5Hz
2	PPS10 (Qr10) – Charge Level at cumulated Pulse Repetition Rate 10Hz
3	Repetition Rate (R)
4	Peak Discharge (Qp)
5	Apparent Charge
6	Average Discharge Current [A]
7	NQN

Table 4: Calculation parameters 0

The parameters shown on the above list are calculated by “rectifying” the bipolar partial discharge signal prior their calculation.

Calculation parameters Set 1 – typically in mV unit

Parameter	Description
0	Peak Discharge Positive (Qp+)
1	Peak Discharge Negative (Qp-)
2	Mean Discharge Positive (Qm10+)
3	Mean Discharge Negative (Qm10-)
4	NQN Positive (NQN+)
5	NQN Negative (NQN-)
6	Qp
7	Qm10

Table 5: Calculation parameters Set 1

Calculation parameters Set 2 – typically in nC unit

Parameter	Description
0	Qm1 – Charge Level at windowed Pulse Repetition Rate 1Hz
1	Qm5 – Charge Level at windowed Pulse Repetition Rate 5Hz
2	Qm10 – Charge Level at windowed Pulse Repetition Rate 10Hz
3	Repetition Rate (R)
4	Peak Discharge (Qp)
5	Apparent Charge
6	Average Discharge Current [A]
7	NQN

Table 6: Calculation parameters Set 2

Calculation parameters Set 3 – typically in nC unit

Parameter	Description
0	Qm10+ Positive Charge Level at windowed Pulse Repetition Rate 10Hz
1	Qm10- Negative Charge Level at windowed Pulse Repetition Rate 10Hz
2	Apparent Charge (Qapp+)
3	Apparent Charge (Qapp-)
4	NQN Positive (NQN+)
5	NQN Negative (NQN-)
6	Qm10 Charge Level at windowed Pulse Repetition Rate 10Hz
7	Qiec

Table 7: Calculation parameters Set 3

Calculation parameters Set 4 – typically in nC unit

Parameter	Description
0	PPS10+ / Qr10+ Positive Charge Level at cumulated Pulse Repetition Rate 10Hz
1	PPS10- / Qr10- Negative Charge Level at cumulated Pulse Repetition Rate 10Hz
2	Apparent Charge (Qapp+)
3	Apparent Charge (Qapp-)
4	NQN Positive (NQN+)
5	NQN Negative (NQN-)
6	PPS10 / Qr10 Charge Level at cumulated Pulse Repetition Rate 10Hz
7	Qiec

Table 8: Calculation parameters Set 4

3.6.1 Qr (PPSx) & Qm Parameters

“PPS” stands for Pulse per Second, and the PPSx parameter is representing the amplitude at a specific pulse repetition frequency.

To represent the pulse height repetition frequency, there are 2 methods:

- By Window (Qm)
- By Cumulated Window (Qr)

3.6.1.1 Pulse Height Distribution by Window (Qm)

The Window based pulse height distribution will simply scan the PRPD pattern, and summing up the amplitude window over the entire phase angle. It is important to know, that the extracted Qm values are different between systems with different amplitude resolutions (See chapter below for detailed explanation)

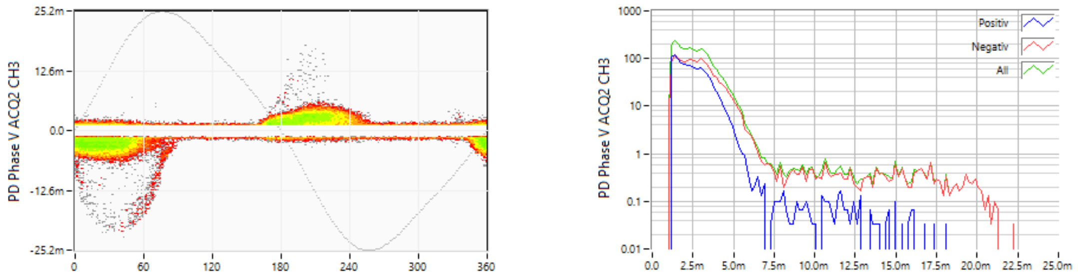


Figure 24: Phase Resolved PD Pattern (left) and Pulse Height Distribution (right)

3.6.1.2 Pulse Height Distribution cumulated (Qr)

The cumulated pulse height distribution cumulates the pulses from the highest PD magnitude window down to 0 over the entire phase angle.

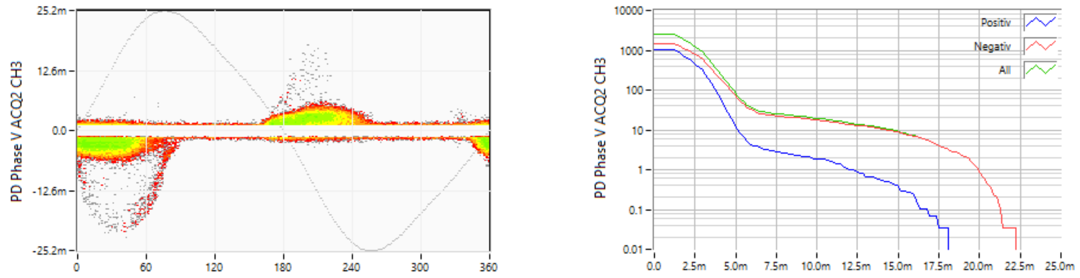


Figure 25: Phase Resolved PD Pattern (left) and Pulse Height Distribution (right)

3.6.1.3 Qm / Qr Calculation

The IEC60034-27-1 (Annex B2) defines the differences between Qm and Qr. As Qm depends on the resolution of the PRPD pattern, the resulting value is different between systems using different PRPD resolutions. Therefore, the use of Qr values is generally a better approach.

The following illustration shows the different pulse height distribution under different PRPD resolutions

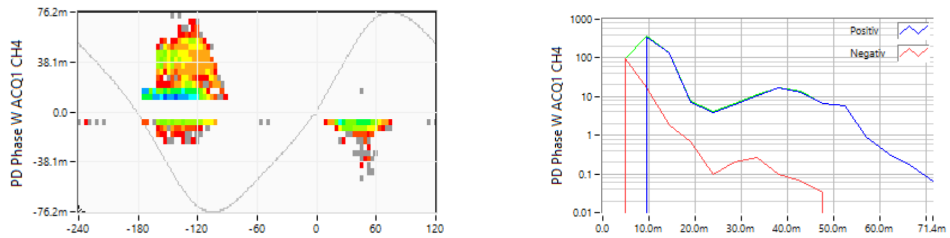


Figure 26: Pulse Height Distribution based on 2x16 Amplitude Windows

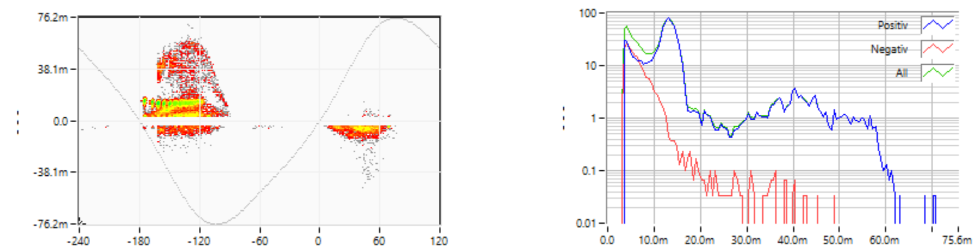


Figure 27: Pulse Height Distribution based on 2x128 Amplitude Windows

The PD pulse magnitude at 5Hz Repetition rate is at around 48mV for a PRPD Pattern with 2x16 windows, where it is around 15mV for a PRPD pattern with 2x128 Windows.

As the “window” based pulse height distribution depend on the amplitude resolution of the PRPD pattern, calculating a parameter based on this information will be valid only within the same system / same manufacturer, this is simply due to the fact that higher resolution will spread the detected pulses into more windows, hence, the pulse repetition rate per window is smaller.

Therefore, for the calculation of the PPSx parameters, the cumulated pulse height distribution graph is used, and in order to reduce the number of parameters per PD channel, the PPSx value is calculated based on the “unipolar” pattern (rectified), Refer to the green “trace” All.

Similar PRPD data with a cumulated pulse height distribution

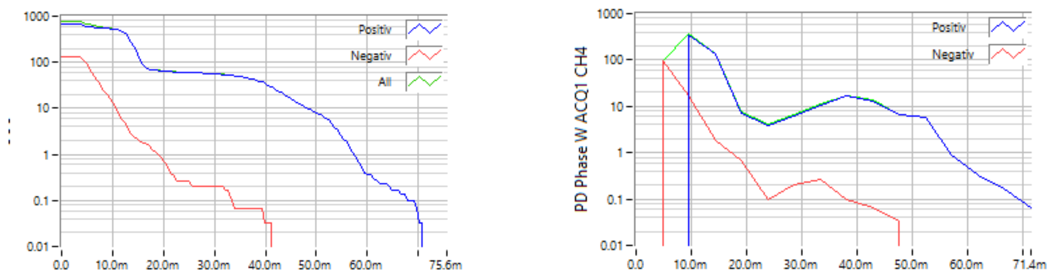


Figure 28: Cumulated Pulse Height Distribution based on 2x16 resp. 2x128 Amplitude Windows

The PD pulse magnitude at 5Hz Repetition rate is at around 52mV for a PRPD Pattern with 2x16 windows, where it is around 50mV for a PRPD pattern with 2x128 Windows, clearly showing that the cumulated pulse height distribution will show similar amplitudes independent of the PRPD resolution.

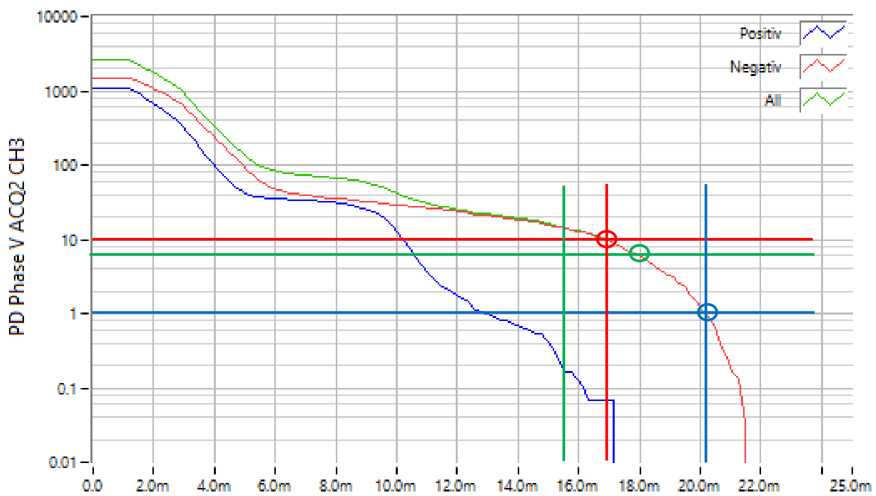


Figure 29: Cumulated Pulse Height distribution and Qr amplitudes

Blue: 1Hz Pulse Repetition Rate at rectified signal (green trace) → ~20mV
Green: 5Hz Pulse Repetition Rate at rectified signal (green trace) → ~18mV
Red: 10Hz Pulse Repetition Rate at rectified signal (green trace) → ~17mV

If no sufficient pulse repetition frequency found, the results is indicating 0.

Parameter	Description
PPS1 / Qr1	Surface Discharges often do have strong magnitudes but lower pulse repetition rates, therefore this parameter, if deviated stronger than the PPS5 and PPS10 indicating a surface discharge activity.
PPS10 / Qr10	Internal discharges or slot type discharges do have generally a strong repetition frequency but with much lower amplitudes, therefore this parameter indicates more for internal discharges
PPS5 / Qr5	This parameter is very close to Qiec and can be understood as a good mean value, representing an average PD activity

Table 9: Qr values and their meanings

The Qr values are ideal parameters for online partial discharge monitoring as they are generally less affected by external disturbances are other known parameters. In order to achieve this, it is mandatory that the disturbances are lower than the actual measured pd activity.

For machines which do have a very low PD activity, it is possible that the disturbances cannot fully removed or reduced. Under such situations, it must then be considered, that the given time series data are driven by the disturbance and not by the pd activity. This is generally not an issue, as disturbances are generally stay the same, but the partial discharge activity will get higher with ongoing operation time and whenever the partial discharge activity is getting critical, it magnitude will be higher than the disturbances if the system has been configured correctly.

3.6.2 Repetition Rate Parameter (R)

The repetition rate parameter is the sum of all discharges divided by the acquisition time. It is mandatory that the trigger setting is set in such way, that it is above the base noise level, as otherwise this parameter is influenced by it.

3.6.3 Peak Discharge Parameter (Qp)

The peak discharge represents the highest discharge measured during the acquisition time. Generally, one single discharge pulse does not represent the quality of the insulation system, but as this parameter is requested by certain applications, it is available.

3.6.4 Peak Discharge Parameter (Qiec)

The Qiec is calculated based on the pulse train response according to IEC60270:2015

3.6.5 Apparent Charge Parameter (Ap)

The apparent charge is an average value of all measured partial discharge patterns acquired during the defined time interval.

The parameter is calculated as follows:

$$Ap = \frac{1}{N}\sum_{i=0}^{i=N} Q_i$$

N: Number of Discharges
Q: Actual Discharge Pulse Magnitude

The apparent charge is widely used in offline partial discharge measurement and often users are comparing the offline with online measurements using the same parameter result. It must be understood, that the apparent charge parameter is influenced by the base noise level and special attention must be taken, when using this parameter on online measurements with high background noise level. Ensure that the trigger level of the system is set in such way, that the trigger level is set higher than the base noise level to avoid this effect.

3.6.6 Average Discharge Current (Adc)

The Average Discharge current is the sum of all discharge pulse quanties divided by the acquisition time:

$$Adc = \frac{1}{t}\sum_{i=0}^{i=N} Q_i$$

N: Number of Discharges
Q: Actual Discharge Pulse Magnitude
t: Acquisition time

If the system is normalized into nC value, the result is representing a current value in Ampere.

3.6.7 NQN Parameter (NQN)

The NQN stands for Normalised Quantity Number and indicates the partial discharge activity as per IEEE1434. It is calculated based on the pulse height distribution with a normalized magnitude. The result does not have any unit, as it is normalized towards the selected measurement range.

3.6.8 Peak Discharge Parameter (Qp+ and Qp-)

The Qp parameters indicating the highest discharge level during one acquisition period, separated for each polarity.

3.6.9 Mean Discharge Parameter (Qm10+ and Qm10-)

The mean value of each polarity is calculated on the base of the window based pulse height distribution of 10Hz. (Qm10+ & Qm10-)

3.6.10 NQN Parameter (NQN+ and NQN-)

The NQN stands for Normalised Quantity Number and indicates the partial discharge activity as per IEEE1434. It is calculated based on the pulse height distribution with a normalized magnitude separately for each polarity. The result does not have any unit, as it is normalized towards the selected measurement range.

3.7 General parameter handling

The UDL-8000 system is capable to handle 8 Channels with 8 parameters per channel. This gives a total of 64 parameters.

The addressing of the parameters is fixed and depends on the acquisition module, input channel and parameter channel. Refer to the general user manual for a complete addressing information of the UDL-8000 system.

The first 64 channels (0..63) are reserved for the controller, channels 64..127 are for the acquisition module 1, 128..191 for the software module 2 etc.

These channels are called channel ID's and the structure is kept identical for the Modbus RTU interface and for the UDL-DataServer.

In order to identify the location of the specific parameter, simply add the following numbers depending on the software module ID:

- Acquisition module ID 1: 64
- Acquisition module ID 2: 128
- Acquisition module ID 3: 192
- Acquisition module ID 4: 256
- Acquisition module ID 5: 320
- Acquisition module ID 6: 384
- Acquisition module ID 7: 448

3.8 Calculated parameters

Note: Add the offset depending on the Acquisition module ID.

Channels not listed up here are not used.

The First Channel includes the reference voltage values. Channel 2-7 include the PD channel values (depending on the number of channels used). Channel 8 include the values from the gating channel (if used).

For input modules with more than 6 Channels as the M8019-12+/M8019-18+/M8019-24+, multiple acqauisition modules need to be added, and therefore the additional channels become at another location (each acquisition module used up to 64 Channels)

To simplify the description of the parameters, the tables below are based on calculation parameter set 0.

3.8.1 Reference Voltage – CH1

The following parameters are calculated from channel 1

CH ID	Calculation Type	Unit	Remarks
0	Reference Voltage Frequency	Hz	
1	Reference Voltage Peak / SQRT2	V	Value from last measurement
2	Reference Voltage RMS Amplitude CH1	V	
3	Reference Voltage RMS Amplitude CH2	V	
4	Reference Voltage RMS Amplitude CH3	V	
5	Reference Voltage RMS Amplitude CH4	V	
6	Reference Voltage RMS Amplitude CH5	V	
7	Reference Voltage RMS Amplitude CH6	V	

Table 10: Reference Voltage Parameter Table - Channel 1

3.8.2 PD Channel 1/7/13/19 Input – CH2

The following parameters are calculated from PD channel 1

CH ID	Calculation Type	Unit	Remarks
8	PD CH1/7/13/19 - PPS1	V or C	
9	PD CH1/7/13/19 - PPS5	V or C	
10	PD CH1/7/13/19 - PPS10	V or C	
11	PD CH1/7/13/19 - Repetition Rate (R)	Hz	
12	PD CH1/7/13/19 - Peak Discharge (Qp)	V or C	
13	PD CH1/7/13/19 - Apparent Charge	V or C	
14	PD CH1/7/13/19 - Average Discharge Current	V or C	
15	PD CH1/7/13/19 - NQN		

Table 11: PD Channel 1/7/13/19 Parameter Table

3.8.3 PD Channel 2/8/14/20 Input – CH3

The following parameters are calculated from PD channel 2

CH ID	Calculation Type	Unit	Remarks
16	PD CH2/8/14/20 - PPS1	V or C	
17	PD CH2/8/14/20 - PPS5	V or C	
18	PD CH2/8/14/20 - PPS10	V or C	
19	PD CH2/8/14/20 - Repetition Rate (R)	Hz	
20	PD CH2/8/14/20 - Peak Discharge (Qp)	V or C	
21	PD CH2/8/14/20 - Apparent Charge	V or C	
22	PD CH2/8/14/20 - Average Discharge Current	- or A	
23	PD CH2/8/14/20 - NQN		

Table 12: PD Channel 2/8/14/20 Parameter Table

3.8.4 PD Channel 3/9/15/21 Input – CH4

The following parameters are calculated from PD channel 3

CH ID	Calculation Type	Unit	Remarks
24	PD CH3/9/15/21 - PPS1	V or C	
25	PD CH3/9/15/21 - PPS5	V or C	
26	PD CH3/9/15/21 - PPS10	V or C	
27	PD CH3/9/15/21 - Repetition Rate (R)	Hz	
28	PD CH3/9/15/21 - Peak Discharge (Qp)	V or C	
29	PD CH3/9/15/21 - Apparent Charge	V or C	
30	PD CH3/9/15/21 - Average Discharge Current	- or A	
31	PD CH3/9/15/21 - NQN		

Table 13: PD Channel 3/9/15/21 Parameter Table

3.8.5 PD Channel 4/10/16/22 Input – CH5

The following parameters are calculated from PD channel 4

CH ID	Calculation Type	Unit	Remarks
32	PD CH4/10/16/22 - PPS1	V or C	
33	PD CH4/10/16/22 - PPS5	V or C	
34	PD CH4/10/16/22 - PPS10	V or C	
35	PD CH4/10/16/22 - Repetition Rate (R)	Hz	
36	PD CH4/10/16/22 - Peak Discharge (Qp)	V or C	
37	PD CH4/10/16/22 - Apparent Charge	V or C	
38	PD CH4/10/16/22 - Average Discharge Current	- or A	
39	PD CH4/10/16/22 - NQN		

Table 14: PD Channel 4/10/16/22 Parameter Table

3.8.6 PD Channel 5/11/17/23 Input – CH6

The following parameters are calculated from PD channel 5

CH ID	Calculation Type	Unit	Remarks
40	PD CH5/11/17/23 - PPS1	V or C	
41	PD CH5/11/17/23 - PPS5	V or C	
42	PD CH5/11/17/23 - PPS10	V or C	
43	PD CH5/11/17/23 - Repetition Rate (R)	Hz	
44	PD CH5/11/17/23 - Peak Discharge (Qp)	V or C	
45	PD CH5/11/17/23 - Apparent Charge	V or C	
46	PD CH5/11/17/23 - Average Discharge Current	- or A	
47	PD CH5/11/17/23 - NQN		

Table 15: PD Channel 5/11/17/23 Parameter Table

3.8.7 PD Channel 6/12/18/24 Input – CH7

The following parameters are calculated from PD channel 5

CH ID	Calculation Type	Unit	Remarks
48	PD CH6/12/18/24 - PPS1	V or C	
49	PD CH6/12/18/24 - PPS5	V or C	
50	PD CH6/12/18/24 - PPS10	V or C	
51	PD CH6/12/18/24 - Repetition Rate (R)	Hz	
52	PD CH6/12/18/24 - Peak Discharge (Qp)	V or C	
53	PD CH6/12/18/24 - Apparent Charge	V or C	
54	PD CH6/12/18/24 - Average Discharge Current	- or A	
55	PD CH6/12/18/24 - NQN		

Table 16: PD Channel 6/12/18/24 Parameter Table

3.8.8 Gating Channel Input – CH8

The following parameters are calculated from the gating channel

CH ID	Calculation Type	Unit	Remarks
56	Gating Channel - PPS1	V	
57	Gating Channel - PPS5	V	
58	Gating Channel - PPS10	V	
59	Gating Channel - Repetition Rate (R)	Hz	
60	Gating Channel - Peak Discharge (Qp)	V	
61	Gating Channel - Apparent Charge	V	
62	Gating Channel - Average Discharge Current	- or A	
63	Gating Channel - NQN		

Table 17: Gating Parameter Table

4 Hardware & Software Requirements

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The UDL-8000 monitoring system used for the partial discharge monitoring with sequential data acquisition can be equipped with up to 7 hardware modules, providing a system with up to 56 analogue input channels. It must be noted, that whenever input modules with more than 6 input channels are used, additional acquisition modules are required, reducing the number of input modules accordingly.

For the complete monitoring, the following equipment is required for the acquisition:

- 1x UDL-8000 Controller
- 1x Hardware Module M8019-x for PD measurement
- 1x Hardware Module M8019-1 for Noise gating (optional)
- 1x Software Module PD or PD+
- UDL-Configurator Software for the configuration of the system
- UDL-Monitor Software for instant data presentation on a windows computer
- UDL-DAQ Software (optional) for direct data acquisition control of the partial discharge signals (commissioning, temporary measurement)

Depending on the number of required channels, the following M8019 Input Modules are available:

- M8019-3+ 3 PD Input Channels + Ref Channels
- M8019-6+ 6 PD Input Channels + Ref Channels
- M8019-12+ 12 PD Input Channels + Ref Channels
- M8019-18+ 18 PD Input Channels + Ref Channels
- M8019-24+ 24 PD Input Channels + Ref Channels

If more than 24 input channels are required, an additional M8019-x+ input module can be used.

In case multiple devices are monitored with different power frequencies, multiple M8019 input modules are required, as beside the voltage reference from the RF PD Inputs, one 1 external input is available for the entire module.

For automatic long-term trending and data storage, the UDL-DataServer is required. The UDL-DataServer offers continuous data recording simultaneously over multiple devices across an ethernet network (LAN/WAN). All data is stored within an SQL database and are presented on a windows-based application software. Further Details about the functions of the PD monitoring within the UDL-DataClient can be found within the documentation of the UDL-DataServer and UDL-DataClient.

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5 Hardware Module M8019

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5.1 Module Description

For the measurement of the RF partial discharges the Input module M8019 is used. The M8019 Module is available with different number of input channels in order to adapt the system to the customer needs. The Module has the following key features:

- Reference Measurement by each PD input, BNC input, RogowskiCoils, standard voltage input and AC voltage input, selectable by software
- RF Partial discharge input ranges from 15mV to 50V, allowing to measure partial discharges down to about 1mV. The sensitivity in pC depends on the selected PD sensor and the actual noise level.
- Variable High- and Low Pass Filters for the selection of the best signal to noise ratio
- Bipolar PD Pulse measurement (Unipolar PD measurement selectable by software)
- mV or pC Measurement

5.2 Module Overview and Technical Specifications

RF PD Inputs

Function	Description
Input Range	5mV .. 50V
Input Impedance	50 Ohm
Frequency Range	40kHz .. 300MHz
Max Pulse repetition Frequency	50kHz

Reference Input via PD Input

Input Range	5mV .. 50Vrms
Input Impedance	20 kOhm

Reference Input via BNC Connector (REF1)

Input Range 1	10Vrms
Input Range 2	1Vrms (for Rog Coils)
Input Impedance	100kOhm Differential

Reference Input via Terminals (REF2)

Input Range 1	30Vrms
Input Impedance 1	1kOhm differential
Input Range 2	300Vrms
Input Impedance 2	10MOhm, optically insulated

Terminals

Function	Description
Section	0.25 .. 1.5mm2
Max Voltage	250VAC
Max Current	8A

Module

Function	Description
Width	5TE (25.4mm)
Height	4 HU (177.8mm)
Power Consumption	24V, ~250mA

Figure 30: Technical Specifications of the M8019-3+

Alternatively, the M8019 input module is available with more input channels.

M8019-6+: Width 9TE M8019-12+: Width 18TE

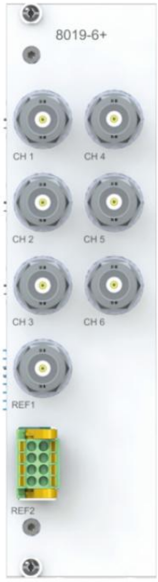

Figure 31: Technical Specifications of the M8019-6+ and M8019-12+

M8019-18+: Width 26TE M8019-24+: Width 24TE

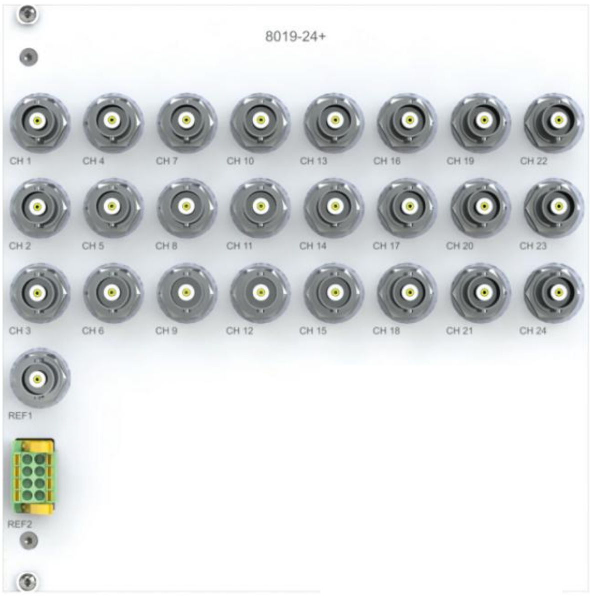

Figure 32: Technical Specifications of the M8019-18+ and M8019-24+

5.3 Module Function Overview

The M8019 includes up to 24 RF partial discharge inputs and 2 different reference inputs for the synchronisation of the partial discharge data acquisition

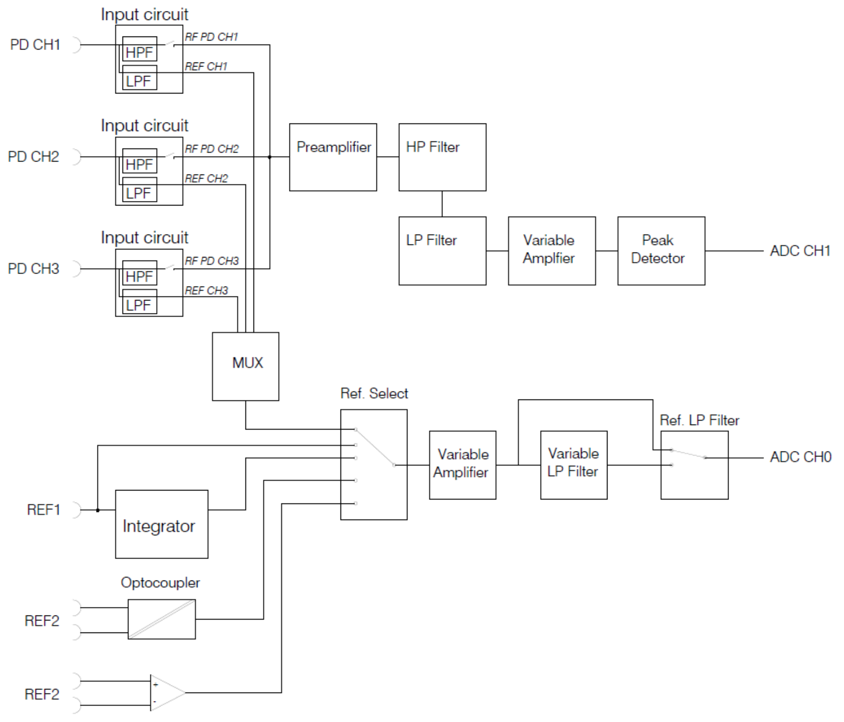

Figure 33: M8019 Operation Principle

5.4 Module Function Details

5.4.1 RF Partial Discharge Input Ranges

Gain Step	With Attenuator (G0.05)	No Attenuator (G1)	With Pregain (G10)	With Pregain & Att. (G0.5)
0: x1	50V	2.5V	0.25V	5V
1: x1.66	30V	1.5V	0.15V	3V
2: x2.5	20V	1.0V	0.1V	2V
3: x3.33	15V	0.75V	0.075V	1.5V
4: x5	10V	0.5V	0.05V	1V
5: x7.5	6.66V	0.33V	0.033V	0.66V
6: x10	5V	0.25V	0.025V	0.5V
7: x16.66	3V	0.15V	0.015V	0.3V

Table 18: Selectable Input Voltage Ranges

5.4.2 RF Partial Discharge Frequency Ranges

The total frequency range of the partial discharge inputs depend on the frequency range provided by the partial discharge sensor and can be further filtered by the M8019 input module.

The following high pass filters can be selected via software

Filter Step	Frequency
0	40kHz
1	100kHz
2	500kHz
3	1MHz
4	2MHz
5	3MHz
6	5MHz
7	10MHz

Table 19: Selectable High Pass Filters

The following low pass filters can be selected via software

Filter Step	Frequency
0	800kHz
1	5MHz
2	10MHz
3	20MHz
4	300MHz

Table 20: Selectable Low Pass Filters

5.4.3 Reference Voltage Ranges

Each reference voltage input range can be extended with an integrated voltage amplifier with the following gain steps:

Gain Step	Gain Value
0	1
1	2
2	5
3	10
4	20
5	50
6	100

Table 21: Voltage reference amplifier gains

For the reference voltage from the coupler, the above gain steps will result into the following input Ranges:

Gain Step	With Attenuator (G0.1)	No Attenuator (G1)	With Pregain (G10)	With Pregain & Att. (G0.5)
0: x1	25V	2.5V	0.25V	5V
1: x2	12.5V	1.25V	0.15V	3V
2: x5	5V	0.5V	0.1V	2V
3: x10	2.5V	0.25V	0.075V	1.5V
4: x20	1.25V	0.125V	0.05V	1V
5: x50	0.5V	0.05V	0.033V	0.66V
6: x100	0.25V	0.025V	0.025V	0.5V

Table 22: Selectable reference voltage ranges for the PD input channels

5.4.4 Reference Voltage Frequency Ranges

The frequency range of the reference voltage input is from 3Hz up to 500Hz. An additional low pass filter can be activated in order to filter unwanted harmonics, as it typically exists on frequency converter driven machines as e.g. gearless mill drives (GMD’s) or VFD Motors:

Filter Step	Frequency
0	12Hz
1	20Hz
2	30Hz
3	40Hz
4	50Hz
5	60Hz
6	100Hz
7	200Hz

Table 23: Selectable Low Pass Filters for the voltage reference

The resulting phase shift due to the filtering is compensated within the acquisition software module.

5.5 Module Terminal Connections

5.5.1 M8019-1+

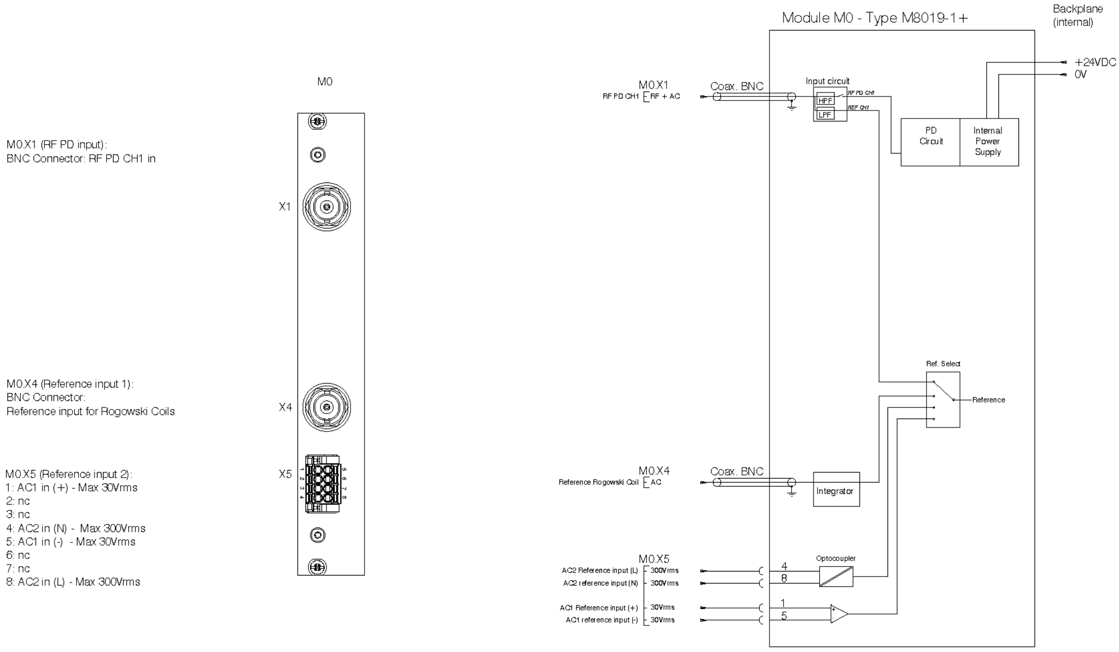

Figure 34: M8019-1+ Terminal Connections

5.5.2 M8019-1

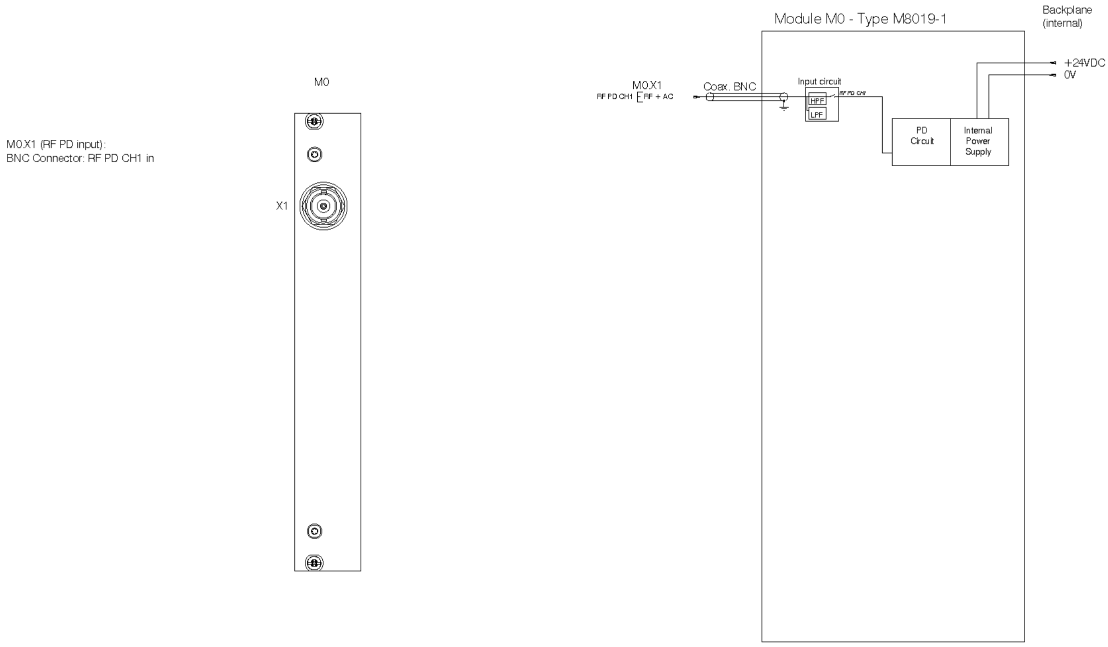

Figure 35: M8019-1 Terminal Connections

5.5.3 M8019-3+

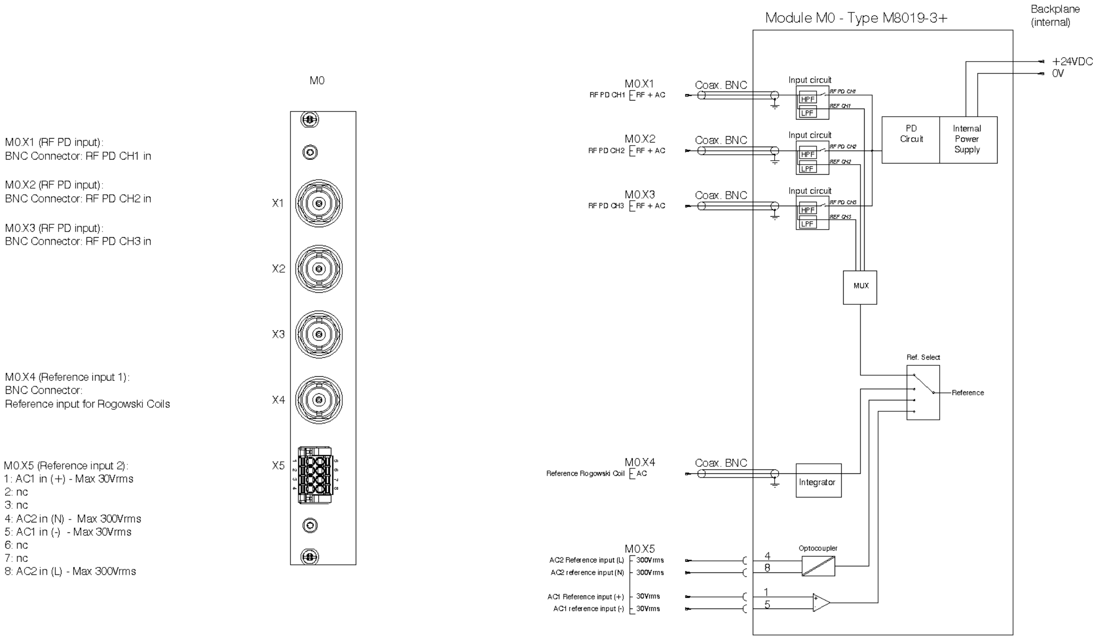

Figure 36: M8019-3+ Terminal Connections

5.5.4 M8019-6+

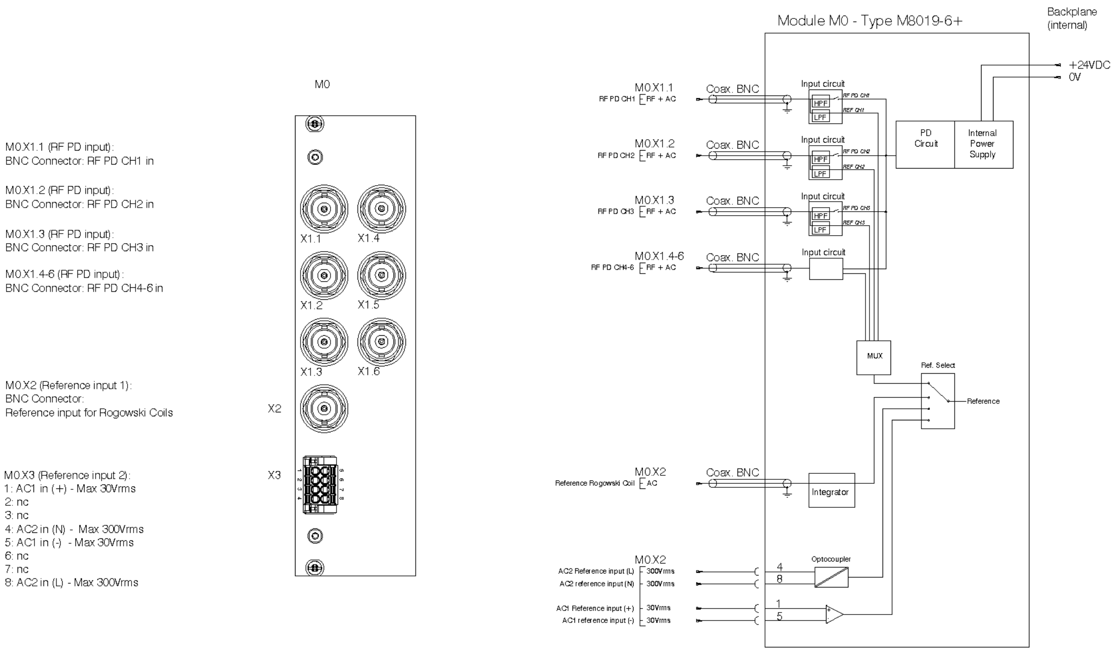

Figure 37: M8019-6+ Terminal Connections

5.5.5 M8019-12+

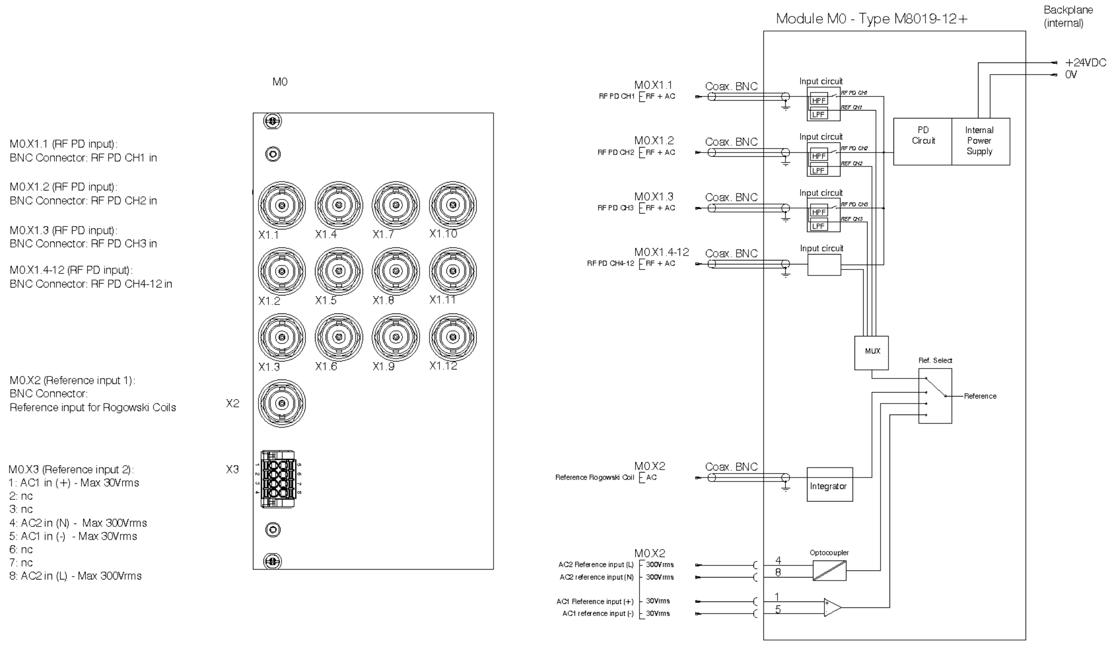

Figure 38: M8019-12+ Terminal Connections

5.5.6 M8019-18+

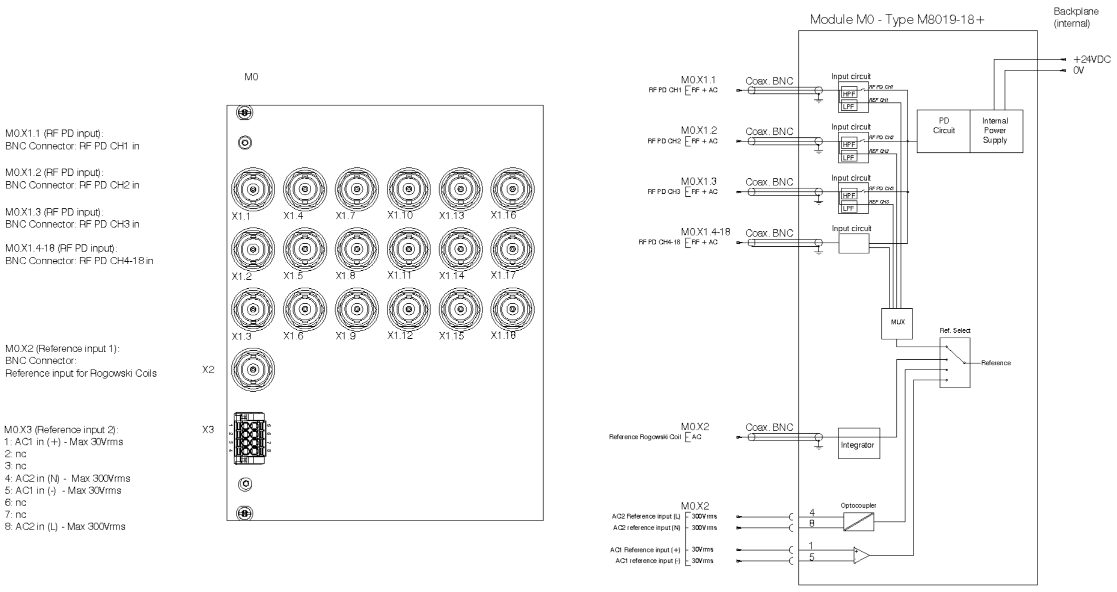

Figure 39: M8019-18+ Terminal Connections

5.5.7 M8019-24+

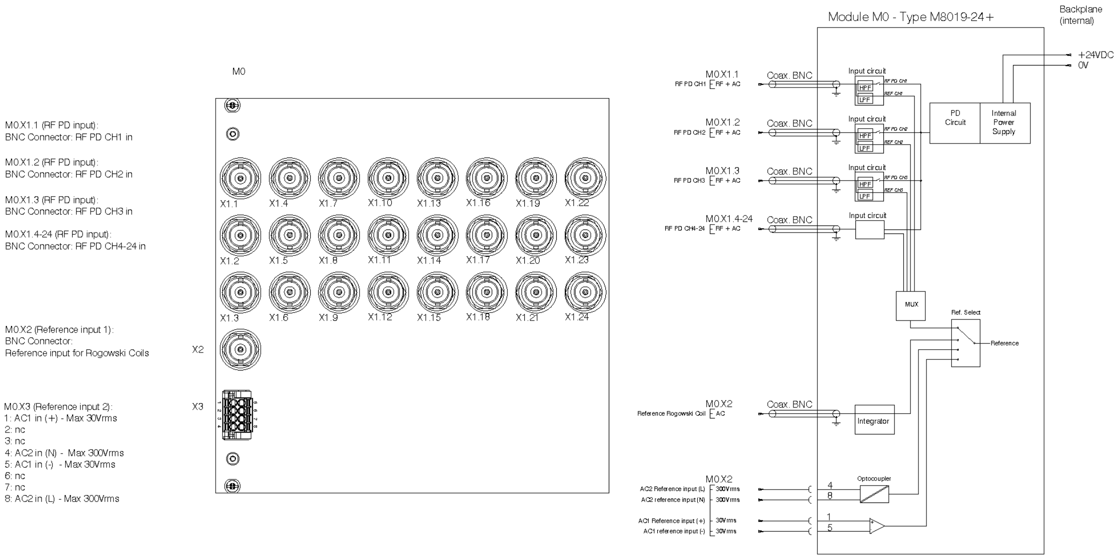

Figure 40: M8019-24+ Terminal Connections

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6 Acquisition Module Configuration

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The main acquisition configuration is supplied by a template which can be loaded under "Acquisition Modules" → "Change" → button "Load" (PD or PD+).

Whenever possible, do not change the advanced acquisition parameter settings, unless it is known what should be done. In any doubts, please contact Sparks Instruments for advice for any changes of the Advanced Acquisition Settings

6.1 Advanced Acquisition Module Configuration

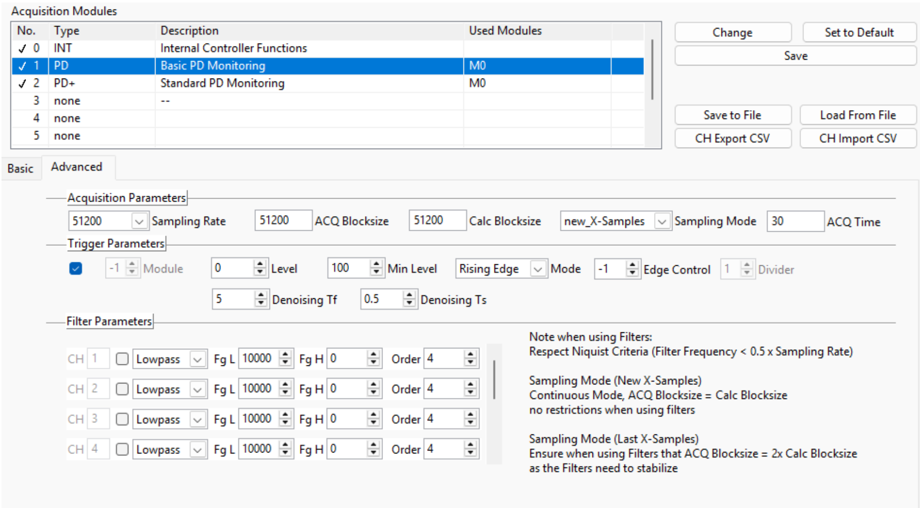

Figure 41: UDL-Configurator – Advanced Acquisition Module Configuration

The above configuration will acquire the input signal with a sampling Rate of 51'200 Samples/second. The calculation is started as soon 51'200 Samples are ready from the Analogue Digital Converter and continues until the acquisition time, defined under the advanced configuration is completed. Using the sampling mode "new X-Samples" will ensure, that the data acquisition is continuously without overlapping or missing samples.

Parameter	Description
Module	Reserved Parameter
Level	The Threshold level for the zero crossing detection, value in "bit" of the ADC, default value = 0
Min Level	The Threshold level for the detection of a reference signal, value in "bit" of the ADC, default value = 100
Mode	Defines the sense of detection of the AC reference voltage which must be set to Rising Edge, representing the crossing from negative to positive cycle
Denoising Tf	Trigger settings are handled by the acquisition module and are not used
Denoising Ts	Trigger settings are handled by the acquisition module and are not used
Filter Parameters	Filter parameters are handled by the acquisition module and are not used

Table 24: Advanced – Acquisition parameters

6.2 Basic Acquisition Module Configuration

Within the basic acquisition module configuration, the main acquisition parameters can be defined.

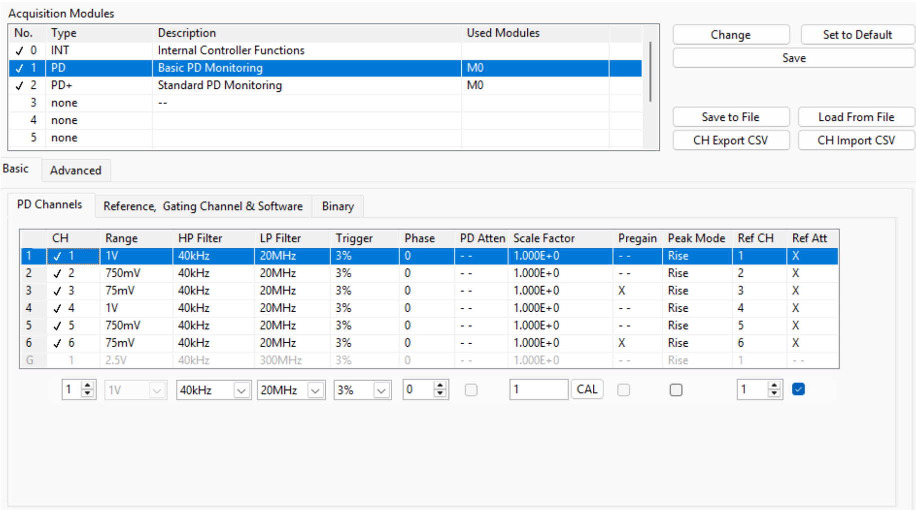

Figure 42: PD/PD+ Module PD Channel parameters

The Basic configuration is separated into 3 parts:

- PD Channel Configuration
- Reference, Gating and Software Configuration
- Binary (Expert Configuration)

6.2.1 PD Channel Configuration

The PD Channel Configuration allows to set the settings for each of the 6 PD Channels the Acquisition module can handle. Select the channel from the table and change the setting below the table accordingly. Once all settings are set, press the button “Save” to save the new configuration to the device.

Parameter	Description
Channel	Define the PD Input Channel to be used under this acquisition module. Double click on the line to activate or deactivate the channel to be used
PD ATT	Activates the RF Input Attenuator with a Gain x 0.05
Ref ATT	Activates the Ref Input Attenuator with a Gain x 0.05
Range	Sets the Gain Step (see table above for detailed information)
Trigger	Sets the Trigger Step
HP Filter	Sets the Filter step for the High Pass Filter
LP Filter	Sets the Filter step for the Low Pass Filter
Phase	Defines the Phase angle between the Reference voltage and the PD Channel. If the Voltage reference is selected from the PD input channel, the phase angle is always 0, and with the RefCH the channel to pick the voltage reference is selected. It is possible to select any PD input channel for reference. If e.g. 2 sets of sensors are used as e.g. coupling capacitors on CH1 and an RF CT on Channel 4 (both sensors are installed at the same phase), the RefCH can be set on channel 4 to 0, means when the PD is measured by the RF CT (CH4), the voltage reference is used from the coupling capacitor 8CH0). For the second pair of sensors, the RefCH for the channel 5 (CT) will be set to 1, taking the reference voltage from the coupler from channel 2 (Phase V) If an external voltage reference is used, e.g. the voltage from the power socked via REF 2 input, or a Rogowski Coil on the REF1 input, the phase shifts bust be

	defined for every input channel individually, for a 3 phase system the phase shift for PD channel 2 will be -120 and for the PD Channel 3 it will be -240.
Ref CH	Defines the PD input channel to be used for Reference. See further details under “Ph”
Scale Factor	Defines the Scaling factor for the mV to nC conversion. The scaling factor can be determined wither by using the UDL-DAQ software, or by performing the normalisation through the configuration software while pressing the “CAL” button. In order to perform the normalisation, connect the PD pulse generator to the test object, use the UDL-Monitor software to visualize the PRPD Pattern and adjust the Range and Filter settings in such way, so that the generated signal is in approx. middle of the scale of the PRPD pattern. Press the button “CAL” – the system will read out the actual PPS5 value of the selected channel and will show all information on the pop-up window (See below) enter the “new Value” and press the button “Calculate” to calculate the new scaling factor. Press the button “OK” to take over the new scaling factor.
Peak Mode	The Peak Mode defines which type of peak signal is used. If unchecked, the first rising edge determines the polarity of the pules, if checked, the highest pulse magnitude (positive or negative) is taken.
Pregain	Activates the Preamplifier of the PD input signal

Table 25: Basic – PD Channel related Parameters

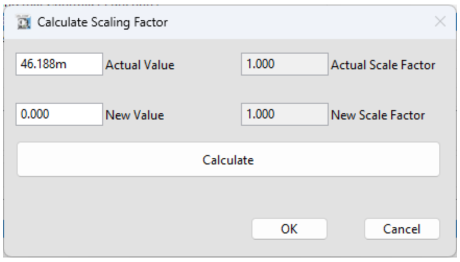

Figure 43: Calculation of new Scaling Factor

6.2.2 Reference, Gating and Software Configuration

Define in this section the parameters related to the voltage reference, the noise suppression (Gating) and some software depending parameters.

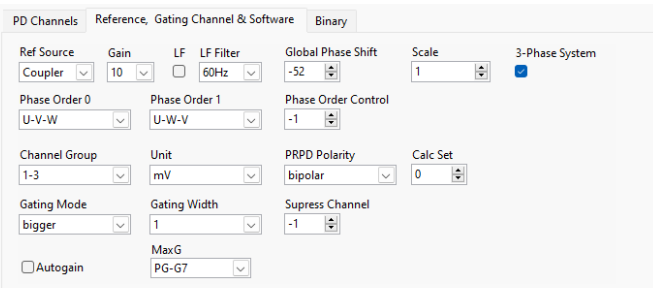

Figure 44: PD/PD+ Module Reference, Gating and Software Configuration

Parameter	**Description**
Ref Source	Defines the voltage reference source to be used for the acquisition *Setting 0* Uses the voltage reference from the coupler *Setting 1* Uses the voltage reference from the BNC input (REF1) *Setting 2*

	Uses the voltage reference from the BNC input (REF1) by using the additional integrator (to be used whenever Rogowski-coils are used) *Setting 3* Uses the voltage input from the REF2 terminal (30V input) *Setting 4* Uses the voltage input from the REF2 terminal (300V input) *Setting 5* Uses the voltage reference from the AC supply (if installed)
Gain	Sets the gain of the selected reference source
LF	Activates the Low Frequency Mode for the voltage reference (activating the Low Pass Filter, typically to be used for GMD measurements)
LF Frequency	Defines the filter step of the low pass filter used on the reference signal
Global Phase Shift	Defines the common phase shift for the selected voltage reference source. The phase sift can be defined in a range of -359 .. +359Deg
Scale	Defines the multiplier for the voltage reference. This is used to indicate the true high voltage value and typically the voltage divider ratio is set here. The scales are typically set by the UDL-DAQ software.
Channel Group	Defines which channels are used within the acquisition modules, valid options are *Setting 1-3* Use this if the M8019-3+ module is used *Setting 1-6* Use this if the M8019-6+ module is used *Setting 7-12* Use this if the M8019-12+ or higher is used, and the channels 7-12 are used, typically on the second acquisition module *Setting 13-18* Use this if the M8019-18+ or higher is used, and the channels 13-18 are used, typically on the third acquisition module *Setting 19-24* Use this if the M8019-24+ is used, and the channels 19-24 are used, typically on the fourth acquisition module
Unit	Define if the system will be used with mV measurement or if the measurement results are normalized to nC. This parameter is only used to place the correct unit (mV or nC). Change the setting, go to “parameter channels” and use the “set to default” function for the specific acquisition module in order to put the correct unit for every parameter channel correctly.
Calc Set	Defines the type of calculation parameters to be used *Setting 0* Param1: PPS1 Param2: PPS5 Param3: PPS10 Param4: Repetition Rate Param5: Peak Discharge Param6: Apparent Charge Param7: Cumulated Apparent Charge Param8: NQN *Setting 1* Param1: Qp+ Param2: Qp- Param3: Qm+ Param4: Qm- Param5: NQN+ Param6: NQN- Param7: not used Param8: not used *Setting 2*… refer to chapter 3.6 for further details
Bip/unip Pattern	If unset, bipolar PRPD Patterns are generated If set, unipolar PRPD Patterns are generated
3-Ph System	Defines if the measurements are taken on a 3 phase system. Channel 1 is referred to Phase U Channel 2 is referred to Phase V

	Channel 3 is referred to Phase W Channel 4 is referred to Phase U Channel 5 is referred to Phase V Channel 6 is referred to Phase W If the 4th channel is used on the neutral point of a rotating machine the PRPD pattern will be assigned with a phase shift aligned to phase U. If the setting is activated, whenever the parameter channels are set to default of the specific acquisition module, the channel names are generated by phase U, V and W, if unchecked, the channel names are defines as CH1, 2, 3 etc.
Gating Mode	Activates the Gating channel (requires an additional M8019-1 input module) *Setting "none"* No Gating is used *Setting "bigger"* Gating is activated, and PD signals are ignored as soon the signal on the gating channel exceeds the Trigger treshold
G-Width	Defines the window width (of the PRPD pattern) of the gating signal
Phase order CH	Defines the channel ID to be used to determine the phase order. This is typcically used on pump storage powerplants where the generator is running on both directions. Typically the MW information is used to determine the phase order. Use the Math function to determine the logic. A logic 0 is typically a phase order of UVW, and a logic 1 can be any other phase order.
Phase Order 0 / 1	Defines the phase order for the specific logic.
Suppress CH	Defines the channel ID of the Supress channel. Whenever the specified channel id is "1", the system ignores any partial discharge results. This can be used, if e.g. the machine has a certain condition while partial discharges cannot be measured, due to high disturbances.
Auto Gain	Mark this to activate the autogain function. If activated the measurement result (PPS1) shall fall into the range between 40 and 90% of the actual measurement range. If under 40%, the gain will be increased in the next measurement, if over 90%, the gain will be decreased. The autogain is working for every channel individually
Max Gain	The max gain defines the maximum gain to be used if the measured level falls below the 40% range. This is especially required, if under very high gains, also the background noise is amplified. The Maximum gain is defined with attenuator, without attenuator and with the internal preamplifier.

Table 26: General Acquisition parameters

6.2.2.1 Binary Module Configuration

The Binary module configuration includes the entire configuration how it is send to the device and is usually only used by configuration experts.

To simplify the description of the above settings, the functions are separated into 2 parts, the RF PD related parameters and the common parameters for the partial discharge acquisition. The example below shows a 3 phase measurement configuration where the voltage reference is taken from an external source and the phase shift is defined for -120° for phase V respectively -240° for phase W. the main Phase shift (see below) is then further used to correct the phase angle between the reference and the phase U.

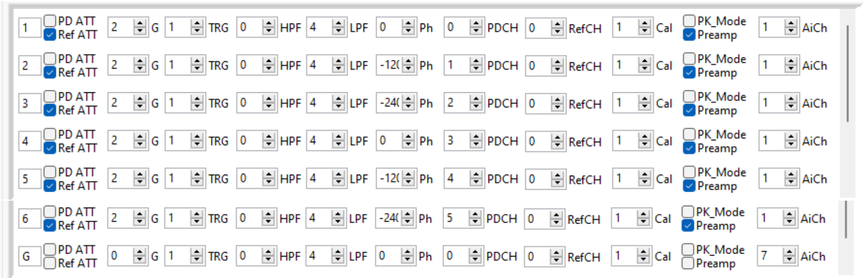

Figure 45: PD/PD+ PD Channel Related parameters

Parameter	Description
Channel No	Is a placeholder and has no effect
PD ATT	Activates the RF Input Attenuator with a Gain x 0.05
Ref ATT	Activates the Ref Input Attenuator with a Gain x 0.05
G	Sets the Gain Step (see table above for detailed information)
TRG	Sets the Trigger Step
HPF	Sets the Filter step for the High Pass Filter
LPF	Sets the Filter step for the Low Pass Filter
Ph	Defines the Phase angle between the Reference voltage and the PD Channel. If the Voltage reference is selected from the PD input channel, the phase angle is always 0, and with the RefCH the channel to pick the voltage reference is selected. It is possible to select any PD input channel for reference. If e.g. 2 sets of sensors are used as e.g. coupling capacitors on CH1 and an RF CT on Channel 4 (both sensors are installed at the same phase), the RefCH can be set on channel 4 to 0, means when the PD is measured by the RF CT (CH4), the voltage reference is used from the coupling capacitor 8CH0). For the second pair of sensors, the RefCH for the channel 5 (CT) will be set to 1, taking the reference voltage from the coupler from channel 2 (Phase V) If an external voltage reference is used, e.g. the voltage from the power socked via REF 2 input, or a Rogowski Coil on the REF1 input, the phase shifts bust be defined for every input channel individually, for a 3 phase system the phase shift for PD channel 2 will be -120 and for the PD Channel 3 it will be -240.
PD CH	Define the PD input channel to the used Software Channel, this is usually set as shown above, unless the signal cables are connected in the wrong order and cannot be changed during commissioning (e.g. while doing the commissioning by remote)
RefCH	Defines the PD input channel to be used for Reference. See further details under “Ph”
Cal	Defines the Scaling factor for the mV to nC conversion. The scaling factor is usually determined by using the UDL-DAQ software.
PK_Mode	The Peak Mode defines which type of peak signal is used. If unchecked, the first rising edge determines the polarity of the pules, if checked, the highest pulse magnitude (positive or negative) is taken.
Preamp	Activates the Preamplifier of the PD input signal
AiCh	Determines the channel of the Analogue / Digital converter to be used. For PD and PD+ it is always 1 for all the PD input channels. Use 7 for the gating channel if installed.

Table 27: Basic – PD Channel related Parameters

The second part of the acquisition module configuration defines the parameters for the acquisition itself.

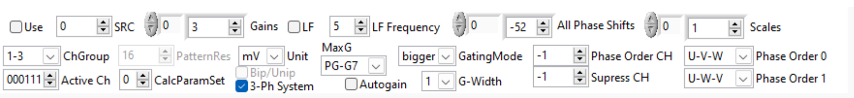

Figure 46: PD/PD+ general acquisition module parameters

Parameter	Description
Use	This parameter is not used
SRC	Defines the voltage reference source to be used for the acquisition *Setting 0* Uses the voltage reference from the coupler *Setting 1* Uses the voltage reference from the BNC input (REF1) *Setting 2* Uses the voltage reference from the BNC input (REF1) by using the additional integrator (to be used whenever Rogowski-coils are used) *Setting 3* Uses the voltage input from the REF2 terminal (30V input) *Setting 4* Uses the voltage input from the REF2 terminal (300V input) *Setting 5* Uses the voltage reference from the AC supply (if installed)
Gains	Sets the gains to be used for each voltage reference input. The first number determines the SRC (0..5) and the second number determines the gain step
LF	Activates the Low Frequency Mode for the voltage reference (activating the Low Pass Filter, typically to be used for GMD measurements)
LF Frequency	Defines the filter step of the low pass filter
All Phase Shifts	Defines the common phase shift for each voltage reference input. The first number determines the SRC (0..5) and the second number determines the phase shift in degrees (-359 .. +359Deg)
Scales	Defines the multiplier for the voltage reference. This is used to indicate the true high voltage value and typically the voltage divider ratio is set here. The scales are typically set by the UDL-DAQ software.
Channel Group	Defines which channels are used within the acquisition modules, valid options are *Setting 1-3* Use this if the M8019-3+ module is used *Setting 1-6* Use this if the M8019-6+ module is used *Setting 7-12* Use this if the M8019-12+ or higher is used, and the channels 7-12 are used, typically on the second acquisition module *Setting 13-18* Use this if the M8019-18+ or higher is used, and the channels 13-18 are used, typically on the third acquisition module *Setting 19-24* Use this if the M8019-24+ is used, and the channels 19-24 are used, typically on the fourth acquisition module
Active Channels	Defines the channels to be used, a binary code from right to left If the M8019-3+ module is used, set it to 000111 If the M9019-6+ module is used, but only 4 channels, set it to 001111 If the M9019-6+ module is used, with all 6 channels, set it to 111111
PatternRes	Defines the resolution of the PRPD Pattern, this parameter is fixed and cannot be changed
Unit	Define if the system will be used with mV measurement or if the measurement results are normalized to nC. This parameter is only used to place the correct unit (mV or nC). Change the setting, go to “parameter channels” and use the “set to default” function for the specific acquisition module in order to put the correct unit for every parameter channel correctly.
CalcParamSet	Defines the type of calculation parameters to be used *Setting 0* Param1: PPS1 Param2: PPS5 Param3: PPS10 Param4: Repetition Rate Param5: Peak Discharge Param6: Apparent Charge Param7: Cumulated Apparent Charge Param8: NQN

	Setting 1 Param1: Qp+ Param2: Qp- Param3: Qm+ Param4: Qm- Param5: NQN+ Param6: NQN- Param7: not used Param8: not used Setting 2 .. refer to chapter 3.6 for further details
Bip/unip Pattern	If unset, bipolar PRPD Patterns are generated If set, unipolar PRPD Patterns are generated
3-Ph System	Defines if the measurements are taken on a 3 phase system. Channel 1 is referred to Phase U Channel 2 is referred to Phase V Channel 3 is referred to Phase W Channel 4 is referred to Phase U Channel 5 is referred to Phase V Channel 6 is referred to Phase W If the 4th channel is used on the neutral point of a rotating machine the PRPD pattern will be assigned with a phase shift aligned to phase U. If the setting is activated, whenever the parameter channels are set to default of the specific acquisition module, the channel names are generated by phase U, V and W, if unchecked, the channel names are defines as CH1, 2, 3 etc.
Gating Mode	Activates the Gating channel (requires an additional M8019-1 input module) *Setting "none"* No Gating is used *Setting "bigger"* Gating is activated, and PD signals are ignored as soon the signal on the gating channel exceeds the Trigger treshold
G-Width	Defines the window width (of the PRPD pattern) of the gating signal
Phase order CH	Defines the channel ID to be used to determine the phase order. This is typcically used on pump storage powerplants where the generator is running on both directions. Typically the MW information is used to determine the phase order. Use the Math function to determine the logic. A logic 0 is typically a phase order of UVW, and a logic 1 can be any other phase order.
Phase Order 0 / 1	Defines the phase order for the specific logic.
Auto Gain	Mark this to activate the autogain function. If activated the measurement result (PPS1) shall fall into the range between 40 and 90% of the actual measurement range. If under 40%, the gain will be increased in the next measurement, if over 90%, the gain will be decreased. The autogain is working for every channel individually
Max Gain	The max gain defines the maximum gain to be used if the measured level falls below the 40% range. This is especially required, if under very high gains, also the background noise is amplified. The Maximum gain is defined with attenuator, without attenuator and with the internal preamplifier.

Table 28: General Acquisition parameters

6.2.2.2 Example- 12 Channel Configuration

The following example demonstrates the configuration used for an installation with 12 coupling capacitors, where 4 coupling capacitors are installed per phase. The channels are then assigned as follows:

Channel	Description
1	Part Phase U-1
2	Part Phase V-1
3	Part Phase W-1
4	Part Phase U-2
5	Part Phase V-2
6	Part Phase W-2
7	Part Phase U-3
8	Part Phase V-3
9	Part Phase W-3
10	Part Phase U-4
11	Part Phase V-4
12	Part Phase W-4

Table 29: Channel and phase assignment using M8019-12+

In the next step, 2 acquisition modules are configured, both using the same hardware modules, while the first acquisition module is configured for “ChGroup” 1-6 and the second acquisition module is set for “ChGroup” 7-12.

The actual configuration is also defined in such way, that the voltage reference is taken from each individual coupler, assuming that every coupling capacitor is providing a sufficient high voltage level.

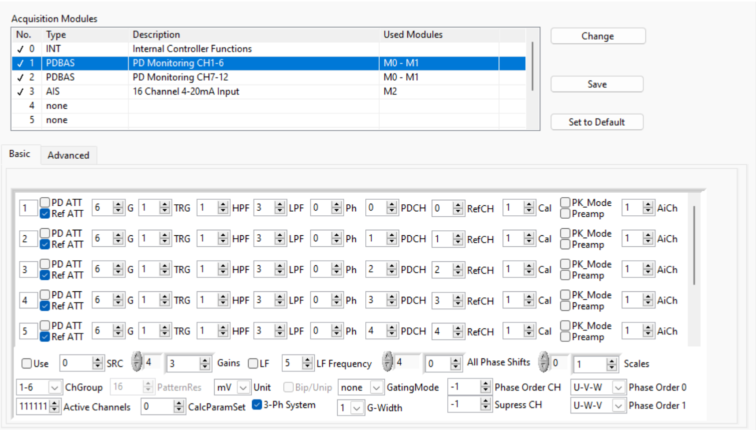

Figure 47: ACQ Module 1 - Channel 1-6 configuration

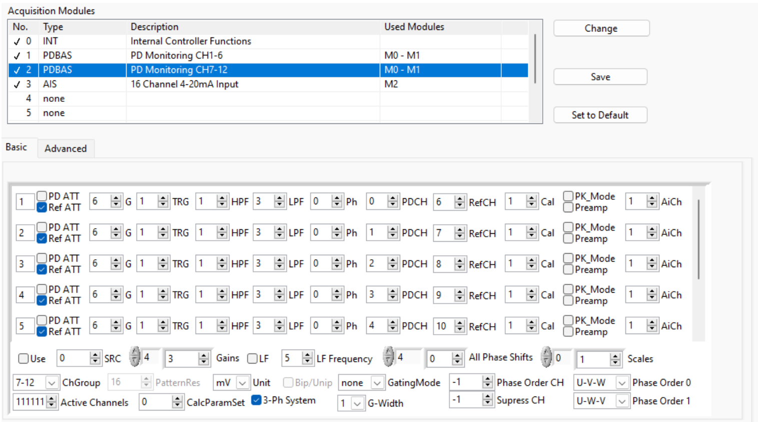

Figure 48: ACQ Module 2 - Channel 7-12 configuration

6.2.2.3 Example- 12 Channel Configuration for 4 units

While generally one device is used per machine, under certain requirements, multiple machines can be monitored with one multichannel device. In order to simplify the data handling, it is recommended to use one acquisition module for each test object.

Such a configuration will lead to the following configuration

Channel	Acquisition Module	Resulting Channel ID PPS5	Description
1	ACQ-1	73	Motor #1 - Phase U
2	ACQ-1	81	Motor #1 - Phase V
3	ACQ-1	89	Motor #1 - Phase W
4	ACQ-2	137	Motor #2 - Phase U
5	ACQ-2	145	Motor #2 - Phase V
6	ACQ-2	153	Motor #2 - Phase W
7	ACQ-3	201	Motor #3 - Phase U
8	ACQ-3	209	Motor #3 - Phase V
9	ACQ-3	217	Motor #3 - Phase W
10	ACQ-4	265	Motor #4 - Phase U
11	ACQ-4	273	Motor #4 - Phase V
12	ACQ-4	281	Motor #4 - Phase W

Table 30: Multi-Object Channel and phase assignment using M8019-12+

Each acquisition module is configured for 3 channels, and only the first 3 channels must be configured on each ACQ module.

The PD Channel and Reference Channel needs then adjusted for each module as shown on the below tables. On the configuration, the channels are indicated as index, starting with 0. Use for the first acquisition module ACQ-1, the channels 0..2 for the PDCH and the RefCH.

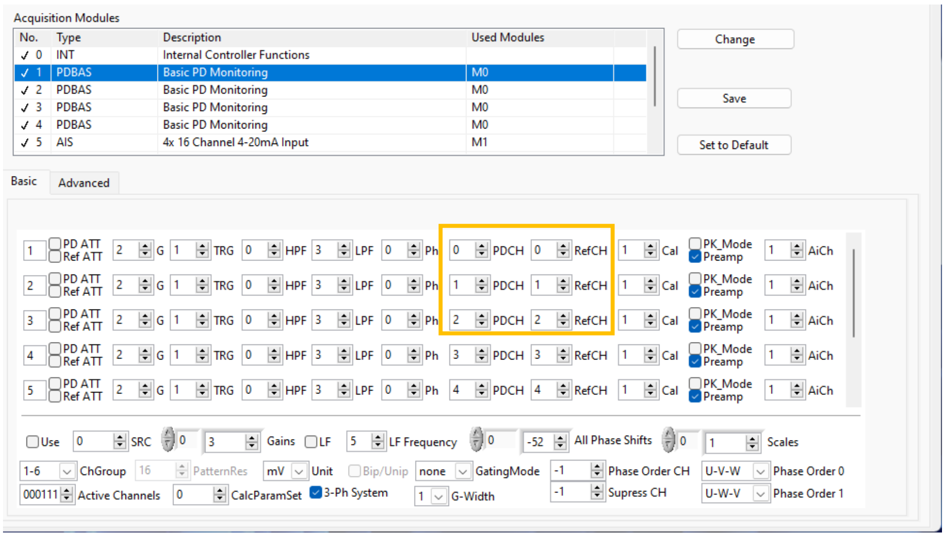

Figure 49: ACQ Module 1 - Channel 1-3 configuration

Use for the second acquisition module ACQ-2, the channels 3-5 for the PDCH and the RefCH.

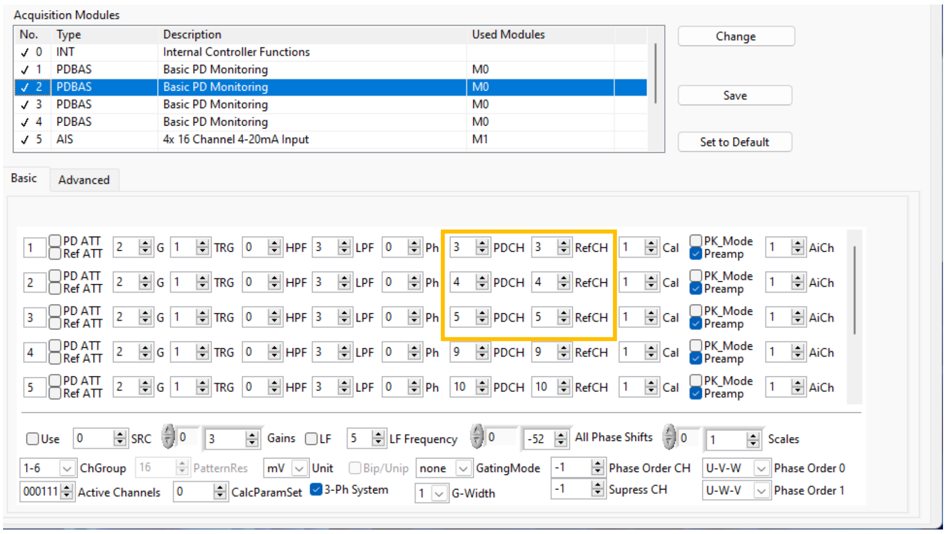

Figure 50: ACQ Module 2 - Channel 4-6 configuration

Use for the third acquisition module ACQ-3, the channels 6-8 for the PDCH and the RefCH.

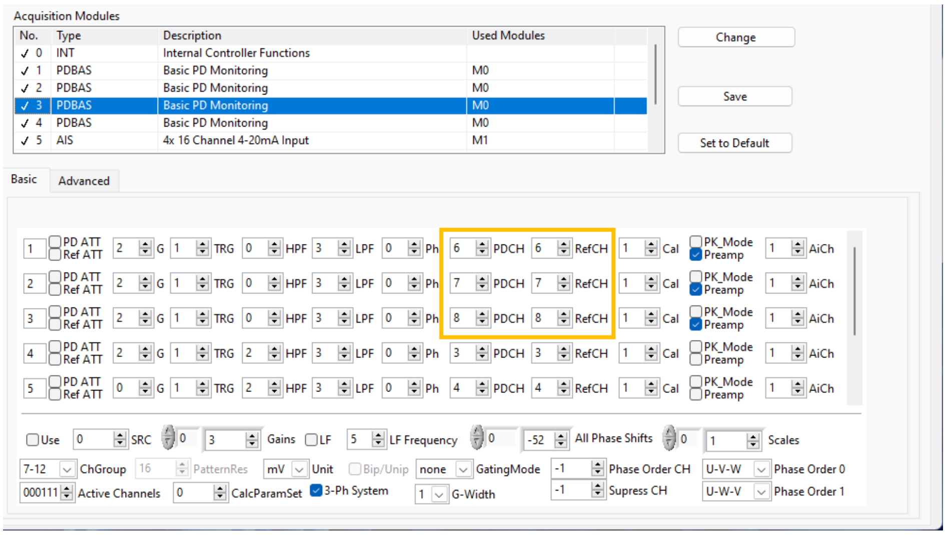

Figure 51: ACQ Module 3 - Channel 7-9 configuration

Use for the second acquisition module ACQ-4, the channels 9-11 for the PDCH and the RefCH.

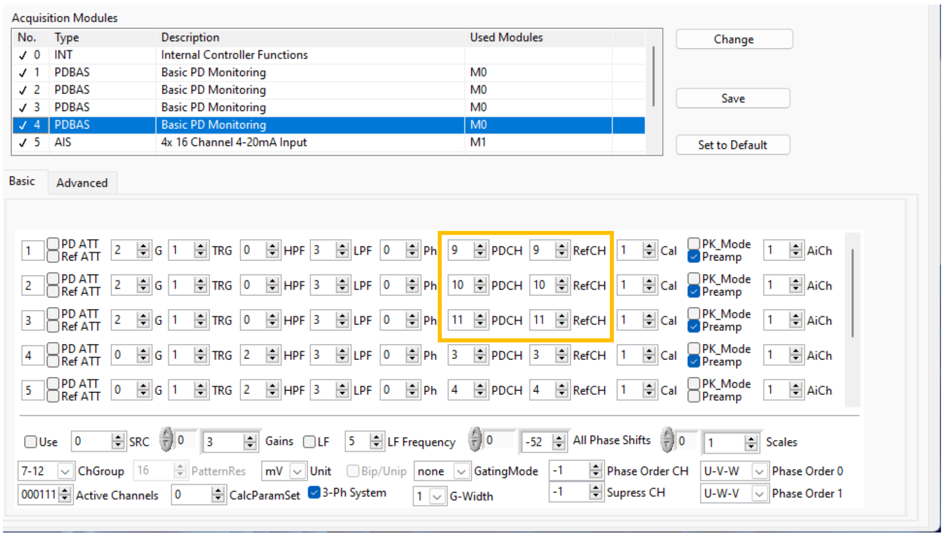

Figure 52: ACQ Module 1 - Channel 10-12 configuration

6.3 Alarm Configuration

By default, the PPS5 parameters are activated for alarming, and a default value is defined as a place holder. After commissioning of the system, the alarm threshold must be defined based on the configured measurement range.

It is important to know that in case the alarm threshold is set higher than the measurement range, the system will never be able to set an alarm state.

CH ID	Calculation Type	Alarm Mode	Threshold AL1 low lvl	Delayed	Threshold AL2 low lvl	Delayed
9	PPS5 PD Channel 1	above	500mV	Yes, 500s	800mV	Yes, 500s
17	PPS5 PD Channel 2	above	500mV	Yes, 500s	800mV	Yes, 500s
25	PPS5 PD Channel 3	above	500mV	Yes, 500s	800mV	Yes, 500s
33	PPS5 PD Channel 4	above	500mV	Yes, 500s	800mV	Yes, 500s
41	PPS5 PD Channel 5	above	500mV	Yes, 500s	800mV	Yes, 500s
49	PPS5 PD Channel 6	above	500mV	Yes, 500s	800mV	Yes, 500s

Table 31: Default Alarm Configurations

Notes on Alarm thresholds: For many test objects, no direct alarm thresholds are given by international standards and the values need to be defined during commissioning. on rotating machines, the IEC standard recommends to set an alarm level of 2x the magnitude defined during the commissioning. By default, the alarm levels are set to the mV values, and must be adapted to pC values in case the system is normalized.

Notes on Delays: it is recommended to set a delay of at least 2 consecutive measurements, which depends on the number of channels used. If 6 channels are measured, and each channel is acquired by 30 seconds, one full measurement cycle will take 3minutes or 180 seconds plus some few seconds for the calculation and channel change. 2 full cycnles will therefore take at least 400 seconds, therefore an alarm delay of 500s is a good value if all 6 channels are used. If more channels are used, then the alarm delay must be adapted accordingly. By default the delays are deactivated, in order to be able to perform testing during commissioning. once the system is commissioned, the alarm delays shall be activated.

6.4 4-20mA Output Configuration

Generally, for the analogue outputs the PPS5 / Qr5 Values are used. Depending on the customer requirements, other channels as NQN or Qp values might be requested to provide via analogue outputs.

As the partial discharge measurement does have multiple measurement ranges, defined via gain, attenuator and pregain, the maximum range of the 4-20mA output must be defined once the system is commissioned.

The output value is typically set as 4mA = 0 and 20mA = Max Scale.

Important note: whenever the measurement range is changed, the max scale shall be adapted to the new resulting value. It also must be noted, that max scale needs to be adapted whenever the system is normalized (using pC values instead of mV values) and the 4-20mA range must be adapted to the new pC value.

6.5 MIMIC Visualization Configuration

Use one of the templates representing the machine and it is recommended to use the following channels when using 3 input channels

CH ID	Calculation Type	Si Notation	Digits
2	Reference Amplitude	yes	1
9	PPS5 PD Channel 1	yes	1
17	PPS5 PD Channel 2	yes	1
25	PPS5 PD Channel 3	yes	1
8	PPS1 PD Channel 1	yes	1
16	PPS1 PD Channel 2	yes	1
24	PPS1 PD Channel 3	yes	1

Table 32: Default Mimic Channels for 3 Channel measurement

Whenever 6 PD Channels are used, it is suggested to use only the PPS5 Values on the mimic, by using the following channels.

CH ID	Calculation Type	Si Notation	Digits
2	Reference Amplitude	yes	1
9	PPS5 PD Channel 1	yes	1
17	PPS5 PD Channel 2	yes	1
25	PPS5 PD Channel 3	yes	1
33	PPS5 PD Channel 4	yes	1
41	PPS5 PD Channel 5	yes	1
49	PPS5 PD Channel 6	yes	1

Table 33: Default Mimic Channels for 6 Channel measurement

Depending on the customer requirements and project specifications, other parameter channels might be required to show on the mimic. It is also possible to add an additional mimic with other parameters for the same acquisition module.

6.5.1 Local Visualization Mimic example

As the visualization is fully customizable, the graphics below show an example of a possible visualization layout:

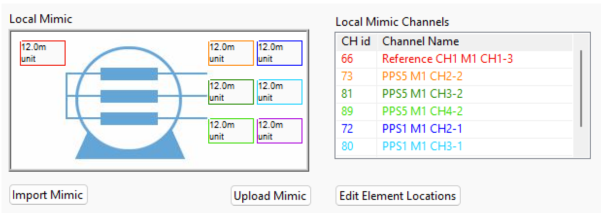

Figure 53: PD Example of a local visualisation mimic

6.5.2 External Visualization Mimic example

A similar visualization layout can be used to present the mimic within the UDL-Monitoring Software.

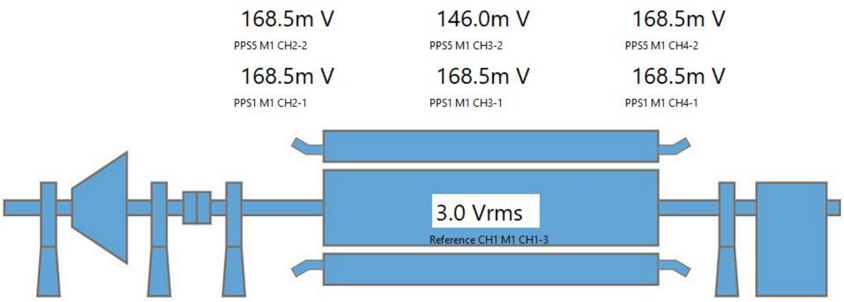

Figure 54: PD Example of an external visualisation mimic for turbo generators

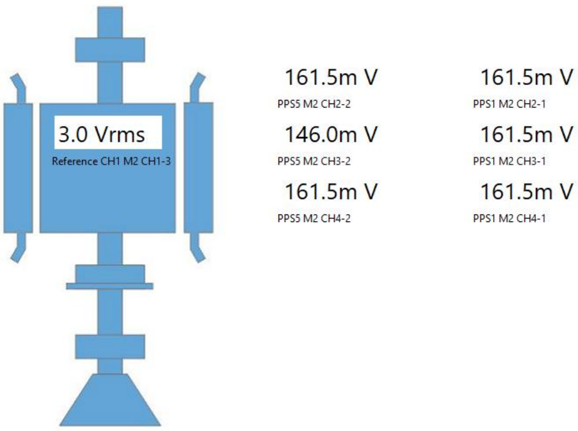

Figure 55: PD Example of an external visualisation mimic for Hydro generators

6.6 Data Recording

In order to avoid excessive data recording which will occupy a lot of disk space, it is recommended to use the following recording options.

6.6.1 Data Recording based on alarm

It shall be evaluated, if in case of an alarm other acquisition parameters should also be recorded. Add the specific acquisition modules to the defined recording.

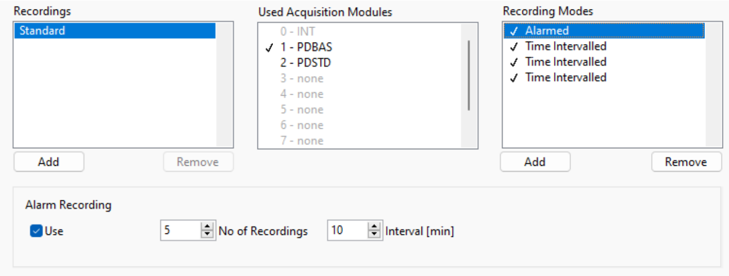

Figure 56: Typical recording configuration for alarm-based recording

Whenever an alarm of the specific acquisition module is active, 5 recordings with an interval of 10minutes are saved. The counter for the number of recordings is restarted once all of the recorded data are saved.

6.6.2 Data Recording based on time interval

In in order to avoid a lot of recordings of the same data, a the time interval recording shall be used. The time intervalled recording will save the data with the highest magnitude over the defined time interval.

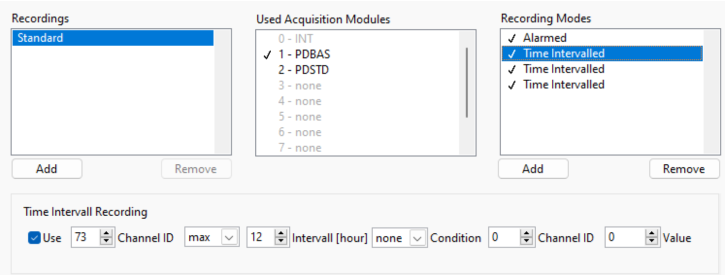

Figure 57: Typical recording configuration for time interval-based recording

Parameter	Description
Channel ID	Define the channel id of the parameter to be used for the maximum magnitude definition.
Max/min	Define the “memory mode” of the interval. Data are memorized if a new parameter value is larger (max) or smaller (min) of the previous data
Intervall [hour]	Define the time interval the data shall be saved, use 24h by default, or shorten the time if the machine is not running all day.
Condition	Define, if the data shall be acquired only while a parameter condition is met, e.g. record data if the machine runs at a minimum active power.
Channel ID	Define the channel id of the condition parameter
Value	Define the threshold of the condition parameter

Table 34: Basic – time interval-based recording.

In the above example, the channel 73 (PPS5 Value of PD Channel1) is used to determine the highest PD magnitude. At every recording, the entire data of the acquisition module is saved, and in order to check the activity of the other channels, a time interval recording must be added for every present pd channel.

Add a “Time intervalled” recording mode for every used channel, and as suggested use the PPS5 values paramaters.

For a 12 channel pd system, the configuration will include 12 “Time Intervalled” recording mode, using PPS5 parameters, for a standard configuration, that will be:

Recording Mode	Description
Time Intervalled #1	ACQ Module 1, PPS 5 Phase U, CH id 73*
Time Intervalled #2	ACQ Module 1, PPS 5 Phase V, CH id 81*
Time Intervalled #3	ACQ Module 1, PPS 5 Phase W, CH id 89*
Time Intervalled #4	ACQ Module 1, PPS 5 Phase U, CH id 97*
Time Intervalled #5	ACQ Module 1, PPS 5 Phase V, CH id 105*
Time Intervalled #6	ACQ Module 1, PPS 5 Phase W, CH id 113*
Time Intervalled #7	ACQ Module 2, PPS 5 Phase U, CH id 137*
Time Intervalled #8	ACQ Module 2, PPS 5 Phase V, CH id 145*
Time Intervalled #9	ACQ Module 2, PPS 5 Phase W, CH id 153*
Time Intervalled #10	ACQ Module 2, PPS 5 Phase U, CH id 161*
Time Intervalled #11	ACQ Module 2, PPS 5 Phase V, CH id 169*
Time Intervalled #12	ACQ Module 2, PPS 5 Phase W, CH id 177*

Table 35: Channel and phase assignment using M8019-12+

* check the correct channel id under “parameter channels”

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7 Acquisition Module Data Presentation

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7.1 Common

The data presentation is the same for the UDL-Monitor and the UDL-DAQ software. While the UDL-Monitoring software can only visualize the data (the system configuration is done via the UDL-Configurator Software) the UDL-DAQ Software offers additionally ful remote control of the hardware settings. Generally the UDL-DAQ Software is used whenever the system is used as a “portable device” in order to perform sporadic measurements. The UDL-DAQ software can alternatively also be used for customers who don’t want a continuous recording – only event based (e.g. alarm). While the data is downloaded with the UDL-FileManager Software, the UDL-DAQ software is used to visualize the individual measurement files.

The measured partial discharge data is updated once the complete acquisition module is finished, and the update rate depends on the number of used channels and the defined acquisition time. This is typically about 1.5 minutes for a 3 channel PD system, and 3 minutes for a 6 channel pd system.

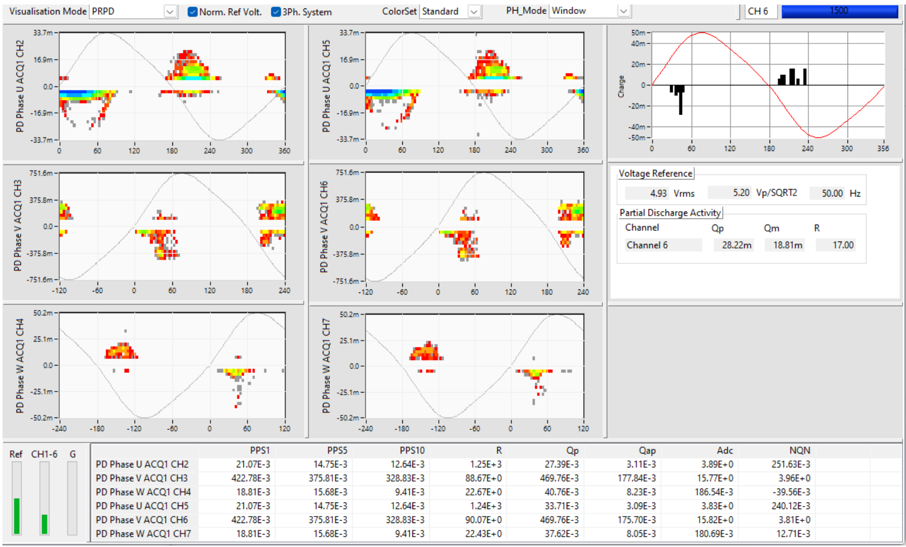

Figure 58: PD Acquisition Module Data Presentation - PRPD

At the top of the window, it is possible to switch between the PRPD pattern visualisation or the pulse height distribution.

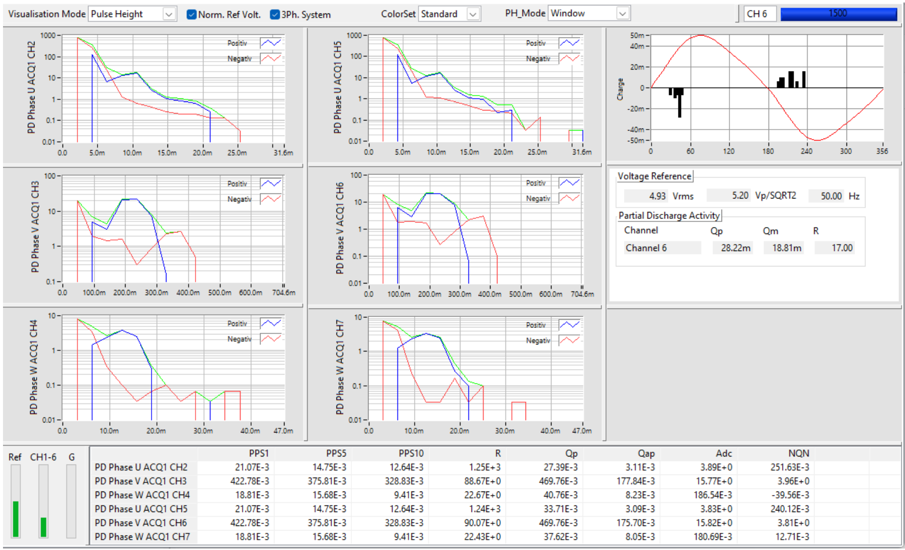

Figure 59: PD Acquisition Module Data Presentation – Pulse Height

The checkbox “show as 3 Phase system” will arrange the PRPD pattern with a 120° shift in order to better analyse the specific partial discharge data.

At the top right side, the actual measured partial discharge data is shown. The actual measured channel and progress of the data acquisition is shown at the top right of the window. Whenever multiple acquisition modules are used, the realtime partial discharge visualisation might not be updated, indicating that actually another acquisition module is processed.

In the right middle of the window, the actual Realtime values are presented.

At the bottom of the window, all key values are shown, and is adapted depending on the calculation parameter set defined under the acquisition module configuration.

The same data is also presented when using the PD+ acquisition module, except that the data is presented with a much higher data resolution, offering further analysis of the partial discharge activity.

For the different pulse height distribution graphs, choose between “Window” and cumulated.

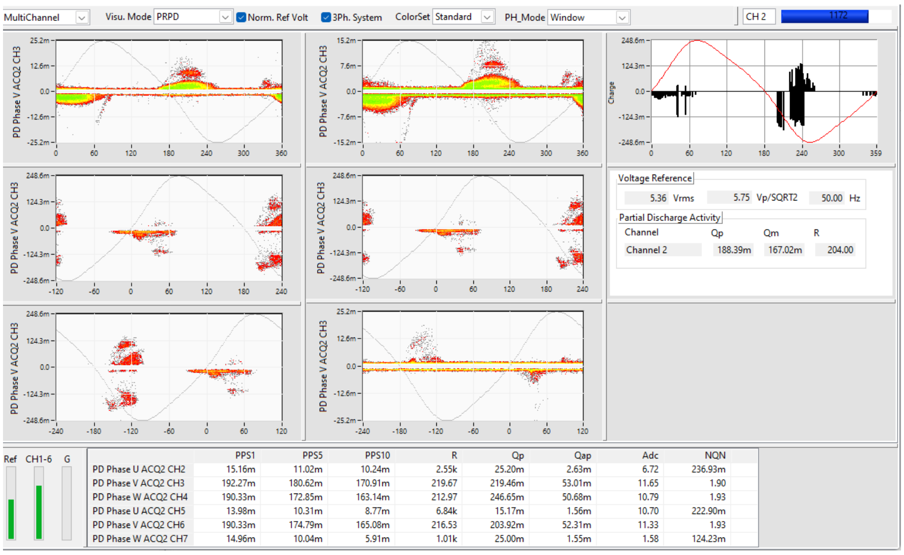

Figure 60: PD+ Acquisition Module Data Presentation – PRPD

7.2 UDL-Monitor Software

The UDL-Monitor software is used to visualize the realtime results if the UDL-8000 is used as a standalone system with trending function only.

Whenever settings must be changed, the UDL-Configurator software shall be used, use the UDL-Monitoring software to visualize the data in order to verify if the partial discharge measurement settings are set correctly.

It is possible to use the UDL-Monitor software and the UDL-Configurator simultaneously.

7.2.1 Normalization / Calibration

Preliminary information:

The system is calibrated for mV measurements as factory default. Ensure before starting with the normalization procedure, that the systems configuration is changed to pC/nC measurements within the UDL-Configurator software. A change between mV and nC Range will automatically reconfigure the entire system for the correct measurement unit and will also automatically change the alarm thresholds to the specific range.

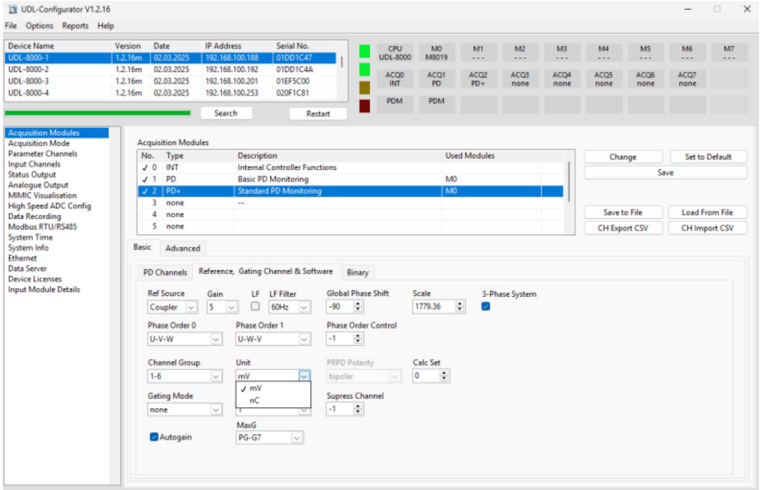

Figure 61: UDL-Configurator – change of measurement unit.

Before starting with the normalization process, ensure that the filter settings are set to the frequency range the system is used. This is can depend on the application and/or the test object the system is used.

For online partial discharge measurements on rotating machines, it is generally recommended to perform the measurements between 0.5MHz and 20MHz, while for offline Measurements, typically 40kHz to 800kHz is used. small changes in the frequency range do generally not much impact the normalization results, but it shall be understood that large differences can be expected if e.g. the system is normalized under 40kHz .. 800kHz and final measurements are performed from 0.5MHz .. 20MHz.

Use the UDL-Configurator to set the initial filter settings

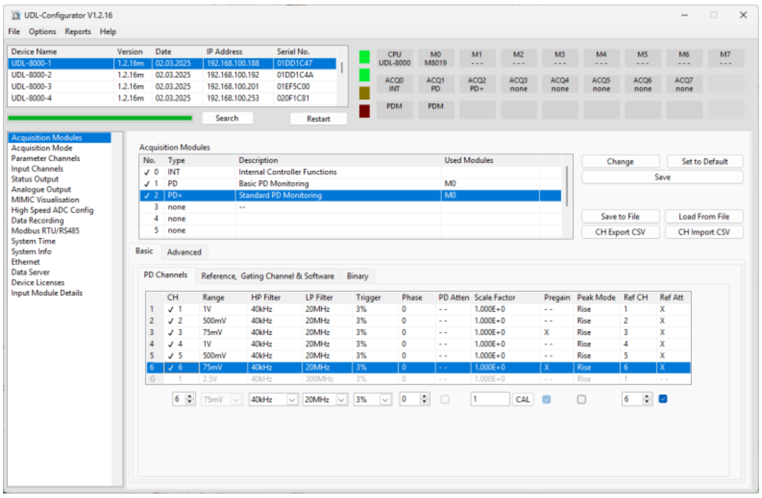

Figure 62: UDL-Configurator – change of initial frequency range

Whenever normalization is performed ensure that the test object is not grounded, or if it is mandatory to ground the test object due to personal safety reasons, that the grounding location is at least 5m away from the object and the coupling capacitors.

Once the filters are defined, connect the pd pulse generator as close as possible to the test object. There is no need for a voltage reference signal, as if no voltage reference signal is present, the system will self-trigger the acquisition to a frequency of 51.2Hz. Choose a normalization value on the PD pulse generator to the level the partial discharges are expected, this is for cables and other low PD level objects to 100 or 500pC, while for rotating machines it is recommended to use 5nC.

Start the UDL-Monitor software, connect to the system and use the DAQ visualization to show the results from the pulse generator-

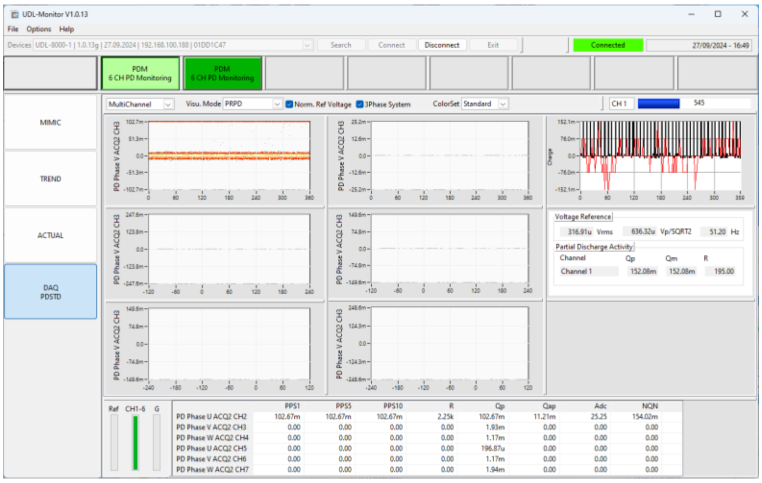

Figure 63: UDL-Monitor Software with PD Pulse generator Results – over ranged

In the illustration above the show results of the PD pulse generator are clearly overranged, this can be seen on the oscilloscope view, that the pulses are reaching the maximum scale, as well as on the PRPD pattern as the results are shown on the maximum scale. Adapt the measurement range by using the UDL-Configurator and changing the Range, PD Attenuator, Pregain in such way, that the PD pulses will be in the middle of the measurement range.

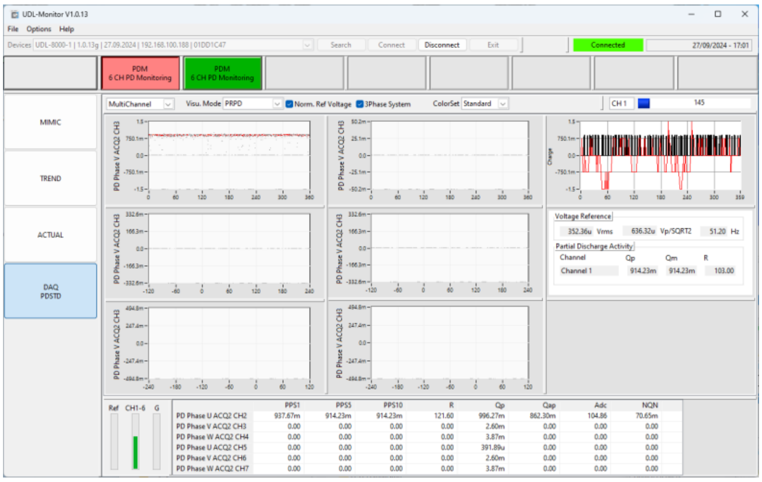

Figure 64: UDL-Monitor Software with PD Pulse generator Results

Wait until the for measurement cycle is completed and the PRPD results are updated. Keep in memory the PPS5 value of the corresponding channel. Switch back to the UDL-Configurator, select the corresponding channel and press the “Cal” button.

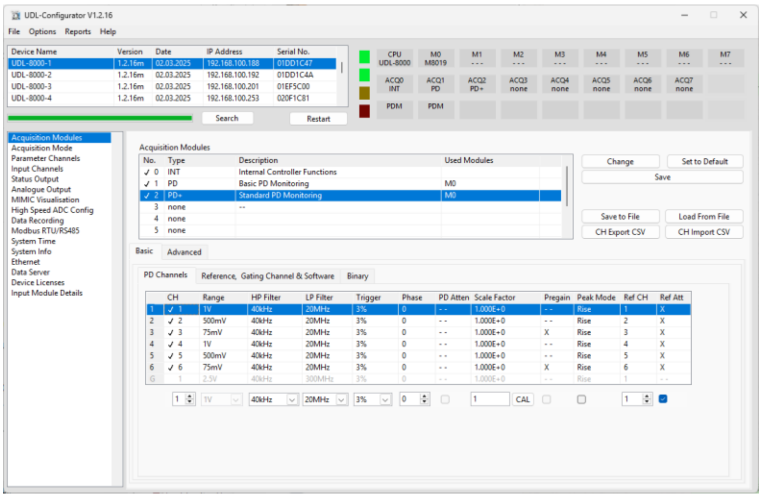

Figure 65: UDL-Configurator

After pressing the “Cal” button, a window will open to calculate the scaling factor.

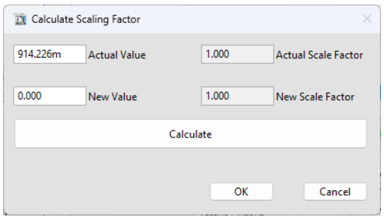

Figure 66: UDL-Configurator – Calculating the scale factor

The actual PPS5 value of the corresponding channel is read from the memory of the device. Compare the results indicated under “Actual Value” with the result shown on the UDL-Monitor software. Enter under “New Value” the charge magnitude set on the PD pulse generator and press the “Calculate” button. In the example below it is set to 5nC.

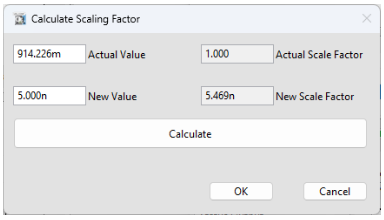

Figure 67: UDL-Configurator – with new Scale Factor

Press the button “OK” to take over the new scaling factor.

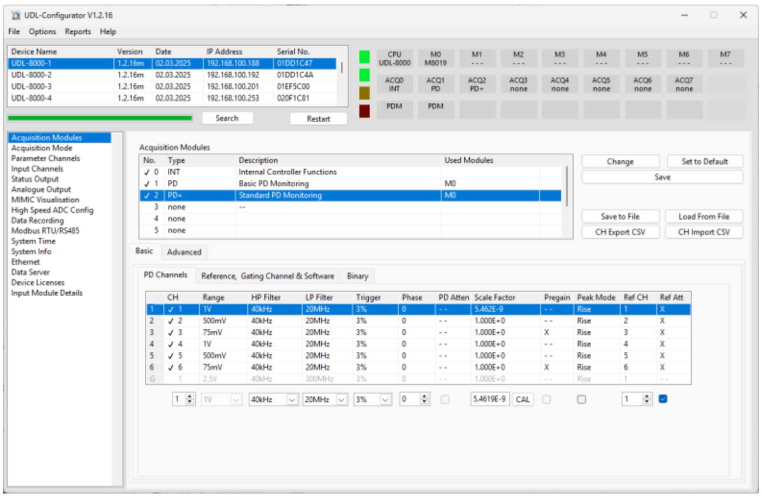

Figure 68: UDL-Configurator with new scaling factor

Repeat the previous steps for every channel and press the button “Save” to store the new channel settings including the new Scaling factors. Wait until the full measurement cycle is completed and verify the scales within the UDL-monitor software.

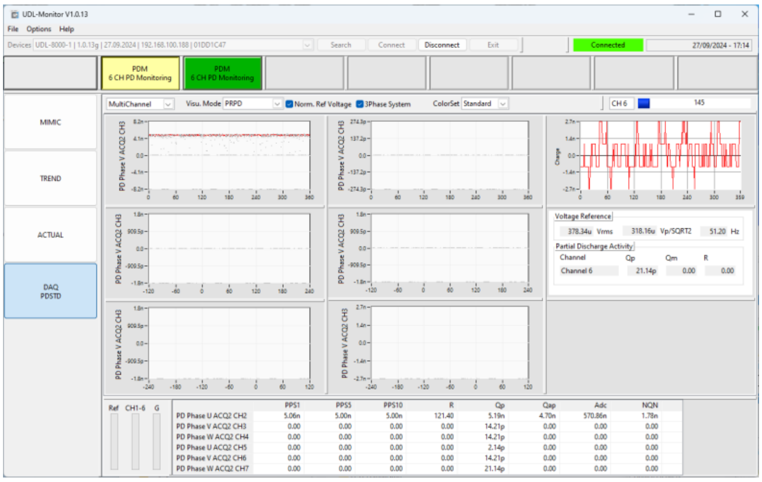

Figure 69: UDL-Monitor software with all channels normalized.

7.3 UDL-DAQ Software

In order to use the UDL-DAQ software, the license of the recording module must be installed. For systems without the recording function activated, only the UDL-Monitor software can be used.

If the system is purchased in the maximum configuration including the database server, the UDL-DAQ software license is included and the software can be used for the commissioning.

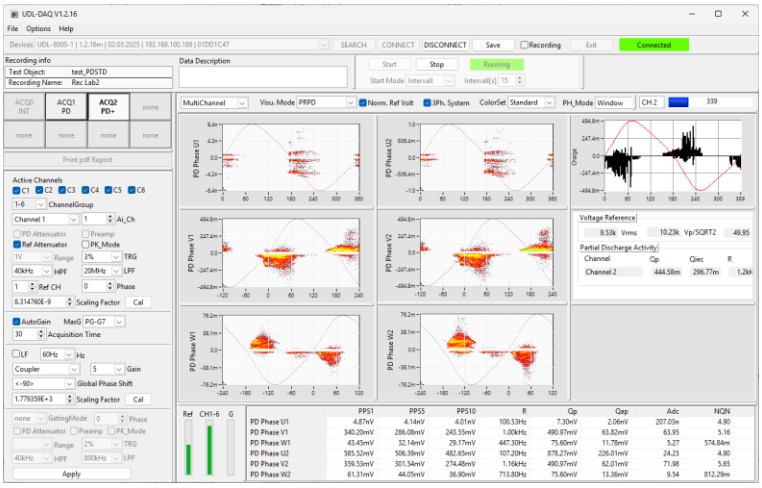

Figure 70: PD+ Acquisition Module Configuration with UDL-DAQ Software

Each shown parameter is also available within the configuration software, and the details of each parameter is described in the previous chapter of this manual.

The UDL-DAQ Software allows to visualize the measurement results and to change the PD Channel settings simultaneously, which is typically used for temporary measurements using the UDL-8000 as a portable device. If the UDL-8000 is used in its maximum configuration (e.g. together with the Database Server) the UDL-DAQ software is included and can be used also for the commissioning, which simplifies a bit the initial measurements compared when using the UDL-Configurator and the UDL-monitoring software.

When using the UDL-DAQ Software in combination with the PD+ module, it is also possible to visualize only the first PD Channel, which is typically used, whenever the system is used for offline partial discharge measurement with only 1 HV source (Single phase Measurement). By changing at the top right from “Multichannel” to “Single channel”, only the first channel is visualized.

It must be noted, that if the system is used for such application, that only the first channel is activated.

At the top left the real-time oscilloscope view is presented and the top right the PRPD pattern.

At the bottom left the real time results are shown, representing the intermediate measurement results within 1 second acquisition blocks.

At the bottom right a small trend graph is shown, indicating the Volatge level and PD level within the PDPD acquisition time (typically 30 Seconds)

At the very bottom of the window, the final results of the PD measurement is shown.

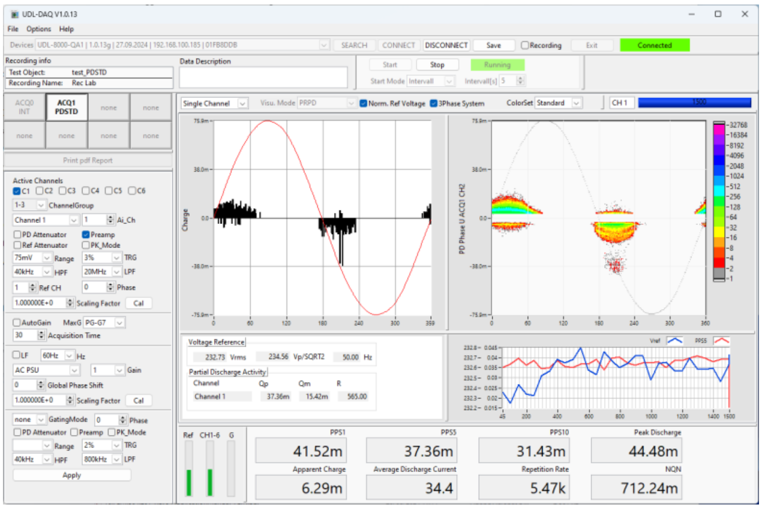

Figure 71: PD+ Single Channel view with UDL-DAQ Software

All other functions remain the same as the Single Channel / Multichannel view is only affecting the visualisation of the data in an optimised way.

7.3.1 Normalization / Calibration

Preliminary information:

The system is calibrated for mV measurements as factory default. Ensure before starting with the normalization procedure, that the systems configuration is changed to pC/nC measurements within the UDL-Configurator software. A change between mV and nC Range will automatically reconfigure the entire system for the correct measurement unit and will also automatically change the alarm thresholds to the specific range.

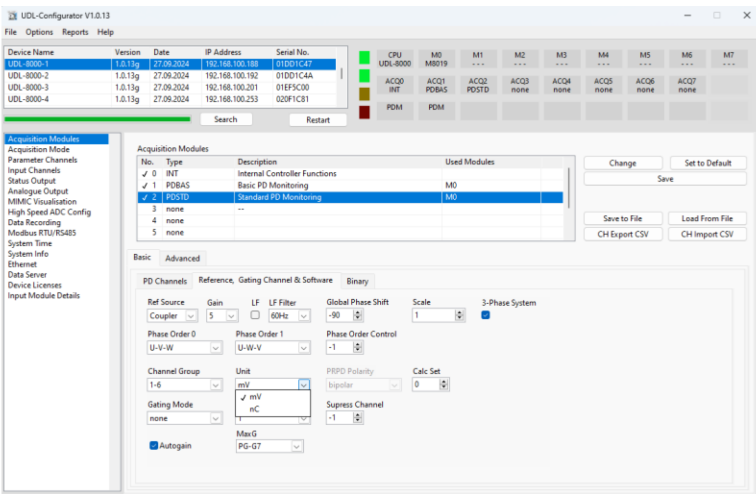

Figure 72: UDL-Configurator – change of measurement unit.

Before starting with the normalization process, ensure that the filter settings are set to the frequency range the system is used. This is can depend on the application and/or the test object the system is used.

For online partial discharge measurements on rotating machines, it is generally recommended to perform the measurements between 0.5MHz and 20MHz, while for offline Measurements, typically 40kHz to 800kHz is used. small changes in the frequency range do generally not much impact the normalization results, but it shall be understood that large differences can be expected if e.g. the system is normalized under 40kHz .. 800kHz and final measurements are performed from 0.5MHz .. 20MHz.

Whenever normalization is performed ensure that the test object is not grounded, or if it is mandatory to ground the test object due to personal safety reasons, that the grounding location is at least 5m away from the object and the coupling capacitors.

Once the filters are defined, connect the pd pulse generator as close as possible to the test object. There is no need for a voltage reference signal, as if no voltage reference signal is present, the system will self-trigger the acquisition to a frequency of 51.2Hz. Choose a normalization value on the PD pulse generator to the level the partial discharges are expected, this is for cables and other low PD level objects to 100 or 500pC, while for rotating machines it is recommended to use 5nC.

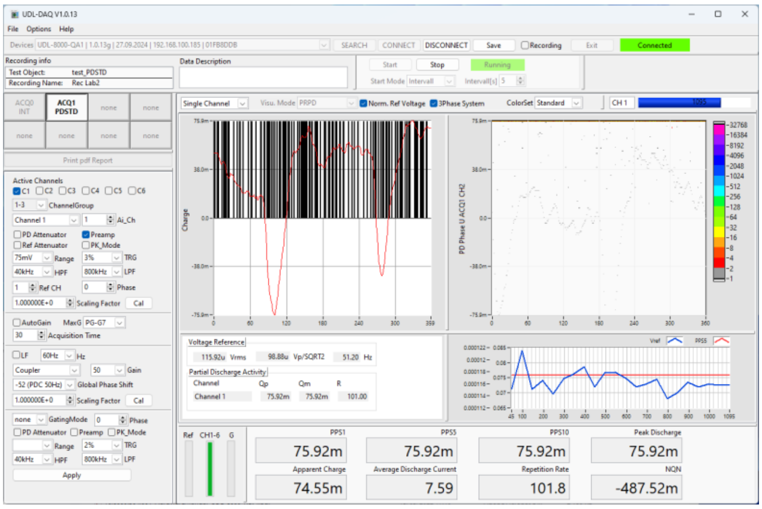

Figure 73: First measurements with wrong measurement range.

Most likely the first measurement will not show the results correctly. As shown in the illustration above, the signal of the PD pulse generator is larger than the actual selected measurement range, therefore the measurement range must be adapted to the received signal. Change the Range, PD Attenuator and Preamp in such way, so that the measured

PD pulses from the PD Pulse generator are in 50% of the measurement range as shown in the next illustration.

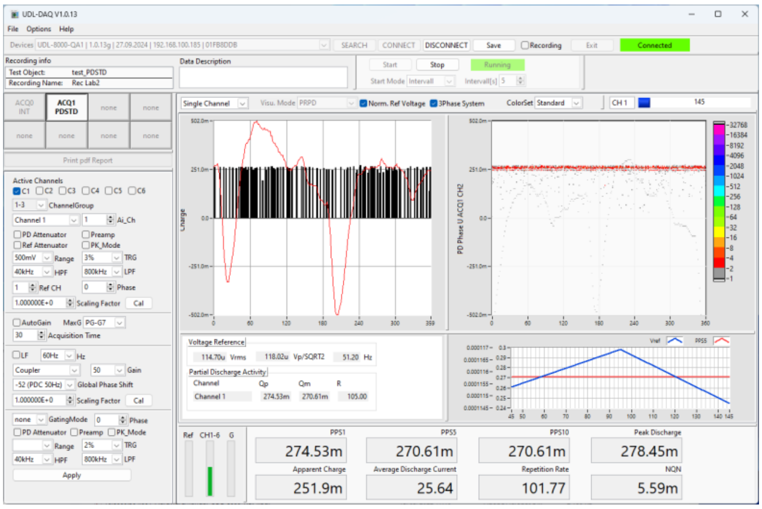

Figure 74: First measurements with correct measurement range.

The system will measure sequentially one channel after the other and will repeat the entire sequence continuously. Wait until the full measurement sequence is completed.

Ensure that the correct channel is selected, then press the button “Cal” near the PD channel settings.

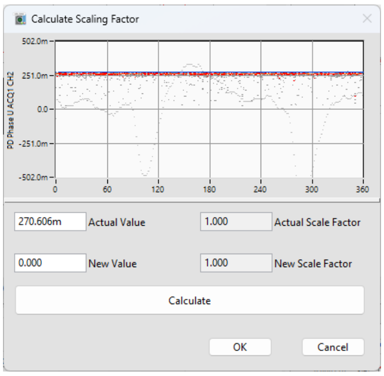

Figure 75: PD+ normalisation window

If the “cal” button is pressed after the measurement sequence is completed, the “Axctual Value” is read from the PPS5 value of the system automatically. In the above example it is 270mV. Under “New Value” enter the charge level set on the PD pulse generator, e.g. 5nC and press the “Calculate” button. The system will calculate the scaling factor user to transform the mV into a nC value.

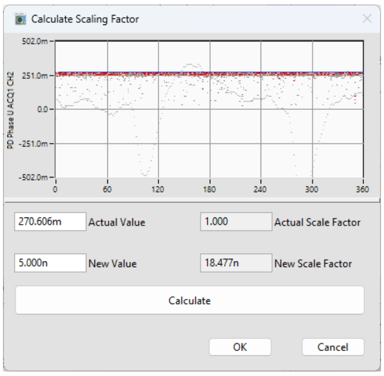

Figure 76: PD+ normalisation window with PD Pulse Generator value

There is a small horizontal blue line, representing the detected PD Level. Alternatively move the cursor to the location of the PD Pulse generator signal, which will change the “actual value”. If you change the actual value, the button “Calculate” must be pressed in order to recalculate the scaling factor. If the results look good, press the button “OK”.

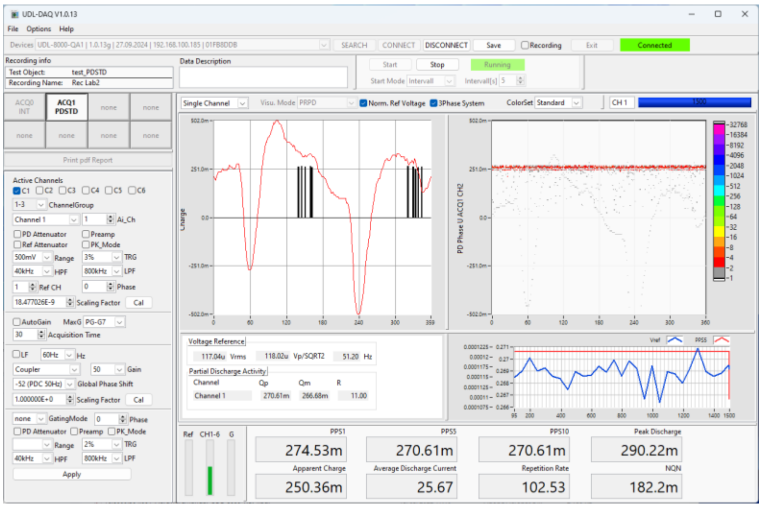

Figure 77: Settings with new Scaling Factor

Press the button “Apply” to send the new settings to the device. Wait until the next full measurement cycle is finished, as new settings are only considered at each start of a full sequence.

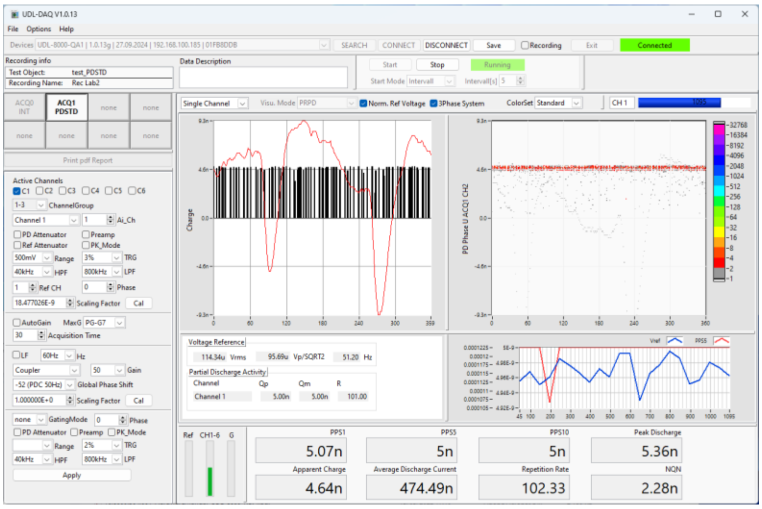

Figure 78: Results with new scaling factor.

If all the above steps are done correctly, the results will show above, indicating 5nC as actual measured value.

It must be noted, that for systems with the PD acquisition module, a larger tolerance of measure value must be expected, as the amplitude resolution of the PD setting is defined to 16 windows, which will cause a final resolution of the measurement results to a 1/16 of the full range. E.g. on a 10nC range the resolution of the results is given by 10nC / 16 = 0.625nC. therefore the results of the normalisation process can vary between 5nC +/- 0.625nC respectively 4.375nC .. 5.625nC.

Repeat the above steps for every used channel.

Please note, that the location of the connection cables to the test object can also have some influence, especially if there are different locations for the ground connections are used between the normalization of different phases. Generally, a variation between the channels of up to 15 to 20% is possible.

Whenever the normalisation process is done, all measured values are now in pC / nC (coulomb) units. In order to show then further the correct unit, the unit parameters of each PD channel and of each parameter must be adapted.

Please note, that the measurement range always is shown as "volt value" independent of the used scaling factor. Therefore, all parameters must be adapted to the new measurement range and alarm thresholds.

The same procedure can be used to normalize the reference voltage, simply press the button "Cal" under the voltage reference section and perform the same procedure as with the PD channel.

7.3.2 File Manipulation - Changing Normalization / Calibration

In some cases, it is not possible to perform the normalisation before the real measurements. That will cause, that saved measurement results will show an incorrect scale. If the normalisation is performed afterwards, the new obtained scale factor can be used to “manipulate” previous recorded results.

Start the UDL-DAQ Software and select the measurement result to be “manipulated”.

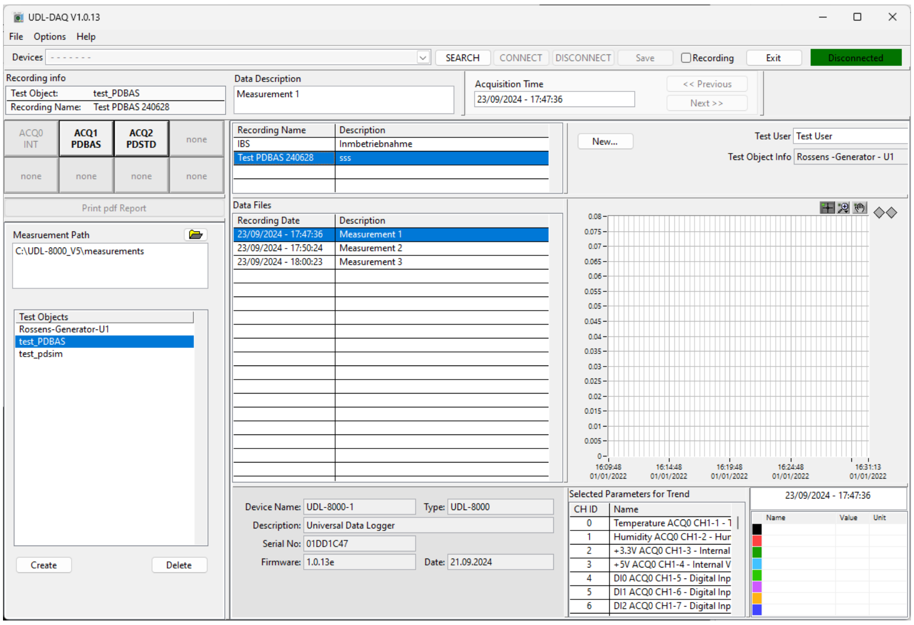

Figure 79: Selecting a file for manipulation

Press the acquisition module to be modified.

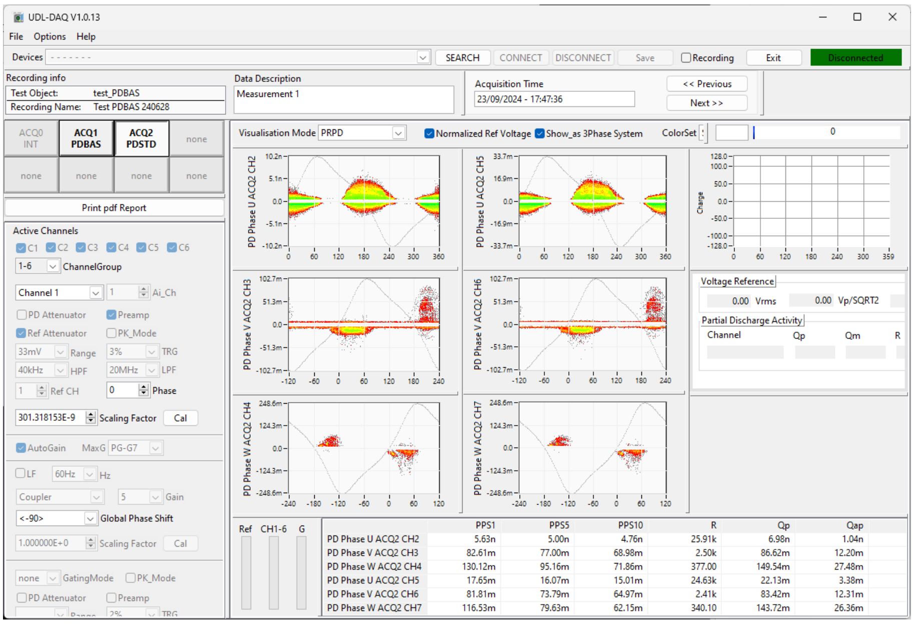

Figure 80: Selecting an acquisition module

In the following example we will use the scale factor from channel 1 to channel 2. Copy the scale factor from channel 1 to the channel 2 and press enter to confirm the value.

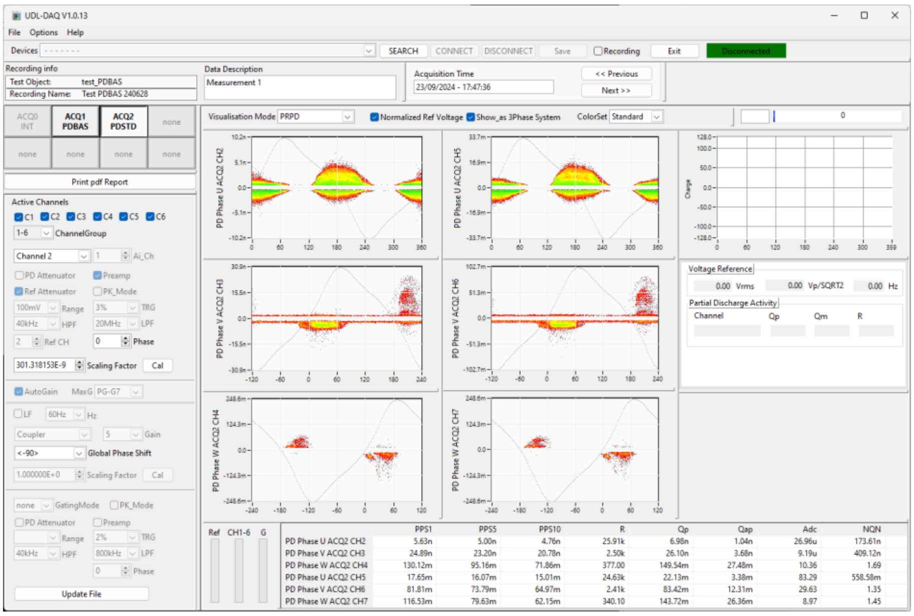

Figure 81: Manual scale factor change.

And once all channels are changed, press the button “update file”.

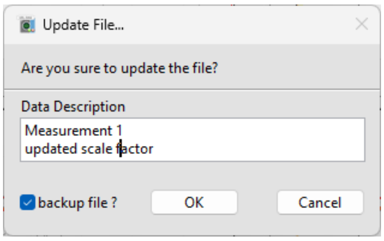

Figure 82: Updating File info

Edit the Data Description if needed and press the button “Save” to save the result. Check or Uncheck the checkbox “Backup File?” if the original file shall be backed up prior the update.

7.3.3 File Manipulation - Changing Phase Angle

The following example shows the manipulation of the PD+ module. Load fist the measurement result:

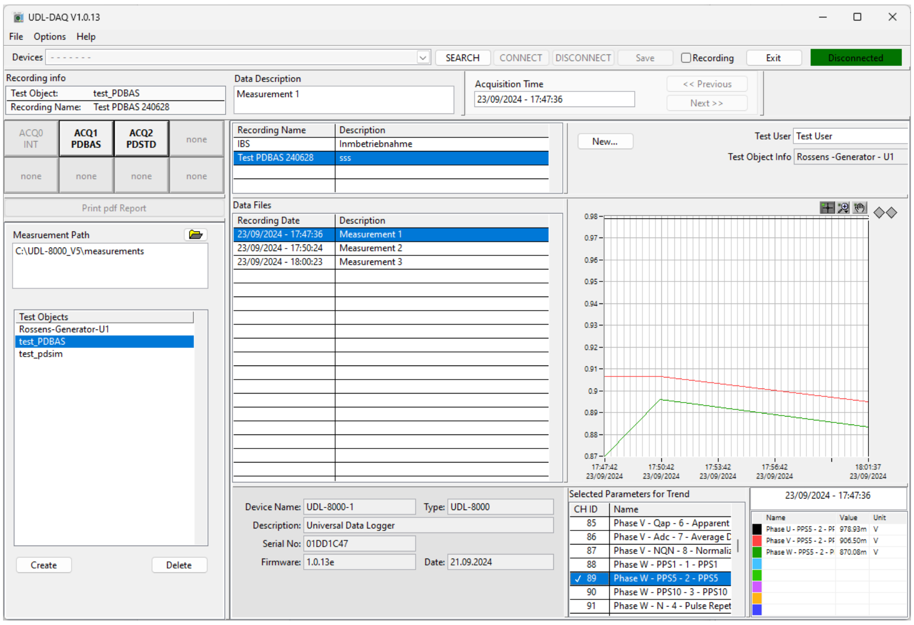

Figure 83: Load a Measurement Result

Then press the Acquisition module button of the result to be presented.

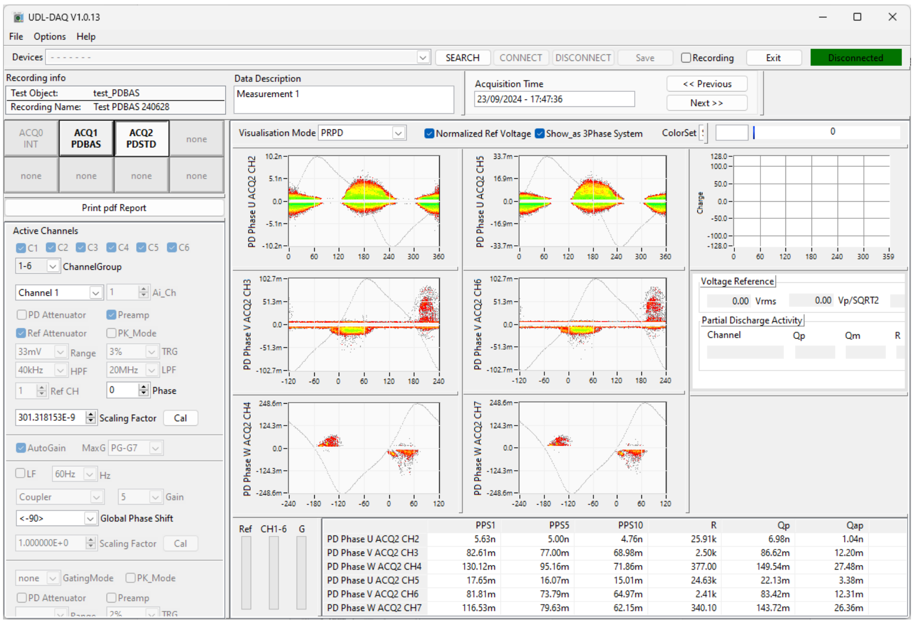

Figure 84: Original Phase of PD+ Module Data

Select first the correct channel. Change the value of the “Phase” and press “enter”. Automatically the PRPD Pattern of the selected channel will be corrected (moved).

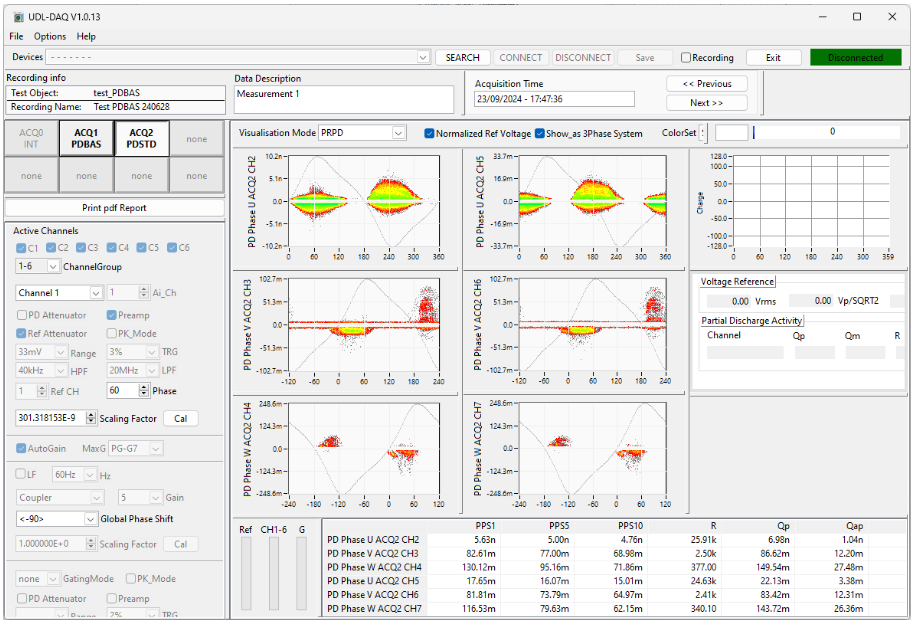

Figure 85: Corrected PRPD Patterns

Repeat the same for every available channel if required.

It is also possible to change all PRPD Patterns by using the “common” phase angle, this will move all PRPD Patterns including the PRPD Pattern of the gating channel.

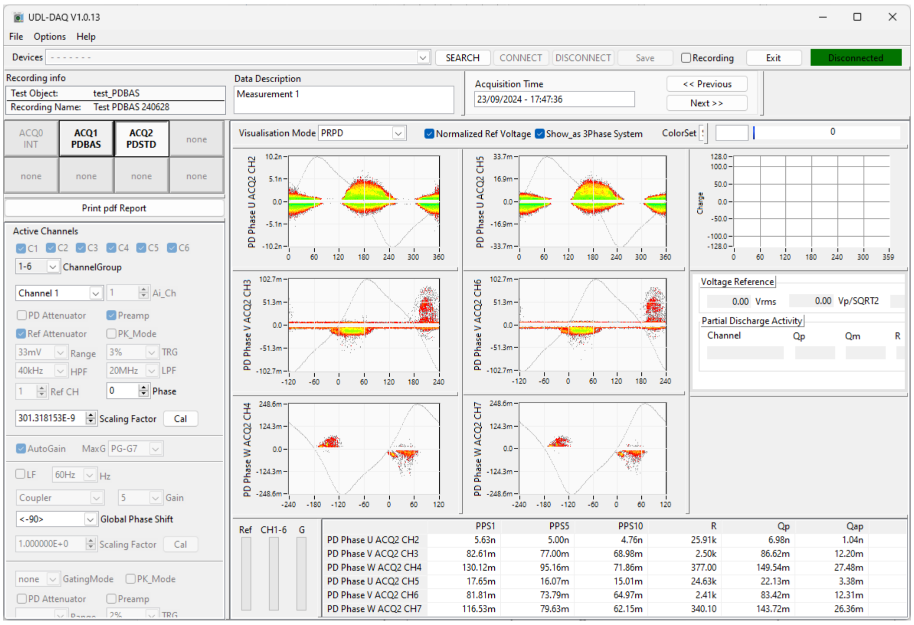

Figure 86: Original Common Phase of PD+ Module Data

In the above example, the common phase angle is set to -90°. From the pull down menu, select “other”…

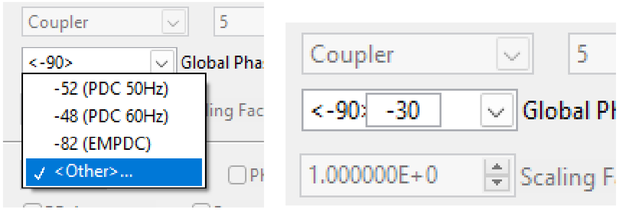

Figure 87: Changing Common Phase of PD+ Module Data

And enter the new phase angle…

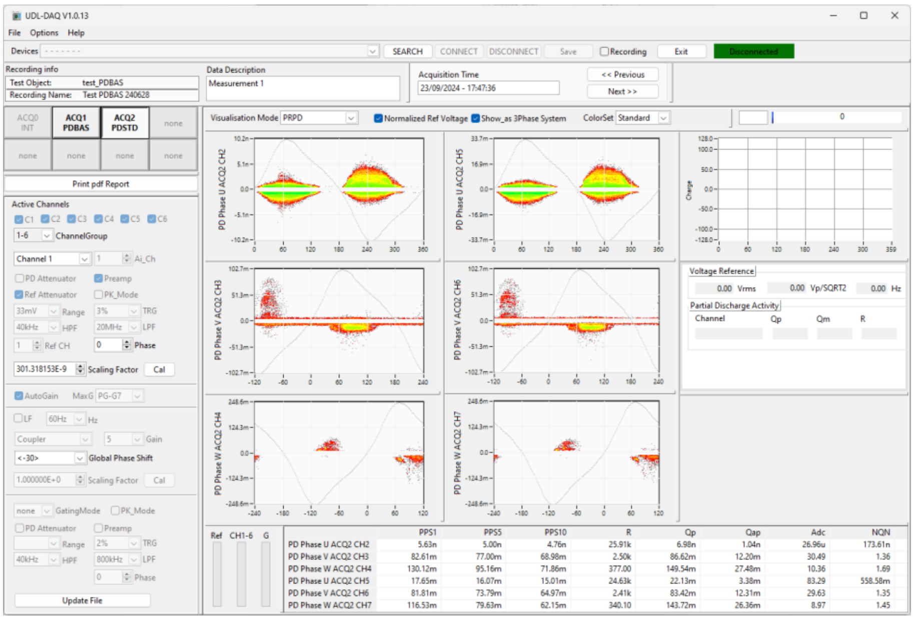

Figure 88: Common Phase of PD+ Module Data changed

If the changes are completed, press the button “Update File”. A pop-up window will open:

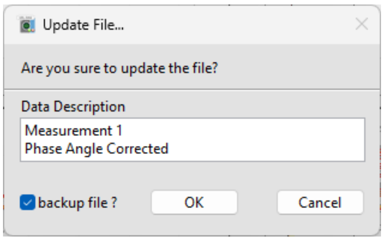

Figure 89: Update File Message

Complement the measurement description and press the “OK” button to overwrite the existing file. If the checkbox “backup file?” is marked, the original measurement file is copied into the same folder, but with a new extension .bak0. if a backup file already exists, the new backup file will get the extension .bak1 etc. In order to undo the modified file, simply rename the file back to the original filename. Then the file will appear again in the file list.

7.3.4 Loading a configuration into the device

It is also possible to load a acquisition module configuration from a measurement file into the device, this is especially helpful if the device is used as a portable device to perform temporary measurements on multiple units.

Start first the software and select the measurement file with the settings to be uploaded.

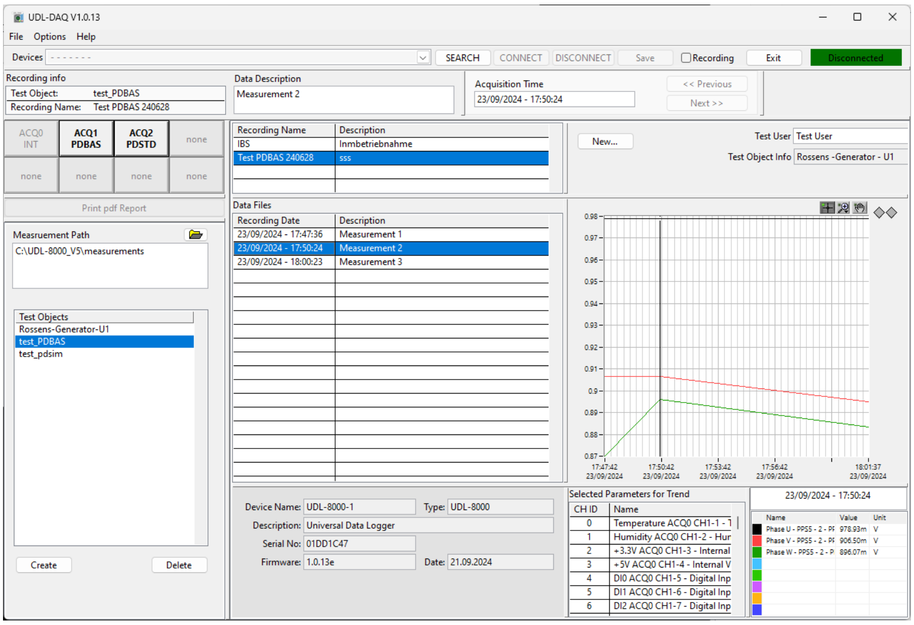

Figure 90: Loading a file

Press the acquisition module button of the module where the settings shall be uploaded

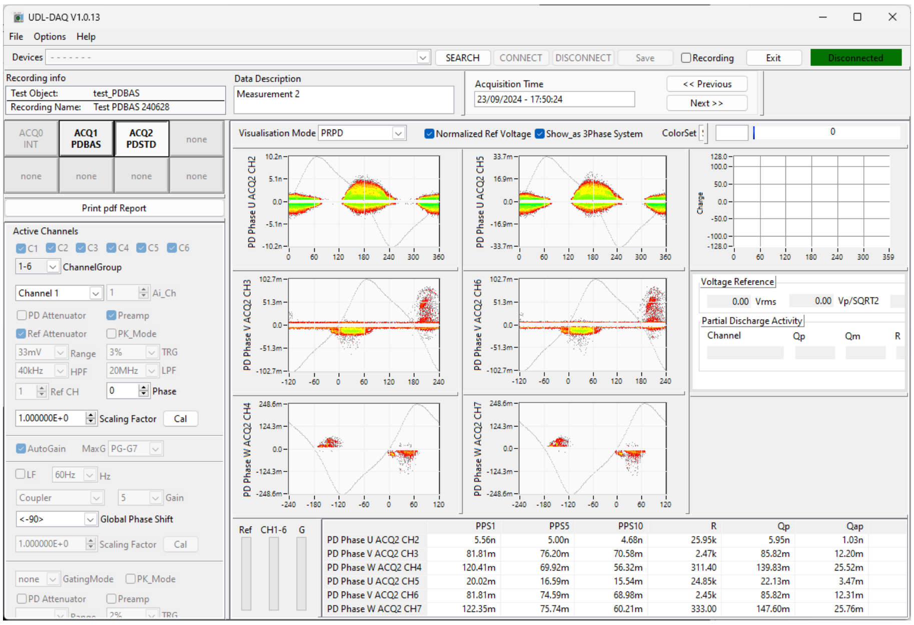

Figure 91: Showing the measurement results.

In the next step, select the device from the list (We assume the device is already connected to the PC, and it has been found during the start of the software. If not, press the search button to search for the device.

Select the device from the pull down menu. A pop-up window will open, asking if he actual module configuration shall be uploaded to the device

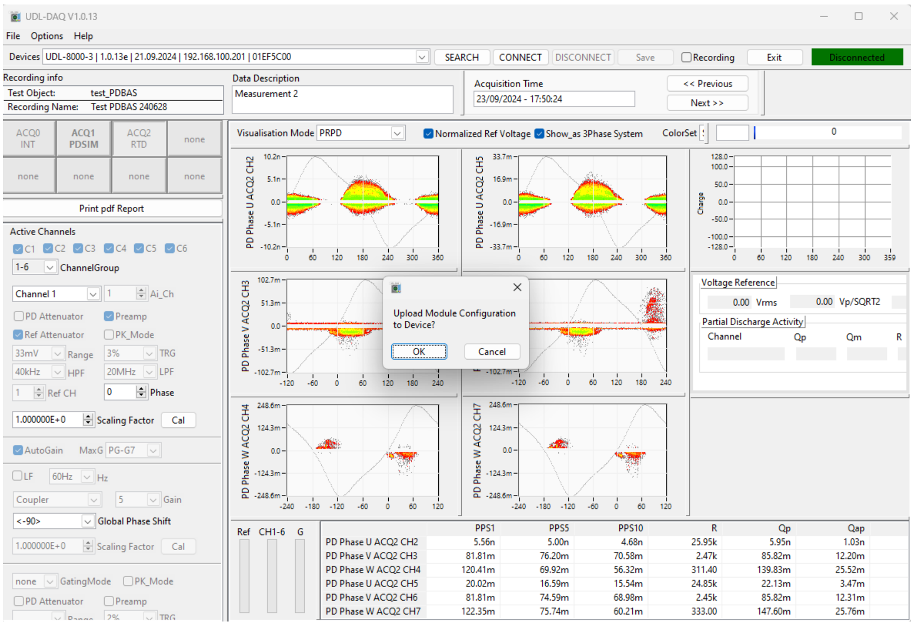

Figure 92: Selecting the device and confirm the upload of the configuration

IMPORTANT NOTE:

This procedure mentioned above works only if the device configuration (configured acquisition module) is identical to the configuration stored inside the device. If a device is used with a different configuration, use the UDL-Configurator software and save the configuration for each acquisition module individually.

Once the configuration is uploaded, press the button “connect” to connect the software to the device and use the software as usual.

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8 UDL-DataClient

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This chapter covers the information for the visualization of the measured data within the centralized data server / client software UDL-DataClient.

While the basic version of the UDL-DataClient presents only one visualization at a time, the UDL-DataClient Pro supports multi window data presentation while the content and the operation of the windows remain the same.

The measured partial discharge data is updated once the complete acquisition module is finished, and the update rate depends on the number of used channels and the defined acquisition time.

8.1 Typical Window Layouts

While the window layout depends greatly on the used monitor resolution, the number of windows presented at the same time also on the operator's preference. The layouts shown within this manual shall give some ideas about the possibilities provided by this software.

8.1.1 Layout for the UDL-8000 Pro

Screen Resolution: 1280 x 800 - WXGA
Using the touchpanel PC for data visualisation allowing to use the benefit of multiple data presentation. However, generally data analysis will then be performed on a connected Desktop computer with a larger screen.

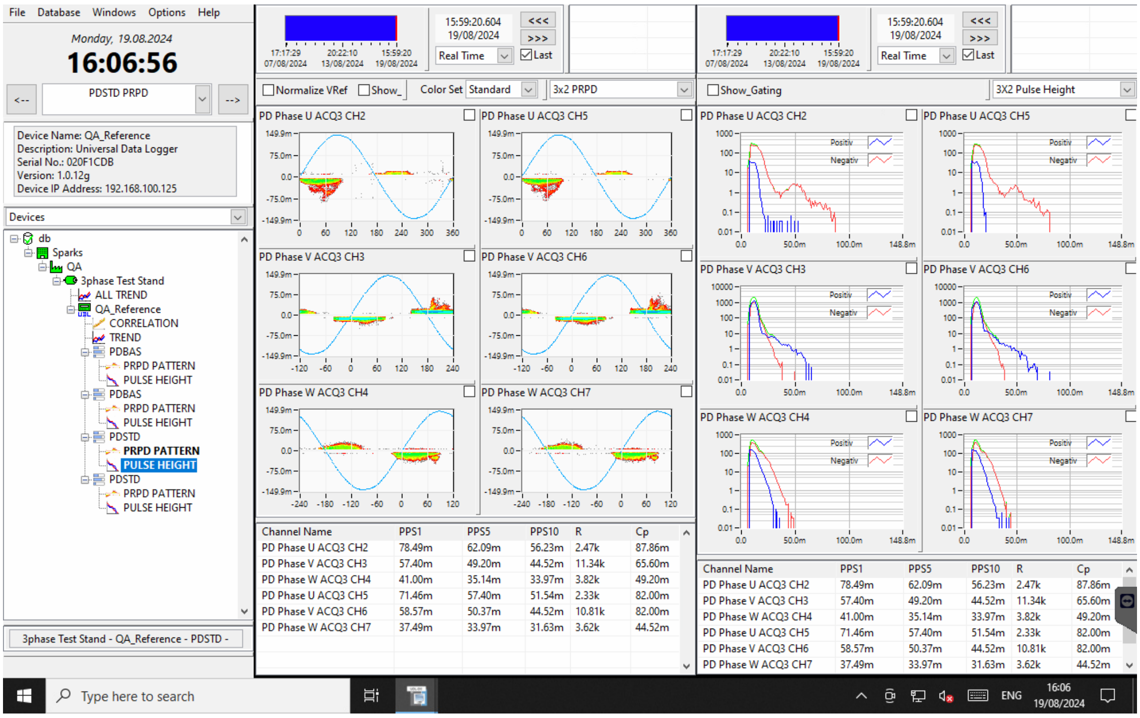


Figure 93: UDL-8000 Pro local data visualisation (PRPD)

As with the limited screen size, the time series data (trend) is placed as a separate view

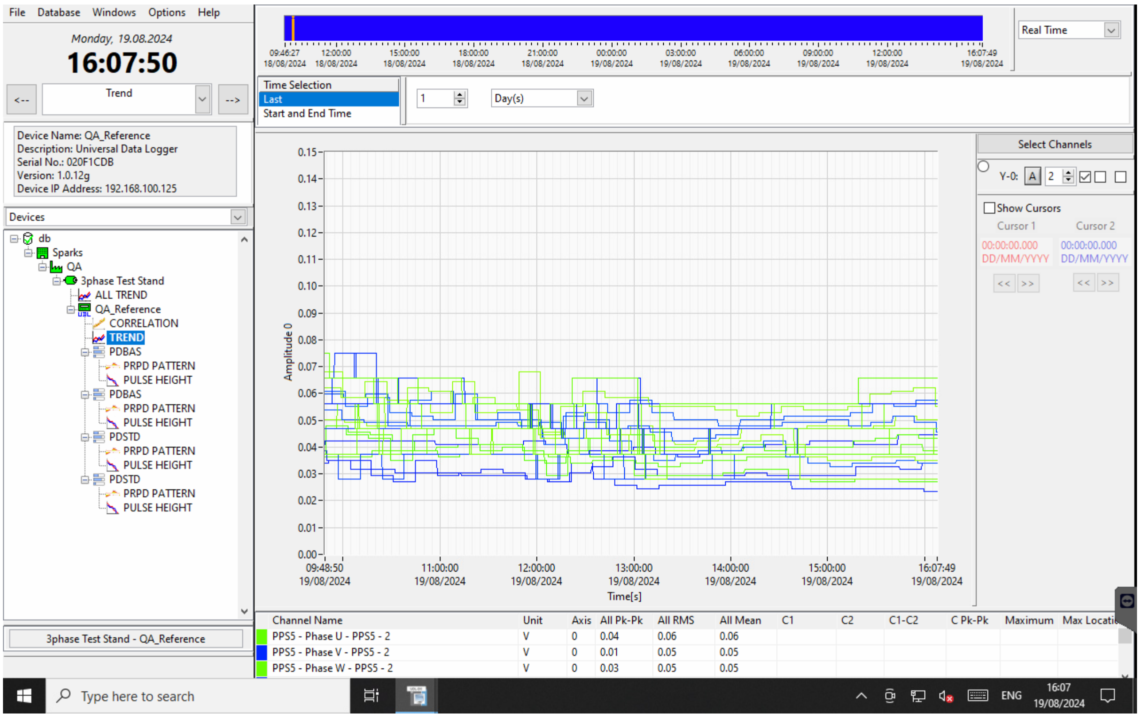


Figure 94: UDL-8000 Pro local data visualisation (Trend)

8.1.2 Layout for Desktop Computers

Screen Resolution: 2560 x 1440 – WQHD - recommended

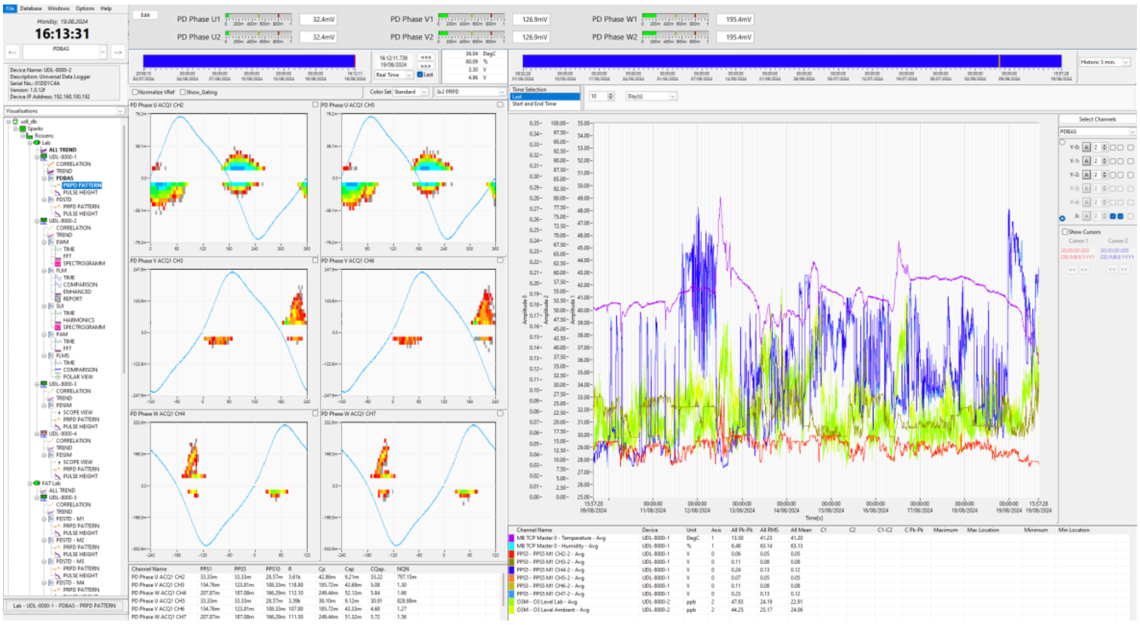


Figure 95: UDL-DataClient desktop data visualisation (PD & Trend)

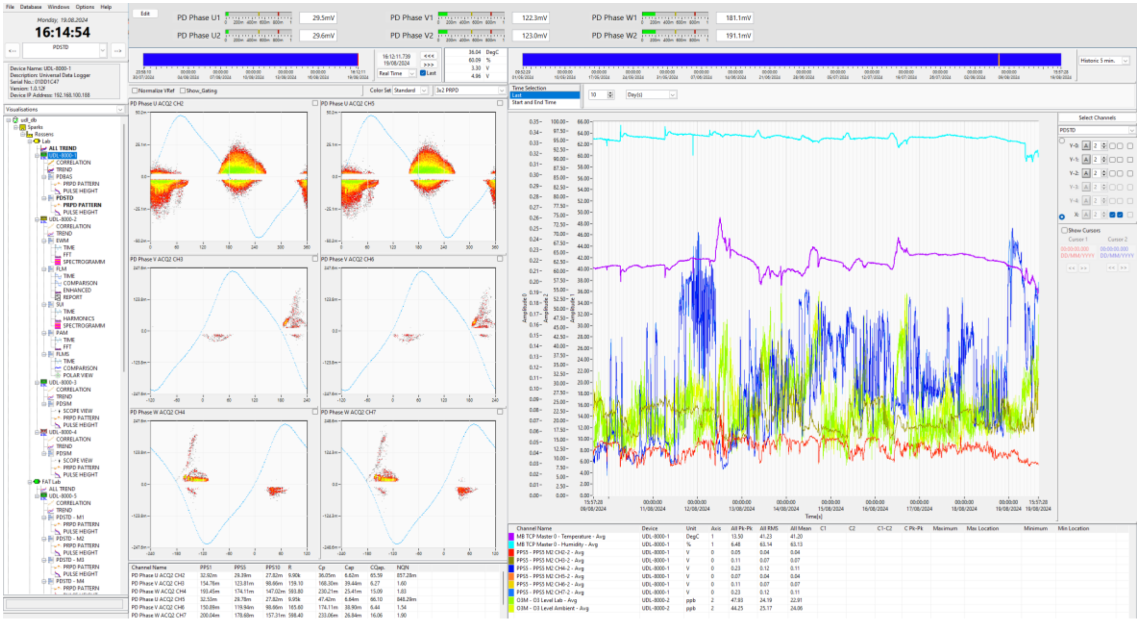


Figure 96: UDL-DataClient desktop data visualisation (PD+ & Trend)

8.2 Data Visualizations

The functions, use and configuration of overview pages and trend are common for all types of acquisition modules and are described in the general user manual of the UDL-DataClient.

Each window is updated once all channels and all installed modules are acquired. Therefore the update rate of the windows depend on the number of modules and number of channels installed.

8.2.1 PRPD (Phase Resolved Partial Discharge Patterns)

The PRPD data presentation functions are identical between the PD and the PD+ acquisition module.

The visualisation is separated into 3 parts:

Window Part	Description
Top	The Top Part contains the time selection of the shown dataset
Middle	In the middle the selected data is presented
Bottom	At the bottom of the window, calculated results are shown

Table 36: Separation of visualisation information

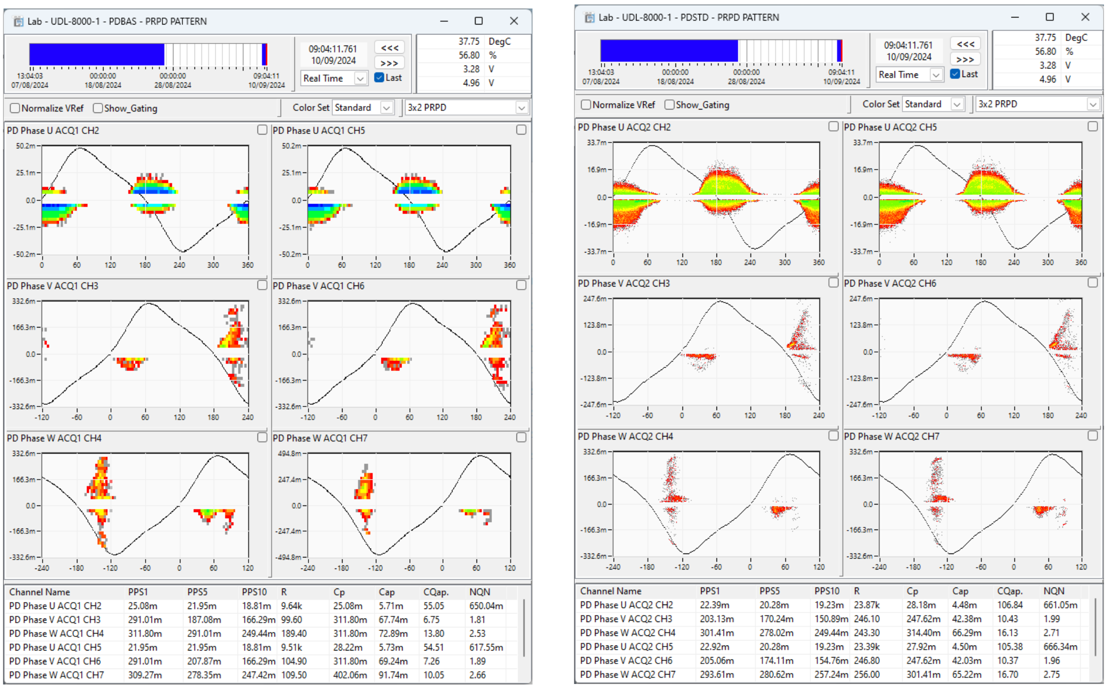


Figure 97: PRPD Data Presentation (left: PD, right PD+)

8.2.1.1 Time Selection

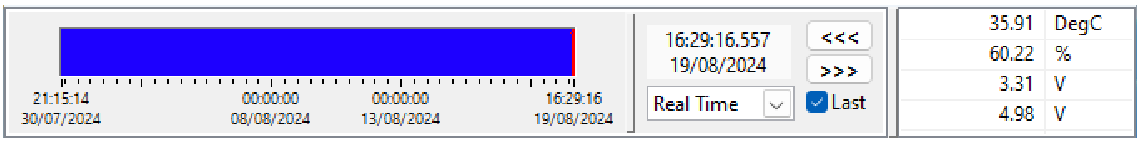


Figure 98: Time Selection

The blue bar shows all the available data records within the database, and the specific dataset can be picked by moving the red cursor at the time of interest.

The time selection in the middle allows to select the time more precisely as

Element	Description
Time Stamp	Enter the timestamp of interest manually. It is also possible to copy/paste the timestamp from another window or from a cursor timestamp. Right click into the timestamp field and assign the timestamp to the “master timestamp 1” or “master timestamp 2” in order to select the dataset of multiple windows with one single time definition.

Button left / right	Jump one record to the left (earlier) or right (later)
Data table selection	Choose between Realtime Data- and Historic Datasets
Last dataset	Select the last data record

Table 37: Time Selection parameters

At the very right side of the time selection view are the operating parameters shown. Up to 4 parameters can be assigned to the “recording header” which will be shown on every raw data visualisation window.

8.2.1.2 Data Presentation

The Channel Names shown on each graph are defined under the Input Channel configuration within the UDL-Configurator Software.

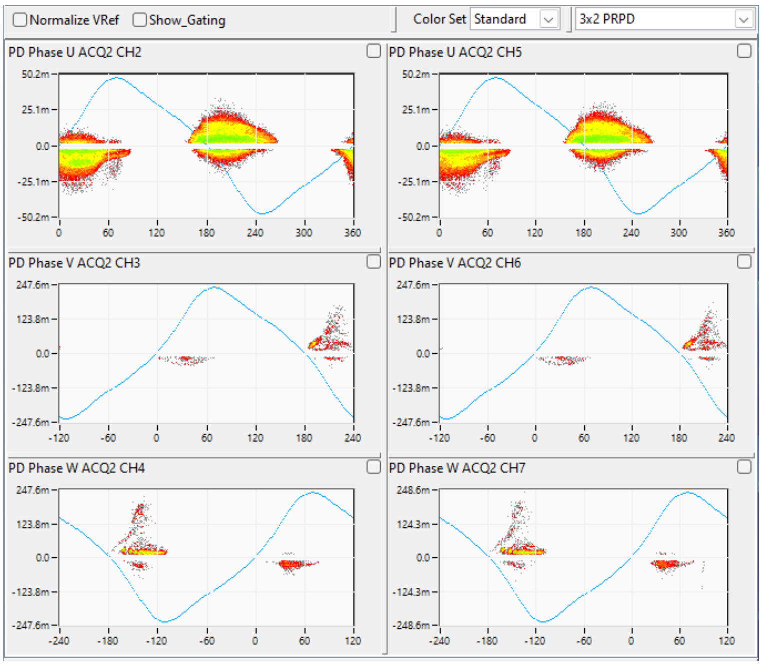


Figure 99: PRPD Data View - General

Select “normalize VRef” in order to show the voltage reference signal maximized on the PRPD Pattern. The “Show Gating” allows to visualize the results from the noise canceling function “Gating)

Use the color set to change the color coding of the PRPD Patterns

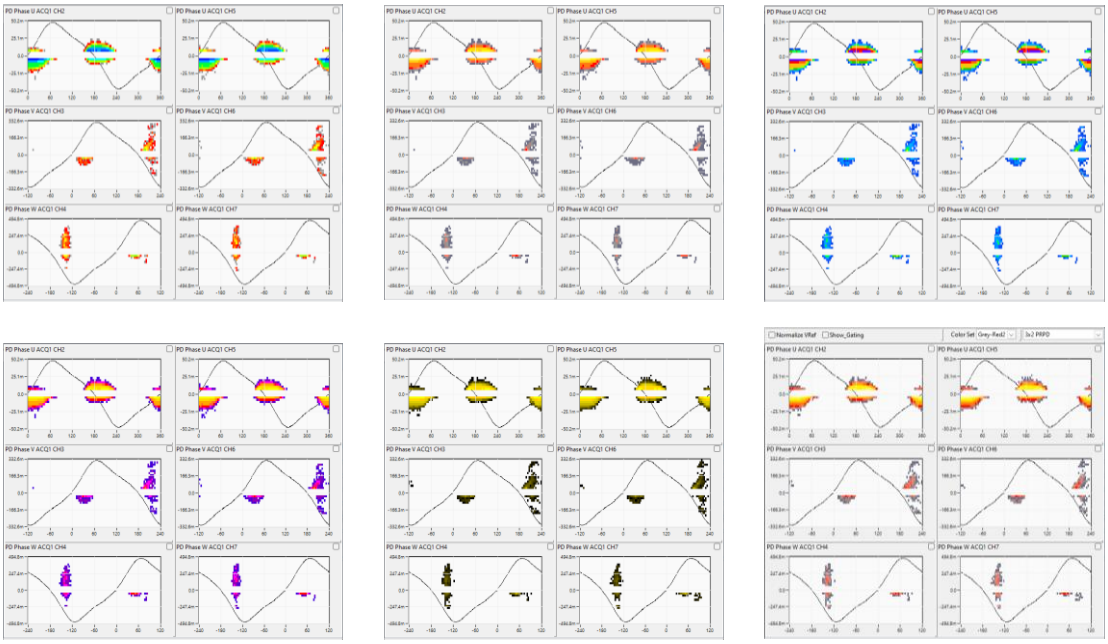


Figure 100: PRPD Data View – PD Color Coding

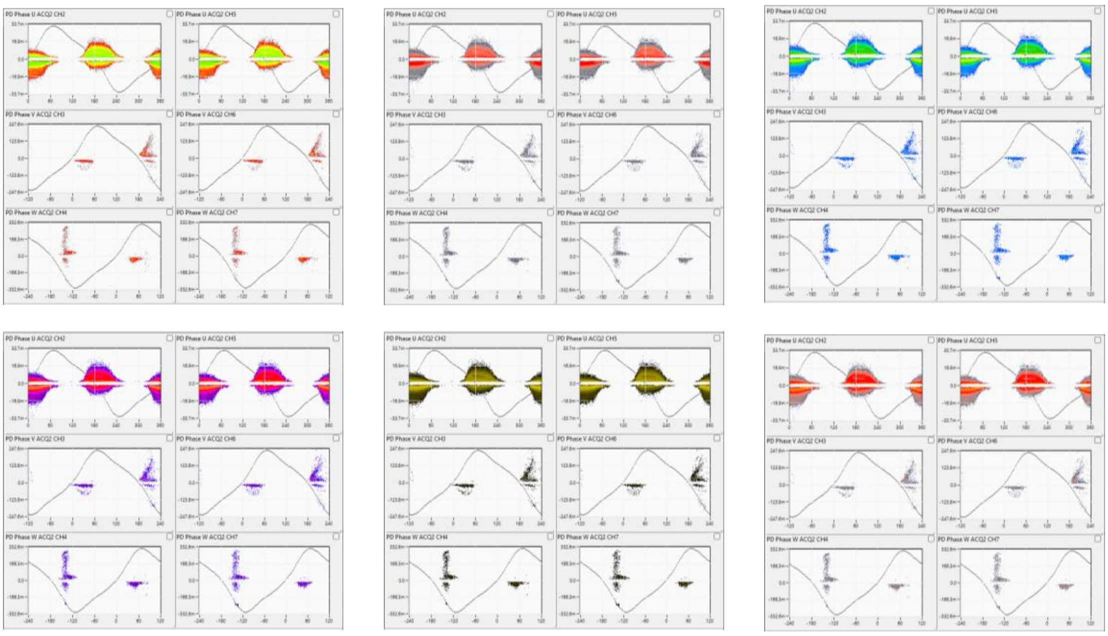


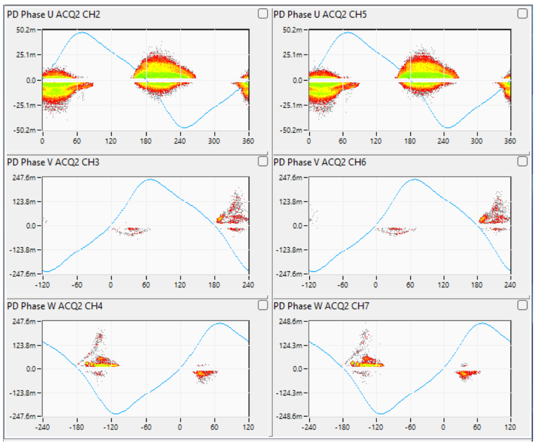
Figure 101: PRPD Data View – PD+ Color Coding

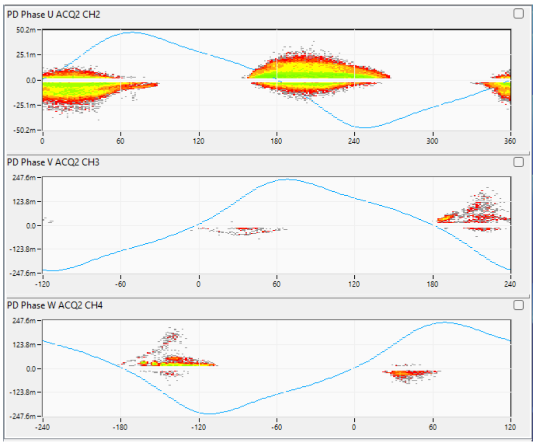
The colors represent the following numbers:

Color Code	Description
Standard	Grey: 1 Pulse Red: >2Pulses Orange: >8 Pulses Green: >64 Pulses Cyan: >256 Pulses Blue: >2048 Pulses Pink: >16384 Pulses
Grey-Red	Grey: 1..5 Pulses RedGrey: >9 Pulses Red: >65 Pulses Yellow: >1024 Pulses Cyan: >16384 Pulses Blue: >32768 Pulses
Blue	Blue: 1 Pulse Green: >16 Pulses Orange: >128 Pulses Red: >512 Pulses Purple: >4096 Pulses Pink: >16384 Pulses
IR	Blue: 1 Pulse Pink: >8 Pulses Red: >64 Pulses Orange: >128 Pulses Yellow: >16384 Pulses
Yellow/Black	Black: >=1Pulse Yellow: >16384 Pulses
Grey-Red2	Grey: 1..3 Pulses RedGrey: >4 Pulses Red: >32 Pulses Yellow: >512 Pulses Cyan: >8192 Pulses Blue: >16384 Pulses

Table 38: Color Coding of PRPD Patterns

At the very right of the data selection is the possibility to define the number of PRPD Patterns shown. The selection allows between 3x2, 3x1, 4x1 and 2x2 PRPD Patterns





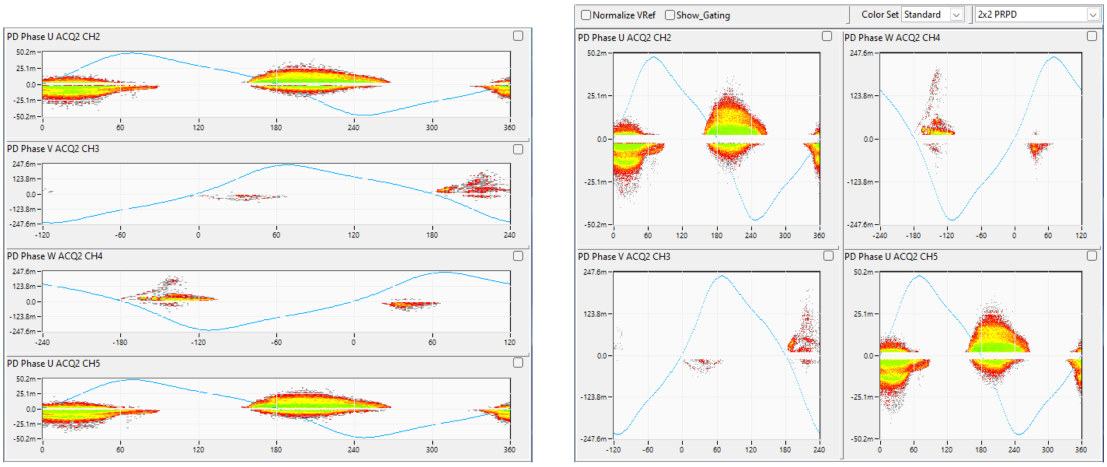


Figure 102: Number of PRPD Patterns shown within the same window

Each PRPD Pattern can also be presented within an individual window. This is especially usefull if the main window shows the PRPD Patterns small, and one or many PRPD patterns shall be additionally be presented larger.
To select the individual PRPD pattern view, click on the little checkbox at the right top side of the pattern.

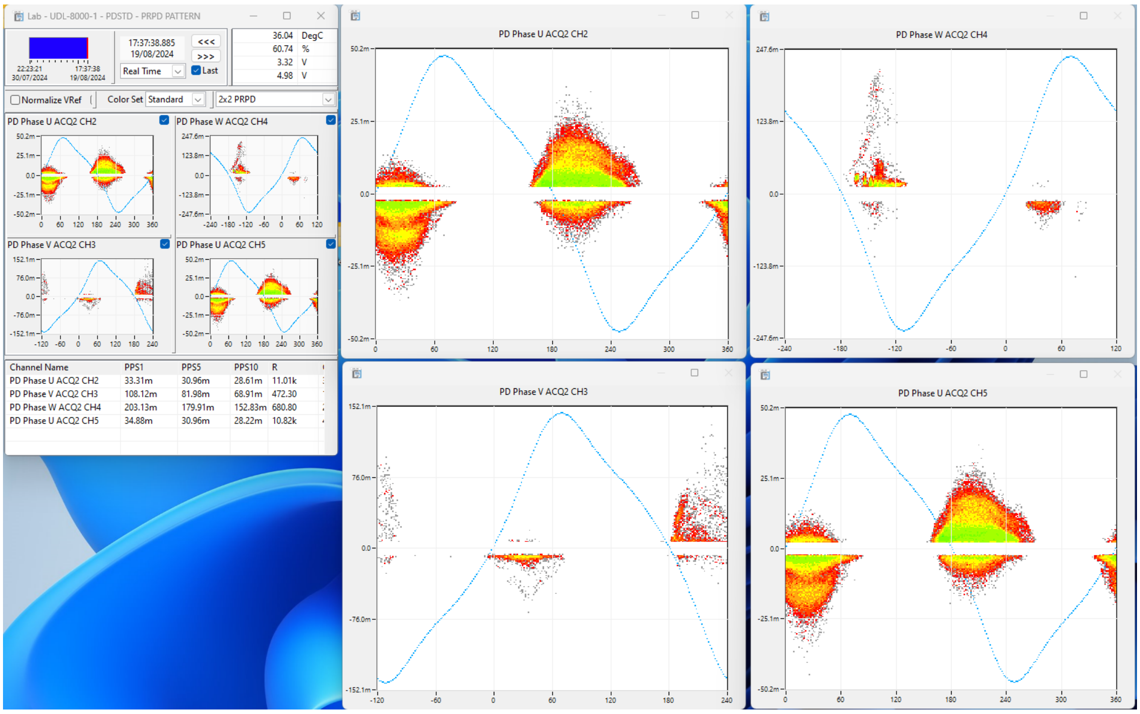


Figure 103: PRPD Patterns shown in Individual Windows

8.2.1.3 Calculated Results

At the bottom of the visualisation window are the results calculated from the PRPD Pattern shown. Depending on the configuration of the PD+/PD acquisition module, different parameters are presented.

Channel Name	PPS1	PPS5	PPS10	R	Cp	Cap	CQap.	NQN
PD Phase U ACQ2 CH2	34.09m	30.18m	28.22m	11.99k	39.58m	7.35m	88.14	901.95m
PD Phase V ACQ2 CH3	81.98m	67.72m	61.78m	566.90	92.67m	19.28m	10.93	1.42
PD Phase W ACQ2 CH4	203.13m	177.98m	145.09m	699.80	216.67m	24.79m	17.35	2.09
PD Phase U ACQ2 CH5	33.31m	29.78m	28.22m	11.72k	38.41m	7.35m	86.10	902.15m
PD Phase V ACQ2 CH6	81.98m	65.35m	59.41m	553.50	93.86m	18.98m	10.51	1.38
PD Phase W ACQ2 CH7	205.87m	184.50m	153.43m	711.00	221.40m	24.95m	17.74	2.03

Table 39: Calculated Results

8.2.2 Pulse Height Distribution

The Pulse height distribution visualization is used to show the PD Pulse Magnitude over their repetition rate.

The visualisation is as with the PRPD patterns separated into 3 parts:

Window Part	Description
Top	The Top Part contains the time selection of the shown dataset
Middle	In the middle the selected data is presented
Bottom	At the bottom of the window, calculated results are shown

Table 40: Separation of visualisation information

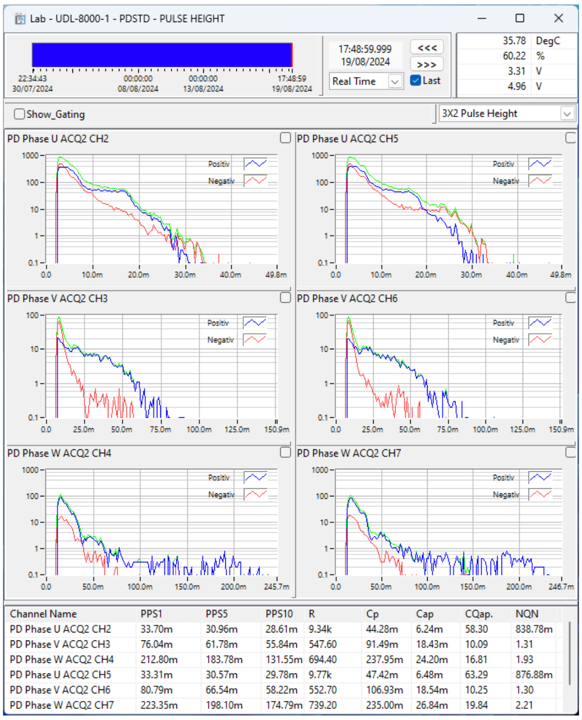


Figure 104: Pulse Height Distribution Window

While the time selection and the calculation results remain the same, the data presentation contains the visualisation of the Pulse Height distribution.

8.2.2.1 Data Presentation

The Channel Names shown on each graph are defined under the Input Channel configuration within the UDL-Configurator Software.

The Checkbox “Show Gating” is used to visualize the data in a separate window of the noise canceling channel “Gating”.

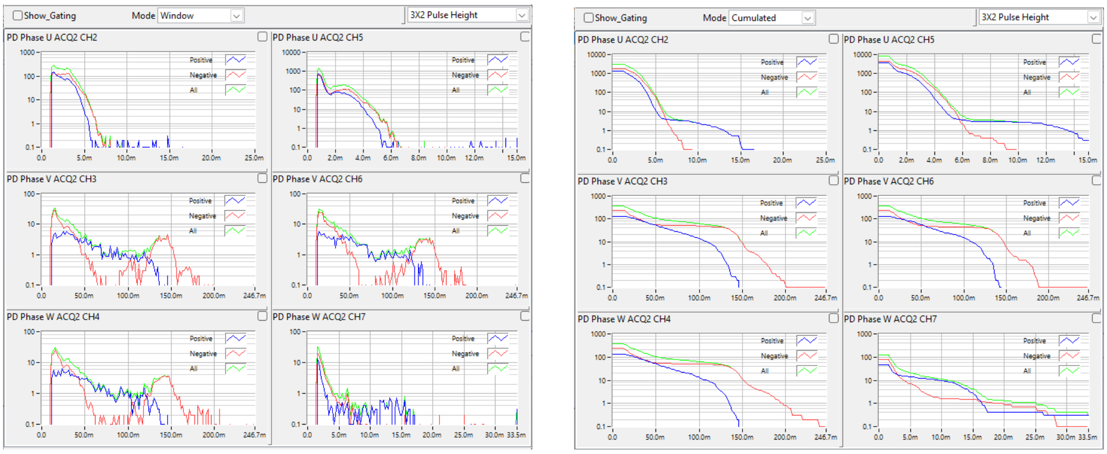
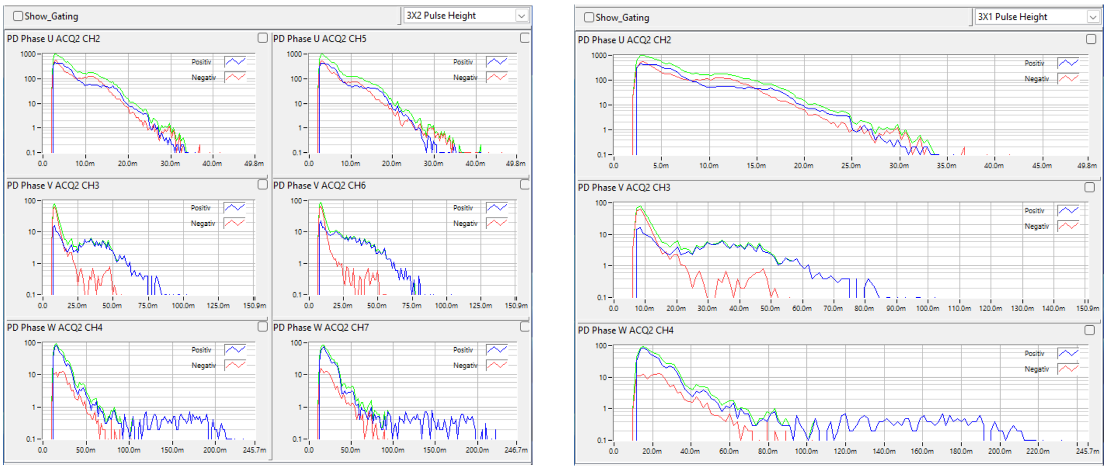


Figure 105: Pulse Height Data Presentation (left window, right Cumulated)

At the top right is a pull-down menu, which allows to select how many Pulse Height distribution graphs are shown within the visualisation window.

Select between 3x2, 3x1 or 2x2 view, depending on how many channels are used.



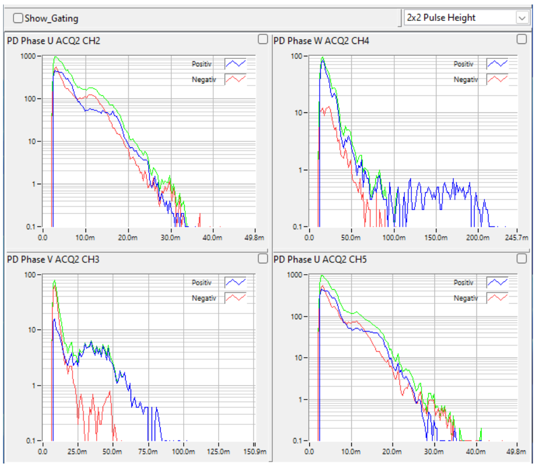


Figure 106: Number of Pulse Height Distribution graphs shown within the same window

As with the PRPD Patterns, it is also possible to show the Pulse Height distribution in a separate window by simply marking the checkbox at the top right of each graph.

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9 PRPD Sample Results

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9.1 General Remarks

The following sample catalogue is specifically representing partial discharge activities found in rotating machines. Other types of machines may have similar results depending on the design of the insulation system.

All stresses act as a TEAM on the insulation system

- Thermal
- Electrical
- Ambient (Environmental)
- Mechanical

Very often Partial Discharges indicate above stresses, they are often not the cause but the result of the problem. Often defects occur in specific locations, there is no overall average ageing, e.g. using a hammer for placing only one bar might harm that specific bar.

Single weak points in the insulation system are indicated by partial discharges. Partial Discharge Patterns represent the best way to identify the defect type.

This Knowledge base gives an overview about typical partial discharge patterns and their physical origin.

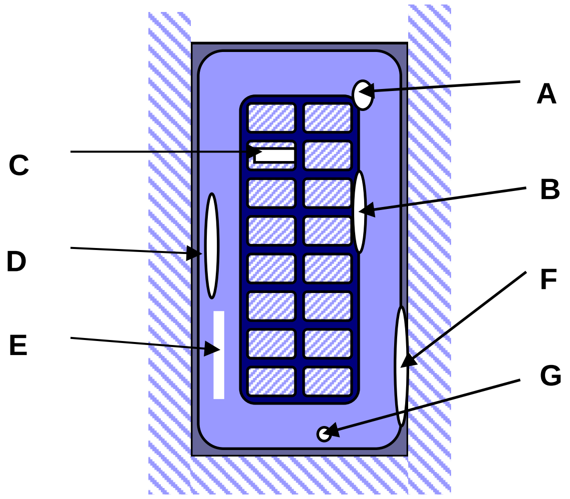
Conventional test methods as tan delta as well are sensitive to partial discharges, but, they represent an integral value as the loss created by the partial discharge pulses must be very high.

Partial discharges are plasma processes which take place generally in a gas. Whenever the electrical field in a gas space exceeds the inception field of the gas, partial discharges are created: on the surface of an insulator, due to conductive contamination, in air inclusions of the insulation as a result of mechanical forces. The gas plasma accelerates ageing and corrosive substances as ozone and NO2 are created. However the mechanical wear or a surface contamination is usually more harmful than the partial discharge action. As the presence of partial discharges cannot be avoided in rotating machines insulation, mica is applied as a partial discharge resistant medium.

By-products of the partial discharge are commonly white powders which can be found in many locations of the machines.

9.2 Partial Discharge Locations

9.2.1 Internal Discharges – Discharge Sources in the slot sections



***A**: Highest electrical field through sharp edges/corners of the single conductors*
***B**: Delamination of the single conductor insulation towards the main insulation*
***C**: Broken conductors*

***D**: Delamination of the main insulation*

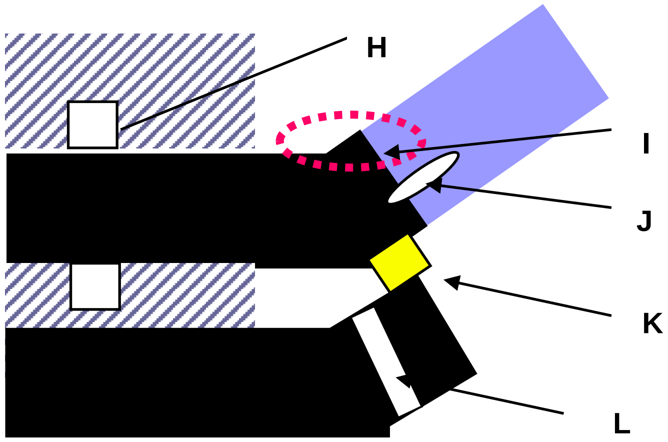
***E**: Treeing within the main insulation*

***F**: Abrasion of the field grading*

***G**: Voids*

Figure 107:Typical insulation failures in slot part

9.2.2 External Discharges – Discharge Sources in the endwinding sections



***H**: Discharges in cooling duct, mainly created by vibration and abrasion of corona protection layers*

***I**: Delamination of insulation in elbow*
J: Endwinding surface discharge (contamination etc.)

***K**: Insufficient spacing, tracking, loosening of spacers, especially between bars with big voltage difference, different phases*
***L**: Corona between slot corona protection and endwinding corona protection*

Figure 108:Typical insulation failures in Endwinding part

9.3 Typical Partial Discharge Patterns in Rotating Machines

9.3.1 Slot Discharges: F-Location

The most harmful defect is called slot discharge. They are usually caused by vibration of the insulation in the slot. This vibration can be caused by loose wedges. Therefore the presence of slot discharges indicates loose wedges and can therefore be verified by wedge tightness tests and ozone detection in air-cooled machines.

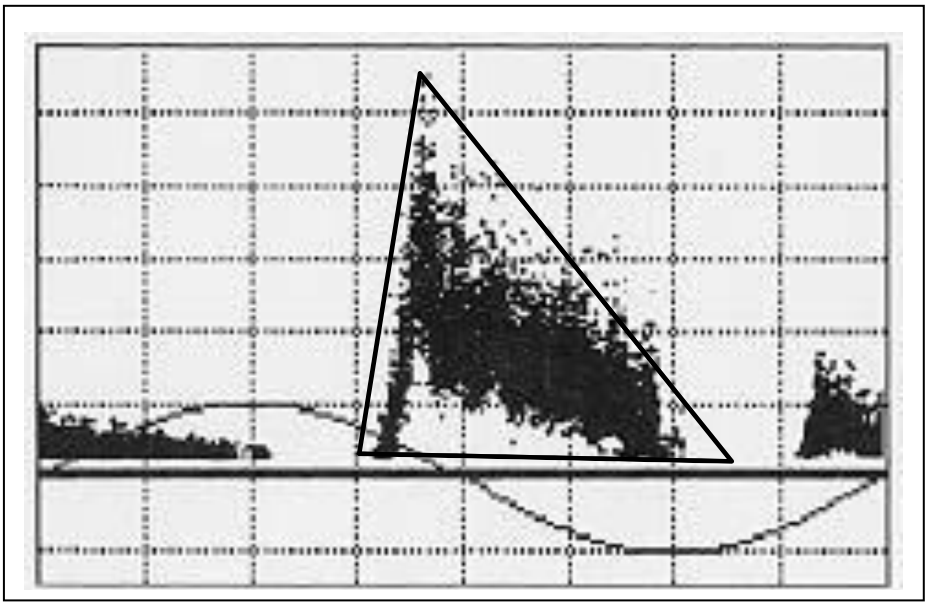


Figure 109:Typical Pattern of Slot Discharges

This pattern is asymmetric: the discharge magnitude is higher in the negative halfcycle than in the positive. The pattern in the negative half-cycle has a distinct triangular shape with a sharp rise around the negative voltage zero.

Typical Discharge Magnitudes around 10 nC.

9.3.2 Slot Discharges + Endwinding: F & J Locations

Sometimes two defects occur at the same time: in the following slot discharge F and sparking in the endwinding due to a light contamination with conductive remnants.

So called sparking can occur between conductors which are not connected to a potential these conductors are capacitively charged and whenever the voltage between these conductors exceed the inception voltage a spark occurs.

Typical is a discharge at nearly constant amplitude in both halfcycles as shown in the next Figure.

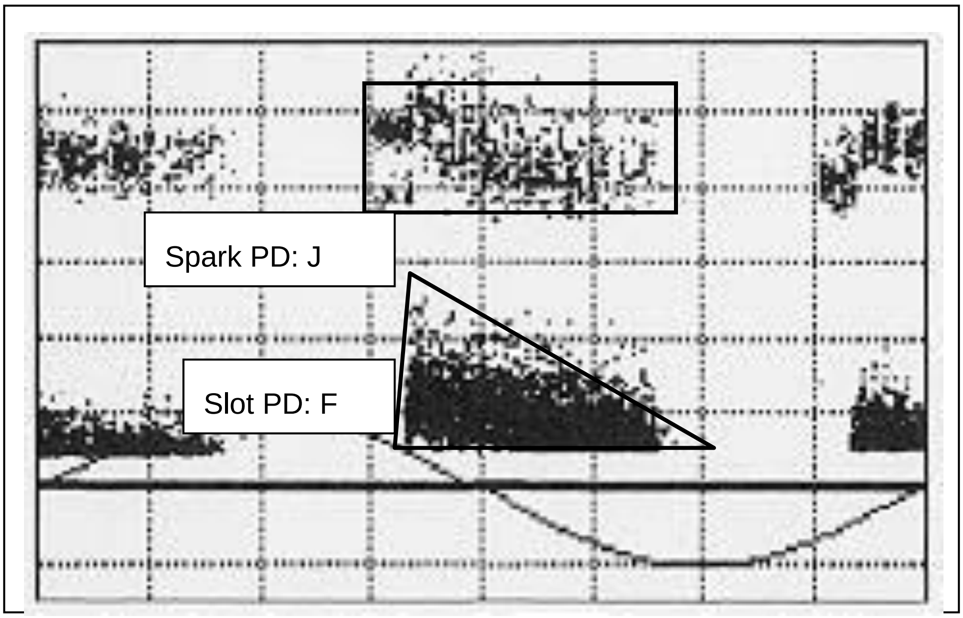


Figure 110:Typical Pattern of Slot Discharges & Sparking

Typical values for sparking are around 20 nC and higher.

9.3.3 Slot + Endwinding Discharges: F & J

A further typical superimposal of different discharge sources is given in the next example which shows the presence of slot discharges and discharges due to an eroded end-winding corona protection:

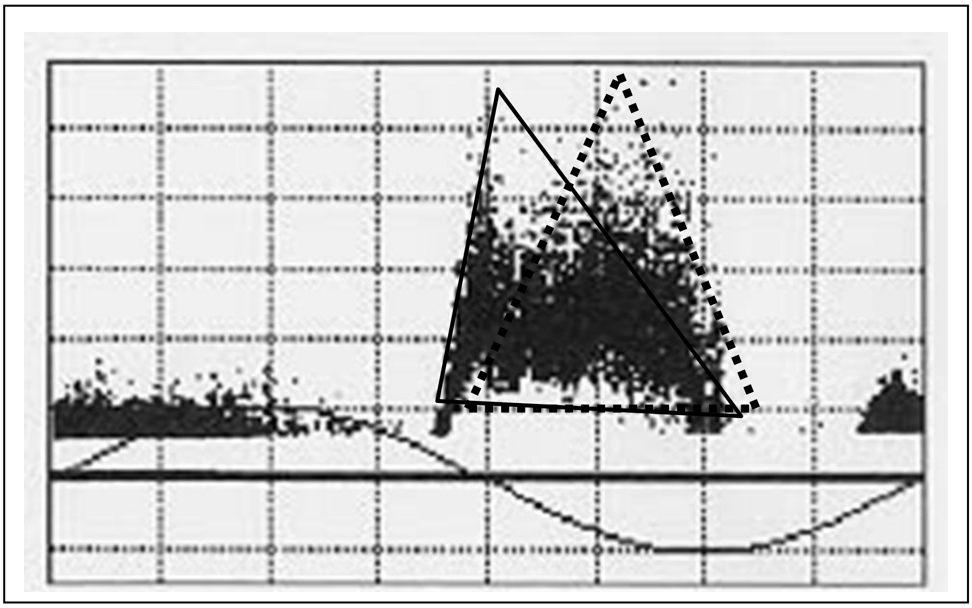


Figure 111:Typical Pattern of Slot & Endwinding Discharges

9.3.4 Endwinding Discharges: J

Endwinding discharges are created by a surface contamination or ageing or inadequate design of the potential grading in the endwinding. This ist usually indicted by white powders on the surface or within the layers of the endwinding tape.

It is very typical that the traces of partial discharge can be seen at the edges of the semiconducting tapes or under the tape layers.

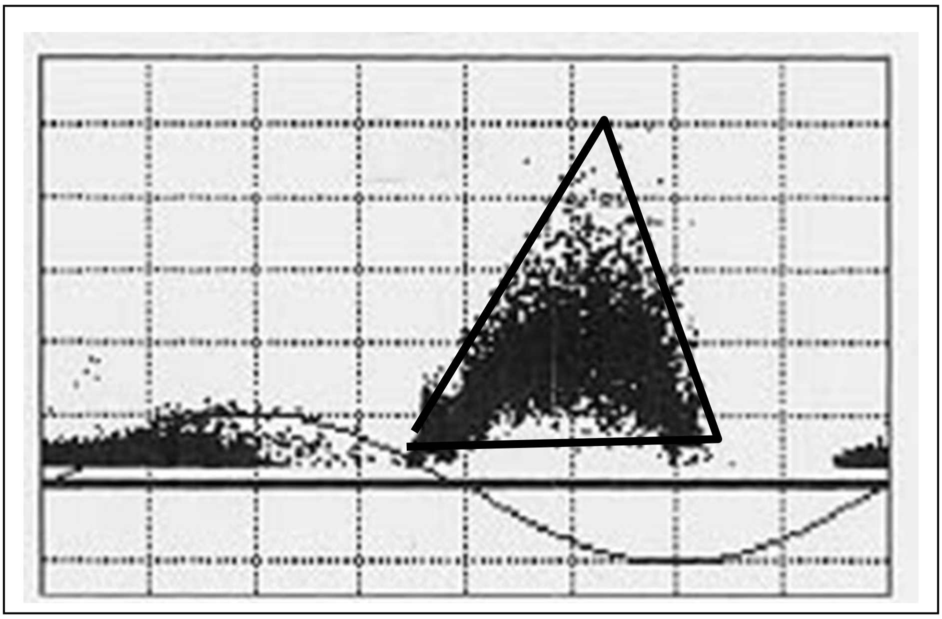


Figure 112:Typical Pattern of Endwinding Discharges

Typical is the asymmetry, negative halfcycle discharges are higher. But compared to slot discharges the triangular shape is different and more oriented to the voltage maximum.

Discharge magnitudes are around 10 nC.

Another modification of endwinding discharges is shown in next example, which is a superimposal of internal discharges in the main insulation (C-location) and surface discharges in an initial state.

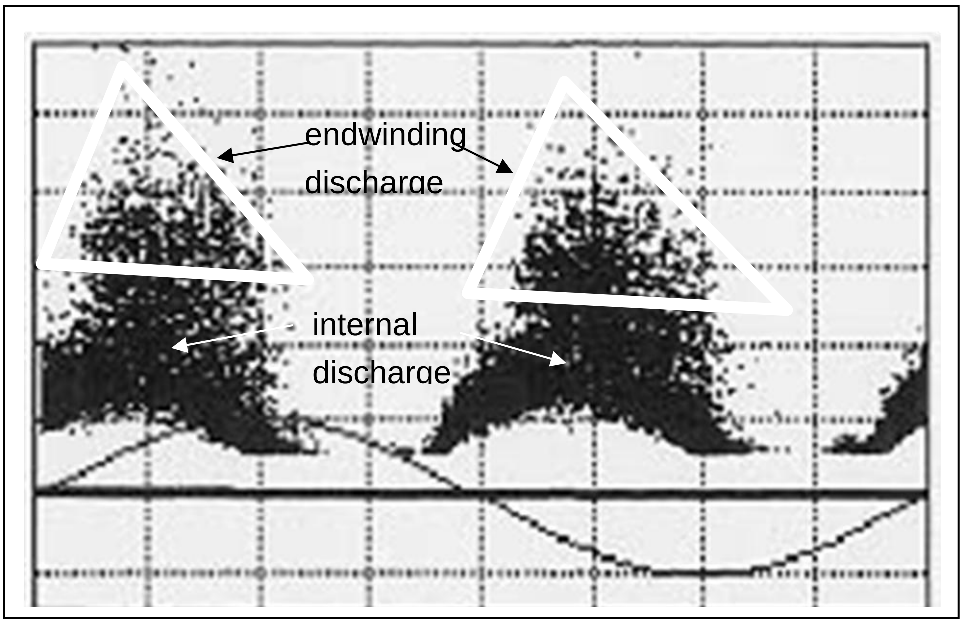


Figure 113:Typical Pattern of External and internal PD

9.3.5 Internal Discharges: C

If discharges prevail mainly in the mica paper layers and many discharge sites are presents usually a pattern depicted in the next Figure is created. The main characteristics are its symmetry with respect to voltage half-cycle and its centre of gravity which lies around 30 deg.

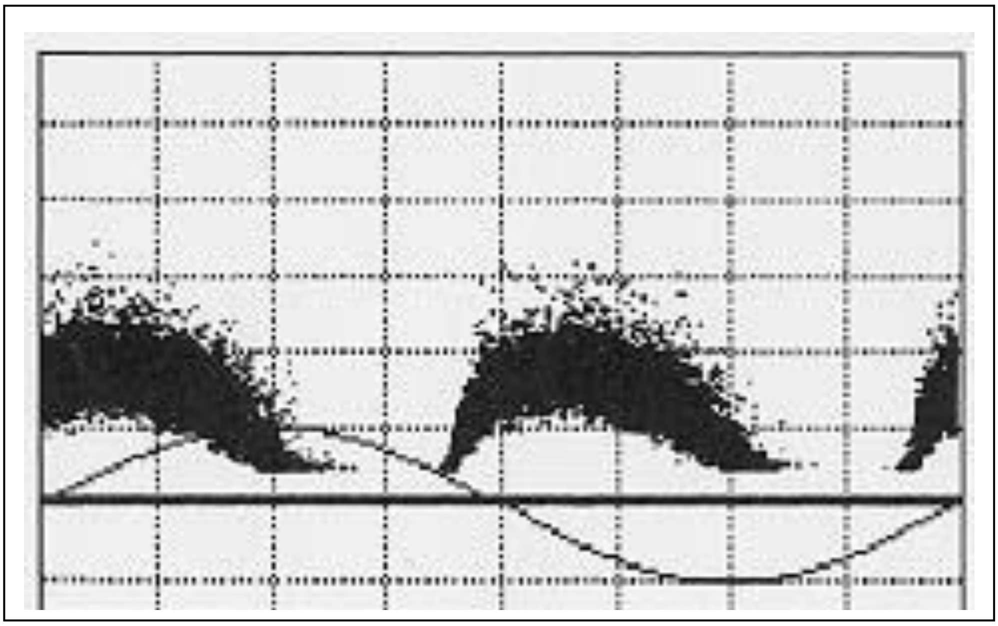


Figure 114:Typical Pattern of internal PD

9.3.6 Internal Discharges: A, B, C

The next Figures show internal discharges of A, B, C type in their initial state , these patterns are often encountered in new insulation (bars and machines and they exist in various similar patterns.

Small defects in A, B and C Location

Initial or birth state, characteristic is the symmetry and sine shaped lines and envelopes:

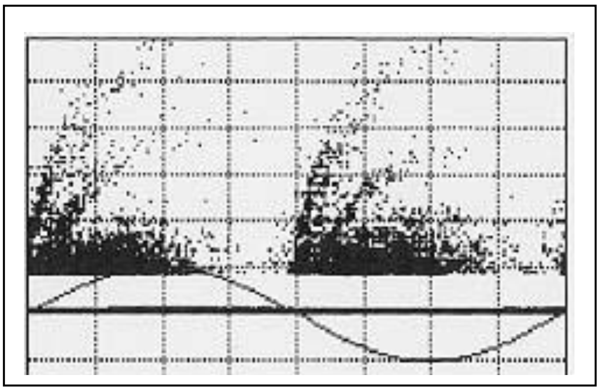


Figure 115:Typical Pattern: No Asymetry, probably C

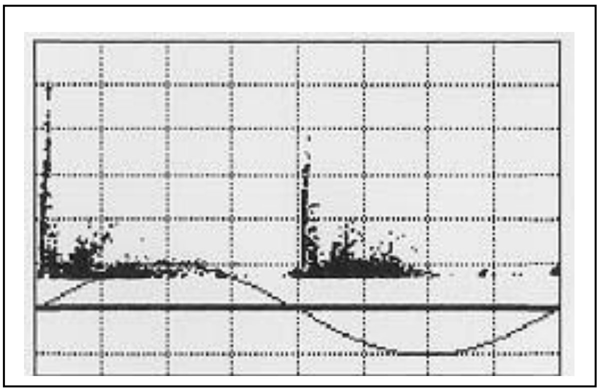


Figure 116:Typical Pattern slight asymmetry, positive higher, probably A or B

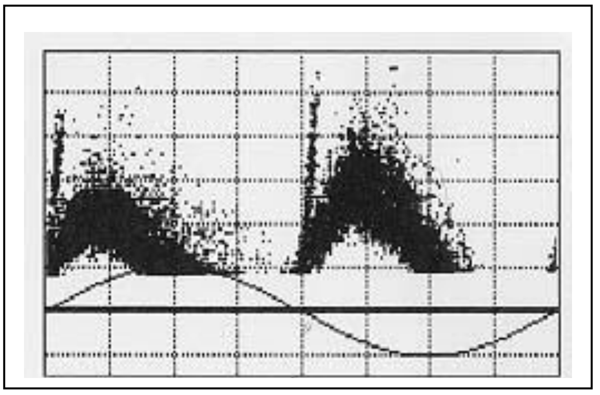


Figure 117:Typical Pattern: Rather symmetrical: Maybe C, probably slight thermal ageing

9.3.7 Endwinding Discharges: J

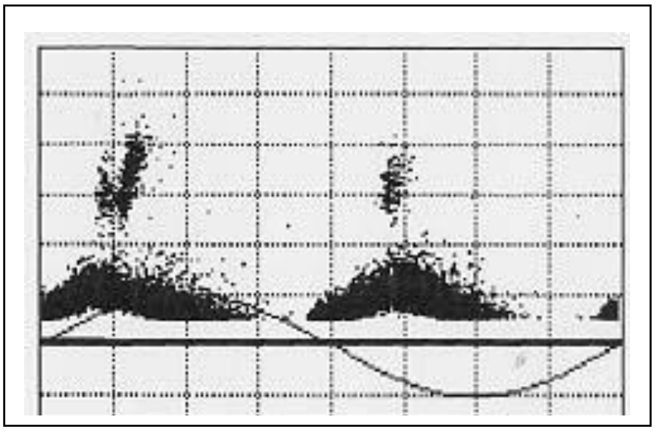


Figure 118:Typical Pattern: maybe surface tracking

Weak endwinding discharge: one or few sites maybe associated to surface tracking

Figure 119: surface tracking

9.3.8 Defect of internal Stress Grading: L

Very strong sparking (200nC) at low repetition rate due to badly contacted internal corona shield

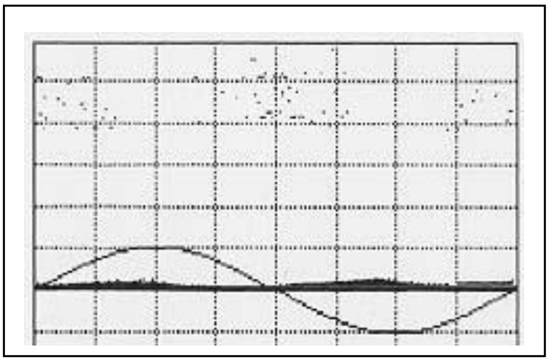


Figure 120: Poor Contact stress grading: L

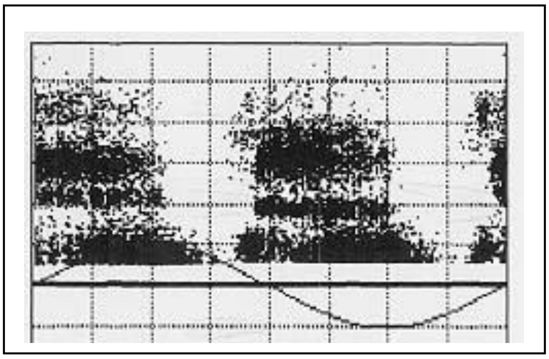


Figure 121: Poor Contact corona protection

Poor contact between slot corona protection and stress grading, capacitive charging effect. Looks like a contact problem, high magnitudes, 30 to 100nC

9.3.9 Internal Discharges C

One of the most prominent defects occurs when the main insulation detaches from the conductors. This is mainly caused by the differential thermal expansion of copper and the insulation material especially if no internal corona shield is applied and the machine is subjected to many load and temperature cycles.

Typical is a pattern which is similar to the slot discharge but the big partial discharge signals occur in the positive half-cycle.

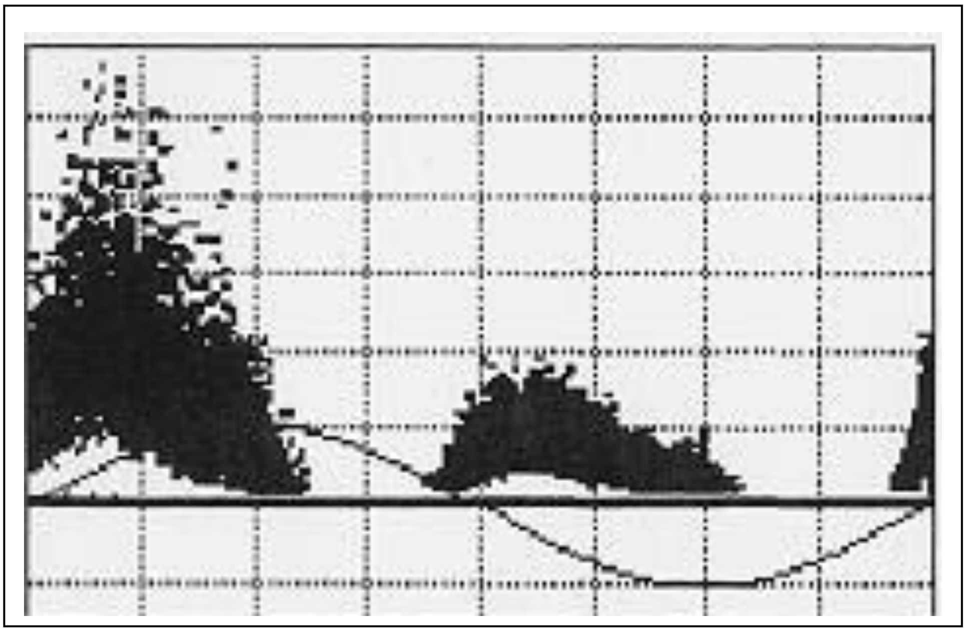


Figure 122: Typical Pattern internal Discharges

This may lead to a strong degradation and consequently to a deposition of pd by-products between main insulation and conductors:

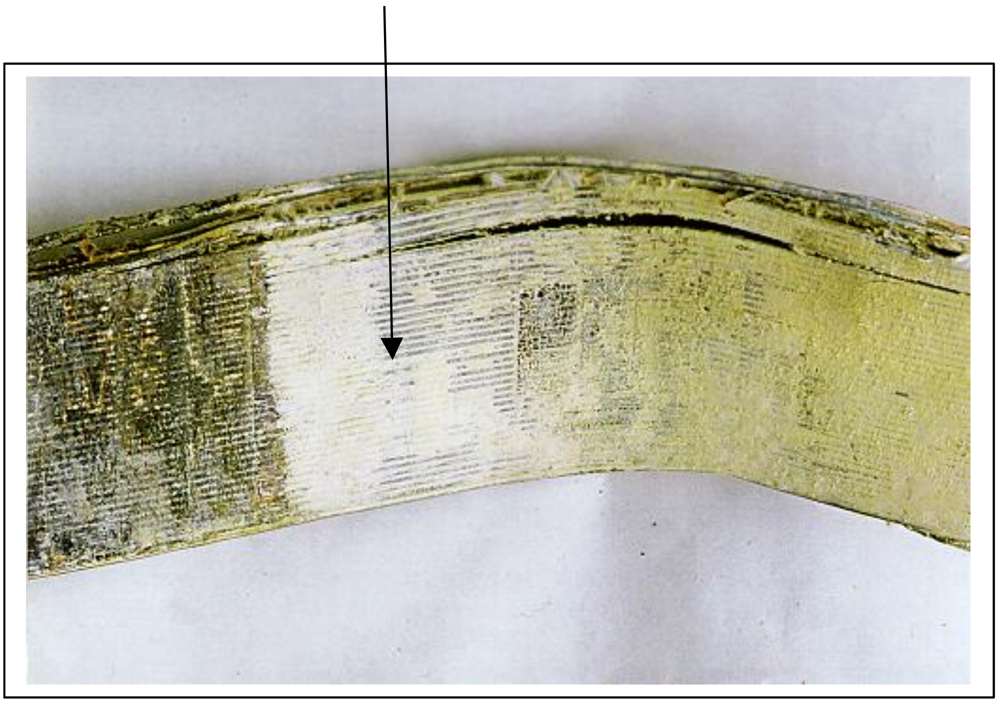


Figure 123: Deposits due to PD activity

9.4 Partial Discharge Measurements

9.4.1 Global Evaluation Table for Rotating Machines

Quality	PD (slot section), nC	PD (endwinding), nC
Excellent	<2	<2
Good	<4 to 5	<4 to 5
Average	4 to 10	4 to 10
Acceptable	~10	<15 – 20
Inspection necessary	>15	>20
Potential problem	>20	>50

Table 41: Global PD Evaluation Table

Special attention: the nC calibration is ambiguous due to the attenuation of partial discharge pulses in the winding. Above table should only be used as a general guideline only and a detailed analysis of each specific case is necessary.

9.4.2 Defect Type – General Risk Assessment Table according to IEC60034-27

PD source	Risk	Remarks
Internal voids Clause 4.2.1	Low	Inner (internal) PD's are generated within air or gas filled pockets that are embedded within the main insulation. They result from the manufacturing process and do not indicate aging factors. Under normal circumstances internal discharges do not lead to remarkable aging.
Internal delamination Clause 4.2.2	High	Internal delamination PD's are generated within air or gas filled elongated pockets (in longitudinal direction) that are embedded within the main insulation. They often result from overheating or from extreme mechanical forces that both lead to separation of large areas between insulation layers.
Delamination between conductors and insulation Clause 4.2.3	High	Delamination PD's between conductors and insulation material are generated within air or gas filled elongated pockets (in longitudinal direction) that are embedded between the main insulation and the field grading material. They often result from overheating or from extreme mechanical forces that both lead to separation of large areas between these layers.
Slot discharges Clause 4.2.4	High	Slot discharges are generated by poor, or missing, contact between the field grading layer and the stator slot wall. Typically these discharges appear only during operation of the machine. Electromechanical forces and vibration lead to contact arcing that can be measured as slot PD. Only in case of large degradation of the field grading layer such slot discharges can be measured off-line, and than they can be characterized as the PD source explained in 4.2.3
Endwinding & surface discharges Clause 4.2.5	Normal	End winding and surface PD's are generated somewhere on the surface of the insulation material and therefore are located naturally in the end winding section of a machine. They result often from conductive contamination (carbon, oily dust, abrasion, ...) or from damaged field grading materials. Since they only appear on the surface of the insulation they naturally do not lead to significant aging.
Conductive particles Clause 4.2.6	Normal	PD's from conductive particles are generated somewhere on the surface of the insulation material and therefore are located naturally in the end winding section of a machine. They result often from large areas of conductive contamination (carbon, oily dust, abrasion, ...) or from separated regions of field grading materials. Since they only appear on the surface of the insulation they naturally do not lead to significant aging.

Table 42: Risk Classification according to IEC60034-27

9.4.3 Alarm Tresholds according to IEC60034-27-2

The IEC standard does not indicate a specific alarm threshold, but states the following information regarding alarm set points under chapter 11.2 “Evaluation of basic trend parameters”

“Doubling of Qm over one year may be an indication that significant deterioration has occurred. Additional off-line tests or a visual inspection of the winding may then be warranted.”

9.4.4 Monitoring

The trend recording devices as the UDL-8000 Series show a deviation from an initially assessed condition. The calibration levels and pattern scales are recorded prior to define initial condition.

The patterns may vary in amplitude. If no drastic changes are detected over time and the shape remains similar the partial discharge process is stable and the risk is usually low. Generally, one might say that maximum charge level reacts on defect size mainly but depends on machine type.

Patterns or signal amplitudes may vary with load and temperature:

Decrease of PD with load/temperature:

- Normal, statistical time lag decreases > lower amplitude.
- Insulation expands with temperature > closing of delaminations > lower amplitudes.

Increase with Load alone.

- Wedge loosens.

9.5 Boundary Conditions and Prerequisites for PD Analysis

PD measurements and their analysis is a powerful tool for detecting locally confined insulation defects in insulation systems of electrical machines and therefore to assess the actual condition of the ground wall and end winding insulation as well as the corona protection system. However, due to the principles of PD, not all machine problems can unambiguously be detected by PD measurements. Usually, insulation defects that can be detected by PD measurements require locally strongly increased electrical fields leading to repetitive current pulses. Therefore insulation failures where continuous leakage currents due to steady conductive paths between different insulation components are involved (e.g. short circuits, burnt out current path’s etc.) may not be detectable.

A lesser part of PD phenomena is stable and continuous. It is therefore normal that partial discharge patterns vary in amplitude from one periodic measurement to another. This is due to the different operational forces and stresses depending on the operating and ambient conditions such as load and temperature at the time of measurement. Recording the operating conditions at the time of measurement is therefore a prerequisite for detail analysis of PD.

The discharge amplitude is considered as part of the evaluation process, its significance is however much lower than the pattern, as only the pattern provides information on the discharge type and hence the endangerment of operational reliability. Generally, if there is no significant change in the partial discharge pattern and no significant increase in amplitude (change greater than factor 2) then the partial discharge trend activity is considered to be stable.

An information always to be provided for a detail PD analysis is the type of the insulation system (mica epoxy, asphalt micafolium, …), preferably including the brand name. The insulation systems show distinct weaknesses and different susceptibility to the various discharge types.

IMPORTANT NOTE: Use of this Knowledge Base:

In no event shall Sparks Instruments SA, Switzerland be liable for special, indirect or consequential loss or damages.