

Universal Data Acquisition and Monitoring System for insula- tion condition monitoring of high voltage machines

UDL-8000 V5

Application Manual

Partial Discharge Monitoring

(PDSIM + M8019)

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

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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

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 (PDSIM) acquisition module is specifically designed for RF partial discharge monitoring of 3 phase 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.

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

The PDSIM Acquisition module is especially designed for 3 phase high voltage equipment as rotating machines, power transformers or Power Cables as it provides additional pulse analysis between the channels.

The UDL-8000 with PDSIM acquisition module is available in 2 main configurations:

- 3 or 4 Simultaneous input channels with an optional noise gating channel
- 18 or 19 Input channels, while 3 respectively 4 input channels are measured simultaneously. The system can be extended with an additional noise gating channel

While the standard version uses multiple single channel M8019 input modules, the 18 Channel version includes 3x 6 channel M8019 input modules which are multiplexed between the measurements.

Depending on the project requirements, the system is integrated in a 63TE or in a 80TE enclosure. The illustration below shows the UDL-8000 with 4 Simultaneous PD inputs, 1 noise gating channel, 16x analogue input and 16x analogue output channels.

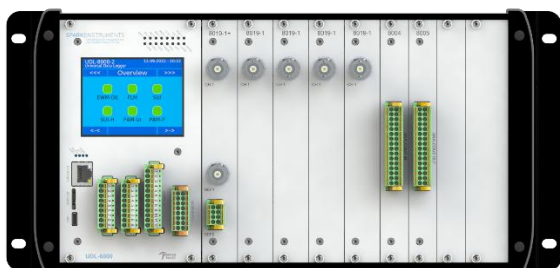


Figure 1: UDL-8000 System pd monitoring with 4 simultaneous PD channels

On the next illustration the UDL-8000 is presented within a 63 TE enclosure, with 18+1 RF PD Channels and 1x noise gating channel

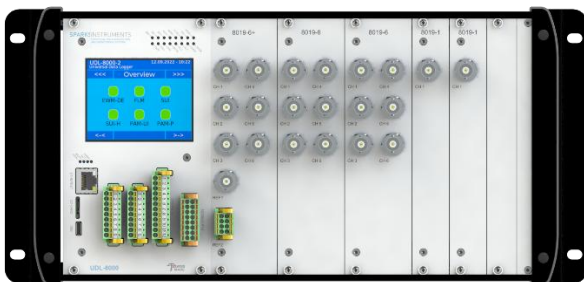


Figure 2: UDL-8000 System pd monitoring with 18+1 RF input channels

For projects which require analogue and digital in and outputs, the system can be provided within a 80TE enclosure as shown below:

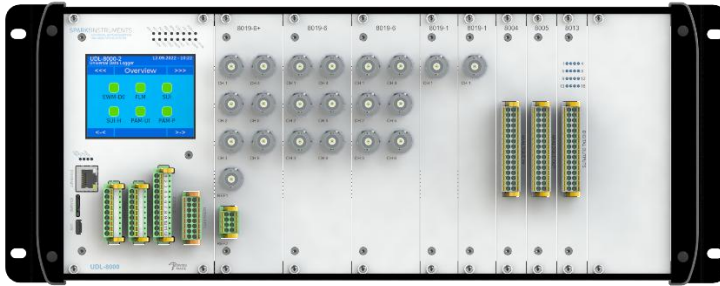


Figure 3: UDL-8000 System pd monitoring with 18+1 RF input channels

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 PDSIM acquisition module handle the acquisition of the RF partial discharges simultaneously over a maximum of 4 channels. For system configurations with 3x M8019-6 input modules, once channel from each module is acquired simultaneously, and switched to the next channel for the next simultaneous acquisition.

While acquiring the data simultaneously over the 3 respectively 4 channels, the acquisition module PDSIM performs additional parameters in regards to the pulse activity between the channels.

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 typi-

cally required whenever partial discharge measurements are performed on power cables by using RT CT's.

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.

Whenever data is acquired simultaneously, only one voltage reference is taken for the synchronization of the acquisition. For 3-phase measurements, the system assumes that the phase angle between the channel is fixed at -120° . The phase angles between the channels can alternatively be configured manually.

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.

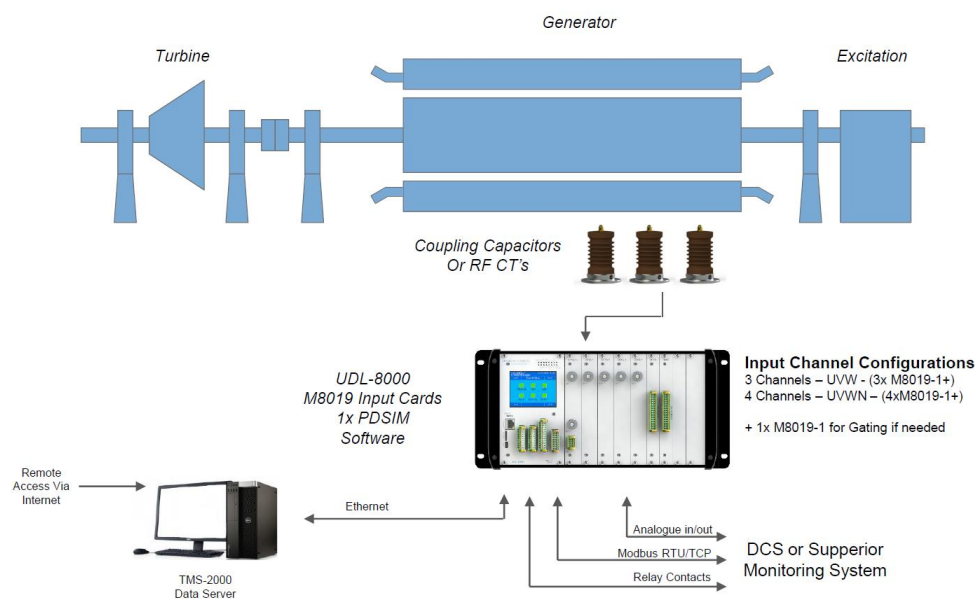


Figure 4: UDL-8000 System for standard PD monitoring on turbo generators

For machines $> \sim 30\text{MW}$, 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 System can be fitted with 3x M8019-6+ input modules to increase the

number of input channels up to 18. Under such a configuration, 3 couplers are acquired simultaneously before switching to the next 3 channels to be acquired.

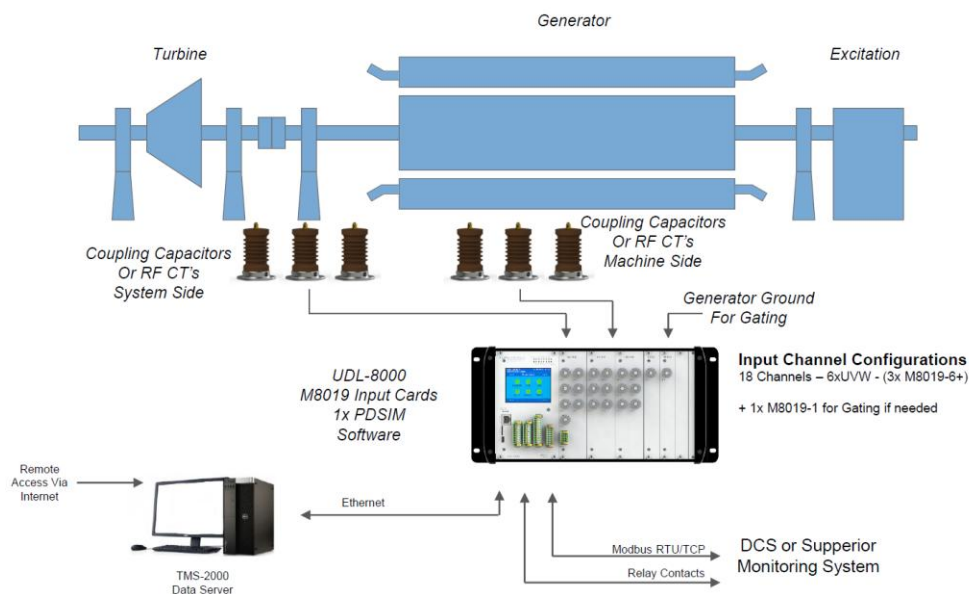


Figure 5: UDL-8000 System for 18 CH. PD monitoring on turbo generators

For generators which are equipped with Stator Slot Couplers (SSC), the multichannel PD system is typically used, allowing to measure simultaneously 3 SSC outputs at a time. The presented system configuration below can be used for up to 9 SSC's with each 2 outputs.

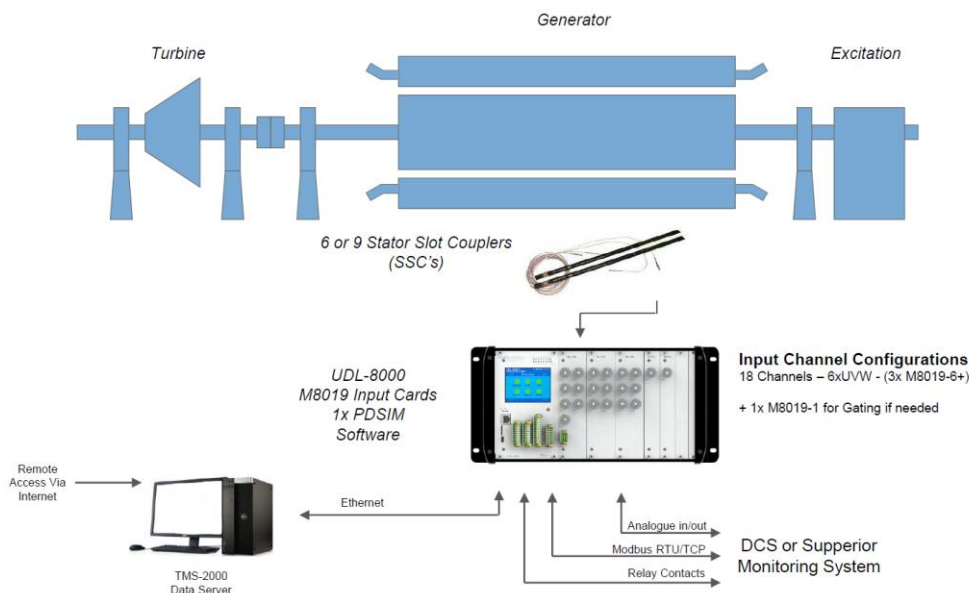


Figure 6: UDL-8000 System for 18 CH. PD monitoring on turbo generators

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, an additional single channel input module M8019 is required.

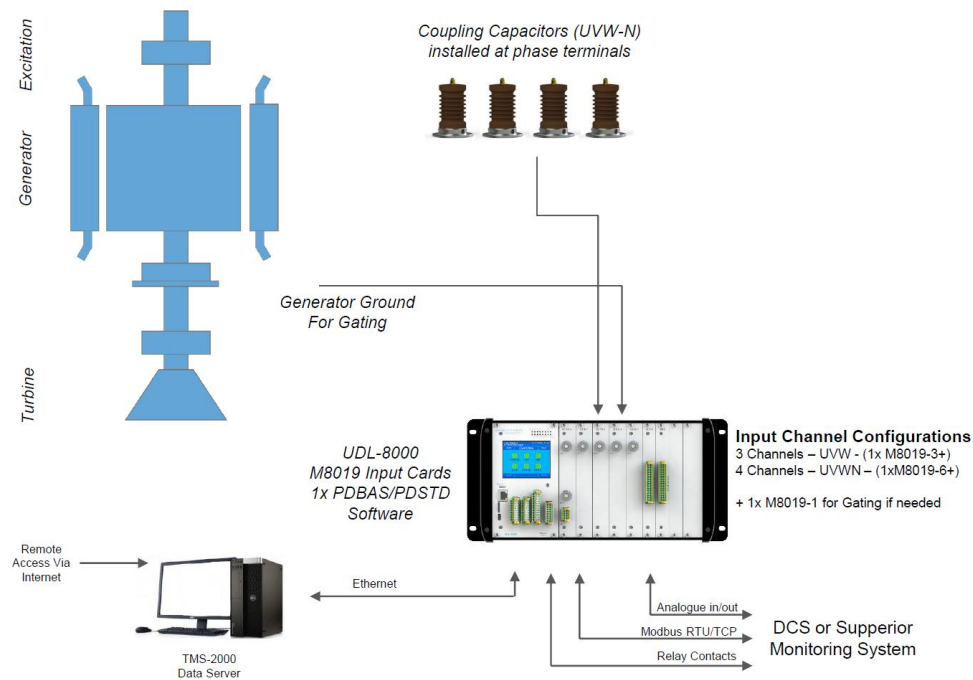


Figure 7: UDL-8000 System for 3/4 CH. PD monitoring on hydro generators

For customers who require coupling capacitors installed within the generator winding, typically for each parallel circuit, the system can be fitted with 3x M8019-6 input modules, offering up to 18 channels (6 parallel circuits).

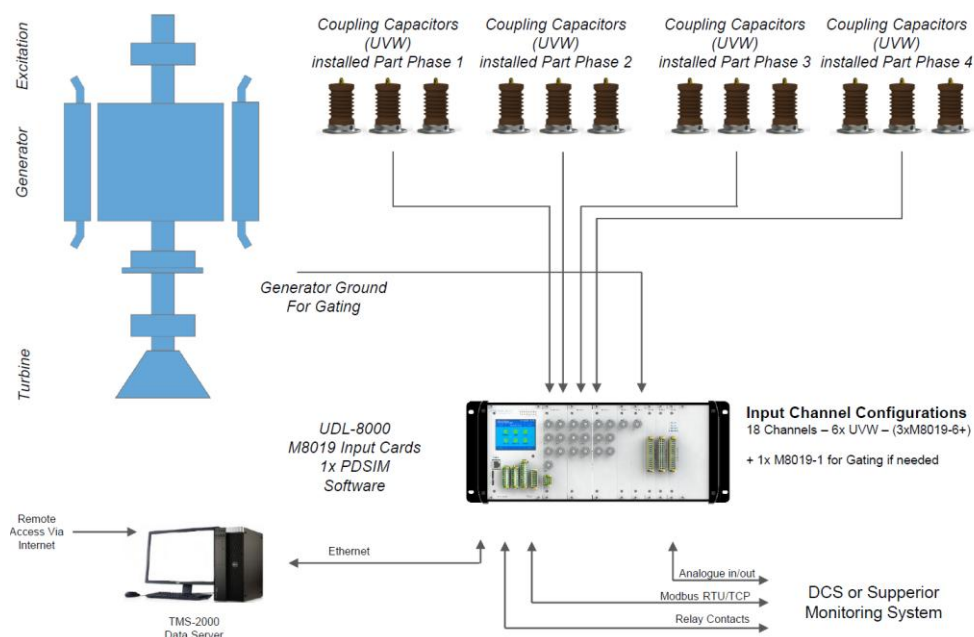


Figure 8: UDL-8000 System for 12 CH. PD monitoring on hydro generators

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.

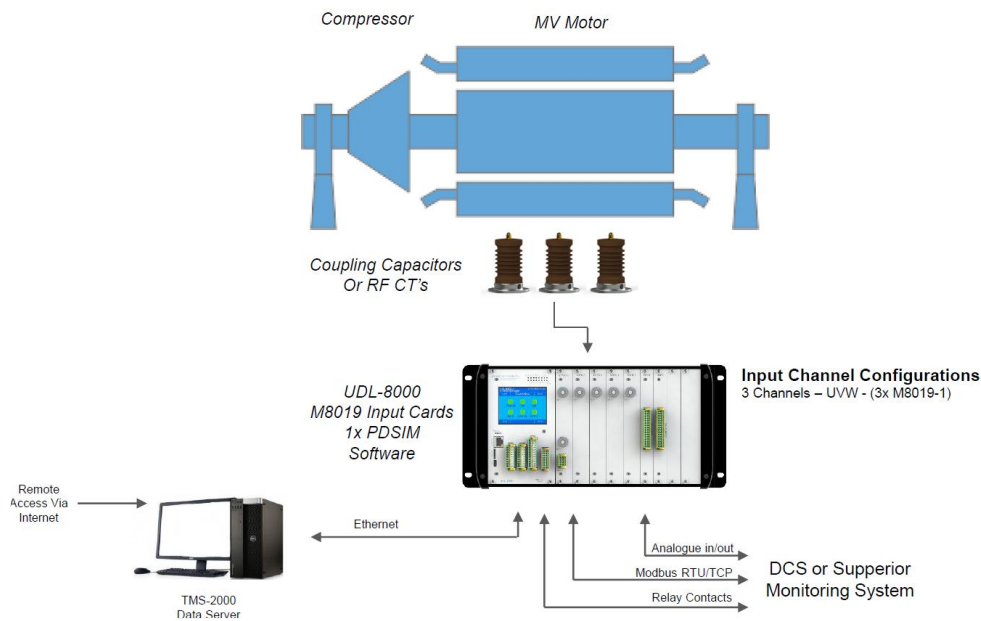


Figure 9: UDL-8000 System for 3 CH. PD monitoring on MV Motors

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.

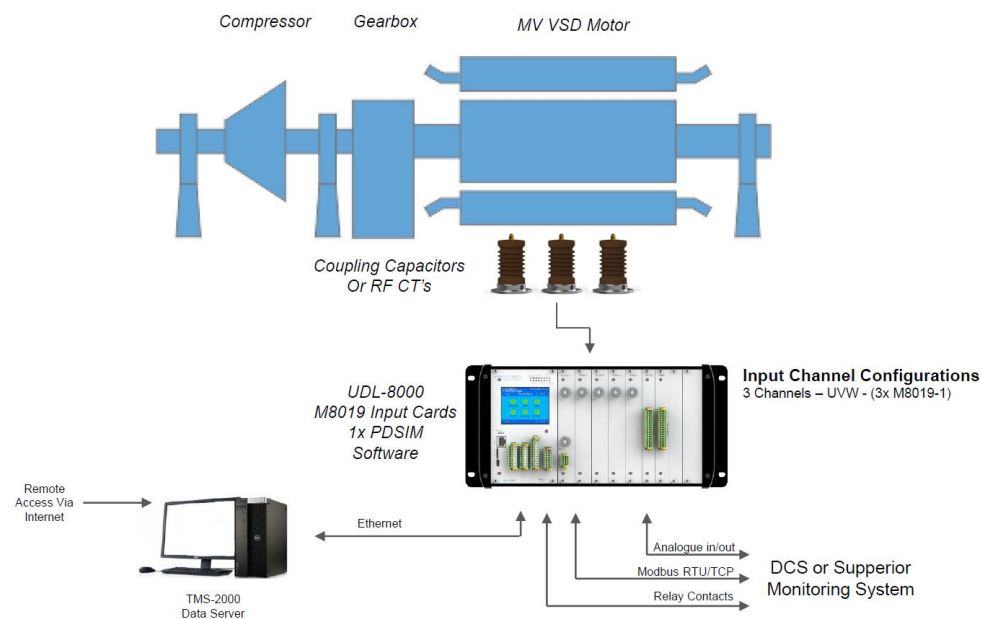


Figure 10: UDL-8000 System for 3 CH. PD monitoring on MV VSD Motors

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.

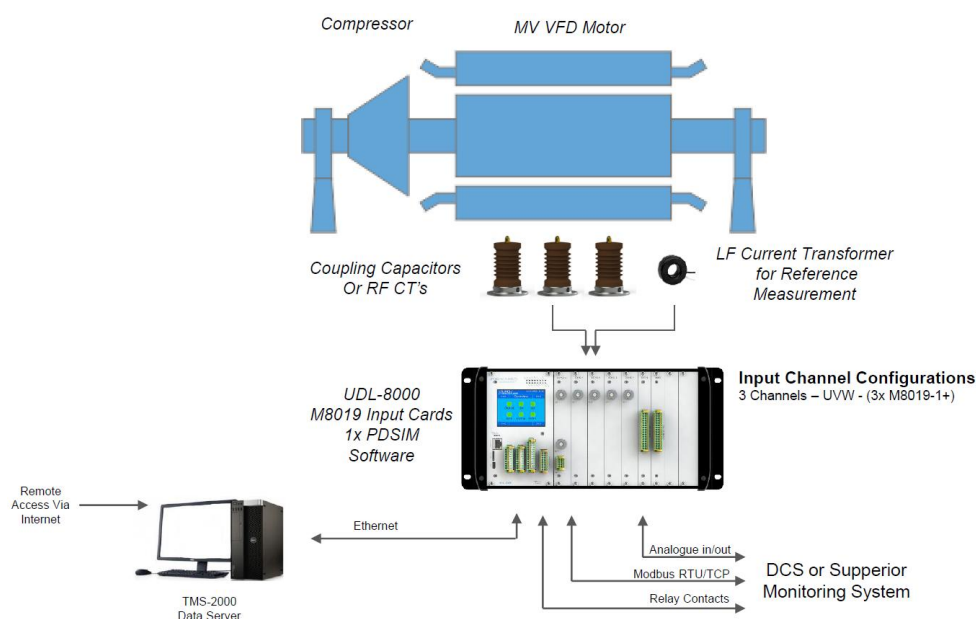


Figure 11: UDL-8000 System for 3 CH. PD monitoring on MV VFD Motors

The M8019-1+ 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).

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.

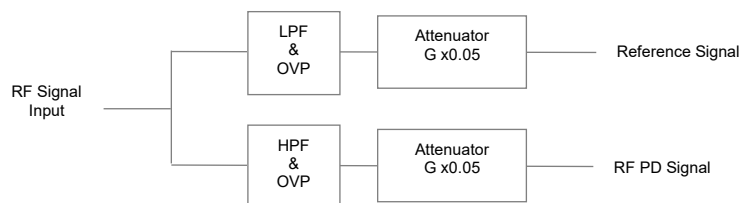


Figure 12: Principle of the partial discharge input

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.

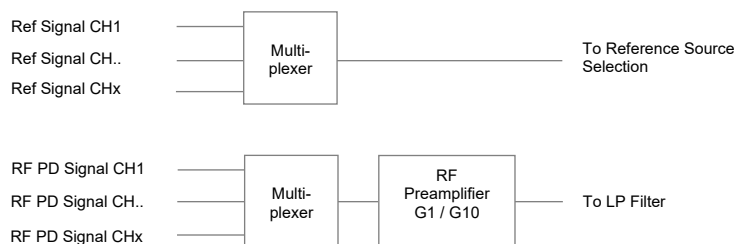


Figure 13: Input Range selection of the partial discharge input

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.

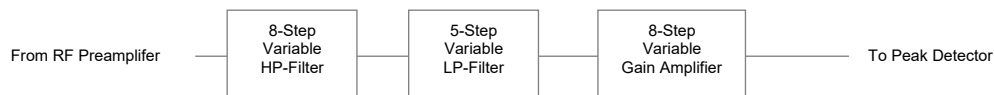


Figure 14: Filtering and amplification of the partial discharge input

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 ana-

logue-digital converter, and the trigger is reset, making the system ready for the next pulse detection.

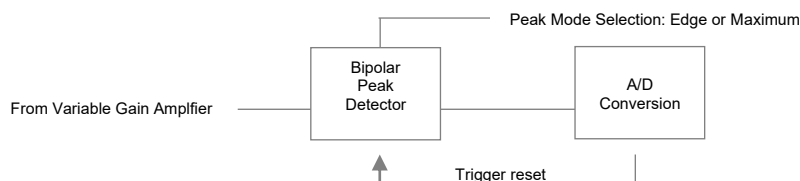


Figure 15: Peak Detection and A/D Conversion

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.

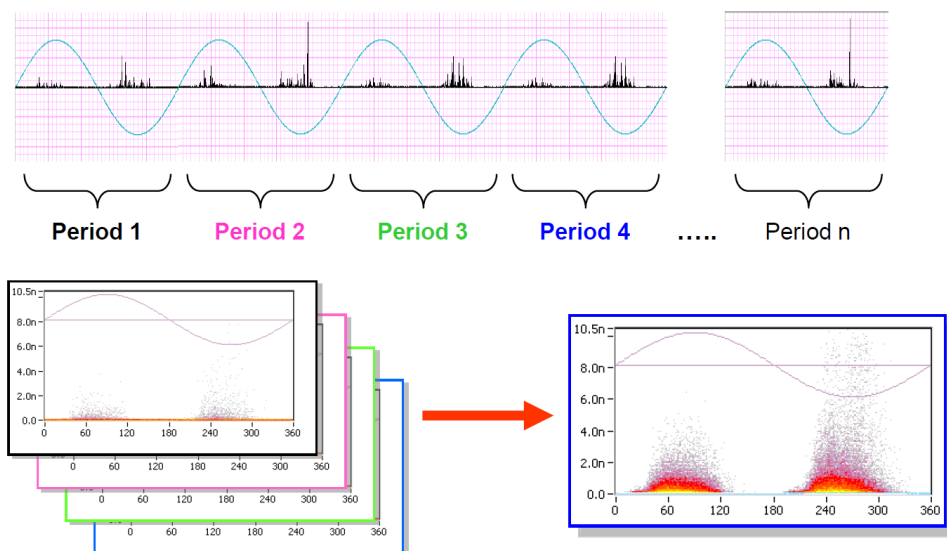


Figure 16: Continuous partial discharge data acquisition

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.

The high resolution PRPD pattern with 512 amplitude windows and 512 phase windows offer enhanced data analysis and help to identify multiple PD sources within one single PD measurement.

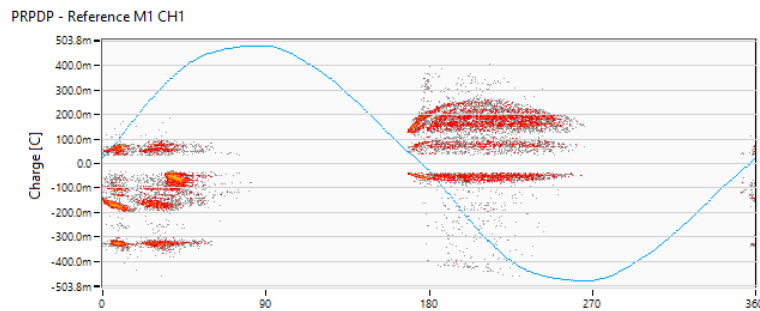


Figure 17: PDSIM – High Resolution PRPD Patterns

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.

The simultaneous partial discharge acquisition with the PDSIM acquisition module provide additional information about the pulse activity between the channels / phases to provide an additional graph called the TR Pattern (Time Relation pattern).

The TR Pattern is created by taking the pulses of the first 3 channels (Phase U / V / W). Each pulse at the specific sample interval will have its amplitude and is attributed with a phase angle to define a vector:

- Phase U: Amplitude + 0°
- Phase V: Amplitude + 120°
- Phase W: Amplitude + 240°

Each vector is further added together as $V_{tr} = |(V_u + 0^\circ)| + |(V_v + 120^\circ)| + |(V_w + 240^\circ)|$. The resulting TR Vector V_{tr} is then shown as a “dot” within the TR pattern. The calculations are made for every acquired pulse / sample and the occurrences are presented with a color coding.

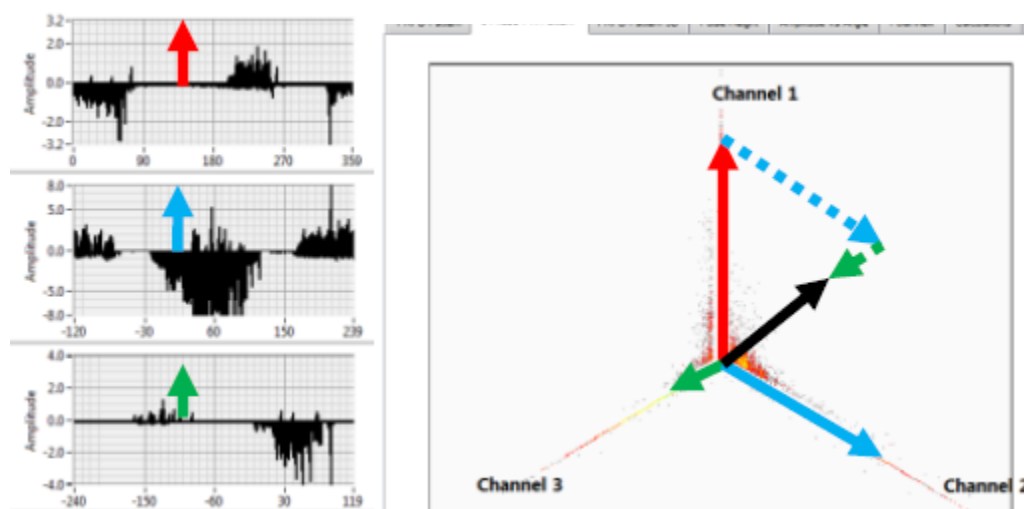


Figure 18: PDSIM – TR Vector calculation

The result of the TR pattern will indicate if the partial discharges are present only on the dedicated phase (drawn into the specific channel direction) or if there are discharges between the phases, which will result in a vector between the phases

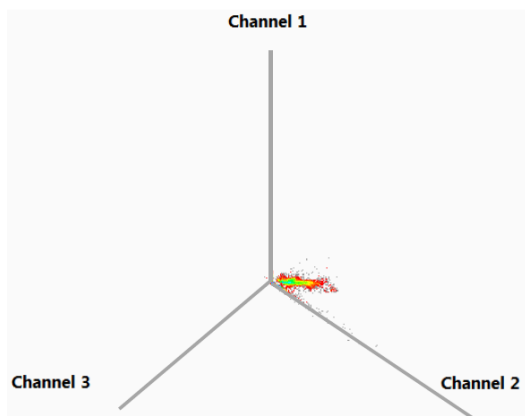


Figure 19: PDSIM – TR Pattern with discharges between phase U and V

Further on, it is possible to activate an additional noise cancelling feature, the TR Gating. The TR Gating will suppress all TR Vectors below a certain vector length, allowing to create PRPD patterns without a common noise level

The results removed from the PRPD patterns is shown as a white circle within the center of the TR pattern.

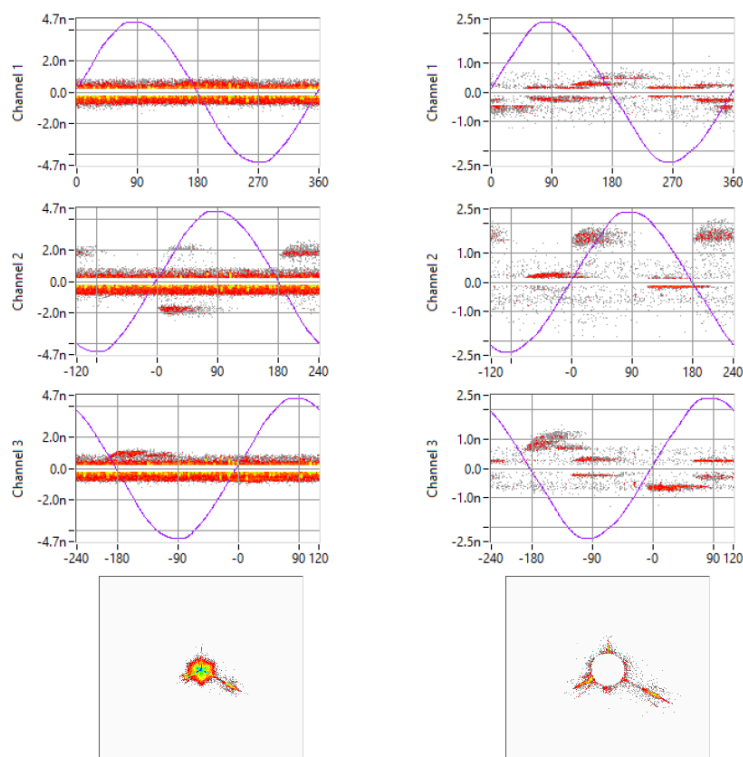


Figure 20: PDSIM – TR Gating

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 PDSIM, the channels are assigned as

Channel 1: Reference Voltage
 Channel 2: PD Input Channel 1
 Channel 3: PD Input Channel 2
 Channel 4: PD Input Channel 3
 Channel 5: PD Input Channel 4
 Channel 6: not used
 Channel 7: not used
 Channel 8: Gating Channel

For the 18-channel solution, with 3x M8019-6 input modules, the acquisition is done per 1 channel of each module. And for every channel, a separate acquisition module must be configured, this results into the following acquisition sequence.

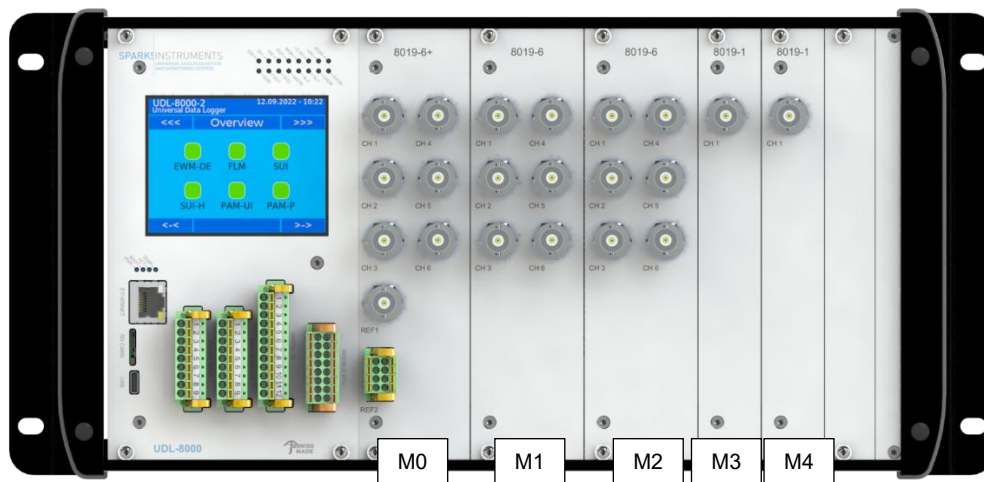


Figure 21: Input Module Assignment

ACQ Module 1 (PDSIM)	ACQ Module 2 (PDSIM)	ACQ Module 3 (PDSIM)	Etc.	Channel
Reference Voltage	Reference Voltage	Reference Voltage	...	CH1
PD Input Channel 1, Input Module M0	PD Input Channel 2, Input Module M0	PD Input Channel 3, Input Module M0	...	CH2
PD Input Channel 1, Input Module M1	PD Input Channel 2, Input Module M1	PD Input Channel 3, Input Module M1	...	CH3
PD Input Channel 1, Input Module M2	PD Input Channel 2, Input Module M2	PD Input Channel 3, Input Module M2	...	CH4
PD Input Channel 1, Input Module M3	PD Input Channel 1, Input Module M3	PD Input Channel 1, Input Module M3	...	CH5
Not used	Not used	Not used	...	CH6
Not used	Not used	Not used	...	CH7
PD Input Channel 1, Input Module M4	PD Input Channel 1, Input Module M4	PD Input Channel 1, Input Module M4	..	CH8

Table 1: PDSIM Acquisition Module and channel grouping

Therefore, for every group of the 3 simultaneous input channels, a separate acquisition module needs to be configured and the used input channel per module needs to be defined for each 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 0 – typically in nC unit

Parameter	Description
0	PPS1
1	PPS5
2	PPS10
3	Repetition Rate (R)
4	Peak Discharge (Qp)
5	Apparent Charge
6	Average Discharge Current [A]
7	NQN

Table 2: Calculation parameters 0

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

Calculation parameters 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	Not used
7	Not used

Table 3: Calculation parameters 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 4: Calculation parameters Set 2

Calculation parameters Set 3 – typically in nC unit

Parameter	Description
0	Qr10+ Positive Charge Level at cumulated Pulse Repetition Rate 10Hz
1	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	Qr10 Charge Level at cumulated Pulse Repetition Rate 10Hz
7	Qiec

Table 5: Calculation parameters Set 3

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
- By Cumulated Window

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

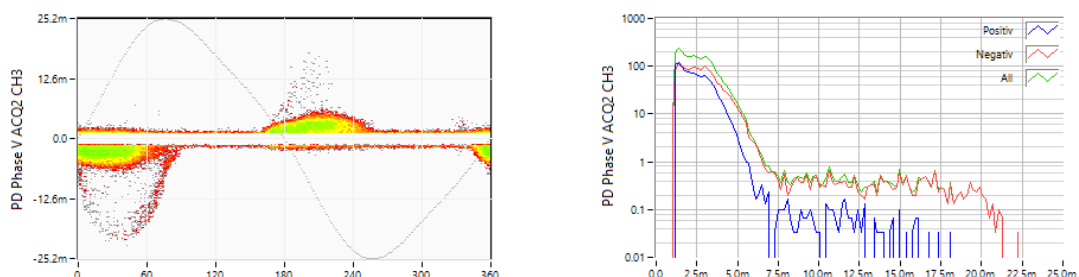


Figure 22: Phase Resolved PD Pattern (left) and Pulse Height Distribution (right)

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

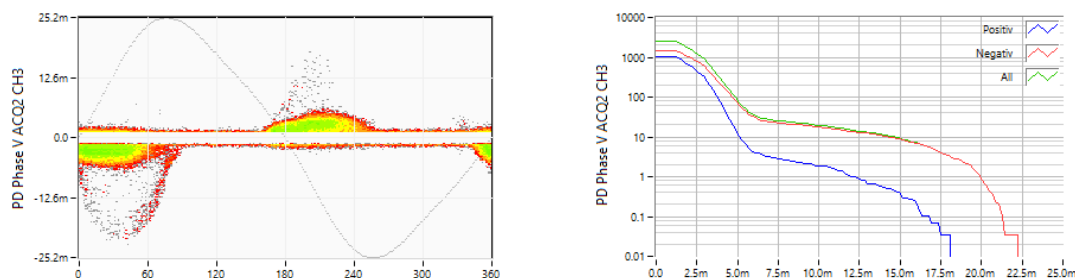


Figure 23: Phase Resolved PD Pattern (left) and Pulse Height Distribution (right)

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

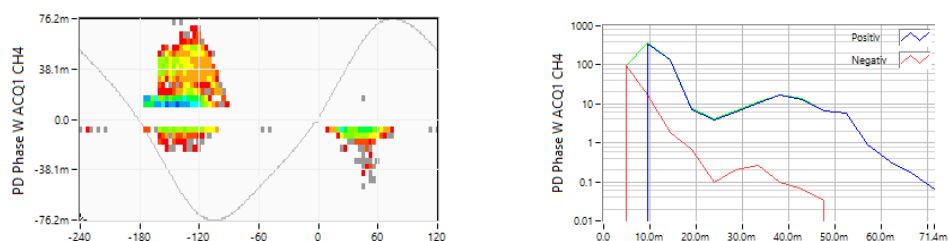


Figure 24: Pulse Height Distribution based on 2x16 Amplitude Windows

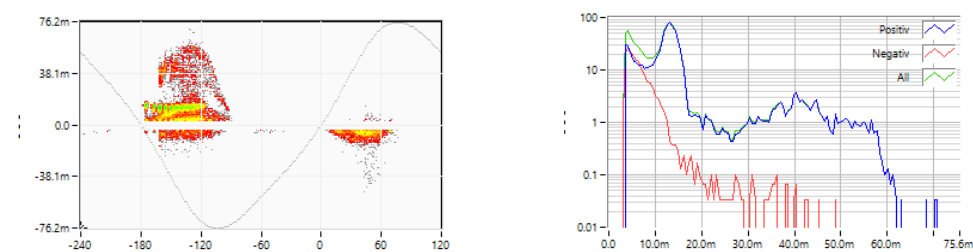


Figure 25: Pulse Height Distribution based on 2x128 Amplitude Windows

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

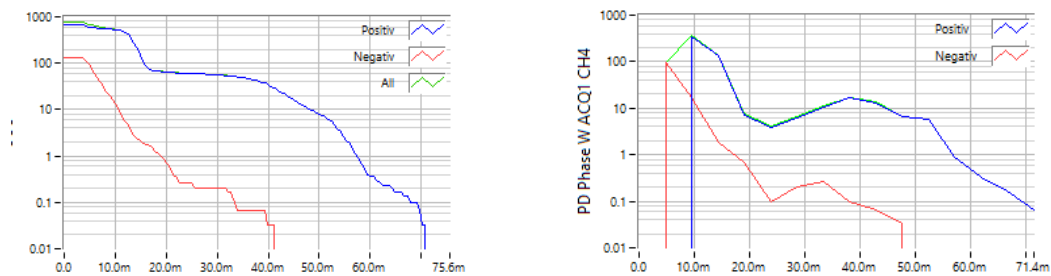


Figure 26: Cumulated Pulse Height Distribution based on 2x16 resp. 2x128 Amplitude Windows

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.

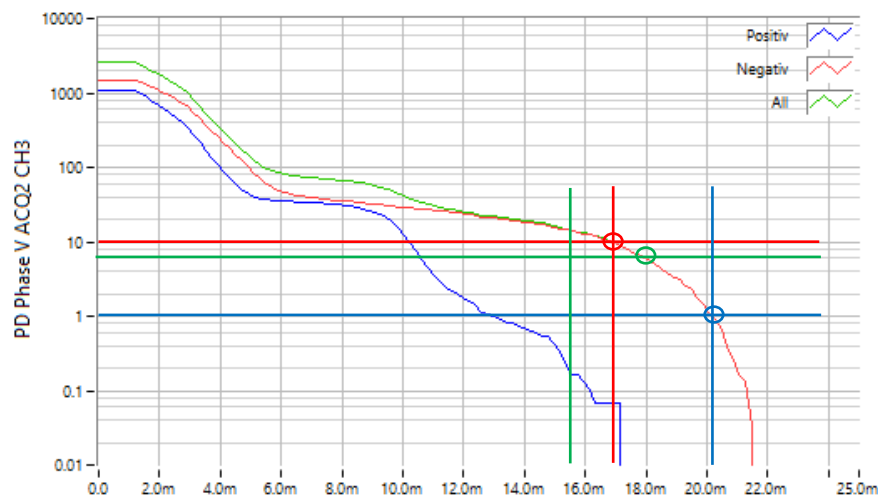


Figure 27: Cumulated Pulse Height distribution and Qr amplitudes

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 6: 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 quantities 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 (Qm+ and Qm-)

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 per acquisition module.

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 maximum of 6 PD channel inputs (depending on the number of channels used). Channel 8 include the values from the gating channel (if used).

To simplify the description of the parameters, the tables below are based on calculation parameter set 0. For the first acquisition module all CH ID's must be incremented by 64. When using the 3x M8019-6 input modules, add 64 for every defined acquisition module.

3.8.1 Reference Voltage from Input Module M0 – 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 7: Reference Voltage Parameter Table - Channel 1

3.8.2 PD Channel 1-6 from Input Module M0 – 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	- or A	
15	PD CH1/7/13/19 - NQN		

Table 8: PD Channel 1-6 M0 Parameter Table

3.8.3 PD Channel 1-6 from Input Module M1 – 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 9: PD Channel 1-6 M1 Parameter Table

3.8.4 PD Channel 1-6 from Input Module M2 – 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 10: PD Channel 1-6 M2 Parameter Table

3.8.5 PD Channel 4 for Input Module M3 – 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 11: PD Channel 1-6 M3 Parameter Table

3.8.6 CH6

Not used

3.8.7 CH7

Not used

3.8.8 Gating Channel Input from input module M4 – CH8

The following parameters are calculated from the gating channel

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

Table 12: Gating Channel M4 Parameter Table

4 Hardware & Software Requirements

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The UDL-8000 monitoring system used for the partial discharge monitoring with Simultaneous data acquisition can be equipped with up to 5 partial discharge Input modules and 3 I/O Modules, providing a system with up to 19 pd input channels with 3x M8019-6 and 2x M8019-1 input modules. Or 5 pd Input channels with 5x M8019-1 input modules.

For the 3 or 4 PD Input Channels, the following equipment is required for the acquisition:

- 1x UDL-8000 Controller
- 3x Hardware Module M8019-1, one for each phase (U/V/W)
- 1x Hardware Module M8019-1 for Neutral Point (optional)
- 1x Hardware Module M8019-1 for Noise gating (optional)
- 1x Software Module PDSIM
- 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 measurement.

For the 18 or 19 PD Input Channels, the following equipment is required for the acquisition:

- 1x UDL-8000 Controller
- 3x Hardware Module M8019-6, one for each phase group (U/V/W)
- 1x Hardware Module M8019-1 for Neutral Point (optional)
- 1x Hardware Module M8019-1 for Noise gating (optional)
- 1x Software Module PDSIM
- 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 measurement.

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

M8019-1+ M8019-1



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 .. 1.5mm ²
Max Voltage	250VAC
Max Current	8A

Module

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

Figure 28: Technical Specifications of the M8019-3+

Alternatively, the M8019-6 input module is available with 6 multiplexed input channels.

M8019-6+: Width 9TE

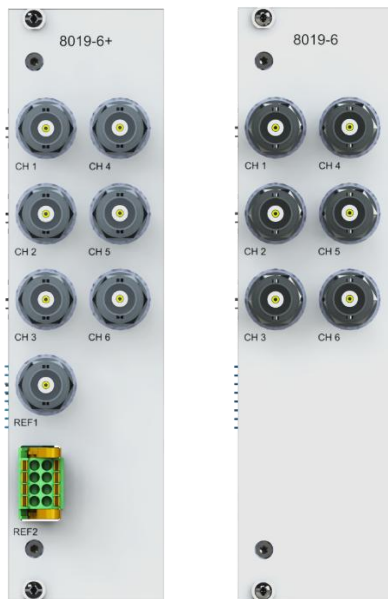


Figure 29: Technical Specifications of the M8019-6+ / M8019-6

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

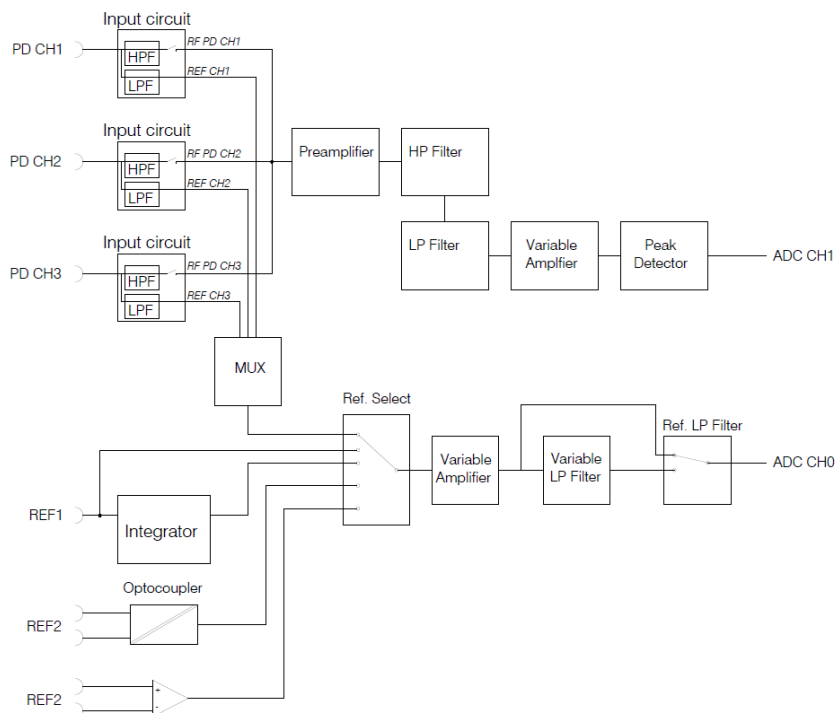


Figure 30: M8019 Operation Principle

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)
x1	50V	2.5V	0.25V	5V
x1.66	30V	1.5V	0.15V	3V
x2.5	20V	1.0V	0.1V	2V
x3.33	15V	0.75V	0.075V	1.5V
x5	10V	0.5V	0.05V	1V
x7.5	6.66V	0.33V	0.033V	0.66V
x10	5V	0.25V	0.025V	0.5V
x16.66	3V	0.15V	0.015V	0.3V

Table 13: 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
1	40kHz
2	100kHz
3	500kHz
4	1MHz
5	2MHz
6	3MHz
7	5MHz
8	10MHz

Table 14: Selectable High Pass Filters

The following low pass filters can be selected via software

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

Table 15: Selectable Low Pass Filters

5.4.3 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):

Filter Step	Frequency
1	12Hz
2	20Hz
3	30Hz
4	40Hz
5	50Hz
6	60Hz
7	100Hz
8	200Hz

Table 16: 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+

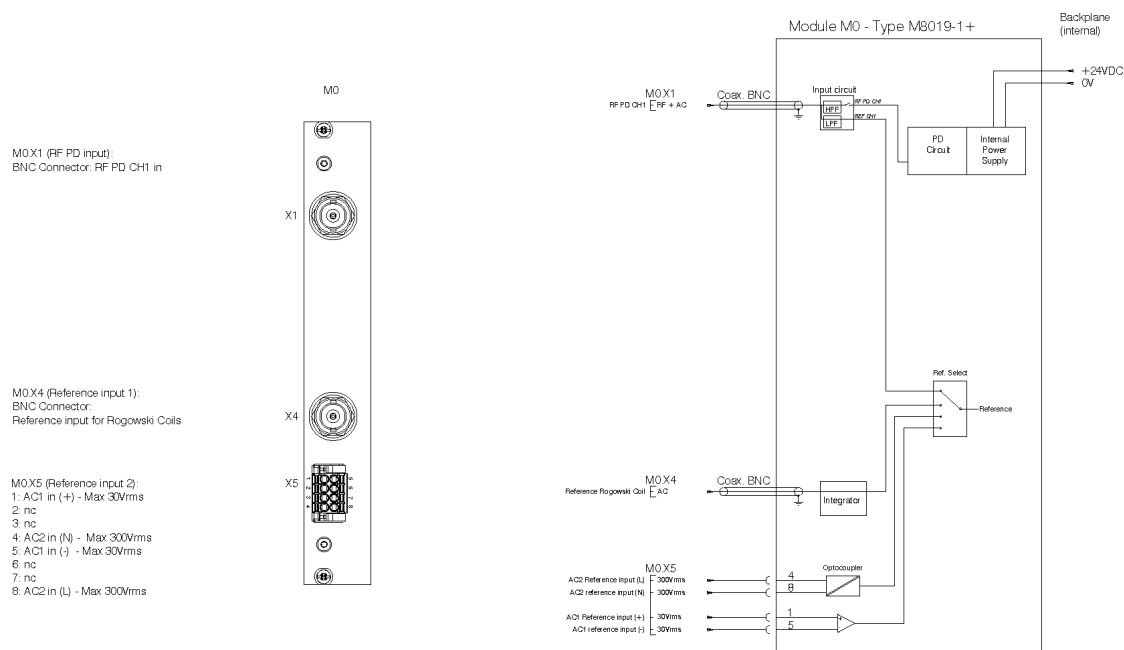


Figure 31: M8019-1+ Terminal Connections

5.5.2 M8019-1

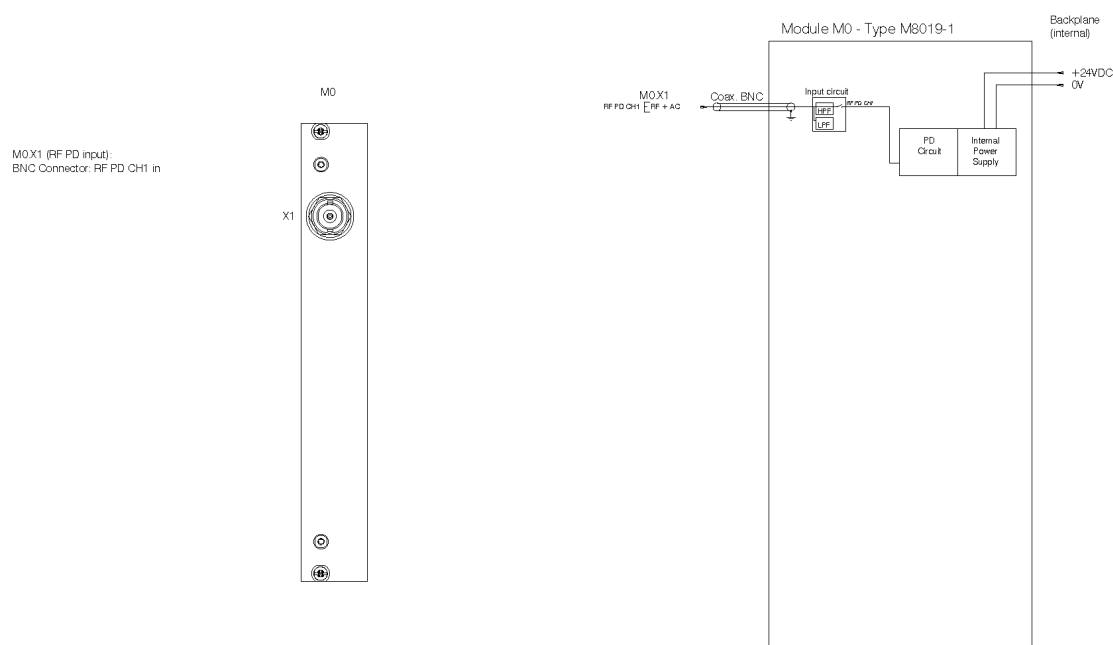


Figure 32: M8019-1 Terminal Connections

5.5.3 M8019-3+

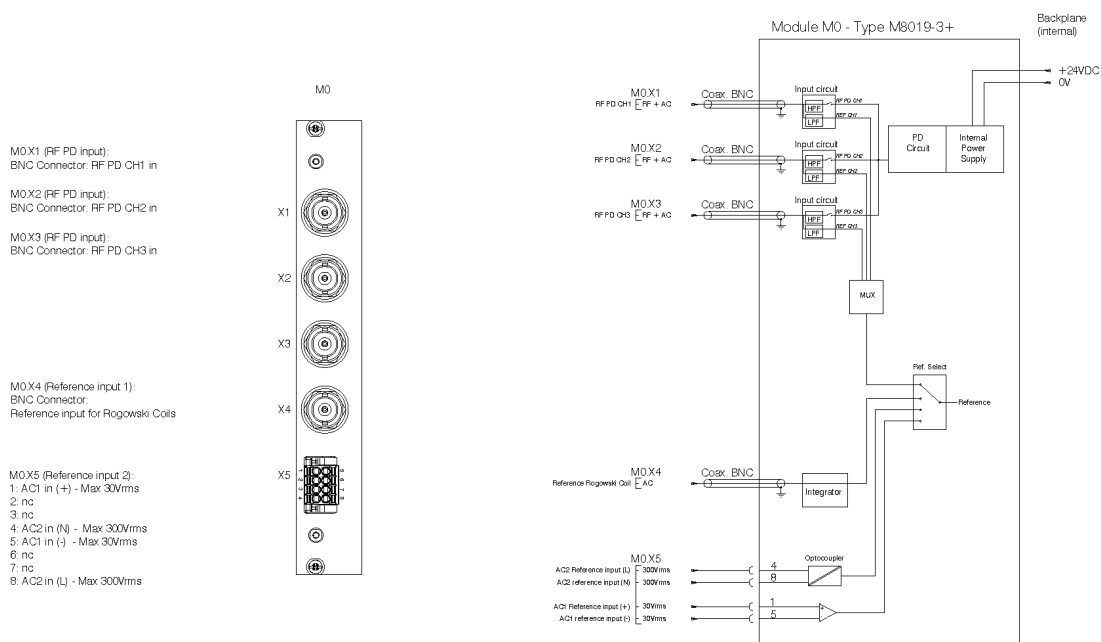


Figure 33: M8019-3+ Terminal Connections

5.5.4 M8019-3

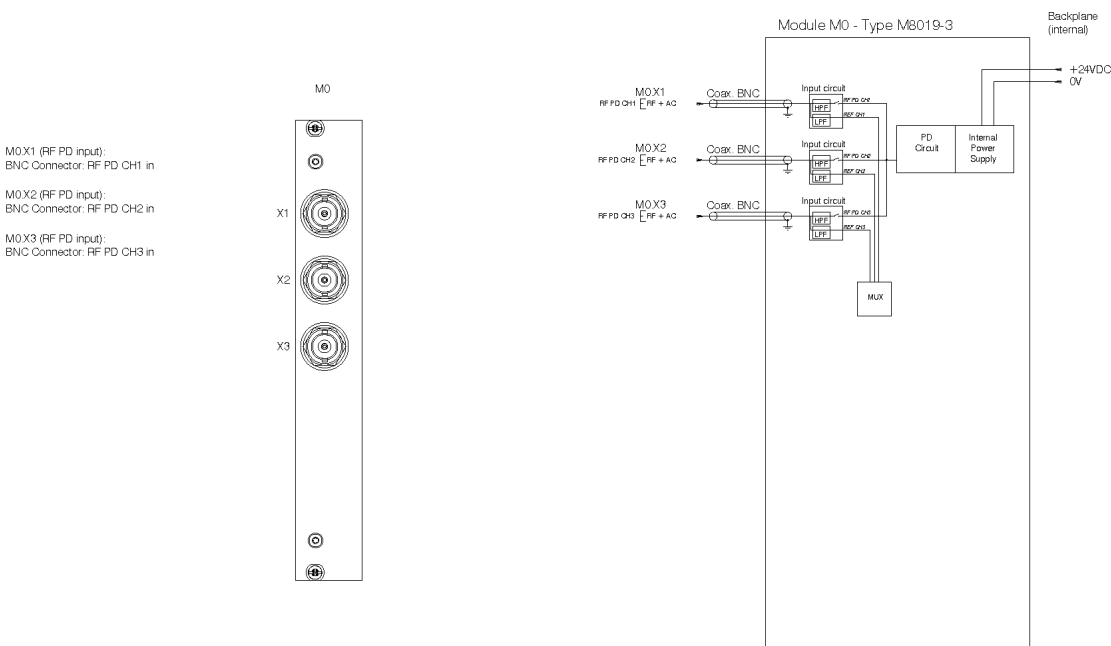


Figure 34: M8019-3 Terminal Connections

5.5.5 M8019-6+

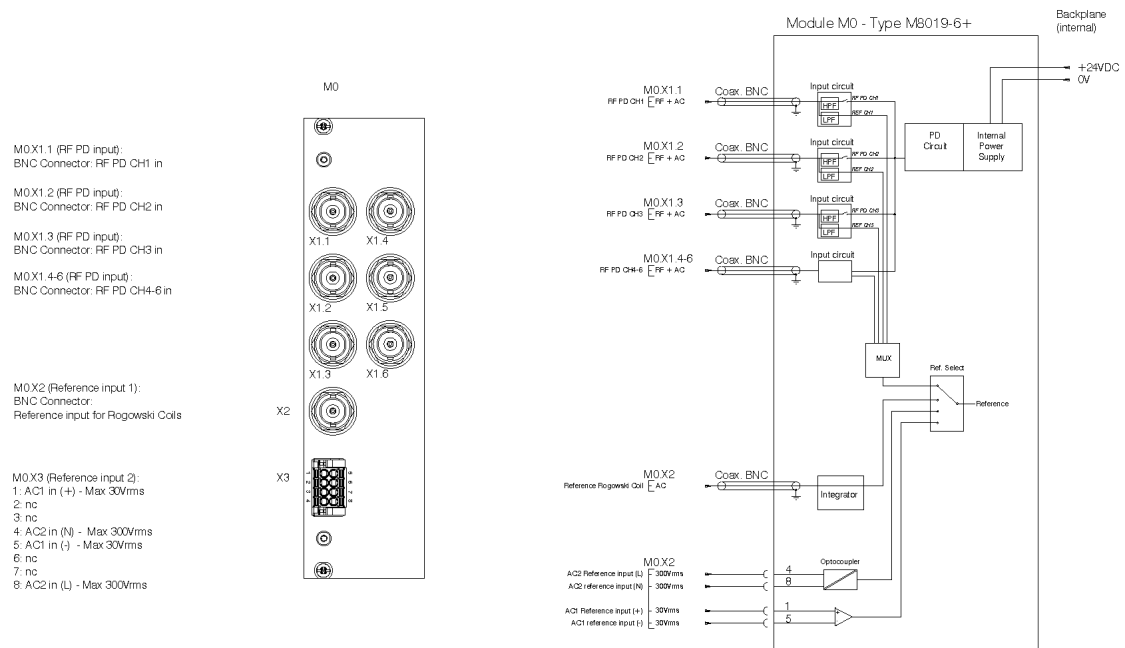


Figure 35: M8019-6+ Terminal Connections

5.5.6 M8019-6

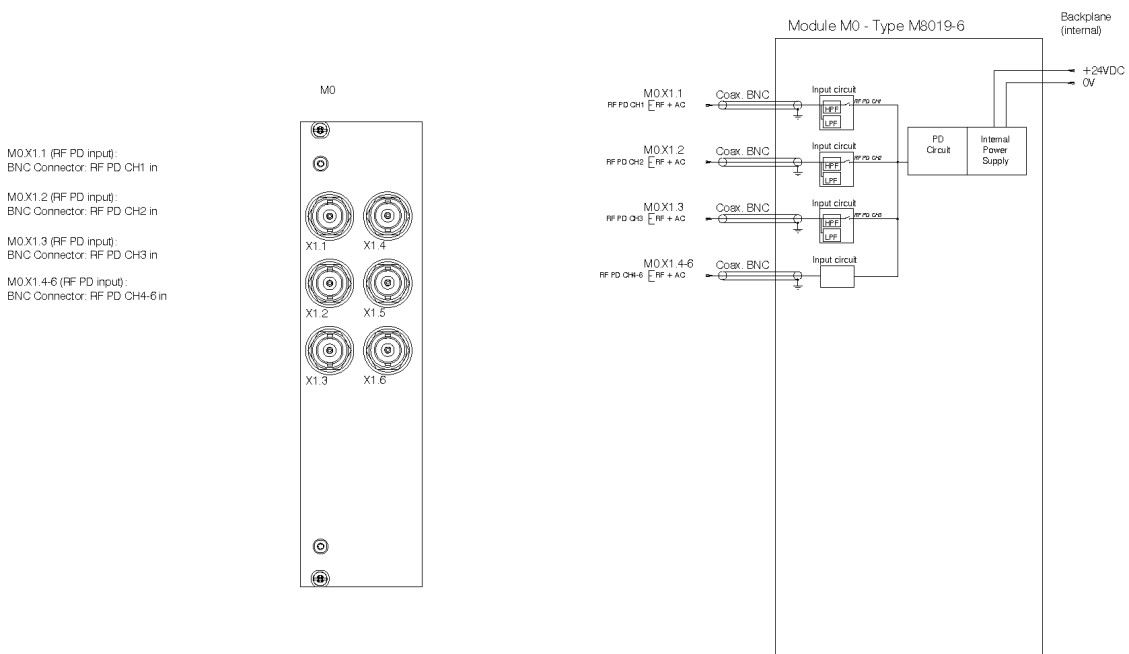


Figure 36: M8019-6 Terminal Connections

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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” (PDSIM).

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

The screenshot displays the 'Advanced' configuration tab of the UDL-Configurator. At the top, a table lists 'Acquisition Modules' with columns for 'No.', 'Type', 'Description', and 'Used Modules'. Below this, the 'Acquisition Parameters' section contains fields for 'Sampling Rate' (51200), 'ACQ Blocksize' (51200), 'Calc Blocksize' (new_X-Samples), 'Sampling Mode' (30), and 'ACQ Time'. The 'Trigger Parameters' section includes a checked 'Module' checkbox, 'Level' (0), 'Min Level' (100), 'Rising Edge' mode, 'Mode' (-1), 'Edge Control' (1), and 'Divider'. The 'Filter Parameters' section shows four channels (CH 1 to CH 4) with 'Lowpass' filters and 'Fg L' (10000) settings. A note on the right states: 'Note when using Filters: Respect Niquist Criteria (Filter Frequency < 0.5 x Sampling Rate)'. Below this, it explains 'Sampling Mode (New X-Samples)' as 'Continuous Mode, ACQ Blocksize = Calc Blocksize' with 'no restrictions when using filters', and 'Sampling Mode (Last X-Samples)' as 'Ensure when using Filters that ACQ Blocksize = 2x Calc Blocksize as the Filters need to stabilize'.

Figure 37: 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 17: Advanced – Acquisition parameters

6.2 Basic Acquisition Module Configuration

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

Acquisition Modules

No.	Type	Description	Used Modules
0	INT	Internal Controller Functions	
1	PDSIM	Simultaneous PD Monitoring	M0 - M1 - M2 - M3 - M4
2	RTD	8x 8 Channel RTD	
3	none		
4	none		
5	none		

Buttons: Change, Set to Default, Save, Save to File, Load From File, CH Export CSV, CH Import CSV

Basic | Advanced

PD Channels | Reference, Gating Channel & Software | Binary

CH	Range	HP Filter	LP Filter	Trigger	Phase	PD Atten	Scale Factor	Pregain	Peak Mode	Ref CH	Ref Att
1	1V	40kHz	20MHz	3%	0	--	1.000E+0	X	Rise	1	X
2	0.33V	40kHz	20MHz	3%	0	--	1.000E+0	--	Rise	1	X
3	0.33V	40kHz	20MHz	3%	0	--	1.000E+0	--	Rise	1	X
4	1.5V	40kHz	20MHz	3%	0	--	1.000E+0	X	Rise	1	X
G	2.5V	0.5MHz	20MHz	3%	0	--	1.000E+0	--	Rise	1	X

Controls for Channel 1: Range: 1V, HP Filter: 40kHz, LP Filter: 20MHz, Trigger: 3%, Phase: 0, PD Atten: --, Scale Factor: 1.000E+0, Pregain: X, Peak Mode: Rise, Ref CH: 1, Ref Att: X

Figure 38: PDSIM 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 must 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 18: Basic – PD Channel related Parameters

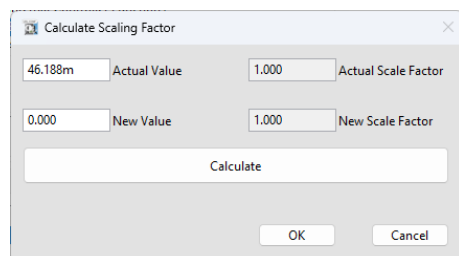


Figure 39: Calculation of new Scaling Factor

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.

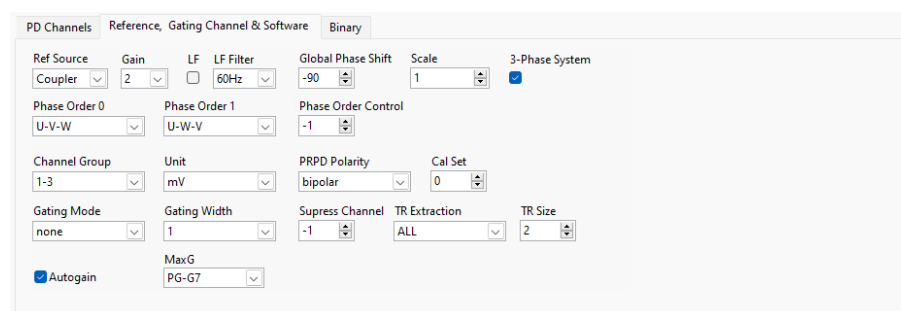


Figure 40: PDSIM Module Reference, Gating and Software Configuration

Parameter	Description
SRC	Defines the voltage reference source to be used for the acquisition <u>Setting 0</u> Uses the voltage reference from the coupler <u>Setting 1</u> Uses the voltage reference from the BNC input (REF1) <u>Setting 2</u>

	Uses the voltage reference from the BNC input (REF1) by using the additional integrator (to be used whenever Rogowski-coils are used) <u>Setting 3</u> Uses the voltage input from the REF2 terminal (30V input) <u>Setting 4</u> Uses the voltage input from the REF2 terminal (300V input) <u>Setting 5</u> Uses the voltage reference from the AC supply (if installed)
Gains	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
Global Phase Shifts	Defines the common phase shift for the selected voltage reference source. The phase shift 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 <u>Setting 1-3</u> Use this if 3 channels + Gating are acquired simultaneous <u>Setting 1-4</u> Use this if 4 channels + Gating are acquired simultaneous
Calc Set	Defines the type of calculation parameters to be used <u>Setting 0</u> Param1: PPS1 Param2: PPS5 Param3: PPS10 Param4: Repetition Rate Param5: Peak Discharge Param6: Apparent Charge Param7: Cumulated Apparent Charge Param8: NQN <u>Setting 1</u> 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.
Gating Mode	Activates the Gating channel (requires an additional M8019-1 input module) <u>Setting "none"</u> No Gating is used <u>Setting "bigger"</u> Gating is activated, and PD signals are ignored as soon the signal on the gating channel exceeds the Trigger threshold

	<u>Setting "TR"</u> Use the TR Gating, in order to suppress common signals from the first 3 simultaneous acquired channels
TR Extraction	Choose how the PRPD Patterns for the first 3 channels are created, based on the result of the TR Pattern: <u>All</u> Write all data, except if TR Gating is activated, then only the data outside of the TR Circle is used for the PRPD Pattern creation <u>L-G</u> Only use PD pulses which are on a dedicated channel, means Phase U, only PD Pulses with a TR Vector angle 0° Phase V, only PD Pulses with a TR Vector angle 120° Phase W, only PD Pulses with a TR Vector angle 240° <u>L-L</u> Only use PD pulses which are between channels Phase U, only PD Pulses with a TR Vector angle between 1..119° Phase V, only PD Pulses with a TR Vector angle between 121 .. 239° Phase W, only PD Pulses with a TR Vector angle between 241..359° <u>L1-L2</u> all 3 PRPD Patterns, only use PD Pulses with a TR Vector angle between 1..119° <u>L2-L3</u> all 3 PRPD Patterns, only use PD Pulses with a TR Vector angle between 121..239° <u>L3-L1</u> all 3 PRPD Patterns, only use PD Pulses with a TR Vector angle between 241..359° If the system shall acquire two or more of the above functions, it is required that for each TR Extraction mode a separate acquisition module is defined
Gating Width	Defines the window width (of the PRPD pattern) of the gating signal
TR Size	Defines the size in window width of the TR Gating circle
Phase order CH	Defines the channel ID to be used to determine the phase order. This is typically 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. If no phase order control is required, set the setting to -1, then, the order is defined by the "Phase Order 0 setting"
Phase Order 0 / 1	Defines the phase order for the specific logic.
Phase Order CH	Defines the channel to be used for the control of the phase order
Suppress CH	Defines the channel ID of the Suppress 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 19: General Acquisition parameters

6.2.3 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.

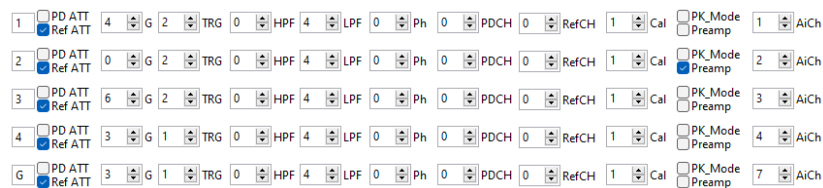


Figure 41: PDSIM PD Channel Related parameters

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, if the RefCH is set to 0 to the same input channel. 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 then the PD is measured by the RF CT, the voltage reference is used from the coupling capacitor. 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 must 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. If the M8009-6 Modules are used, use the PDCH 0 for the ACQ Module 1 PDCH 1 for the ACQ Module 2 PDCH 3 for the ACQ Module 3 PDCH 4 for the ACQ Module 4 PDCH 5 for the ACQ Module 5 PDCH 6 for the ACQ Module 6
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 pulses, 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 PDSIM use the numbers as shown in the above example, valid for all acquisition modules. Use 7 for the gating channel if installed.

Table 20: Basic – PD Channel related Parameters

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

The screenshot shows the 'PDSIM general acquisition module parameters' configuration window. It includes a top bar with a 'Use' checkbox and several numeric input fields for SRC, Gains, LF, LF Frequency, All Phase Shifts, and Scales. Below this are two rows of settings. The first row includes '1-3' (dropdown), 'CHGroup' (512), 'PRPDRes' (mV), 'Unit' (dropdown), 'MaxG' (none), 'Gat.Mode' (1), 'G-Width' (-1), 'Phase Order CH' (U-V-W), and 'Phase Order 0' (dropdown). The second row includes '0' (dropdown), 'Mod. CH' (0), 'CalcSet' (3-Ph System), 'Bip/Unip' (checkbox), 'PG-G7' (dropdown), 'All' (checkbox), 'TR Extr.' (checkbox), 'TR Size' (2), 'Supress CH' (-1), 'U-W-V' (dropdown), and 'Phase Order 1' (dropdown). There are also checkboxes for 'Autogain' and 'All'.

Figure 42: PDSIM general acquisition module parameters

Parameter	Description
Use	This parameter is not used
SRC	Defines the voltage reference source to be used for the acquisition <u>Setting 0</u> Uses the voltage reference from the coupler <u>Setting 1</u> Uses the voltage reference from the BNC input (REF1) <u>Setting 2</u> Uses the voltage reference from the BNC input (REF1) by using the additional integrator (to be used whenever Rogowski-coils are used) <u>Setting 3</u> Uses the voltage input from the REF2 terminal (30V input) <u>Setting 4</u> Uses the voltage input from the REF2 terminal (300V input) <u>Setting 5</u> 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 <u>Setting 1-3</u> Use this if 3 channels + Gating are acquired simultaneous <u>Setting 1-4</u> Use this if 4 channels + Gating are acquired simultaneous
Module Channels	Set which channel is used for the M8019-6 (0 for the first channel), if the M8019-1 Inptu Modules are used, set it to 0
PatternRes	Defines the resolution of the PRPD Pattern, this parameter is fixed and cannot be changed
CalcSet	Defines the type of calculation parameters to be used <u>Setting 0</u> Param1: PPS1 Param2: PPS5 Param3: PPS10 Param4: Repetition Rate Param5: Peak Discharge Param6: Apparent Charge Param7: Cumulated Apparent Charge Param8: NQN <u>Setting 1</u> Param1: Qp+ Param2: Qp- Param3: Qm+ Param4: Qm- Param5: NQN+ Param6: NQN- Param7: not used

	Param8: not used
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 4 th 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.
Gating Mode	Activates the Gating channel (requires an additional M8019-1 input module) <u>Setting "none"</u> No Gating is used <u>Setting "bigger"</u> Gating is activated, and PD signals are ignored as soon the signal on the gating channel exceeds the Trigger threshold <u>Setting "TR"</u> Use the TR Gating, in order to suppress common signals from the first 3 simultaneous acquired channels
TR Extr.	Choose how the PRPD Patterns for the first 3 channels are created, based on the result of the TR Pattern: <u>All</u> Write all data, except if TR Gating is activated, then only the data outside of the TR Circle is used for the PRPD Pattern creation <u>L-G</u> Only use PD pulses which are on a dedicated channel, means Phase U, only PD Pulses with a TR Vector angle 0° Phase V, only PD Pulses with a TR Vector angle 120° Phase V, only PD Pulses with a TR Vector angle 240° <u>L-L</u> Only use PD pulses which are between channels Phase U, only PD Pulses with a TR Vector angle between 1..119° Phase V, only PD Pulses with a TR Vector angle between 121 .. 239° Phase V, only PD Pulses with a TR Vector angle between 241..359° <u>L1-L2</u> all 3 PRPD Patterns, only use PD Pulses with a TR Vector angle between 1..119° <u>L2-L3</u> all 3 PRPD Patterns, only use PD Pulses with a TR Vector angle between 121..239° <u>L3-L1</u> all 3 PRPD Patterns, only use PD Pulses with a TR Vector angle between 241..359° If the system shall acquire two or more of the above functions, it is required that for each TR Extraction mode a separate acquisition module is defined
G-Width	Defines the window width (of the PRPD pattern) of the gating signal
TR Size	Defines the size in window width of the TR Gating circle
Phase order CH	Defines the channel ID to be used to determine the phase order. This is typically 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. If no phase order control is required, set the setting to -1, then, the order is defined by the "Phase Order 0 setting"
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.
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Table 21: General Acquisition parameters

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	Delayed	Threshold AL2	Delayed
9	PPS5 PD Channel 1	above	500mV	Yes, 100s	800mV	Yes, 100s
17	PPS5 PD Channel 2	above	500mV	Yes, 100s	800mV	Yes, 100s
25	PPS5 PD Channel 3	above	500mV	Yes, 100s	800mV	Yes, 100s
33	PPS5 PD Channel 4	above	500mV	Yes, 100s	800mV	Yes, 100s

Table 22: 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 acquisition modules used. If only single channel modules are used, the simultaneous acquisition will update after the acquisition time is completed, which is typically 30 seconds. If multiple acquisition modules are used, the alarm delay must be changed at least for 2x 30 seconds x the number of acquisition modules used. For an installation with 18 channels (6 Measurements of 30 seconds x 2 Measurements) an alarm delay of 500s is suggested. 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 / Qm 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	PPS1 PD Channel 1	yes	1
17	PPS1 PD Channel 2	yes	1
25	PPS1 PD Channel 3	yes	1
8	PPS5 PD Channel 1	yes	1
16	PPS5 PD Channel 2	yes	1
24	PPS5 PD Channel 3	yes	1

Table 23: Default Mimic Channels for 3 Channel measurement

Whenever 4 Simultaneous 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

Table 24: 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:

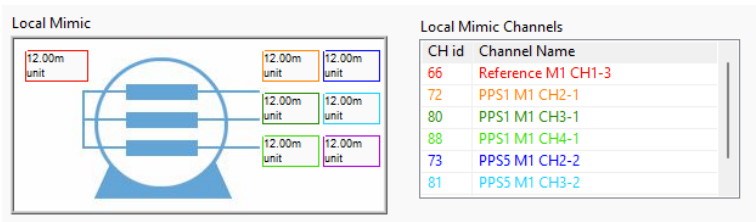


Figure 43: PD Example of a local visualisation mimic

6.5.2 External Visualization Mimic example

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

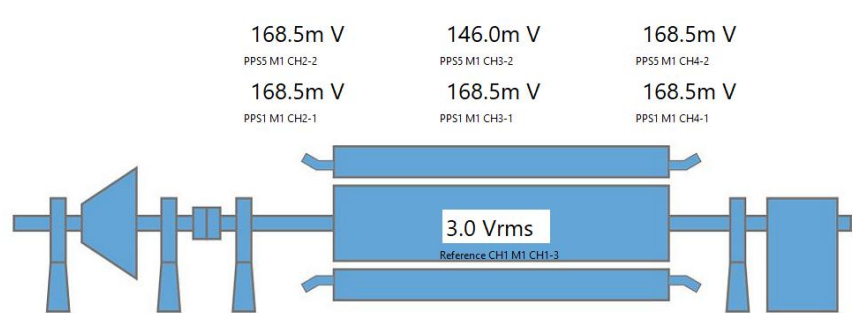


Figure 44: PD Example of an external visualisation mimic for turbo generators

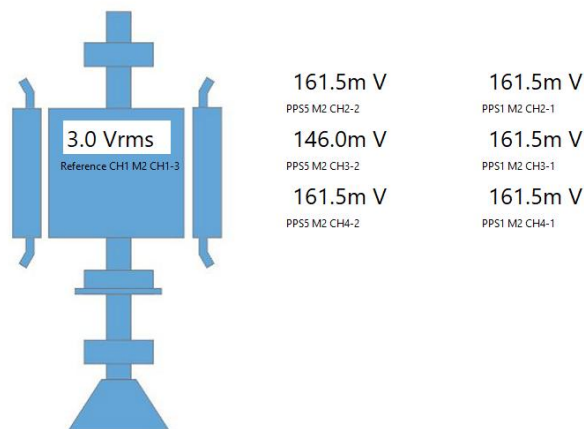


Figure 45: PD Example of an external visualisation mimic for Hydro generators

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.

The figure shows a configuration window for alarm-based recording. It consists of three main panels at the top: 'Recordings', 'Used Acquisition Modules', and 'Recording Modes'. The 'Recordings' panel has a list with 'Standard' selected. The 'Used Acquisition Modules' panel has a list with '1 - PDSIM' checked. The 'Recording Modes' panel has a list with 'Time Intervalled', 'Time Intervalled', 'Time Intervalled', and 'Alarmed' checked. Below these panels are 'Add' and 'Remove' buttons. At the bottom is the 'Alarm Recording' section, which has a 'Use' checkbox checked, a 'No of Recordings' spinner set to 5, and an 'Interval [min]' spinner set to 10.

Figure 46: 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.

The figure shows a configuration window for time interval-based recording. It consists of three main panels at the top: 'Recordings', 'Used Acquisition Modules', and 'Recording Modes'. The 'Recordings' panel has a list with 'Standard' selected. The 'Used Acquisition Modules' panel has a list with '1 - PDSIM' checked. The 'Recording Modes' panel has a list with 'Time Intervalled', 'Time Intervalled', 'Time Intervalled', and 'Alarmed' checked. Below these panels are 'Add' and 'Remove' buttons. At the bottom is the 'Time Interval Recording' section, which has a 'Use' checkbox checked, a 'Channel ID' spinner set to 73, an 'Interval [hour]' spinner set to 12, and a 'Condition' dropdown set to 'none'.

Figure 47: 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
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 25: 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.

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7 Acquisition Module Data Presentation

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7.1 Common

The measured partial discharge data is updated once the complete acquisition module is finished, and the update rate depends on the number of used acquisition modules and the defined acquisition time. This is typically about 30 seconds when using 1 acquisition module and 3 Minutes when using 6 acquisition modules.

The partial discharge measurement results are presented in different visualizations. The Scope Visualization shows the realtime partial discharge activity of all simultaneous acquired channels.

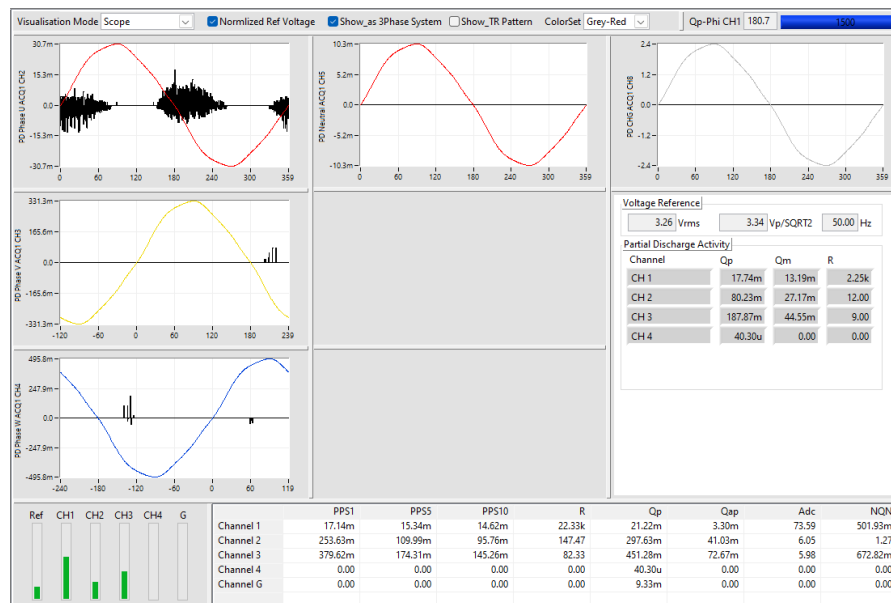


Figure 48: PDSIM Acquisition Module Data Presentation - Scope

At the top of the window, it is possible to switch between the other visualisations, as e.g. the PRPD Patterns.

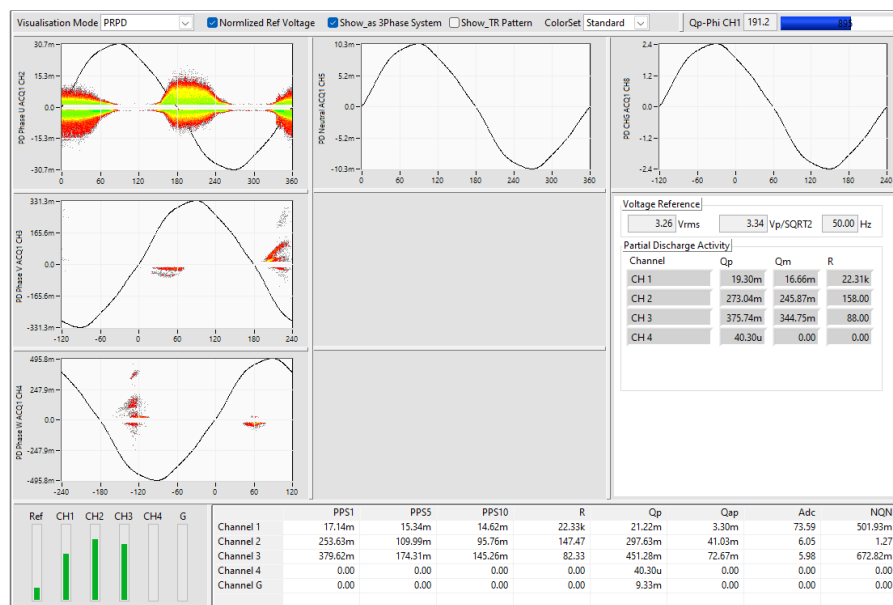


Figure 49: PDSIM Acquisition Module Data Presentation – PRPD

The PRPD Patterns can also be presented with different color codings by selecting the desired Color Set.

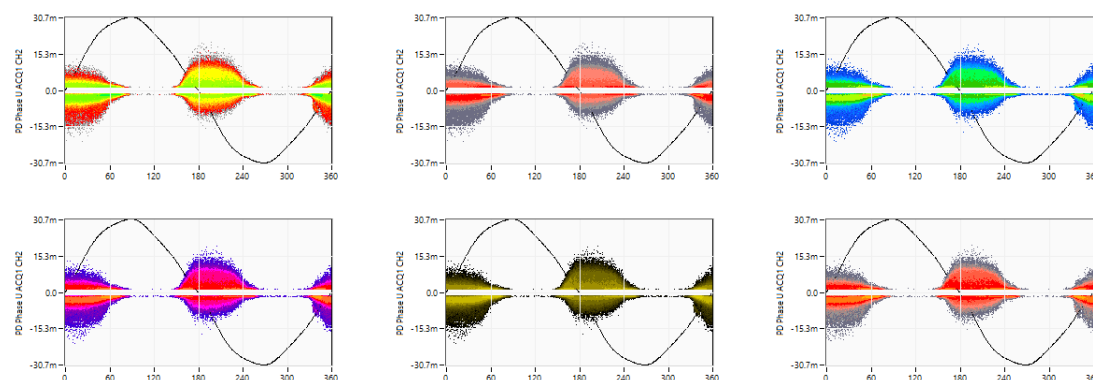


Figure 50: PDSIM Acquisition Module Data Presentation – PRPD Color Codings

Each color represents the number of pulses detected, the table below shows the number of pulses and its associated color code.

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 26: Color Coding of PRPD Patterns

The Data can also be presented as pulse height distribution as shown in the below illustration

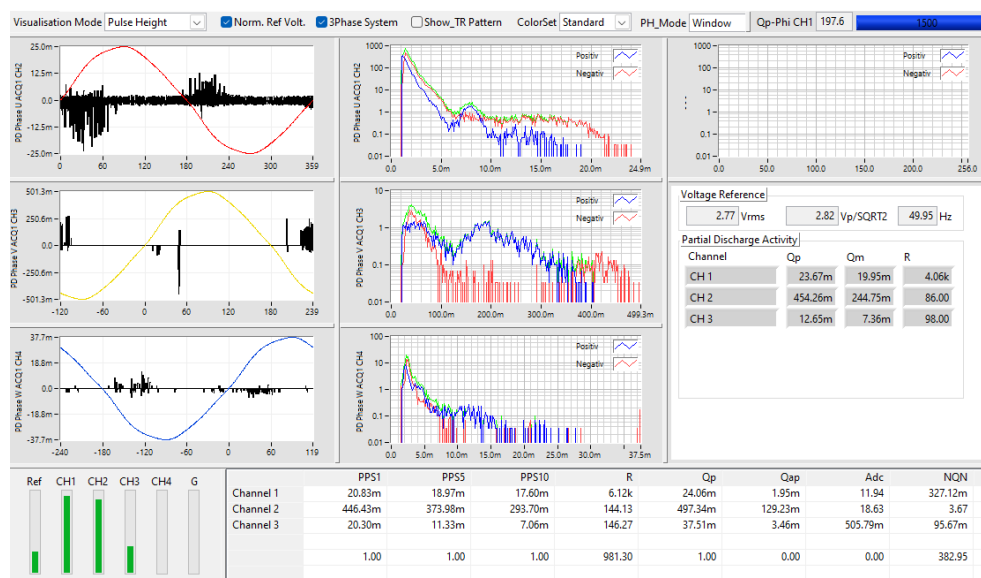


Figure 51: PDSIM Acquisition Module Data Presentation – Pulse Height (by window)

Within the top middle of the window, the TR pattern can be activated. The TR pattern will then be presented at the location of the Real Time Partial discharge results.

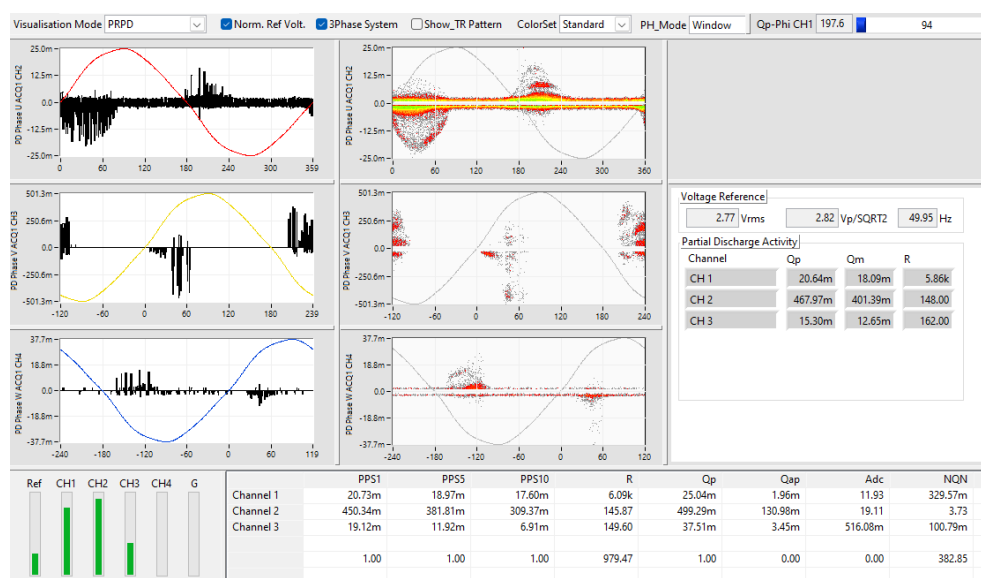


Figure 52: PDSIM Acquisition Module Data Presentation – TR pattern

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.

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.

7.2 UDL-DAQ Software

As the configuration of the PDSIM acquisition module has many parameters to be configured, the configuration of the system is best done by using the UDL-DAQ software package, which allows to configure the system in real time. Additionally, the handling of the parameter is presented in a much more user-friendly way as it is shown within the configuration software.

In order to change any parameter, select first the specific PD Channel from the pull down menu and change the parameter accordingly. In order that the changes are used with the new acquisition, the button “Apply” must be pressed. It is possible to change many parameters of all the channels before applying the entire configuration to the system.

Once the button “apply” is pressed, the actual measured channel is repeated. If the settings of multiple channels are changed, the operator must wait until the entire acquisition module is completed.

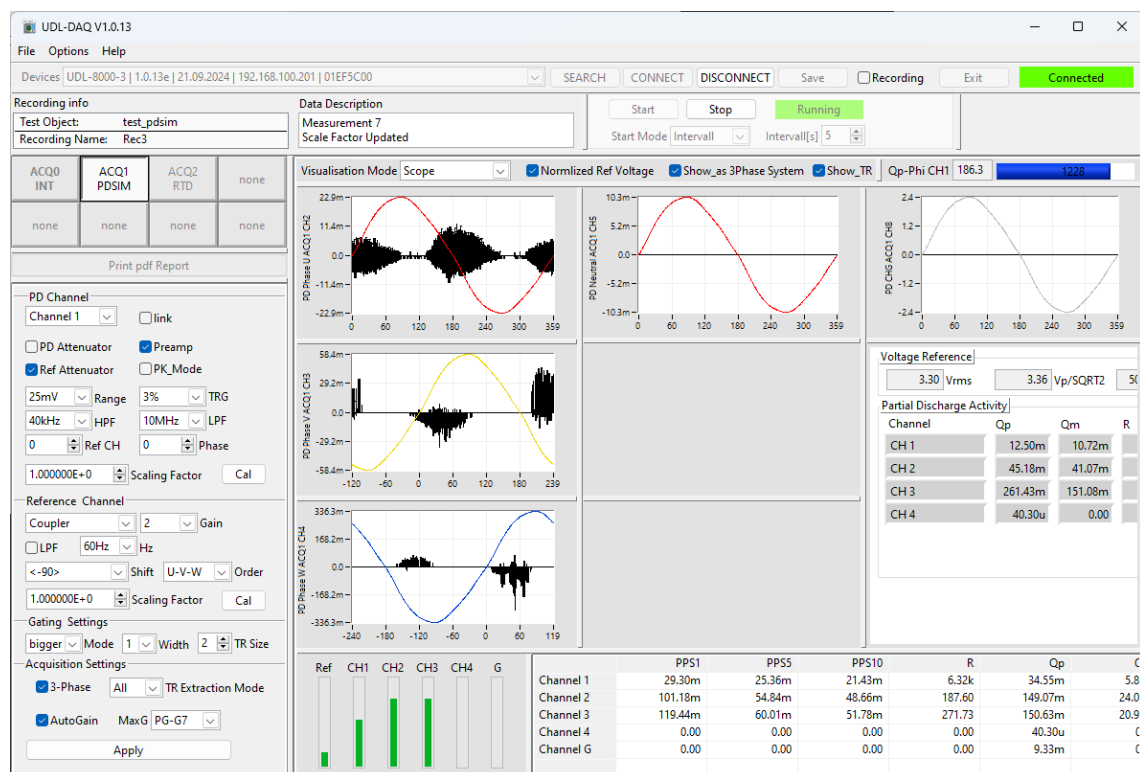


Figure 53: PDSIM Acquisition Module Configuration with UDL-DAQ Software

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.

7.2.1 Normalization / Calibration

Before starting with the normalization process, ensure that the system is configured for nC measurements, by changing the corresponding setting within the UDL-Configurator software

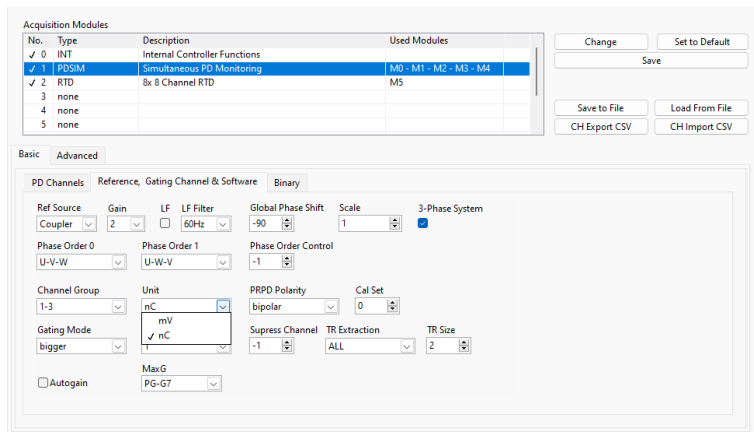


Figure 54: UDL-Configurator – Change to nC unit

In the next step, ensure that the “autogain” function is deactivated, as it will interfere with the manual gain control during the normalization process.

Start the UDL-DAQ Software, connect to the system and select the PDSIM module

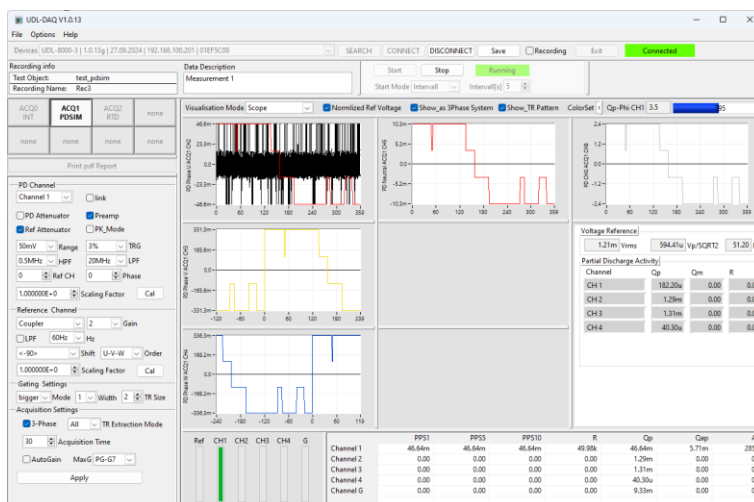


Figure 55: UDL-DAQ – First start and setting the Frequency Range

Ensure that the correct frequency range is selected depending on the application of the PD monitoring. For rotating machines, typically 0.5..20MHz frequency range is used.

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 dis-

charges 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.

Most likely the PD Measurement range is not set correctly, either there is no visible signal from the PD Pulse generator, or the measured signal is over ranged as shown on the above measurement results.

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.

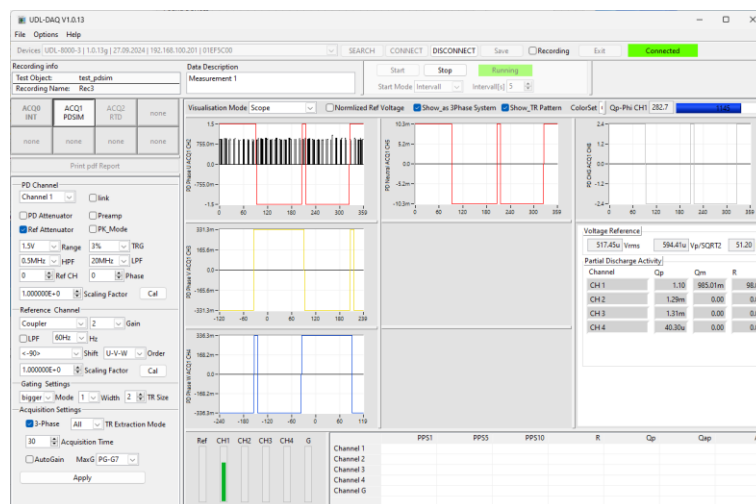


Figure 56: UDL-DAQ – Adapted measurement Range

In order to normalize the PD acquisition to nC/pC measurement check the realtime Qm/PPS5 value at the right side of the graph, or wait until the acquisition is completed to take the Qm/PPS5 value from the result table at the bottom of the window. Choose the channel at the left side and press the button “Cal” under the PD channel settings.

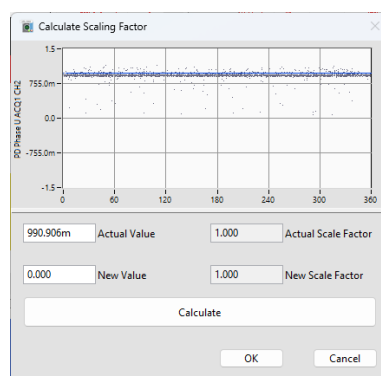


Figure 57: PDSIM Normalisation start

There is a small blue horizontal cursor which can be moved the the level of the PD Pulse generator signal. While moving the horizontal cursor, the “Actual Value” number will change automatically.

Set under “New Value” the value set on the PD Pulse generator in our example we choose 5nC. Press “Calculate” to define the new scaling factor.

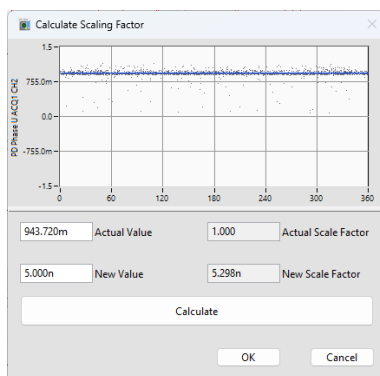


Figure 58: PDSIM Normalisation calculated new scaling factor

Press the button “Ok” to confirm the new scaling factor. Press the “Apply” button to send the new calibration value to the device.

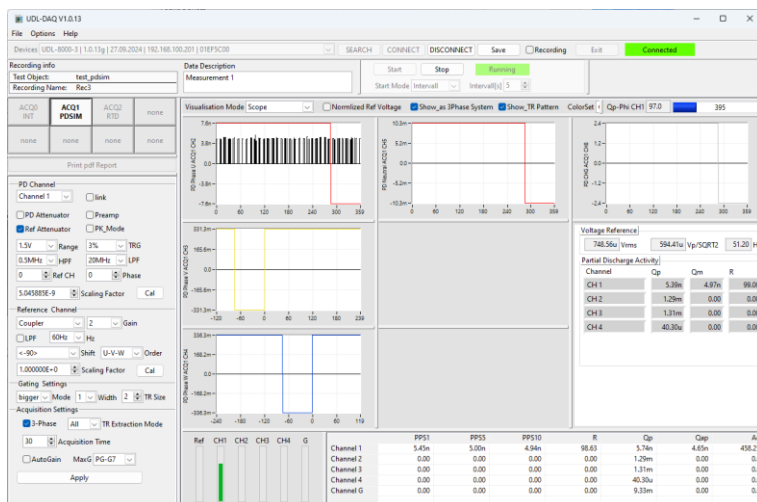


Figure 59: PDSIM Acquisition Module Configuration with new Scaling factor

Repeat the same procedure for every channel and press the “Apply” button to make changes affect.

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.

Also to be noted, that the measurement range always is shown as “volt value” independent of the used scaling factor.

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.

7.2.2 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”.

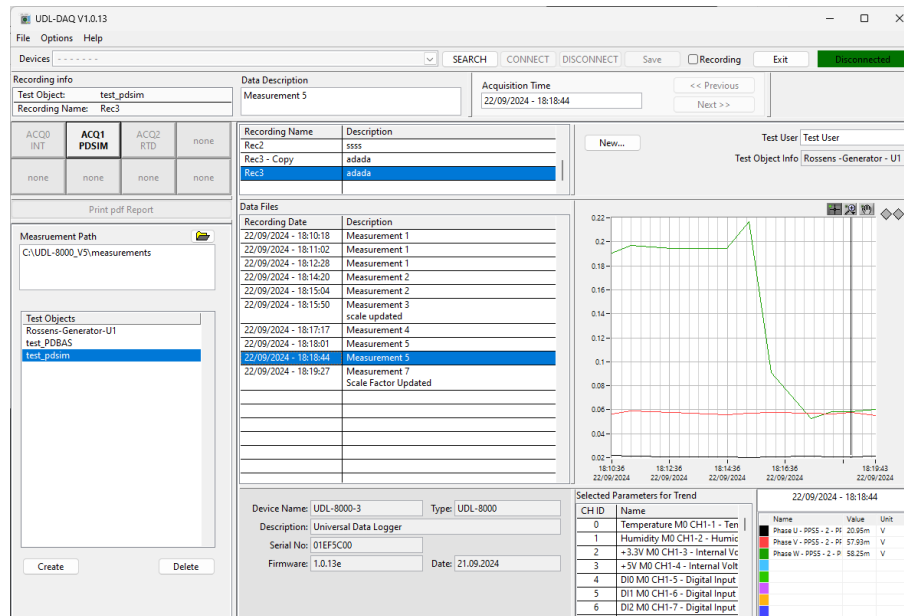


Figure 60: Selecting a previous recorded file

In the next step select the desired acquisition module in order to show the results and the settings used during the acquisition. Select the Visualisation to “PRPD”.

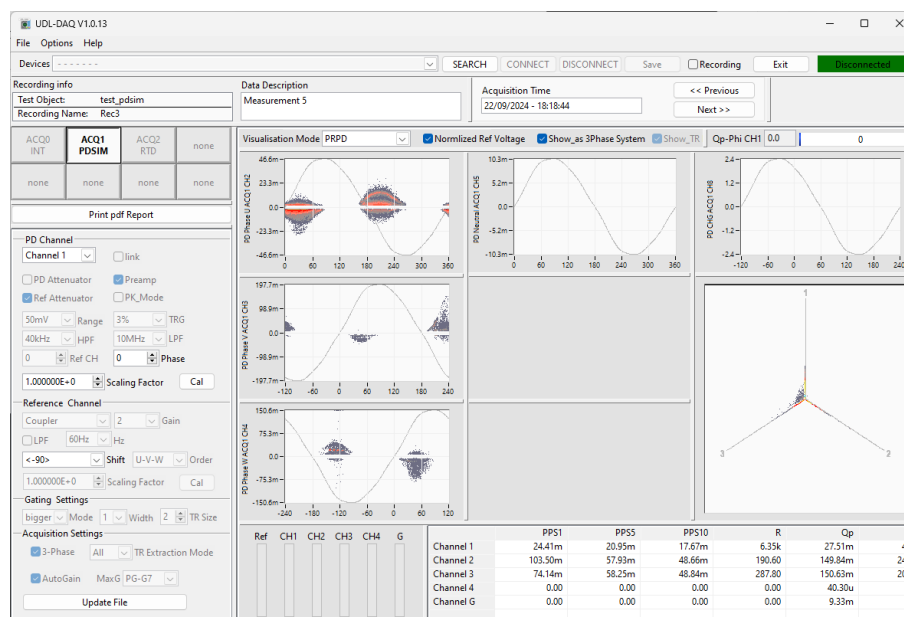


Figure 61: Showing the file results of an acquisition module

Under “Scaling Factor” enter the new scaling factor or if the amplitude of the PRPD Pattern is known press the “Cal” button to perform a rescaling as during the normal normalisation process.

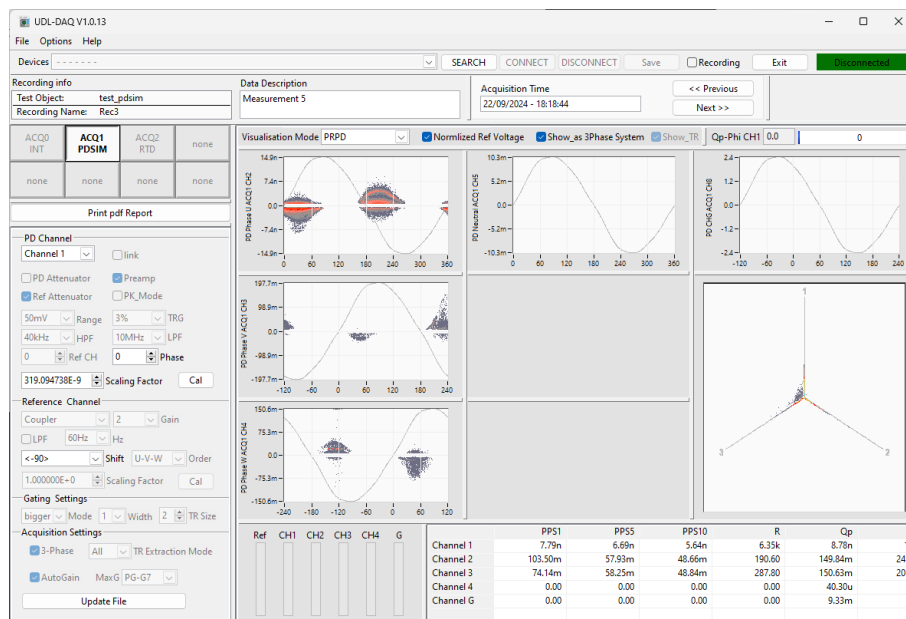


Figure 62: Offline Normalisation

Repeat the task for every used channel and press the button “Update File” to update the measurement file.

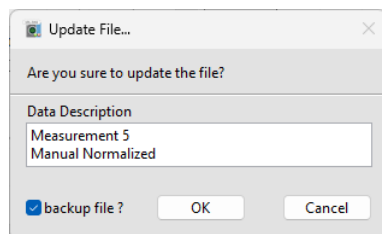


Figure 63: Updating File info

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.

7.2.3 File Manipulation - Changing Phase Angle

The following example shows the manipulation of the PDSIM module. Load first the measurement result:

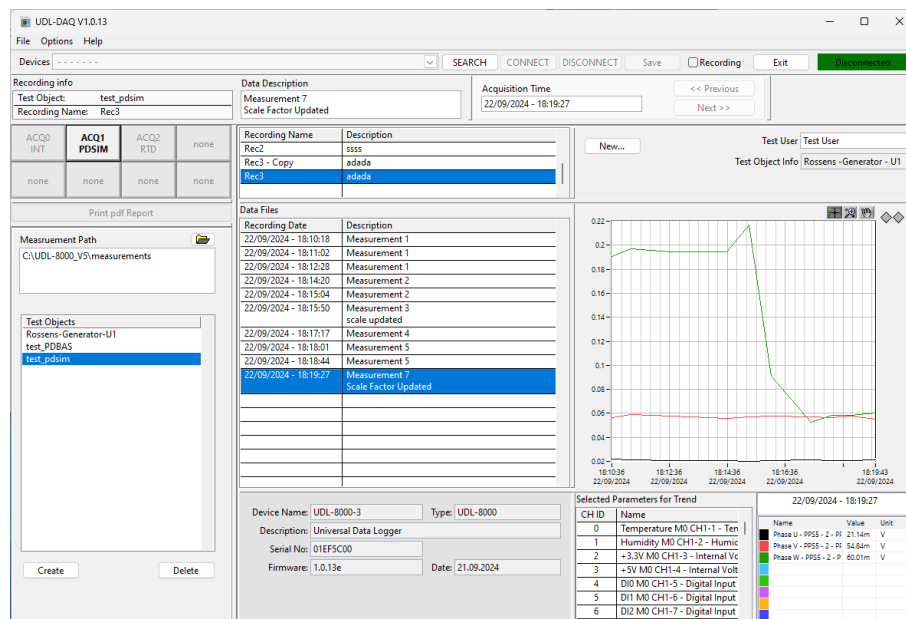


Figure 64: Load a Measurement Result

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

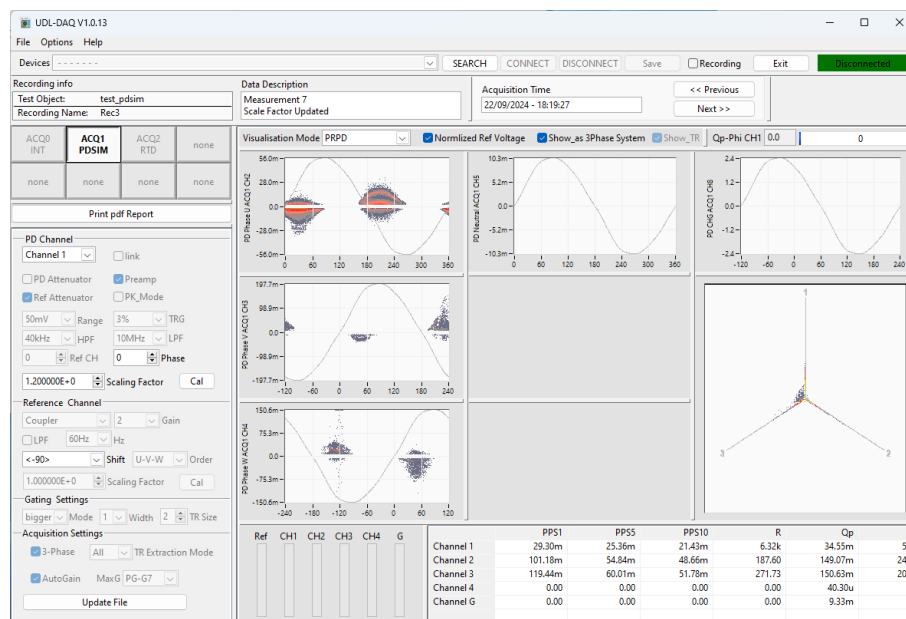


Figure 65: Original Phase of PDSIM Module Data

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).

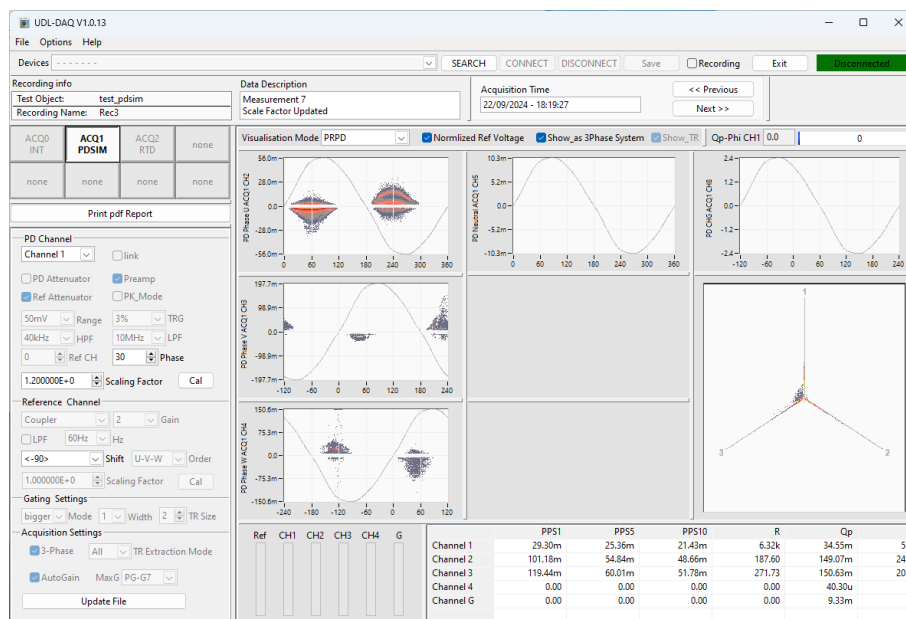


Figure 66: Corrected PRPD Patterns

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.

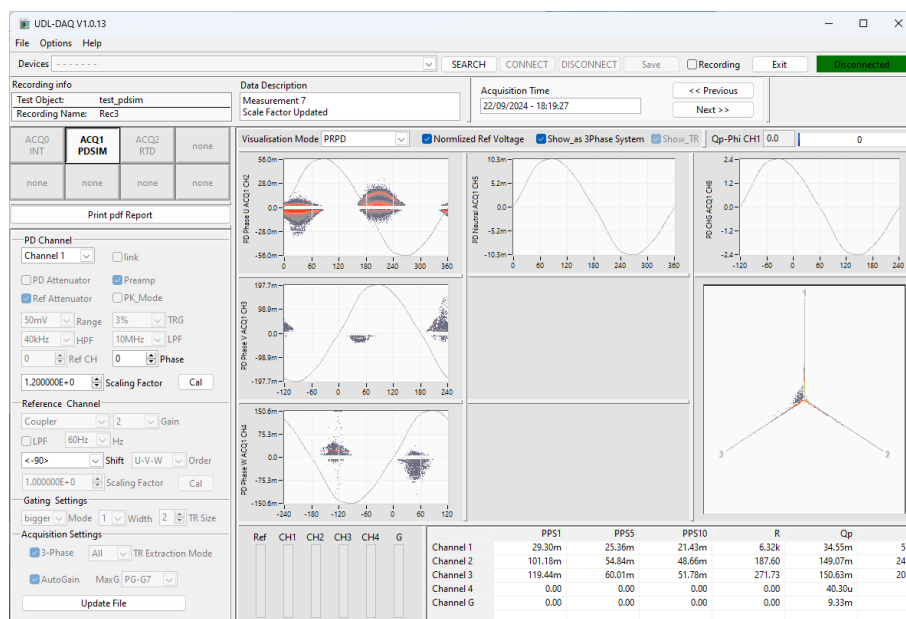


Figure 67: Original Common Phase of PDSIM Module Data

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

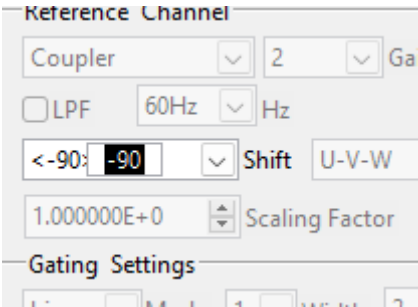


Figure 68: Changing Common Phase of PDSIM Module Data

And enter the new phase angle...

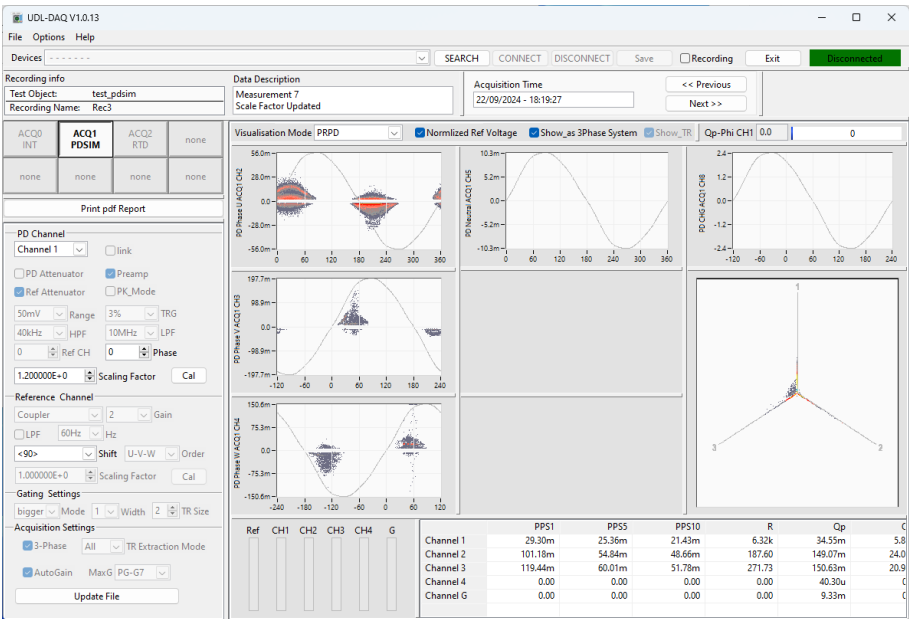


Figure 69: Common Phase of PDSIM Module Data changed

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

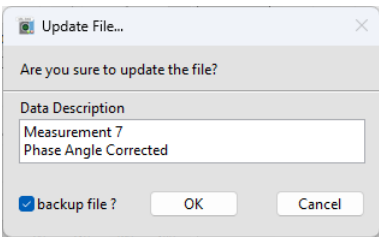


Figure 70: Update File Message

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.

7.2.4 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.

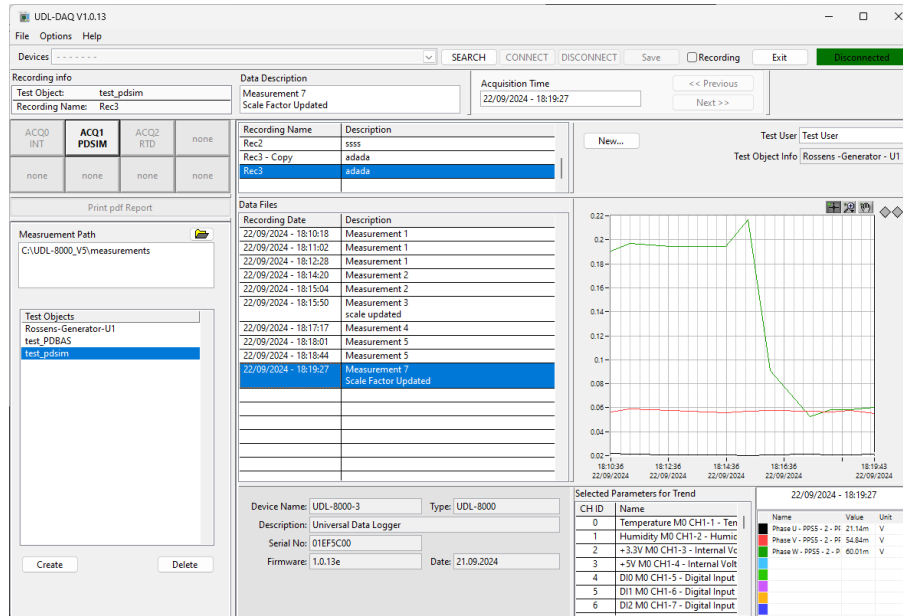


Figure 71: Loading a file

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

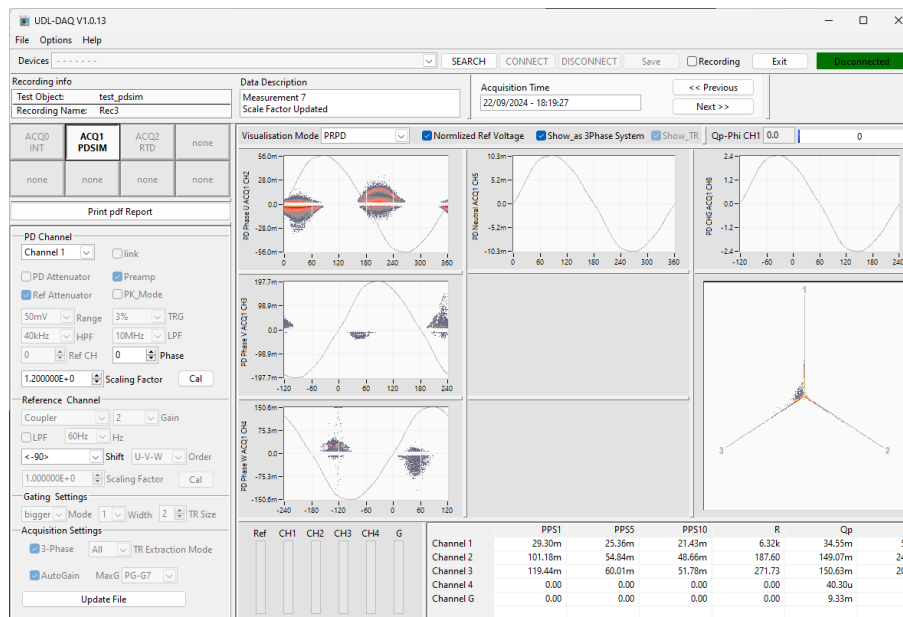


Figure 72: Showing the measurement results.

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 the actual module configuration shall be uploaded to the device

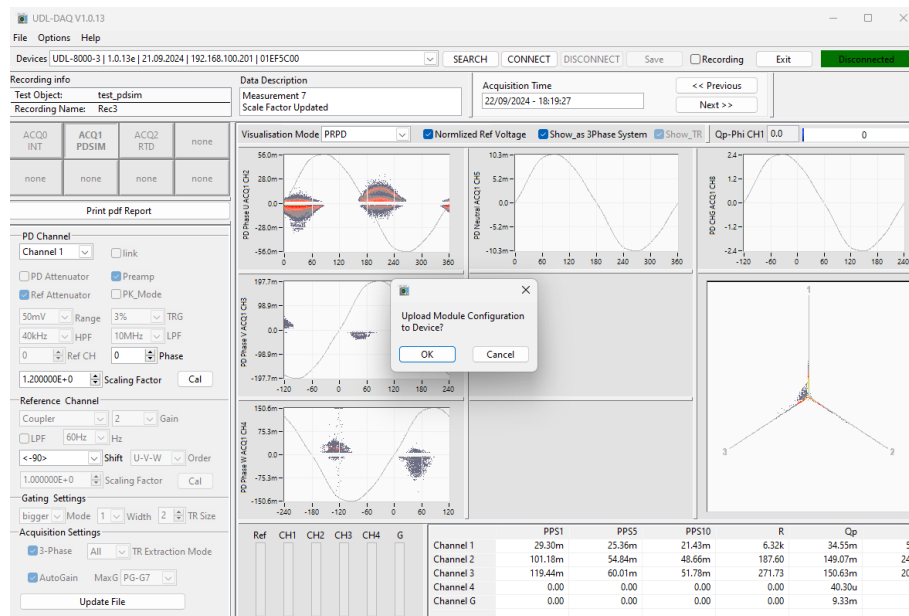


Figure 73: Selecting the device and confirm the upload of the configuration

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.

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.

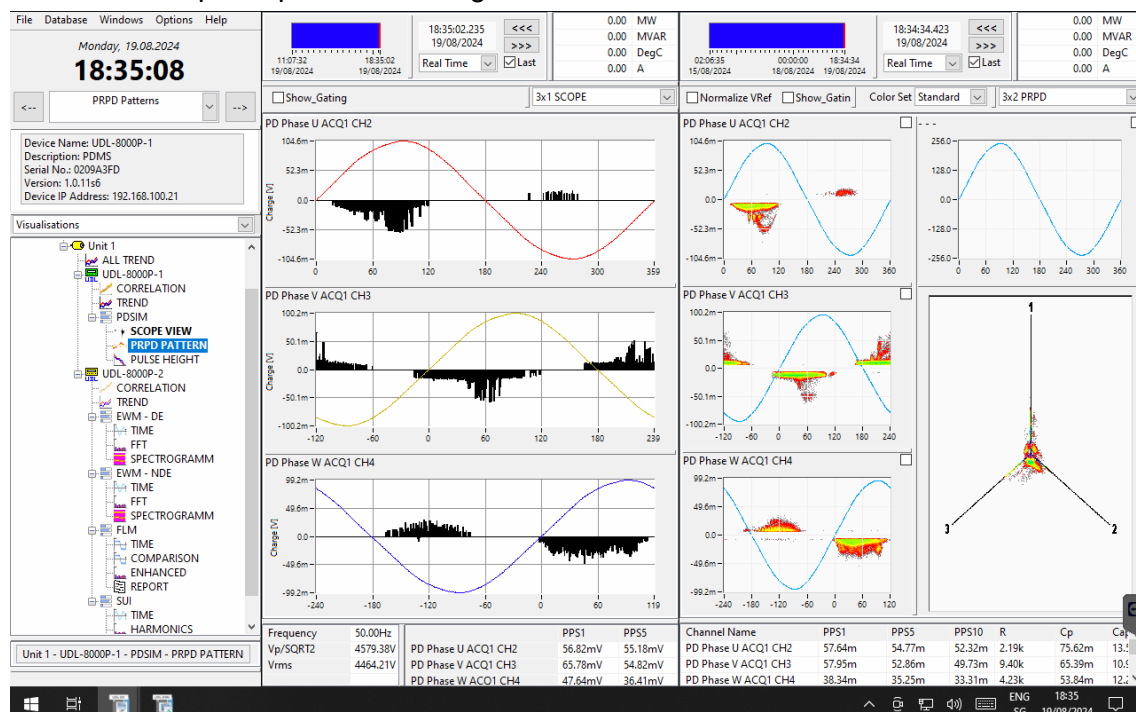


Figure 74: UDL-8000 Pro local data visualisation (PRPD)

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

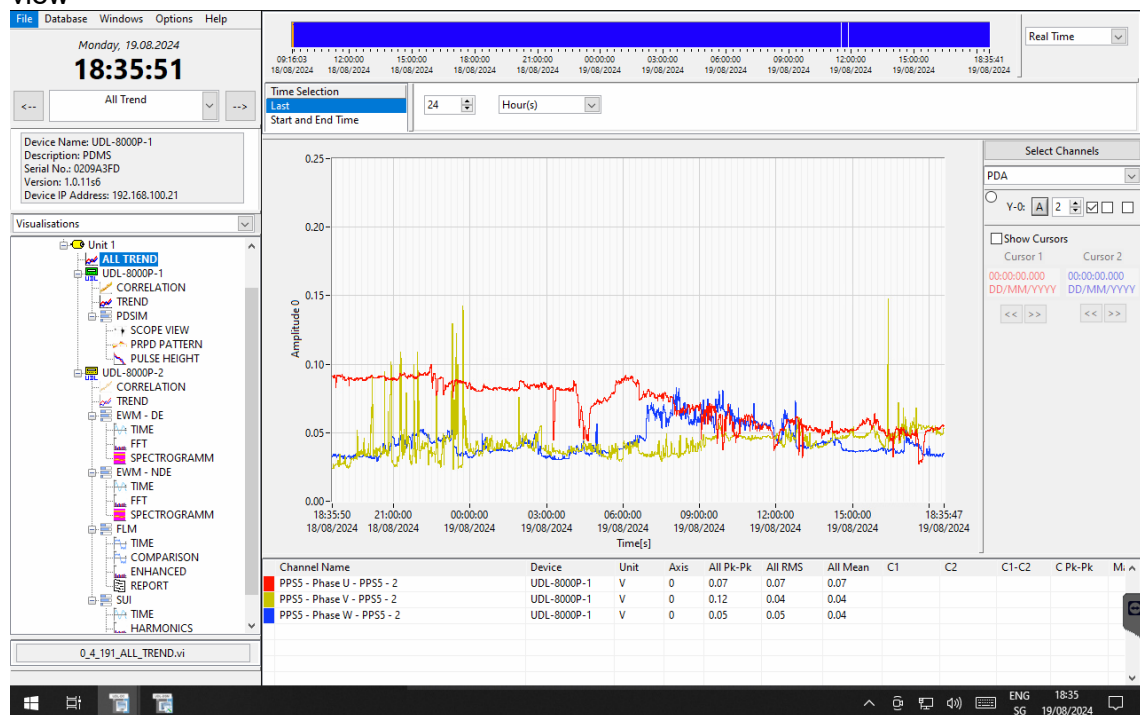


Figure 75: UDL-8000 Pro local data visualisation (Trend)

8.1.2 Layout for Desktop Computers

Screen Resolution: 2560 x 1440 – WQHD - recommended



Figure 76: UDL-DataClient desktop data visualisation (PDSIM & 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. The Update Rate of the windows depend on the number of acquisition modules and the number of channels used. While the PDSIM module acquires up to 4 channels (plus the noise canceling channel) simultaneously, each channel can be additionally multiplexed in order to increase the number of channels used per test object.

8.2.1 SCOPE (Partial Discharge Oscilloscope View)

The scope view updates in an interval of 1 second and contains the number of periods included in 1 second (50 or 60 depending on the network frequency). This style of data representation is also often called “persistence mode”.

The visualization 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 27: Separation of visualisation information

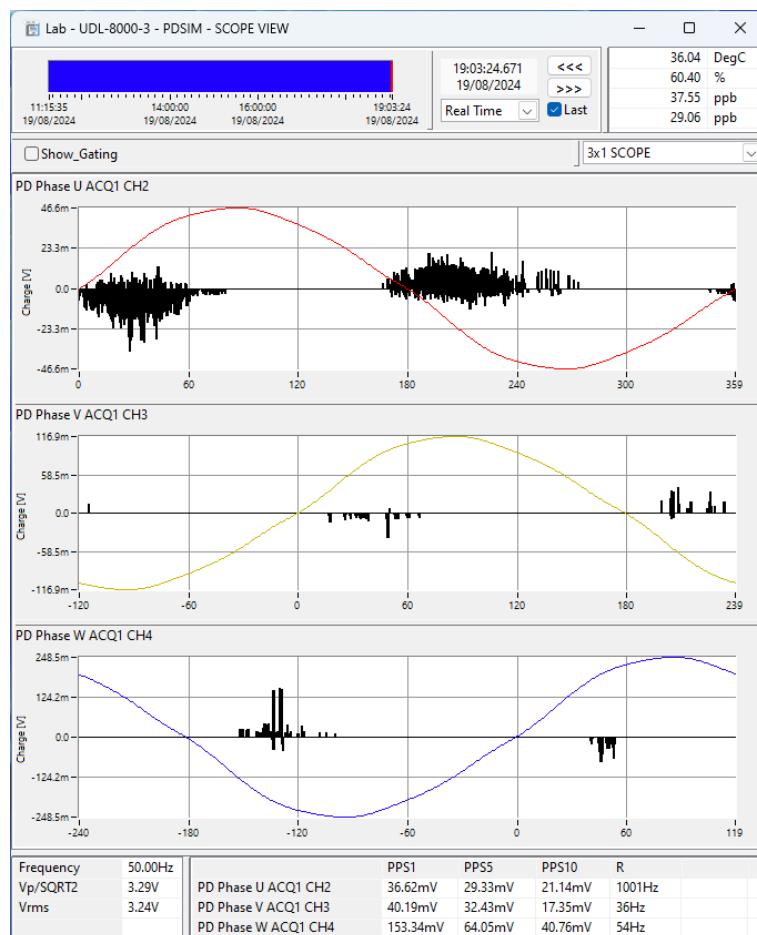


Figure 77: Scope Data Presentation

The time selection as well as the calculated results are identical to the PRPD pattern visualisation and are therefore described in the next chapter.

8.2.2 PRPD (Phase Resolved Partial Discharge Patterns)

The visualization 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 28: Separation of visualisation information

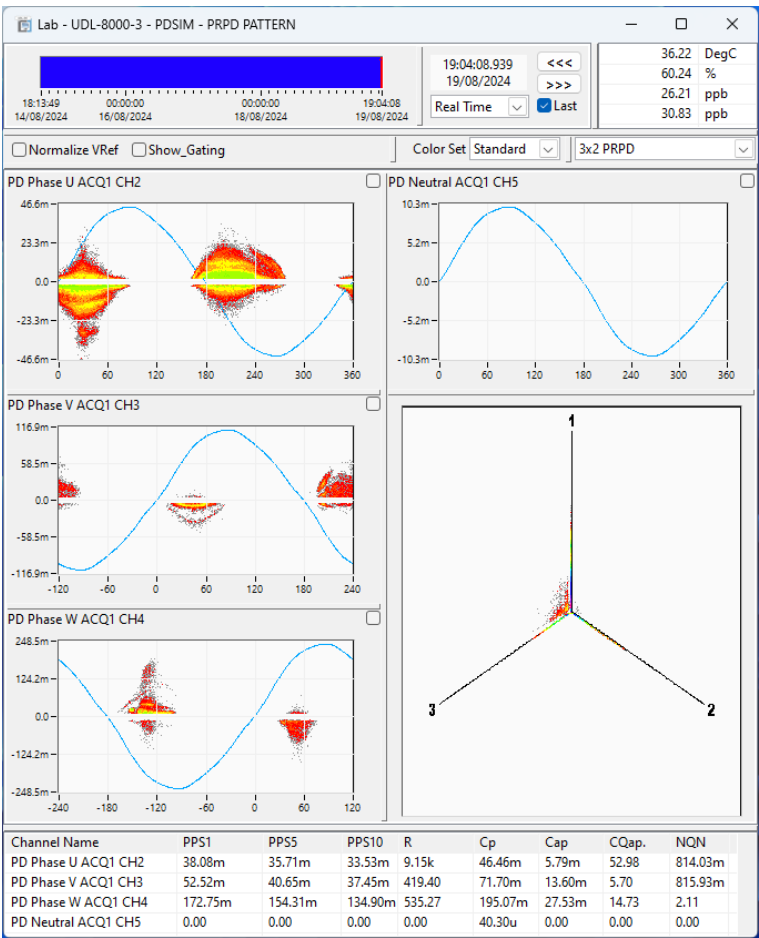


Figure 78: PRPD Data Presentation

8.2.2.1 Time Selection

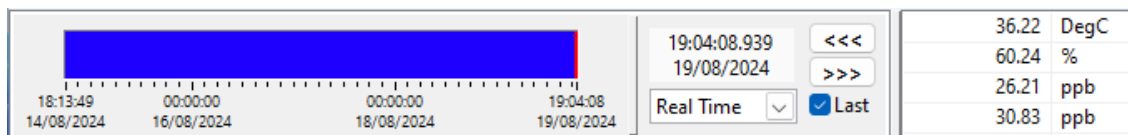


Figure 79: Time Selection

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 29: 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.

8.2.2.2 Data Presentation

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

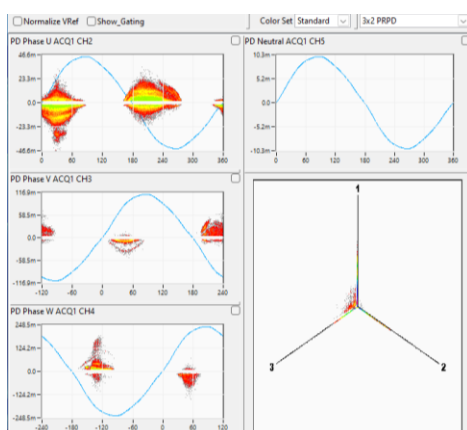


Figure 80: PRPD Data View - General

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

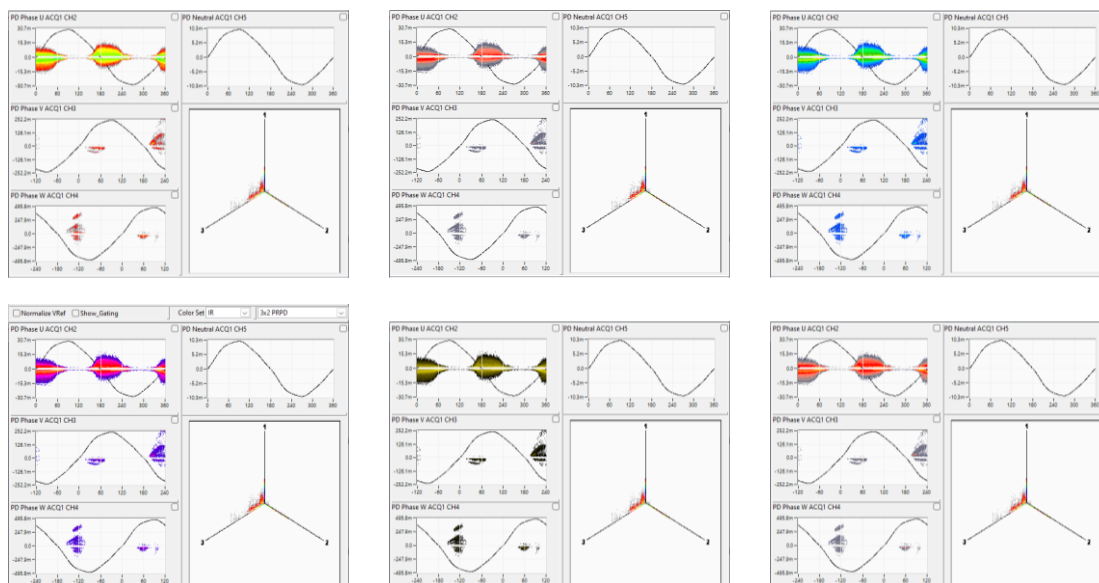


Figure 81: PRPD Data View – Color Coding

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 30: 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

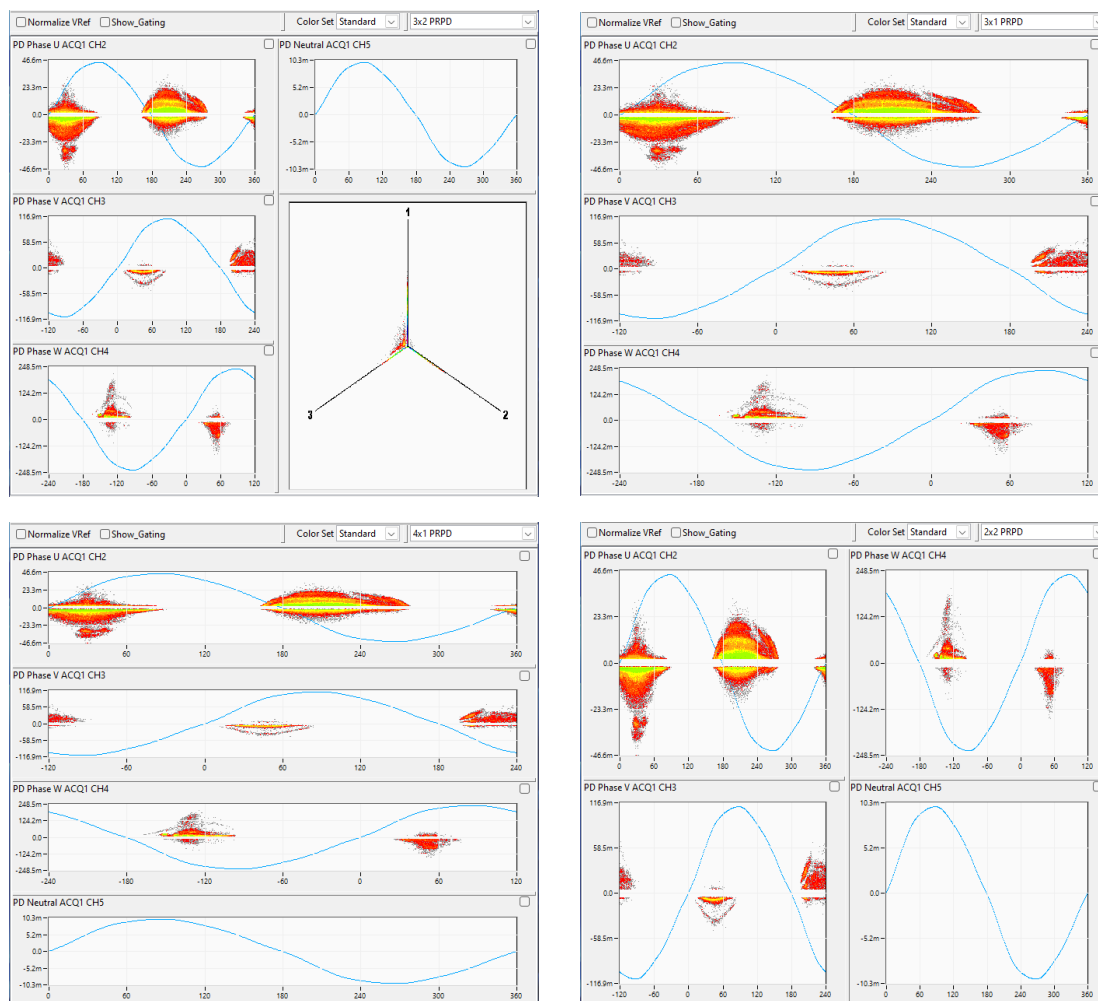


Figure 82: Number of PRPD Patterns shown within the same window

Each PRPD Pattern can also be presented within an individual window. This is especially useful 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.

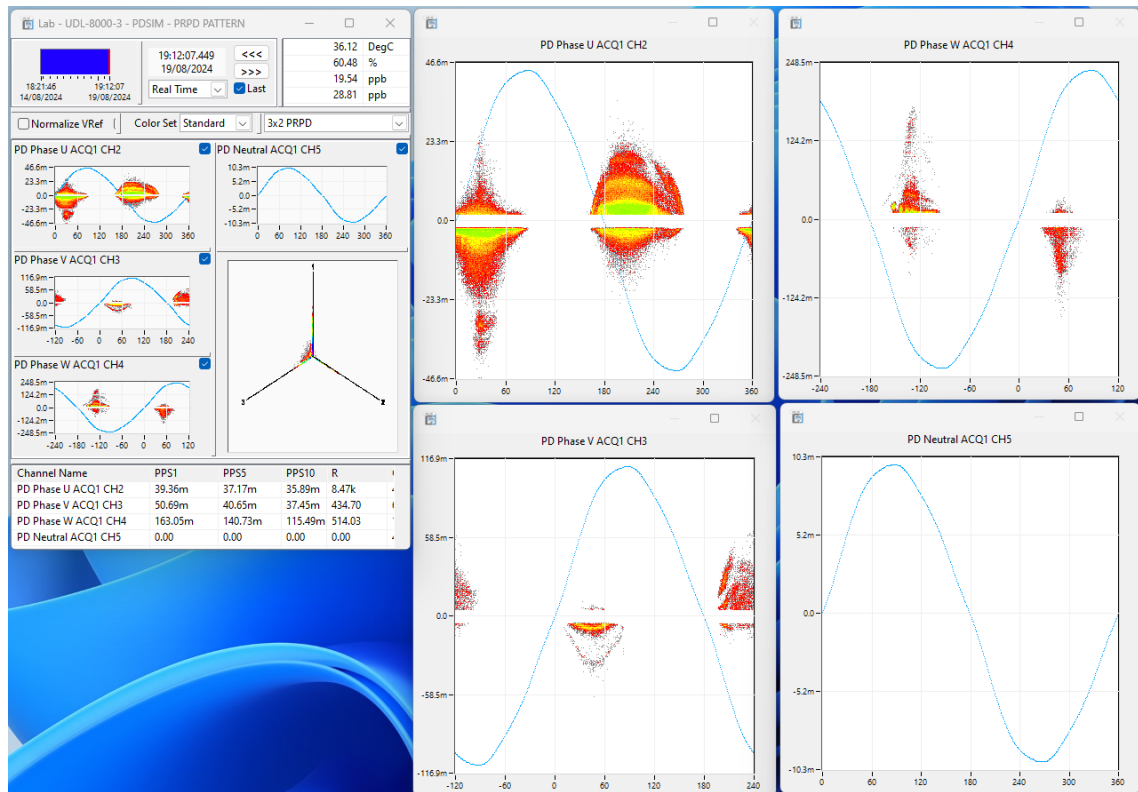


Figure 83: PRPD Patterns shown in Individual Windows

8.2.2.3 Calculated Results

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

Channel Name	PPS1	PPS5	PPS10	R	Cp	Cap	CQap.	NQN
PD Phase U ACQ1 CH2	38.08m	35.71m	33.53m	9.15k	46.46m	5.79m	52.98	814.03m
PD Phase V ACQ1 CH3	52.52m	40.65m	37.45m	419.40	71.70m	13.60m	5.70	815.93m
PD Phase W ACQ1 CH4	172.75m	154.31m	134.90m	535.27	195.07m	27.53m	14.73	2.11
PD Neutral ACQ1 CH5	0.00	0.00	0.00	0.00	40.30u	0.00	0.00	0.00

Table 31: Calculated Results

8.2.3 Pulse Height Distribution

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

The visualization 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 32: Separation of visualisation information



Figure 84: 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.

8.2.3.1 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”.

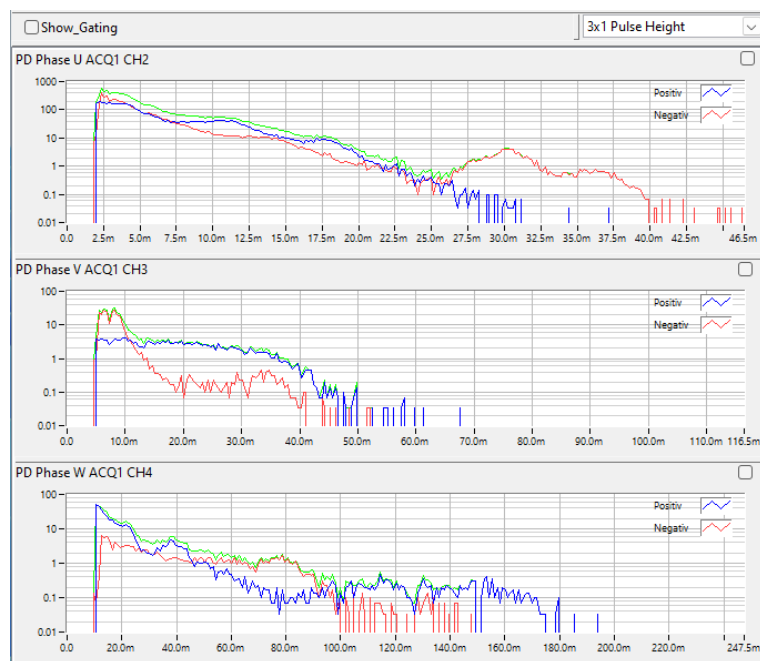


Figure 85: Pulse Height Data Presentation.

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.

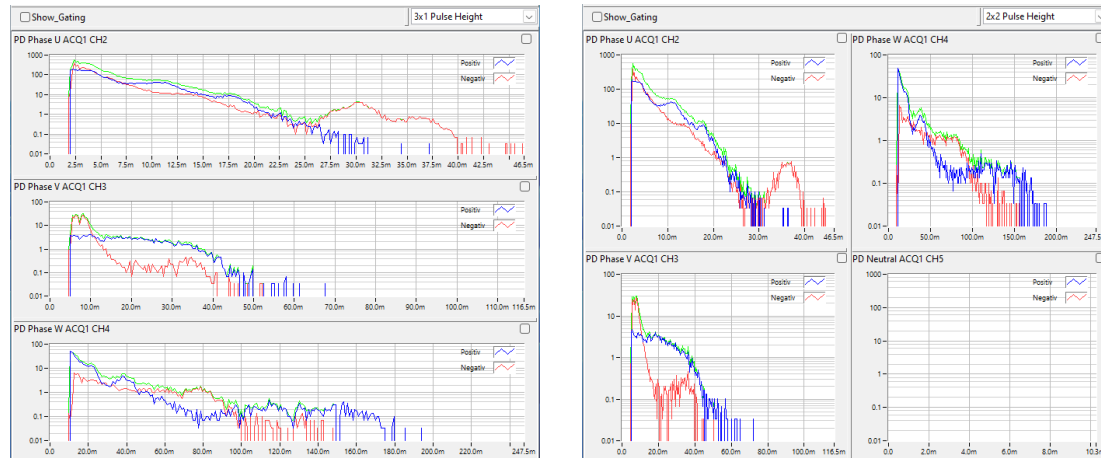


Figure 86: Number of Pulse Height Distribution graphs shown within the same window

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.

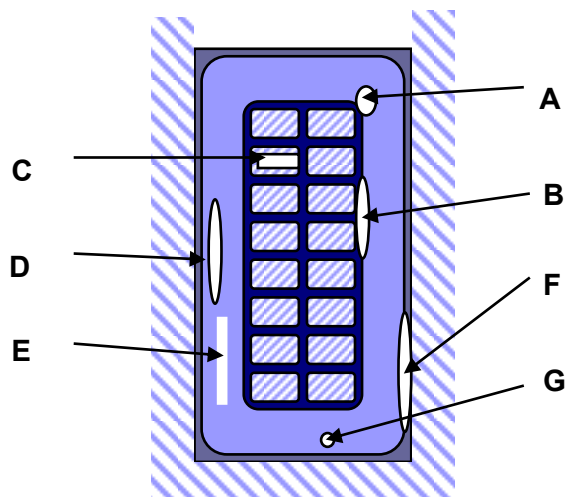
Conventional test methods as tan delta as well are sensitive to partial discharges, but, they represent an integral value as the loss created by the partial discharge pulses must be very high.

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

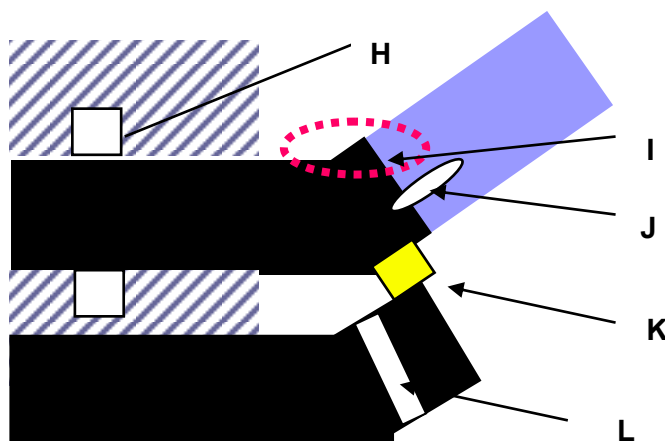
9.2.1 Internal Discharges – Discharge Sources in the slot sections



- 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 87: 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 88: 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.

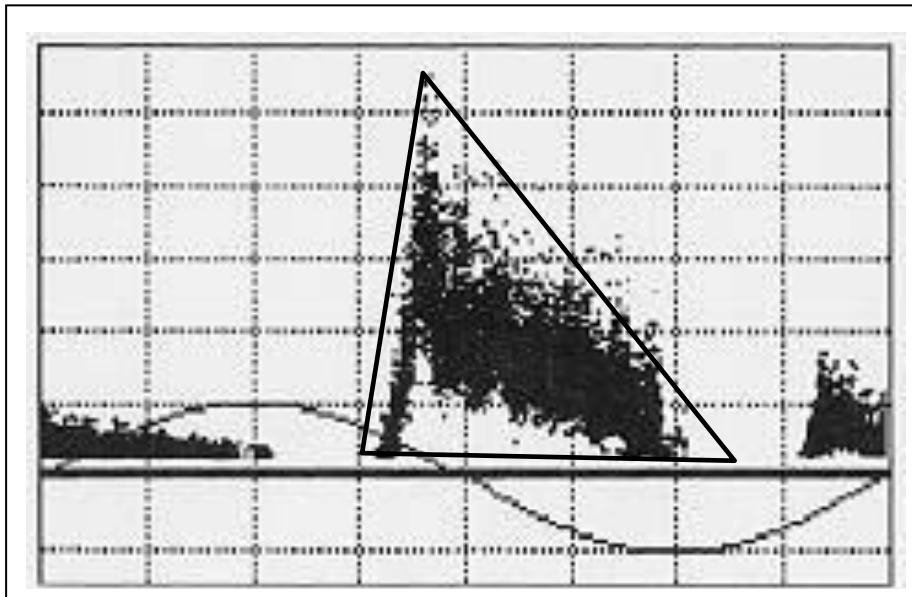


Figure 89: Typical Pattern of Slot Discharges

This pattern is asymmetric: the discharge magnitude is higher in the negative half-cycle 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.

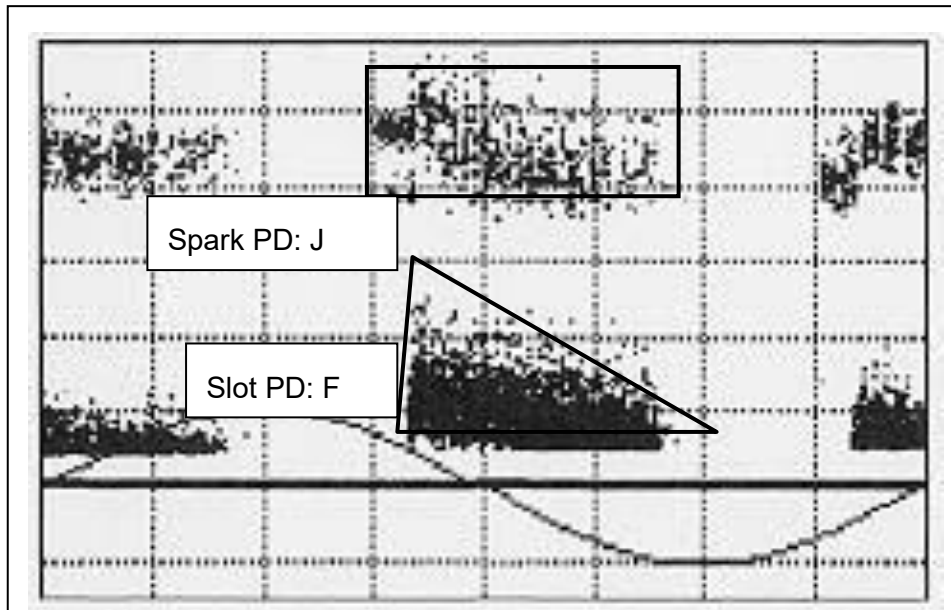


Figure 90: Typical Pattern of Slot Discharges & Sparking

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 endwinding corona protection:

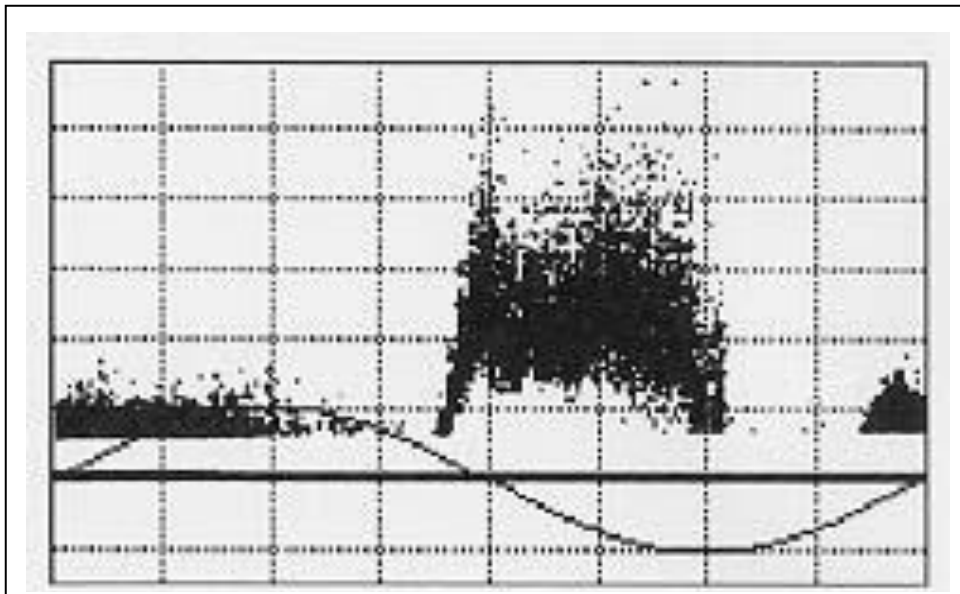


Figure 91: Typical Pattern of Slot & Endwinding Discharges

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 is usually indicated 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.

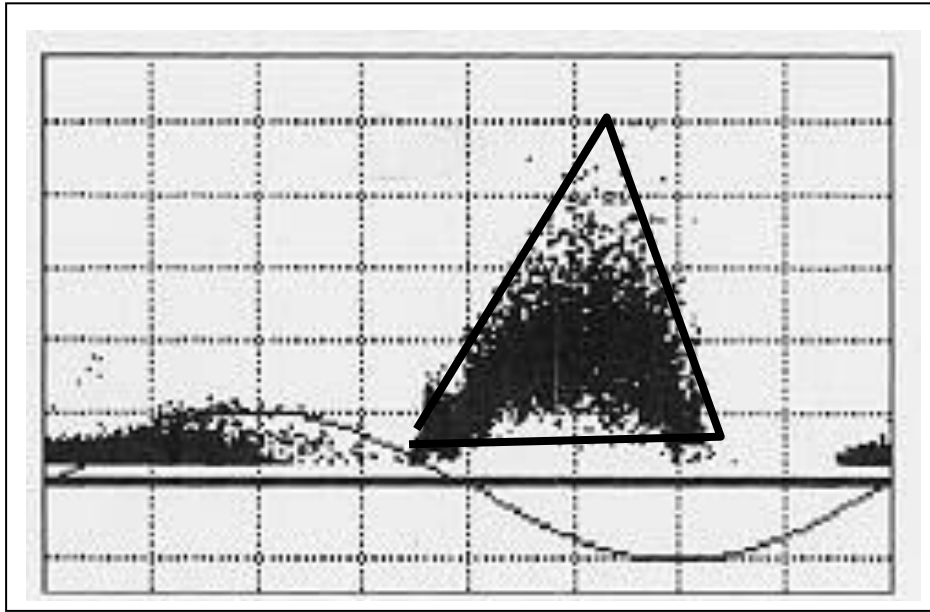


Figure 92: Typical Pattern of Endwinding Discharges

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 superimposition of internal discharges in the main insulation (C-location) and surface discharges in an initial state.

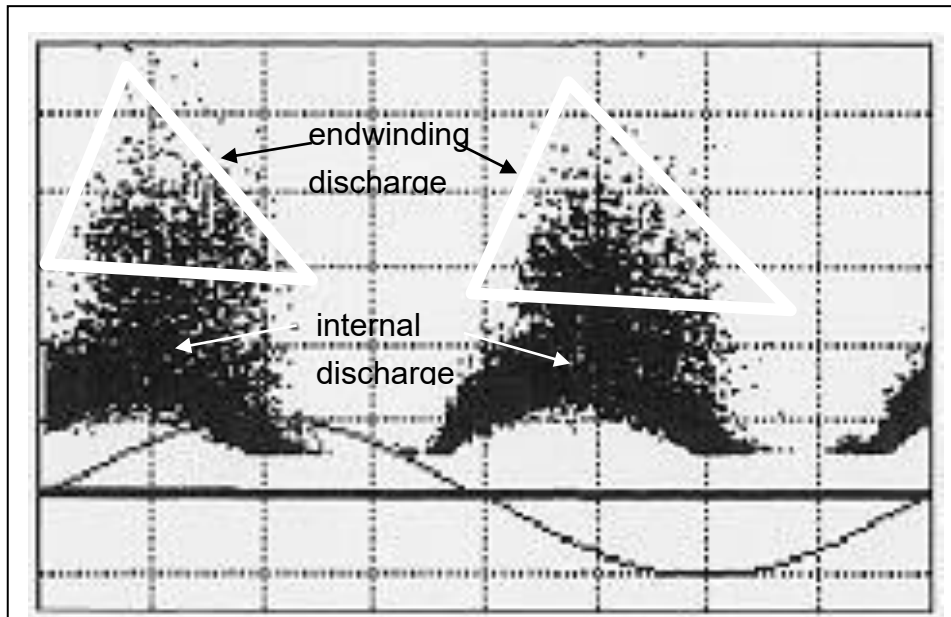


Figure 93: Typical Pattern of External and internal PD

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.

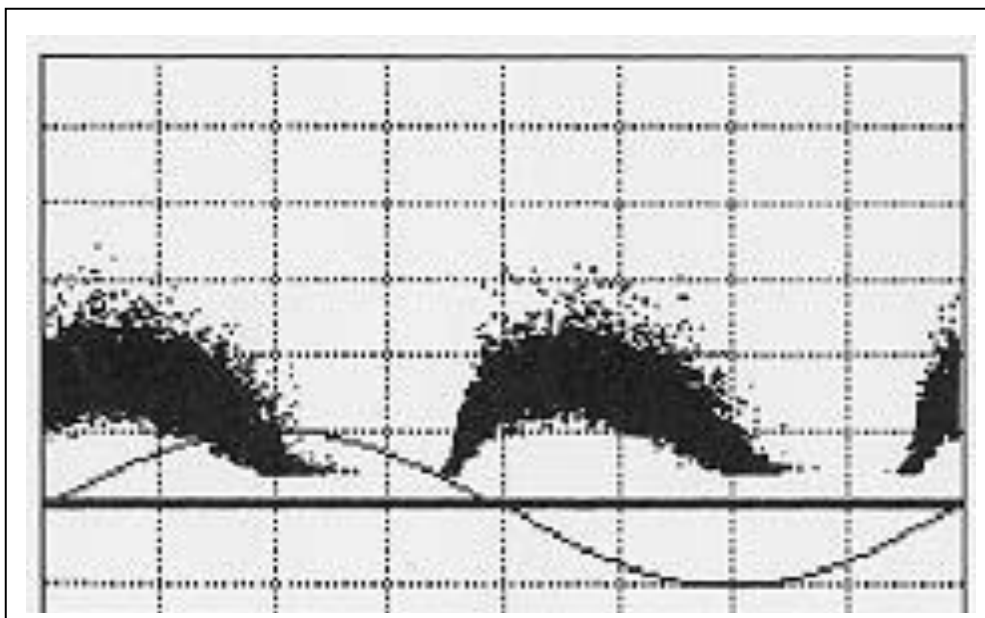


Figure 94: Typical Pattern of internal PD

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:

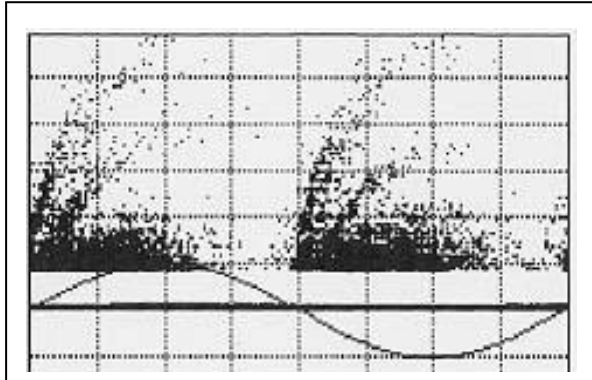


Figure 95: Typical Pattern: No Asymmetry, probably C

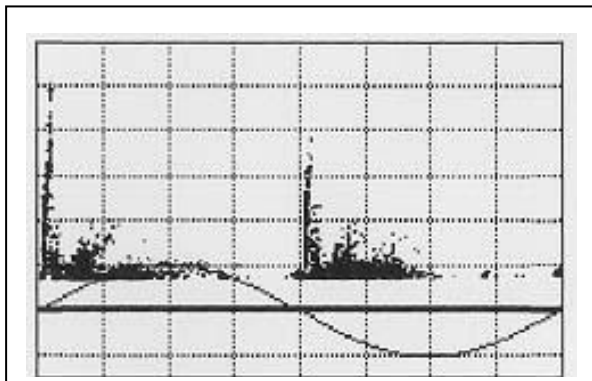


Figure 96: Typical Pattern slight asymmetry, positive higher, probably A or B

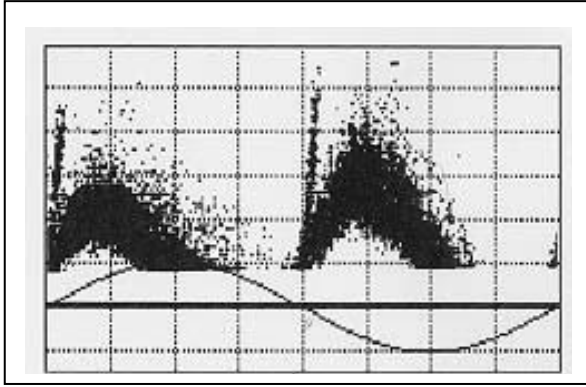


Figure 97: Typical Pattern: Rather symmetrical: Maybe C, probably slight thermal ageing

9.3.7 Endwinding Discharges: J

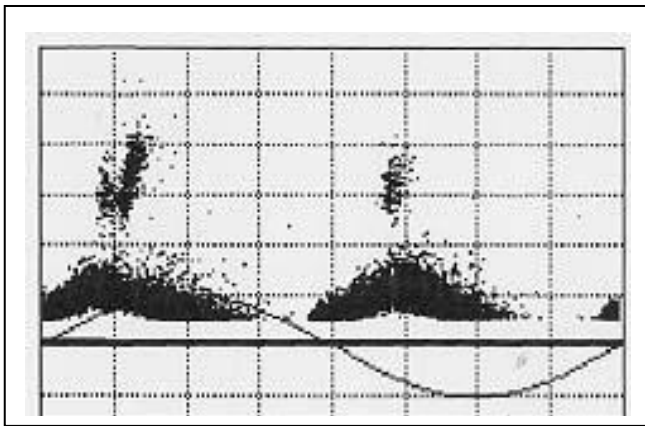


Figure 98: Typical Pattern: maybe surface tracking

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



Figure 99: 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

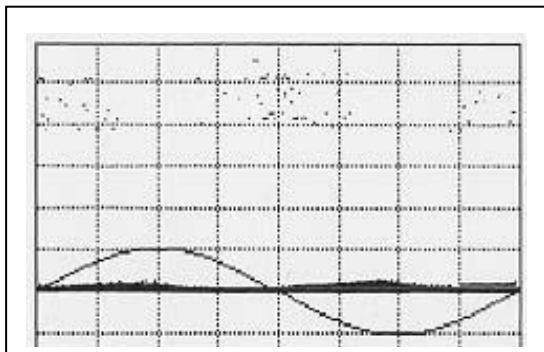


Figure 100: Poor Contact stress grading: L

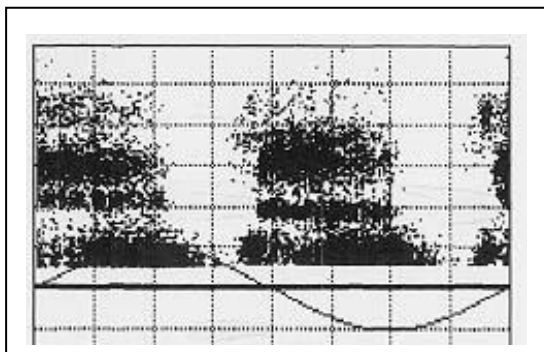


Figure 101: Poor Contact corona protection

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.

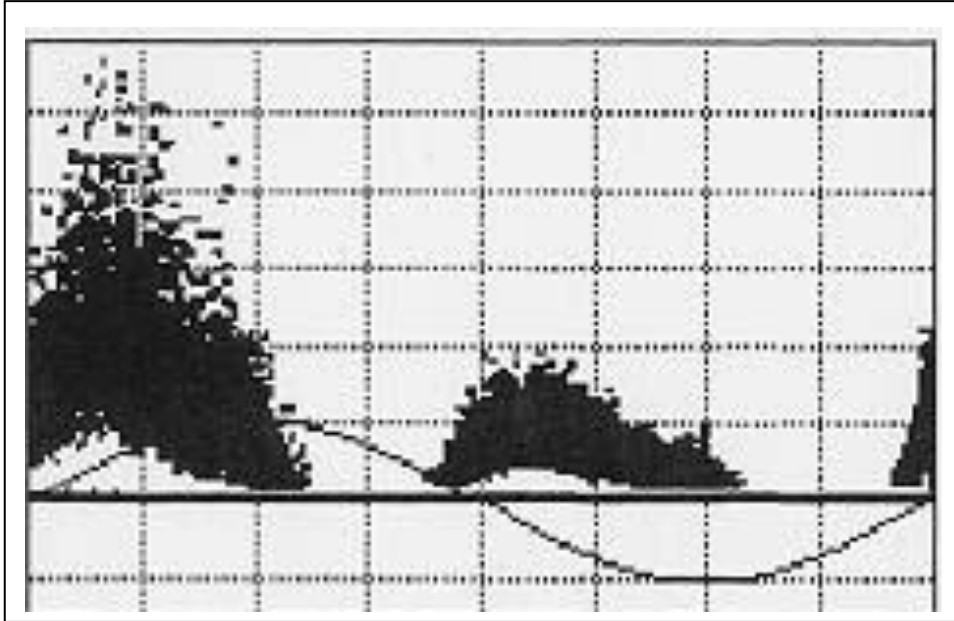


Figure 102: Typical Pattern internal Discharges

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

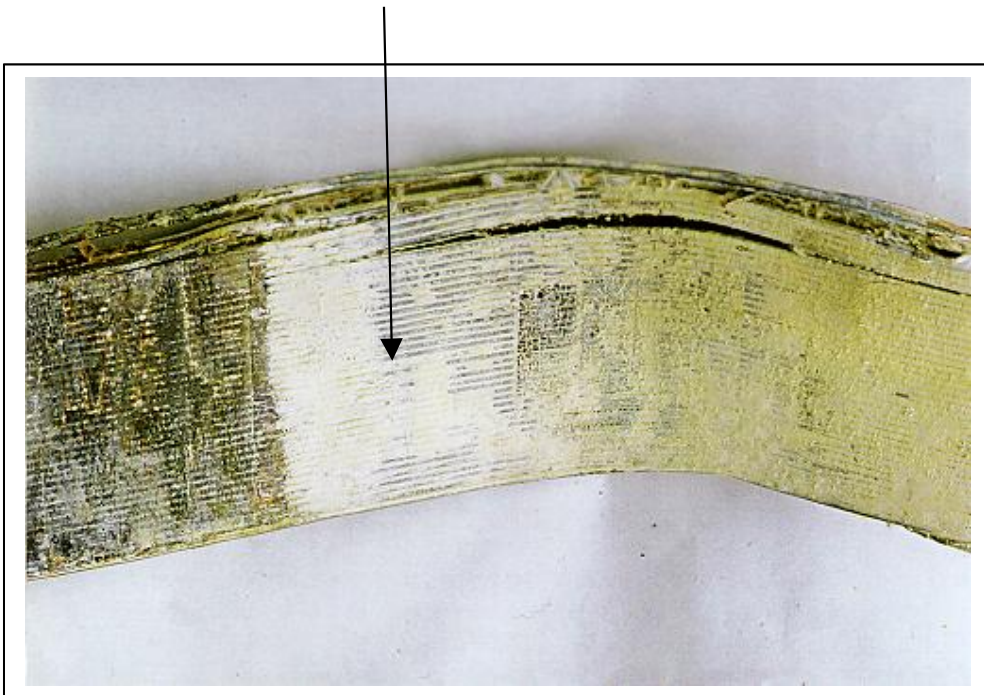


Figure 103: Deposits due to PD activity

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 33: 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 then 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 34: Risk Classification according to IEC60034-27

9.4.3 Alarm Thresholds 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 micafoilium, ...), 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.