OMICRON MPD Suite **User Manual for Version 1.40**

OMICRON Energy Solutions

March 7, 2023

Contents

I	Overview	6
1	Introduction	7
2	The start page	8
3	The main measurement window 3.1 The text zoom selector (1) 3.2 The language selection area (2) 3.3 The About button (3) 3.4 The Help button (4) 3.5 The Help for button (5) 3.6 The action buttons (6) 3.7 The channel group display (7) 3.8 The channel gating area (8) 3.9 The hot buttons area (9) 3.10 The upper diagram view (10) 3.11 The measured values display (11) 3.12 The control panel (12) 3.13 The lower diagram view	
4	Introduction to user profiles 4.1 Using built-in profiles	16 17 17
II	Using the MPD Suite	18
5	Setting up the MPD Suite to perform measurements 5.1 System requirements	19 19 19 20 23
6	6.1 Calibrating PD measurements	



7	Performing PD measurements	29
	7.1 Performing IEC 60270-compliant measurements	
	7.2 Dealing with superposition	. 32
	7.3 Performing RIV measurements according to CISPR 16-1-1/18-2 and NEMA 107	. 32
	7.4 Measuring PD as a voltage rather than a charge	. 33
	7.5 Performing PD/UHF measurements with the UHF 800	
	7.5.1 Using UHF frequency sweeps	. 34
	7.5.2 Using spur suppression	
	7.6 Performing PD measurements with HVDC assets	
	7.6.1 Exporting PD events and DC voltages to CSV files	
	7.7.7 Measuring PD at VLF (very low AC frequencies)	_
	7.8 Using 3FREQ to separate PD from disturbances	
	7.8 Using Strict to separate FD from disturbances	. 41
8	Working with PRPDs	43
	8.1 Capturing PRPDs	. 45
	8.2 Using phase-/amplitude gating	
9	Using assessments	50
	9.1 Working with pass/fail assessments	. 50
	9.2 Determining the PD inception and extinction voltages	. 51
	9.2.1 Using the Q(V) diagram	
10	Working with multiple measurement channels	54
	10.1 Using channel gating	. 55
	10.2 Using 3PARD to separate PD from disturbances	
11	Using dataset files	60
	11.1 Recording dataset files	. 60
	11.2 Loading dataset files	. 61
	11.3 Replaying loaded dataset files	. 62
	11.4 Re-exporting dataset files	
12	Exporting diagrams to image files	64
Ш	Reference	66
•••	Reference	
13	User interface concepts	67
	13.1 Expanders	. 67
	13.2 Foldable panels	. 68
	13.3 Splitters	
	13.4 Channel groups	
	13.5 Selection states	
	13.6 Value edits	
	15.0 Value Cales	. 70
14	Main window user interface elements	72
-	14.1 The channel group display	
	14.2 The channel gating area	
	14.3 The upper diagram view	
	14.3.1 The system overview display	. 75
	# 1131# 1116 JVJCIII CVCIVICW UIJDIUV	. /.)



	14.3.2 The PRPD view	80
	14.3.3 The H(Q)/H(V _{PD}) view	82
	14.3.4 The Ellipse view	83
	14.3.5 The PD/DC view	84
	14.3.6 The Meters view	86
14.	4 The lower diagram view	87
	14.4.1 The assessment view	87
	14.4.2 The PD scope view	88
	14.4.2.1 Analysis filters for scope and FFT	90
	14.4.3 The 3PARD view	91
	14.4.4 The 3FREQ view	92
	14.4.5 The trend view	94
	14.4.6 The FFT view	96
	14.4.7 The Q(V)/V _{PD} (V _{AC}) view	98
	14.4.8 The UHF sweep diagram	99
	14.4.9 The UHF spectrum diagram	
	14.4.10The replay diagram	
1/	5 The measured values display	
14.	Ji Tile Tileasureu values display	10.
15 Th	e control panel	L 07
	1 The SETUP & CALIBRATION tab	107
	15.1.1 AC/DC setup	
	15.1.1.1 AC/DC setup for MPD 800 and UHF 800 devices	
	15.1.1.2 Measurement setup for MPD 600 devices	
	15.1.1.3 Advanced measurement setup options	
	15.1.1.4 Additional note about quadripoles	
	15.1.2 Charge sub-tab	
	15.1.2.1 PD measurement settings	
	15.1.2.2 Charge calibration settings	
	15.1.3 RIV sub-tab	
	15.1.3.1 RIV measurement settings	
	15.1.3.2 RIV calibration settings	
	15.1.4 mV PD sub-tab	171
	15.1.5.1 Test voltage measurement settings	
15	15.1.5.2 Test voltage calibration settings	
15.	2 The PRPD & AC tab	
		124
	5	125
1 -		126
15.		128
		129
		129
	5	130
	· ·	130
15.		131
	1 3 3	133
	5	133
	15.4.3 Report information settings	133



	15.4.3.1 General information	4
	15.4.3.2 Test and specimen data	5
	15.4.3.3 Custom fields	5
	5.4.4 Advanced settings	5
15.5	he EXPORTING tab	8
	5.5.1 Image export options	9
	5.5.2 Export PD scopes as CSV	1
	5.5.3 Export FFTs as CSV	2
	5.5.4 Export data for 3rd party applications	.3
15.6	he RECORD/REPLAY tab14	6
	5.6.1 The RECORD sub-tab	.7
	5.6.2 The REPLAY sub-tab	0
15.7	he UHF 800 tab	4
	5.7.1 AC level and gain settings	5
	5.7.2 PD level and gain settings	5
	5.7.3 PD measurement settings	6
	5.7.4 Spectrum settings	6
	5.7.5 Spectrum diagram settings	7
	5.7.6 Sweep settings	7
	5.7.7 Sweep diagram settings	7
	5.7.8 Advanced settings	8
15.8	he PD/DC tab	0
	5.8.1 PD/DC measurement settings	1
	5.8.2 PD/DC diagram settings	1
	5.8.3 Channel-specific PD/DC diagram settings	2
	5.8.4.CSV export entions	2



Part I Overview



Introduction

Welcome to the OMICRON MPD Suite! The MPD Suite is used to control the OMICRON MPD series of PD measurement and diagnosis systems, including the MPD 800, the MPD 600, and the UHF 800. It allows you to perform measurements, diagnosis and analysis using these devices. It can also be used to replay measurement sessions that were previously recorded, and to generate measurement reports.

The OMICRON MPD series of systems provide the most advanced and complete solution for detecting, measuring, analyzing and visualizing partial discharge phenomena available today. Some unique features include:

- · High-precision, low-noise digital processing allows highly sensitive and accurate measurements,
- A fully synchronous distributed architecture using fiber optical links between channels allows flexible setups with multiple measuring points, thus enabling advanced noise suppression and source separation techniques,
- Fully digital signal processing, PD detection and analysis,
- Fully standards-compliant charge measurements according to IEC 60270,
- Complete support for RIV measurements according to CISPR 16-1-1 and NEMA 107.
- Flexible, highly customizable and automatable control software,
- Industry-leading analysis and noise suppression technologies, including 3PARD and 3FREQ,
- Full support for accurate measurements of AC signals.

This document describes all features available in the MPD Suite when used with MPD 800, MPD 600, and UHF 800 devices. The next sections will describe the start page and the main measurement window, the two windows you will interact with the most. Chapter 2 explains how to perform common tasks and describes techniques in detail. Finally, chapter 3 contains the reference documentation of every part of the MPD Suite.

Note that this document describes all functionality of the MPD Suite, including features that you may not have purchased. If your licensed packages do not include some functionality, your MPD Suite will not show the corresponding user interface elements (control panel items, diagrams, etc.). Also, your software's user interface may be customized via user profiles, which may have disabled or hidden some functionality described here. Using the default user profile will make sure that the software enables all functionality you are licensed for.

Please take note of the section User interface concepts. This section describes concepts that are used throughout the user interface of the MPD Suite. It may be beneficial to read through that first.



The start page

When you first open the MPD Suite, the *start page* will appear. It is your main gateway into the functionality of the software.

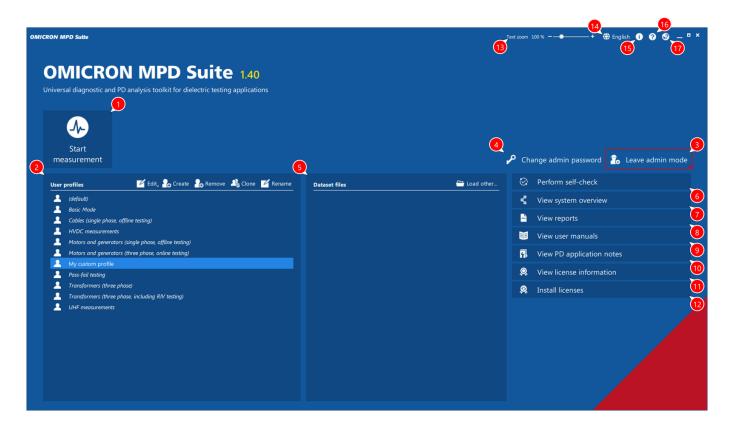


Figure 2.1: The start page

The start page allows you to start a measurement session, manage user profiles, and replay previously recorded measurement sessions stored in files known as *dataset files*¹. It is also the place where you can perform some management tasks such as viewing and updating your licensed features, and executing a



¹Starting with version 1.20 of the MPD Suite, *stream files* can also be replayed. Stream files are similar to dataset files. They represent measurement sessions that were recorded by the older *Software for MPD and MI*, which was previously used to control MPD 600 devices.

system self check of the attached MPD 800s. Finally, the start page allows you to open a folder containing product documentation.

On the start page:

- The **Start measurement (1)** button switches to the main measurement window. When this button is clicked, the start page is closed and the main measurement window is opened instead. You can return to the start window at any time from the main measurement window via the *Home* action button.
- The **User profiles (2)** area shows all currently defined user profiles and allows you to manage them.
- The **Enter admin mode (3)** button switches the MPD Suite to admin mode, which enables certain features such as user profile management and user interface customization. The *Enter admin mode* button will change to read *Leave admin mode* when admin mode is enabled, and will be highlighted to indicate that the software is currently in admin mode. Clicking the highlighted button will switch the software back out of admin mode and into *normal mode*.
- The **Change admin password (4)** button is only visible when in admin mode, and allows you to set the password required to enter admin mode. By default, no password is set, so anyone can switch to admin mode. If a password is set, you need to enter the correct password upon clicking the **Enter admin mode** button in order to successfully switch the software to admin mode.
- The **Dataset files (5)** area allows you to select one or more previously recorded measurement sessions stored in a dataset file for replaying. You can click the *Load other* link to browse and load any dataset files, or you can select a file from the list of files shown in the area. Every time you record a dataset file, or you replay an existing file, this list is updated, so it always shows the most recently used dataset files. After selecting a file, the **Start measurement** button changes to **Replay dataset**, indicating that instead of performing an online measurement, the software is preparing to replay the dataset file. You can load the file by either clicking on the **Replay dataset** button or by double-clicking on the file in the list. To remove the selection from the currently selected dataset file, click on any empty place in the dataset files list. Doing so will also switch the **Replay dataset** button back to **Start measurement**.
- The Perform self-check (6) button opens a window, similar to the system overview window, that shows the currently connected MCU controller and all MPD devices connected to the active MCU.
 On the window, you can start a self-check on all connected MPD 800s. The self-check will verify that your devices function properly and that measurements taken with your devices are accurate.
- The **View system overview (7)** button opens the system overview display in a new window. The system overview display shows all connected MPD devices and how they are connected to the computer. It also displays some basic measurement values and settings for each measurement channel.
- The **View reports (8)** button opens the report viewer window, allowing you to select an XML report file that was created by the MPD Suite. The report viewer can also load files generated by the older Software for MPD and MI that was previously used for measuring with MPD 600 devices.
- The View user manuals (9) button opens this MPD Suite user manual.
- The **View PD application notes (10)** button opens a folder that contains a number of application notes that describe the use of the MPD Suite for specific applications.
- The **View license information (11)** button opens the license information window, which shows all licensed features currently available.
- The **Install licenses (12)** button opens a new window that allows you to install license files on to any connected OMICRON MCUs and MPDs.

The start page also allows you to select the change the text size (13), user interface language (14),



display the **About** window (15), open the context-sensitive user manual (16), and show the user manual for a specific element of the user interface (the "What's this?" functionality, 17). This functionality is also available on the main measurement window and is described in the next section.

The main measurement window

This section describes the main measurement window of the MPD Suite.

The main measurement window offers access to most of the measurement functionality within the MPD Suite. You will use it to measure PD activity, view PRPD and other diagrams, suppress noise and disturbances, perform separation of PD sources and to create reports and record and replay measurement sessions using dataset files.

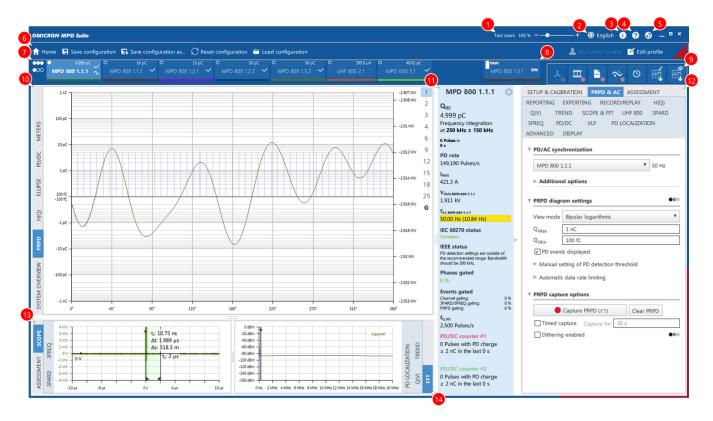


Figure 3.1: The main measurement window

The window contains the following areas:



3.1 The text zoom selector (1)

The text zoom selector allows you to change the size of the text used throughout the software. By default, it is set to 100%. You can use the slider as well as the + and - buttons to change the text size. Clicking on + will increase the text size by 10%, while the - button will decrease the text size by 10%. Using the slider, you can drag it to any value between 80% and 200%. The change in the text size takes effect when you release the slider.

You can also change the text size using the keyboard. Pressing the CTRL and + keys together will increase the text size by 10%, and pressing the CTRL and - keys together will decrease the text size by 10%. Pressing the CTRL and 0 keys together will reset the text size to 100%.

Note that the meaning of 100% depends on the Windows text display settings.

3.2 The language selection area (2)

The language selection area shows the currently used language of the user interface and allows you to change it. By default, the software uses the language of the system it is running on (if it is one of the supported languages – otherwise English is used). The currently used language is shown both in its native spelling and in the system language. For example, on a computer whose system language is set to Spanish, choosing English as the user interface language will show as "English (Inglés)".

Clicking on the language selection area will open the list of supported languages. You can then choose the user interface language by clicking on the desired line, and the user interface of the software will automatically switch to the new language.



Figure 3.2: Changing the user interface language

The user interface can be configured to display the following languages: English, German, French, Span-

ish, Portuguese, Russian¹, Chinese², Japanese, Polish, and Turkish.

3.3 The About button (3)

Clicking the *About* button will open an information window showing information about the MPD Suite, including version information about the algorithms used in the MPD Suite internally.

3.4 The Help button (4)

Clicking the *Help* button will open this user manual. Depending on which user element has the keyboard focus when this button is clicked, a suitable section in the manual will be shown. Instead of clicking this button, you can also press the F1 key.

3.5 The Help for... button (5)

The *Help for...* button will allow you to get help for a specific user interface element. When you click on the button, the mouse cursor changes to a *What's this?* icon and any user interface element for which there is an entry in this user manual will get highlighted when the mouse hovers over it. Clicking the highlighted element will open this user manual at the corresponding section. Instead of clicking this button, you can also press the ALT and F1 keys together.

3.6 The action buttons (6)

Action buttons provide simple access to various functionalities.

- The *Home* button hides the main measurement window and opens the start page instead. **Note** that the current measurement session continues even with the main measurement window hidden, and can be returned to at any time by clicking the *Start measurement* button on the start page.
- The Save configuration button stores the current configuration in the configuration file associated with the current user profile. If user profiles are not licensed, the settings are associated with the default user profile, which is always available. When starting the MPD Suite, the configuration file of the currently selected profile is automatically loaded.
- The Save configuration as... button can be used to store the current configuration to a different file (i.e. not the default configuration file).
- The Reset configuration button restores the default configuration and discards any changes made by the user. **Note** that clicking this button does *not* affect purely visual settings, such as the window size and position, the text size, and which diagrams and control panel tabs are open.
- The *Load configuration* button loads a configuration from a user-selectable file. This is useful for working with multiple configuration sets. Together with the *Save configuration as...* functionality this allows switching between different configuration sets quickly.



¹if licensed.

²if licensed.

³Configuration files are stored under c:\ProgramData\OMICRON\MPD Suite\configurations and are named after the user profile they are associated with. The default user's configuration file is named default.conf.

- The user profile indicator shows the currently active user profile. This indicator is only visible if
 the default profile is not active, i.e. it only appears for user-created profiles and the built-in specialpurpose profiles.
- the *Edit profile* button enables customizing of the user interface and available options for certain settings for the currently selected user profile. **Note** that this button is only available when in admin mode and when *neither* the default profile *nor* one of the built-in special-purpose profiles is active.

3.7 The channel group display (7)

The channel group display shows each of the available measurement channel groups. A channel group represents a single PD input and its associated AC or V input. Each MPD 600 and UHF 800 corresponds to single channel group, while each MPD 800 corresponds to **two** channel groups (one for the input section labeled **Channel 1** and another for the input section labeled **Channel 2**). The channel group display also shows status information about each measurement channel, such as whether the channel is selected, if the device's battery is getting low or whether the channel's PD measurement is compliant with IEC 60270, among other things.

3.8 The channel gating area (8)

The channel gating area contains any channel groups that are configured to act as gating channels. Gating channels are used to detect noise and disturbances and suppress the PD measurement on any non-gating channels for the duration of detected disturbances.

3.9 The hot buttons area (9)

Hot buttons allow quick access to some often-used functionality using a single click.

- The button is used to start/stop capturing of *PRPDs*, and
- The button is used to start and stop recording of dataset files,
- The button is used to start and stop recording of report files,
- The button is used to save all currently visible diagrams to image files,
- The button is used to save the diagrams selected on the EXPORTING control panel tab of all config-selected channels to image files,
- The button is used to enable and disable 3PARD processing,
- The button opens a window that contains a simple stop watch and a timer with alarm func-

tionality, which helps with routine tests. Every time you click on the stop watch button, a new and independent window opens. This allows you to have several independent timers running concurrently.

3.10 The upper diagram view (10)

The *upper diagram view* takes up most of the space on the main measurement window. It shows the most important diagrams, including the PRPDs, the H(Q) diagrams, the Ellipse (*Lissajous*) diagrams, the PD/DC views, the Meter views and the System overview display. The upper diagram view is separated from the lower diagram view via a splitter. When you right-click any diagram in the upper diagram view, you will be able to save the diagram as an image file. When multiple diagrams of the same type are visible, all of them will be saved. You can configure the naming, size, and location where the images are stored on the EXPORTING control panel tab.

3.11 The measured values display (11)

The *measured values display* is situated in the middle of the main measurement window, and displays important quantities related to the currently active measurement. It, too, is separated from the upper and lower diagram areas via a splitter. The measured values display can be optionally included in PRPD diagram saved as image files. This behavior is configured on the EXPORTING control panel tab

3.12 The control panel (12)

The *control panel* is the foldable panel that takes up the rightmost part of the main measurement window. It contains most of the settings that configure the operation of the software and any connected devices.

3.13 The lower diagram view

The *lower diagram view*, so called because it is situated at the lower section of the main measurement window, hosts additional diagrams. A splitter separates the area into two sections, the *lower left diagram view* (13) and the *lower right diagram view* (14). The *lower left diagram view* contains the Assessment, the Scope, UHF sweep⁴, 3PARD and 3FREQ views, while the *lower right diagram view* contains the PD localization, Trend, Q(V), UHF spectrum⁵, and FFT⁶ views. Both the lower left and the lower right diagram view can be configured to additionally show the Replay diagram when dataset files are loaded.

Like on the upper diagram view, you can right-click any diagram in the lower diagram view in order to save the diagram to an image file. Naming, size, and location of the stored file are configured on the EXPORTING control panel tab.



⁴Available for UHF 800 only

⁵Available for UHF 800 only

⁶not available for UHF 800 devices

Introduction to user profiles

User profiles are a convenient means of customizing the user interface of the MPD suite to fit your needs. The graphical interface can be adapted based on user skills, requirements of the object to be tested for PD, and other aspects of the test environment.

A *user profile* is a collection of settings and user interface customizations. User profiles can only be managed when the MPD Suite is in admin mode. When in admin mode, you can create, remove, copy, and edit user profiles from the start page.

The most powerful aspect of user profiles is the ability to customize the user interface. When in admin mode, you can choose to *hide* or *constrain* almost any user interface element on the main measurement window. Hidden elements will not be shown when the corresponding profile is selected while in *normal mode*. Constraining a user interface element involves limiting the values that can be set via the element. Elements that configure a numeric setting (such as the f_M setting that controls the PD filter center frequency) can be constrained to a single value or to range of values. Limiting the element to a single value will also *disable* the element, so that it is grayed out in normal mode, indicating that the user can no longer interact with it. Elements that represent a choice between different options (such as the bandwidth of the PD filter) can be constrained to allow only a subset of options. Again, if only a single option is allowed, the element becomes disabled and cannot be interacted with.

You can also hide entire control panel tabs and diagrams. If all diagrams from a section (*upper diagram view*, *lower left diagram view* or *lower right diagram view*) are hidden, the section itself is hidden too. This allows you to present an uncluttered simple interface where desired, while all functionality remains available for when you need the full power of the MPD Suite.

Some user interface elements are available on multiple control panel tabs, and user profiles offer a choice on which tabs the element should appear, based on your preferences.

Note that settings that are constrained via user profiles cannot be overridden through other means, e.g. by attempting to change them through the automation interface or by loading configuration files saved from different profiles. Profile constraints always take precedence.

Profiles are stored in the C:\ProgramData\OMICRON\MPD Suite\profiles folder. Profile-specific configurations are stored in C:\ProgramData\OMICRON\MPD Suite\configurations, with the name of the profile and the extension .conf.



4.1 Using built-in profiles

A set of built-in profiles is installed with the MPD Suite and is available from the user profiles area on the start page. These profiles can be used as-is, or they can be used as templates for your own profiles that you can edit and customize. In the user profiles area on the start page, built-in profiles are shown in italics, like the default profile¹. If you don't need the built-in profiles, you can remove them from the MPD Suite.

You use the profiles simply by clicking on them in the user profiles area on the start page. In order to clone or remove a built-in profile, you have to switch to admin mode. Once you select a profile in the user profiles area on the start page in admin mode, the Clone and Remove buttons become available.

If you remove one or more built-in profiles, and you need to get them back in the future, you can do that by doing a repair installation of the MPD Suite: Press the Windows key, then begin typing the phrase *Add or remove programs* until the corresponding system settings entry appears, then open that. Under *Apps & Features*, search for *MPD Suite*, and click on *Modify*. In the installer window that opens, click *Next*, and then *Repair*.

4.2 The default user profile

There is a special user profile called the *default user profile*, which is always available, even if you haven't licensed *user profiles*. The default profile is labeled *(default)* and cannot be removed or edited. It does not constrain any settings and includes every user interface element.

Apart from offering all functionality of the software directly, the default user profile is also useful as a basis for your own profiles, when you want to start building one from scratch rather than using one of the built-in profiles as a template.



¹which is shown as (default) and cannot be removed, edited, or cloned

Part II Using the MPD Suite

Setting up the MPD Suite to perform measurements

5.1 System requirements

In order to use the MPD Suite, your computer must meet the following system requirements:

Requirement	Description
Operating System Connectivity	Microsoft [®] Windows [™] 10, or 11 64 bit USB 3.0
Hardware	Minimum: Quad-core 64-bit Intel® or AMD® CPU with at least 1.6 GHz, 4 GB of RAM (e.g. Intel® i5, AMD® Ryzen 3) Recommended: Quad-Core 64-bit Intel® or AMD® CPU with at least 2.5 GHz, 816 GB of RAM, dedicated GPU (e.g. Intel® i7, AMD® Ryzen 5) High-end: Octa-Core 64-bit Intel® or AMD® CPU with at least 3.2 GHz, 32 GB of RAM, dedicated GPU (e.g. Intel® i7/i9, AMD® Ryzen 7/9)

5.2 Installing and starting the MPD Suite

The MPD Suite can be installed using the MPDSuite_XX.YY.ZZ_x64.exe web installer, or from the MPD Suite installation DVD. When using the web installer, double-click the file from the folder you downloaded it to and follow the instructions shown on the screen.

When using the installation DVD, simply insert the DVD in your drive, and Windows should prompt you to install the software. Accept that prompt, and then just follow the instructions on the screen.

Once installed, the MPD Suite is available in the start menu. Press the Windows key to open the start menu, then just type MPD and the entry for the MPD Suite should appear. Click the entry (or select it with the cursor keys and press Enter) to launch the MPD Suite.



5.3 Performing self-checks

The MPD Suite supports running fully automated self-checks for MPD 800 devices¹. A self-check should be performed regularly, but certainly after flashovers, or when a test subject suffered a breakdown during a PD measurement, in order to ensure that your MPD devices continue to function properly.

During a self-check, the entire functionality of the device is verified, such that a passing self-check indicates that the device is not defective, has been properly factory-calibrated, and measurements made with the device are accurate.

The self-check works by enabling the test-generator built into the MPD device and measuring the resulting signals with the MPD itself. This is used both for measuring the PD inputs and the AC inputs, exercising the internal quadripole in order to measure the latter. The self-check verifies the accurate measurements of magnitude and phase as well as the timing of the measurements.

You can run a self-check from the start page, via the *Perform self-check* button. Clicking that button will open the self-check window, which shows all connected devices (similar to the system overview display). A message at the top of the window will warn you to disconnect all cables from all connected MPD 800 devices before running the self-check. This is important, as the self-check assumes that there are no cables connected to any of the MPD devices' inputs. *Failing to remove all cables from all MPD 800 devices' inputs will probably lead to a failing self-check.* Once you click the *Start MPD 800 self-check* button located at the bottom of the window, the self-check will be started for all connected MPD 800 devices simultaneously. If a problem with a component of any MPD 800 device is detected, the self-check will fail for that device.

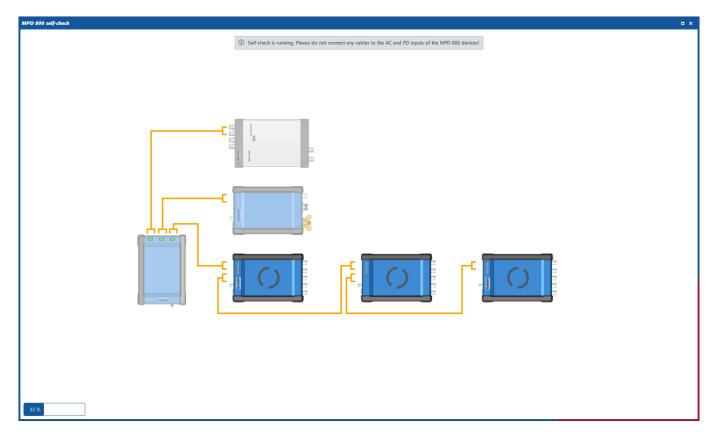


Figure 5.1: An ongoing self-check



¹Self-checks for MPD 600 and UHF 800 devices are not currently supported

Once the self-check is complete, the result of the self-check is indicated on each MPD 800 device by a suitable symbol: a check-mark (\checkmark) for pass and warning (\triangle) symbol for fail:

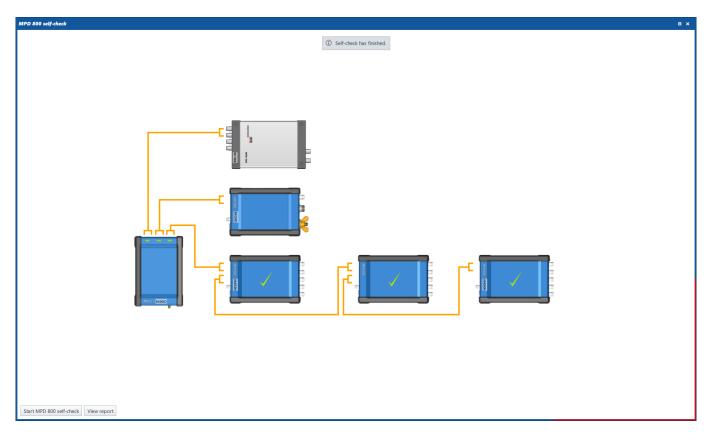


Figure 5.2: Finished self-check

You can view the details of the self-check by clicking the *View report* button. Doing so opens a report window that lists, for each device, the components tested and whether the associated tests passed or failed.



1, position 1 (AM053N)	Passed	Warning! Device is no	t calibrated!
ested component		Channel #1	Channel #2
D pre-amplifier		Passed	Passed
D skew		Passed	Passed
C skew		Passed	Passed
.C offset		Passed	Passed
nternal quadripole		Passed	Passed
D 18 dB attenuator		Passed	Passed
D 36 dB attenuator		Passed	Passed
D 80 mV range		Passed	Passed
D 160 mV range		Passed	Passed
D 320 mV range		Passed	Passed
D 640 mV range		Passed	Passed
D 1.28 V range		Passed	Passed
.C 200 μA range		Passed	Passed
.C 2 mA range		Passed	Passed
.C 20 mA range		Passed	Passed
.C 200 mA range		Passed	Passed
.C 400 mA range		Passed	Passed
1, position 2 (N/A)	Passed	Warning! Device is no	t calibrated!
ested component		Channel #1	Channel #2
D pre-amplifier		Passed	Passed
D skew		Passed	Passed
.C skew		Passed	Passed
C offset		Passed	Passed
nternal quadripole		Passed	Passed
D 18 dB attenuator		Passed	Passed
D 36 dB attenuator		Passed	Passed
D 80 mV range		Passed	Passed
D 160 mV range		Passed	Passed

Figure 5.3: Self-check report

The report also indicates if a device has not been factory-calibrated.

If a self-check report indicates failure for a device, you should first double-check that nothing was connected to the device when the self-check was performed. Once that is verified to have been the case, you should contact OMICRON technical support or your nearest OMICRON office at www.omicronenergy.com/support in order to have the device repaired. If only one channel of a device is affected, you can continue using the other channel until the device is repaired.

5.4 Configuring the measurement setup

Before a measurement can be performed, the measurement setup should be configured. This step ensures that the software correctly computes the voltage and current in the test circuit, and that PD events are properly positioned in the PRPD. To this end, the MPD Suite supports modeling the electrical circuit to which the MPD device channel is connected. This model allows the software to compute both the precise voltage signal and the precise current signal (including the waveforms) at the *measurement point*, i.e. where the MPD device is connected to the test subject via a sensor and a coupling device.

The configuration of the measurement setup takes place on the *Setup & calibration* control panel tab under the *AC/DC setup for ...* expander. The measurement setup can be independently configured for every measurement channel, reflecting the fact that different channels are likely placed at different positions in the test circuit, and may be used with different sensor and coupling devices.

The configuration steps are different for MPD 800 and UHF 800 devices on the one hand and for MPD 600 devices on the other. For MPD 800 and UHF 800, the measurement configuration process requires describing the *sensor* which is used to connect the MPD device to the test circuit, and selecting a *coupling unit* via which the sensor is connected to the MPD device. MPD 600 devices only support choosing whether the MPD's internal quadripole is enabled or not. No sensors and external coupling devices can be configured for MPD 600 devices.

Refer to the reference section for the options available to you as you configure the measurement setup.

Once the measurement setup is configured, the MPD Suite will measure the voltage signal **at the sensor device**², and will use that signal to associate an AC phase position with PD events for PRPDs, compute RMS, peak³ and DC voltage readings, and plot the waveform of the voltage in the PRPD diagrams. When possible, the software will also compute the current waveform through the sensor device and provide readings for the RMS, peak⁴, and DC currents.

Note that when performing AC calibrations with MPD 800 and UHF 800 devices, the voltage calibration factor applies to the *voltage as measured across the sensor device* (the high voltage), and **not** the signal at the MPD 800's AC (or UHF 800's SYNC) input connector. If your measurement configuration matches the physical test setup, the voltage calibration factor will be close to 1, and will only compensate for tolerances in the parameters of the used devices and parasitic effects such as stray capacitances and ohmic resistances of lead wires.

For MPD 600 devices, the voltage calibration factor applies to the voltage at the MPD 600's V input, because MPD 600 devices do not support modelling the circuit connected to the V input. Here, the voltage calibration factor compensates for the entirety of the sensor and coupling circuitry.



²as opposed to at the MPD channel inputs

³more accurately, the peak voltage divided by $\sqrt{2}$: $\frac{\hat{V}}{\sqrt{2}}$

⁴more accurately, the peak current divided by $\sqrt{2}$: $\frac{\hat{1}}{\sqrt{2}}$

Performing calibrations

In general, *calibrating* is a process designed to ensure that measurements produce an accurate value. This is done by deriving the measurement being calibrated from some other measurement that is already known to be correct and accurate. In the MPD Suite, this works by applying a known value of a physical quantity (charge or voltage) to the measurement setup, and then measuring the value via the MPD device and comparing that measured value to the known applied value. The ratio between the applied (known) value and the measured value is known as the *calibration factor*. After calibration, all measurements are multiplied with the calibration factor to yield a value that matches the applied quantity.

In the MPD Suite, calibrations are performed on the SETUP & CALIBRATION control panel tab. This tab has four subordinate tabs: Charge, RIV, mV PD, and Test voltage, each of which provide access to the facilities needed to calibrate the associated measurement. Calibration is generally specific to each measurement channel, and will usually be performed separately for each channel.

Note however that there are currently no common standards for UHF measurements. Also, since UHF measurements deal with voltages (or powers) rather than charges, the provisions of the IEC 60270 standard do not apply. In the MPD Suite, measurements using the UHF 800 are performed in mV PD mode.

6.1 Calibrating PD measurements

The fundamental calibration requirements on PD measurements are defined in the IEC 60270 standard. Related, asset-specific standards that are applicable to a specific testing scenario may prescribe additional requirements. A calibration must generally be performed for every test subject, and is valid only for the specific test setup and settings that were active when the calibration was performed. The MPD Suite tracks the calibration state of all PD measurement channels, and alerts you when changes in the configuration invalidate the calibration. Naturally, changes in the physical test setup that are outside the purview of the software cannot be detected, and will not be reported. It remains the user's responsibility to ensure that calibrations are done according to the relevant standards.

To calibrate a PD measurement, you connect the test setup as required for your measurement, and then connect a *charge calibrator* to the test object (typically in parallel to the high-voltage source). The charge calibrator is a device that produces current pulses with a known charge level. It is itself regularly calibrated and thus verified to produce accurate charge pulses.

When a calibrator is connected to the test setup, the MPD channels will detect its pulses as PD with a certain charge level (what we call the "raw" measurement). PD calibration then consists of computing a



calibration factor that is applied to the raw measurement such that the final measurement value matches the charge of the pulses injected by the calibrator.

The Charge sub-tab on the SETUP & CALIBRATION control panel tab has a section titled Charge calibration for <channel name > (where channel name is the name of the currently primary-selected channel). Below that are some settings that control the calibration:

The *dominant charge* determines which charge measurement is calibrated. You can choose between *IEC/WTD*, *AVG IEC*, and *MAX*. By default, *IEC/WTD* is selected, indicating that the charge magnitude of the *largest repeatedly occurring PD pulses* is used. This value is defined by the IEC 60270 standard, and in the majority of cases will be the one you want to use¹. *AVG IEC* will use the average of largest repeatedly occurring PD magnitude, while *MAX* will use the maximum absolute charge value of all measured PD events. These last two settings consider PD pulses detected over the most recent t_{Ref} time interval². All of these magnitudes disregard the polarity of individual PD pulses.

Below the dominant charge setting you find some measured values to help you verify that the calibration being performed is correct. The first of these, *PD rate*, shows the number of all PD events seen per second. If the dominant charge setting is set to *IEC/WTD*, the corresponding *relevant PD rate* is shown below the *PD rate* value. This value indicates the number of PD pulses per second that contribute to the charge quantity being calibrated. This should match the number of pulses injected by the charge calibrator you are using. For OMICRON CAL 542 calibrators, this value should always read **300 Hz**.

Below the PD rates you see the current measurement reading of the quantity being calibrated³. This reading shows the measurement *before* the current calibration, so it shows the raw measurement multiplied by the current calibration factor. During initial calibration, this value will likely be different from the actual charge injected by the calibrator, but after calibration it should match the actual charge quite closely.

Further below you can configure the charge that the charge calibrator is configured to inject, called the *target value*. In the *Calibrate to* field you enter the charge level that is also set on the charge calibrator and that will be used to compute the calibration factor. Note that the *Calibrate to* field is marked with the config selection symbol , indicating that this setting applies to all currently config-selected channels.

For the actual calibration, you can either type in the calibration factor manually in the *Calibration factor* field, or press the *Compute* button situated below the calibration factor field. Doing the latter will compute the new calibration factor k'_Q by multiplying the current factor k_Q with the ratio between the target value and the current measurement reading: $k'_Q = k_Q \cdot \frac{Q_{\text{target}}}{Q_{\text{measured}}}$.

Every time the calibration factor is updated, the PD channel is considered to become calibrated. Just pressing Enter in the calibration factor field will also set the calibration state of the channel to *calibrated*. Below the *Compute* button there is a message that describes the current calibration state: If it is currently calibrated, the message will indicate when the channel was last calibrated. Otherwise, it will show that the channel is not currently calibrated. The calibration state of the PD channel will also be reflected in the IEC 60270 compliance status shown in the measured quantities display, and if the measurement



¹The WTD abbreviation stands for weighted, and indicates that while the charge measurement is weighted according to the IEC 60270 standard, the measurement itself may not be standards-compliant because it uses settings that are not allowed by the standard.

 $^{^2}$ The t_{Ref} value determines the duration over which some statistical values are computed. It can be changed under the *Miscellaneous settings* section on the *Advanced* control panel tab.

 $^{^{3}}Q_{IEC}$ or Q_{WTD} , respectively, for the IEC/WTD dominant charge setting, $Q_{AVG\ IEC}$ for the AVG IEC setting and Q_{MAX} for the MAX setting

otherwise conforms with IEC 60270, will be indicated in the channel group display as a check mark icon (\checkmark). The calibration state will change to *not calibrated* if a setting is changed that the calibration relies on, such as the f_M center frequency or bandwidth of the measurement channel.

Below the calibration state message, a warning message is shown if there is no PD activity currently measured. The message will indicate why this may be the case (typically, because the effective PD detection threshold is configured too high) and how to remedy this. The *Compute* button will also be disabled while no PD activity is being detected.

When using mV PD measurements, you perform normalizations⁴ on the *mV PD* sub-tab instead of on the charge sub-tab. And instead of calibrating the charge of PD events, you calibrate a PD voltage reading derived from the PD input signal. But apart from that, mV PD and charge calibrations work the same way.

In mV PD measurements, the place of the *dominant charge* is taken by the *dominant PD voltage* setting. You can choose between the *weighted PD voltage* (denoted as $V_{PD \ WTD}$), the *maximum recurring PD voltage* (denoted as $V_{PD \ MRP}$), the peak PD voltage* (denoted as \hat{V}_{PD}), the average PD voltage (denoted as $V_{PD \ AVg \ WTD}$), which averages the weighted PD voltage reading over the most recent t_{Ref} time interval). The weighted PD voltage uses the weighting regime defined for the largest repeatedly occurring PD magnitude (as used in the measurements of $Q\sim IEC/WTD$ described above) and applies it to the voltages of each PD impulse. Similarly, the maximum recurring PD voltage reading considers the largest PD values, prioritizing those that recur at least twice per second. The peak PD voltage takes the maximum value of the peak voltages of all measured PD pulses over the reference time. In contrast, the average PD voltage takes the average of the peak voltages of all PD pulses, also over the reference time. Note that the average PD voltage is heavily influenced by noise pulses and should only be used if the PD detection threshold is set above the noise floor.

6.2 Calibrating AC and DC voltage measurements

AC and DC voltage measurements can also be calibrated in the MPD Suite. Unlike charge or PD voltage calibrations, which must be newly performed for every PD measurement, AC/DC calibrations are generally performed only when the high-voltage circuit changes, but not for every test subject.

Calibration of the AC or DC voltage ensures that the AC and DC voltage and currents reported by the MPD Suite match the high voltage and current applied to the test circuit. This affects the voltage and current readings reported in the software, as well as pass/fail and inception/extinction voltage assessments, reports, Q(V) diagrams and trends.

The AC/DC voltage calibration process is controlled from the *Test voltage* sub-tab of the *Setup & calibration* control panel tab. Like with PD calibration, AC/DC calibration is independent for each measurement channel. The calibration always applies to the primary-selected channel. And also like with PD calibration, you can choose which quantity you want to calibrate by specifying a *dominant voltage*. The available choices are *RMS*, $Peak/\sqrt{2}$ and DC.

When RMS or $Peak/\sqrt{2}$ is chosen as the dominant voltage, the currently detected frequency of the signal applied to the primary-selected AC input (for MPD 800), V input (for MPD 600), or SYNC input (for UHF 800)



⁴with mV PD measurements *calibrations* are not possible because mV PD measurements are not compliant with any standards, and usage of the term *calibration* requires a standard to dictate a procedure and requirements. Instead, the term *normalization* is used, which refers to the same process that is used during *charge calibration*, but makes it clear that the procedure is not standards-compliant.

is displayed below the dominant voltage setting. This reading, labeled f_{AC} , can help you verify that you are attempting to perform an AC voltage calibration on the correct channel: If it shows a stable frequency in the expected range, you're likely calibrating a channel that is properly connected.

The current value of the voltage measurement is shown below the frequency reading. This is the *currently measured value* of the dominant voltage (V_{RMS} , $\frac{\hat{V}}{\sqrt{2}}$, or V_{DC} , as configured in the dominant voltage setting above), using the current calibration factor.

Below the current reading you can configure the *target value* of the calibration in the *Calibrate to* field. This field is marked with the config selection symbol ••• , indicating that this setting applies to all currently config-selected channels. Set this value to the voltage you have applied to your test setup. You must use an independent voltage measurement instrument to accurately measure the high voltage or rely on the voltage that you set on your high-voltage source.

For the actual calibration, you can either type in the calibration factor manually in the *Calibration factor* field, or press the *Compute* button situated below the calibration factor field. Doing the latter will compute the new calibration factor k'_V by multiplying the current factor k_V with the ratio between the target value and the current measurement reading: $k'_V = k_V \cdot \frac{V_{target}}{V_{measured}}$.

Every time the calibration factor is updated, the AC channel is considered to become calibrated. Just pressing Enter in the calibration factor field will also set the calibration state of the channel to *calibrated*. Below the *Compute* button there is a message that describes the current calibration state: If it is currently calibrated, the message will indicate when the channel was last calibrated. Otherwise, it will show that the channel is not currently calibrated.

Note that for MPD 800 and UHF 800 devices, the AC/DC calibration applies to the signal at the sensor, as it is modeled from the information given under Measurement setup.

6.3 Calibrating RIV measurements

Like AC and PD measurements, RIV measurements must also be calibrated. RIV calibrations are performed on the RIV sub-tab of the SETUP & CALIBRATION control panel tab. The calibrations can be done using either a dedicated RIV calibrator such as the OMICRON RIV 1 or a frequency generator. The RIV calibrator or function generator injects a sine wave with a known RMS voltage of the frequency at which RIV measurements should be done (typically at or around 1 MHz). The MPD Suite then performs an RIV measurement at that same frequency and computes a calibration factor such that the measured RMS voltage multiplied by the calibration factor is the same as the injected signal's RMS voltage.

Note for RIV measurements, a sinusoid signal will produce the same value for the quasi-peak RIV voltage, the RIV RMS voltage and the peak RIV voltage ($\frac{\hat{V}_{RIV}}{\sqrt{2}}$). RIV calibrations always calibrate the RMS voltage.

RIV measurements are not supported for UHF 800 devices.

6.4 Overriding calibrations when replaying dataset files

When replaying a dataset file, the calibration state of each measurement channel is also replayed along with the measured data. This includes the calibration factor itself. As a result, all replayed measurement values exactly match what was reported during recording. However, sometimes it is desirable to record a dataset including the calibration impulses, and then perform the calibration during replay. Or perhaps



the calibration that was done during recording was invalid for some reason and when replaying and generating a measurement report, the calibration must be corrected. In order to support this, a calibration can be *overridden* during replay.

Overriding consists of re-computing the calibration factor for a channel and **ignoring recorded changes in the calibration factor during replay**. So when a calibration is overridden, calibration factors recorded in the dataset files are *not* applied during replay, and instead the calibration factor set during replay is used. To ensure that the user remains aware of the override, a warning message is shown both on the *Charge*, *mV PD*, *RIV* and *Test voltage* sub-tabs of the *SETUP & CALIBRATION* control panel tab as well as above the main diagram area. Both of these messages include a *Revert* button that undoes the calibration performed during replay and reinstates the calibration factors that were recorded in the dataset file. The button on the message above the main diagram area is actually called *Revert all*, because it reverts the calibration overrides of all types (Charge, AC, and RIV) for all measurement channels, while the *Revert* buttons under the sub-tabs of the *SETUP & CALIBRATION* control panel tab only revert the calibration override for their associated channel.

Performing PD measurements

Partial discharge (PD) measurements are the core functionality of the MPD Suite, and are supported by many readings and visualizations in the software. The IEC 60270 and related standards define many of these measurements.

In general, when PD occurs, energy is dissipated from the test circuit in the form of electromagnetic radiation and heat. That energy must be replenished by the test circuit, which results in a small transient current (usually measured in μ -Amperes) overlaid over the high voltage (usually measured in k-Volts). Each occurrence of such a transient current is detected and quantified by the MPD device, and is then transmitted to the PC as a *PD event*, characterized by its *charge*¹ and its *time*. This approach allows for continuous, uninterrupted real-time measurement of PD. Additionally, all timing components inside each MPD device are also synchronized such that the times of each PD event can be directly compared, even across devices. This enables fully synchronous, distributed PD measurements and makes advanced analysis techniques such as 3PARD possible.²

The quantification of PD pulses in MPD devices, i.e. the transformation of a PD pulse into a PD event consisting of a charge value and a point in time (a timestamp) is subject to several parameters. You can configure the PD detection parameters on the PD measurement settings section of the Charge calibration sub-tab, located on the setup & calibration tab of the control panel. Firstly, the quantification can happen either in the time domain or in the frequency domain. Frequency domain quantification is by far the more common use case. In the frequency domain, the input signal is filtered by a PD bandpass filter, which filters out all frequencies except for a section with a specific bandwidth Δf^3 around a center frequency f_M . The filtered signal is then integrated (summed), in order to get from a current signal to a charge value. The limited frequency range is used both to accommodate the frequency response of the test circuit and to suppress noise and disturbances that may be predominant in specific frequency bands (PD is generally a wideband phenomenon while some noise sources may be limited to certain parts of the frequency spectrum).

In contrast, in the time domain⁴, the PD input signal (a current) is directly integrated around the detected PD event, including a configurable amount before (t_1) and after (t_2) the actual peak. This implies that the



¹or *voltage* in mV PD mode

²With MCU 2 controllers and an optional GPS antenna, it is even possible to a degree to extend this synchronicity to different measurement sessions performed simultaneously on different computers, by utilizing GPS signals. These measurement sessions can be combined during dataset replay.

³the bandwidth describes the 6 dB limit, i.e. at $f_M - \frac{f}{2}$ and $f_M + \frac{f}{2}$ the signal attenuation is 6 dB (approximately 50%), and getting larger with larger distances from f_M .

⁴Time-domain integration is not supported for UHF 800 devices.

entire frequency spectrum of the input signal⁵ is considered, including any overlaid noise and disturbance signals.

PD events measured in this way are communicated from the MPD devices to the PC and are analyzed by the MPD Suite in various ways, including computing readings prescribed by the IEC 60270 standard (such as the largest repeatedly occurring PD magnitude, the average discharge current, the discharge power, and the quadratic rate.

A very important analysis approach involving individual PD events are phase-resolved PD (PRPD) patterns.

7.1 Performing IEC 60270-compliant measurements

Common PD measurements will follow the recommendations from the IEC 60270 standard. This standard describes quantities that digital PD measurement devices such as the MPD need to measure.

The most important value described by the IEC 60270 standard is the *largest repeatedly occurring PD magnitude*. This value aggregates the *apparent charge*⁶ magnitudes of those PD events that constitute the *PD pulse train*⁷ with the largest apparent charge values. It can be thought of as the average charge value of the largest PD activity that occurs at every AC cycle. Note that as a corollary, the largest repeatedly occurring PD magnitude has no meaning for PD/DC measurements, or in other PD measurement scenarios that do not rely on the presence of an AC high voltage.⁸

Other measurement values defined by the standard include n, the pulse repetition rate, expressed in pulses per second; I_{Dis} , the average discharge current of the PD pulses, expressed as Ampere (A); P_{Dis} , the discharge power of the PD pulses, expressed as Watt (W); and D, the quadratic rate of the PD activity; expressed as Coulombs squared per second ($\frac{C^2}{s}$). All of these values are fully supported by the MPD Suite⁹, and are available for all PD channels. You can view them along with many other values in the measured values display located in the center of the main window. All of these values are also available for trending and are included in the XML files generated during reporting.

The IEC 60270 standard defines a weighting regime for the levels of the *largest repeatedly occurring PD magnitude* based on the rate of recurrence. At recurrence rates of 100 Hz and above the reported value for the *largest repeatedly occurring PD magnitude* is identical to the measured value. However, at rates below 100 Hz, the reported value is weighted "down" (i.e. reduced) according to a table that is defined within the standard. This means that PD events that do not occur at least twice per typical AC cycle (at AC frequencies of 50 Hz) are given a lower value than they would be without the weighting regime. The reasoning for this approach is that spurious disturbance pulses can be very large in magnitude, but have no significant recurrence rate, and should thus not be treated as high levels of PD activity.

The MPD Suite has an option for adjusting this weighting regime to AC frequencies other than 50 or 60 Hz. This is called *dynamic weighting* and can be enabled in the *Miscellaneous settings* section of the *ADVANCED* control panel tab. With dynamic weighting, the actual measured AC frequency of the



⁵effectively 40 MHz for MPD 800 and 20 MHz for MPD 600

⁶The IEC 60270 standard defines the apparent charge as follows: The apparent charge of a PD pulse is that charge which, if injected within a very short time between the terminals of the test object in a specified test circuit, would give the same reading on the measuring instrument as the PD current pulse itself.

⁷According to the IEC 60270 standard, a PD pulse train is a sequence of PD pulses that have the same charge level and occur after equal time intervals.

⁸It is worth pointing out that the *largest repeatedly occurring PD magnitude* shares that limitation with PRPDs, which are also meaningful only when AC voltages are involved.

⁹subject to your licensed packages

currently configured PD/AC synchronization source is used to derive the PD recurrence rates at which "down-weighting" should occur. For PD recurrence rates at or above twice the current AC frequency, no down-weighting will occur, just as with PD signals at or above 100 Hz with dynamic weighting disabled. However, for PD recurrence rates at the AC frequency, the PD will be weighted down the same way as a 50 Hz PD signal would be without dynamic weighting. Likewise, a PD signal with a recurrence rate of 10% of the AC frequency will experience the same down-weighting that a 10 Hz PD signal would see with dynamic weighting disabled. **Note** that using dynamic weighting is **not** compliant with the IEC 60270 standard, which only deals with PD measurements at AC frequencies of 50 and 60 Hz.

In addition to defining measurement readings, the IEC 60270 standard also describes **how** PD measurements should be performed in order for the measured values to be considered compliant. To that end, it prescribes limits for the lower and upper frequency of the PD measurement filter. The MPD Suite aids you in choosing PD measurement settings that are compatible with the IEC 60270 standard by indicating if a chosen bandwidth/ $f_{\rm M}$ combination complies with the IEC 60270 recommendations. Further, since IEC 60270 requires that all PD measurements be calibrated, the MPD Suite also indicates whether a measurement needs to be calibrated or not. This determination is made based on whether measurement parameters that affect the reading of the *largest repeatedly occurring PD magnitude* have changed since the last time a calibration was made.

Many asset-specific standards defer to the IEC 60270 to define the fundamentals of PD measurements, such as the measurement setup and requirements on PD measurement filters. They also often define acceptable PD activity levels in terms of the *largest repeatedly occurring PD magnitude* level. That is why this quantity is so important.

In the MPD Suite, the *largest repeatedly occurring PD magnitude* is called Q_{IEC} or Q_{WTD} , depending on whether the PD measurement parameters currently in effect agree with the recommendations of the IEC 60270 standard. If they do, and the measurement has been calibrated, the value is reported as Q_{IEC} , indicating that the measurement reading fully conforms with IEC 60270. If the parameters are outside the ranges prescribed by the standard, or the measurement has not yet been calibrated for the current settings, the reading is reported as Q_{WTD} , with WTD standing for *weighted*. This expresses that while the value is weighted according to the regime laid out in the standard, the measured value cannot be considered to be fully compliant because the measurement parameters do not fully conform to the standard's recommendations (or the measurement has not been calibrated). The measured values display also reports whether a measurement conforms to IEC 60270. If the measurement is not considered compliant, the measured values display also includes a reason for that assessment.

In order to perform an IEC 60270-compliant measurement, you should follow these steps:

- Ensure that your PD filter settings agree with the recommendations of the standard, for example by using one of the pre-defined filter configurations available from the PD measurement settings section on the SETUP & CALIBRATION tab of the control panel:
 - The Set to 300 kHz IEC button will configure the PD measurement filter to use a bandwidth of 300 kHz and a center frequency of 250 kHz, and
 - The Set to maximum IEC bandwidth button will select a PD measurement filter that covers the entire range allowed for wideband PD measurement devices by the IEC 60270 standard (lower frequency limit f_1 set to 100 kHz and upper frequency limit f_2 set to 1 MHz).
- 2. Perform a charge calibration.
- 3. Measure PD activity by recording the Q_{IEC} value or a PRPD.



¹⁰Note that the standard's language effectively prevents the use of time-domain PD integration for compliant PD measurements.

7.2 Dealing with superposition

It is possible for the signal as measured on an MPD device's inputs to contain multiple PD pulses that are *superimposed* on one another. This can happen, for example, if these PD pulses originate from different parts of the test subject, but the electrical paths between each of the origins and the MPD device have a similar propagation delay. It also commonly occurs e.g. in power cable measurements, when the PD source is located close to the end of a cable segment where PD signals can get reflected, and the reflected signal superimposes with the original PD pulse. This effect is particularly strong when the reflection occurs at the far end of the cable segment, i.e. the open end of the cable where no measurement device is located, because the cable acts as a low-pass filter. Low-pass filters tend to broaden PD pulses, and wider pulse shapes make it more likely that superposition occurs.

Superimposed PD pulses can often not be distinguished from one another. When PD pulses superimpose *positively*, the resulting signal appears as if a single PD pulse with a higher energy than either of the two pulses was measured. But PD pulses can also superimpose *negatively*, in which case multiple PD pulses cancel each other out in the sum signal. In these cases, without additional measures, it is possible that the resulting signal is interpreted as containing no PD pulses.

To combat this effect, the MPD Suite features PD measurement presets called *negative superposition elimination filters*. These filters use the 3FREQ feature to measure the PD signal at three different center frequencies which are spaced in a way to ensure that multiple superimposed PD events cannot cancel out. While multiple PD events may still be counted as a single pulse in this case, these presets guarantee that the measured energy of such superimposed pulses will be at least 90% of the energy of a single pulse.

For the MPD 800, the MPD Suite offers negative superposition elimination presets with the following effective bandwidths: 74 kHz, 247 kHz, 494 kHz, 741 kHz, 988 kHz, 1.48 MHz, 2.47 MHz, 4.94 MHz, 12.35 MHz, and 24.7 MHz. The MPD 600 supports negative superposition elimination presets with effective bandwidths of 28 kHz, 113 kHz, 454 kHz, and 1.84 MHz. **Note** that the 247 kHz preset available for the MPD 800 is compatible with the IEC 60270 standard.

7.3 Performing RIV measurements according to CISPR 16-1-1/18-2 and NEMA 107

 ${
m RIV}^{11}$ measurements were historically used to ensure that electrical equipment does not overly affect reception on nearby AM radios. It turned out that interference measured by this method correlated well with the presence of partial discharge in high-voltage equipment, and standards around using RIV measurements for the purpose of performing PD quantification were created. Today, RIV measurements for PD are still widely used in the USA and Canada and by manufacturers producing for the North American market.

Generally, an RIV measurement uses a narrowband filter to quantify the amount of spectral energy that is present around a certain frequency. While the RMS reading of the RIV measurement best captures continuous signals, pulsed signals are better represented by the peak voltage reading and the output of a quasi-peak detector.

RIV measurements for PD detection follow the CISPR 16-1-1 and 18-2 or the NEMA 107 standards, which specify the recommended settings for the filter as well as the measurement impedances to be used. RIV measurements for PD according to the CISPR and NEMA standards use a frequency range between



¹¹Radio Influence Voltage or Radio Interference Voltage

0.15 MHz and 30 MHz, at bandwidths between 8 kHz and 10 kHz. Commonly, 1 MHz is used as the center frequency and 9 kHz is used as the bandwidth. CISPR 16-1-1 also defines a quasi-peak detector that is used for RIV measurements for PD. Its output will always be between the filter's RMS and peak readings, depending on the ratio between continuous (sinusoid) and transient (pulse-shaped) signal components. The pulse rate represents the number of pulses per second that contribute to the RIV quasi-peak voltage.

RIV measurements are similar to narrowband IEC 60270-compliant PD measurements. Both work at similar frequencies and use similar filters. However, unlike IEC 60270-compliant measurements, which measure the charge levels of individual PD events, RIV measurements look at the peak and RMS voltage of signals caused by PD.

Calibration is also different; IEC 60270-compliant PD measurements use a charge calibrator that injects pulses with a known charge into the test circuit, while RIV calibrations always use a sinusoid signal to calibrate the RMS measurement of the RIV signal.

During tests, very commonly the quasi-peak value is used to quantify the result of a RIV measurement for PD.

7.4 Measuring PD as a voltage rather than a charge

While IEC 60270-compliant measurements express the magnitude of PD events as a charge, sometimes it may be useful to report the PD pulse's peak voltage instead. Such measurements are not comparable between measurement devices, as the peak voltage of a pulse depends on many factors, including the input bandwidth of the measurement device. However, when doing non-standard measurements, such as when using TEV¹² sensors, charge measurements may not be possible. For UHF measurements using the UHF 800, these types of measurements are also the only ones available.

So in order to support these use cases, MPD 800 devices 13. can be configured to report the magnitude of PD events in Volts rather than in Coulombs. This is called mV PD mode and can be configured individually for each channel group on the mV PD of the SETUP & CALIBRATION control panel tab. 14 When mV PD measurements are enabled, all PD-related measurements use V rather than C as the PD magnitude. Instead of showing the largest repeatedly occurring PD magnitude reported as "Q_{IEC}", the MPD Suite gives the weighted PD voltage $(V_{PD,WTD})$. This reading works exactly the same way as the Q_{IFC} reading except that it uses voltages instead of charges. Also provided is a value called maximum recurring PD voltage $(V_{PD,MRP})$. This value is similar, in that it reports the magnitude of the largest recurring PD activity, but it does not perform any weighting. Finally, mV PD mode also supports the average value of the $V_{PD\ WTD}$ reading (known as $V_{PD\ Avg\ WTD}$), the peak PD voltage and the average PD voltage. Also affected by mV PD mode are the PRPD diagrams, the Ellipse views, the H(Q) diagrams, the PD/DC views, and trends, which are all scaled in Volts rather than Coulombs. Furthermore, all settings that normally configure charge-related options (such as the Q_{Max} and Q_{Min} options controlling the PRPD diagram boundaries) are replaced by settings configuring the corresponding voltages. The settings that apply during mV PD mode are separate from the ones that are used during charge-based measurements, because the values for these settings are usually significantly different between the two modes. The settings from each mode are retained when switching between modes, and are restored when switching back to the original mode.

When using mV PD mode on MPD 800 devices, you can use the normal PD filters. 15. Alternatively, you



 $^{^{12}} extbf{T}$ ransient $extbf{E}$ arth $extbf{V}$ oltage

¹³MPD 600 devices do not support mV PD mode

¹⁴For UHF 800, mV PD mode is the only supported PD measurement mode and is always enabled.

¹⁵**Note** that only frequency-domain filters are supported and that the UHF 800 does not currently support digital PD filters. Time-domain integration cannot be used with mV PD mode.

can choose to bypass the PD filters, in which case the unfiltered 16 signal on the PD input is used to detect and quantity PD pulses. This is the only possible mode for UHF 800 devices. Bypassing PD filters results in PD measurements that are similar to measurements performed with an oscilloscope 17 .

7.5 Performing PD/UHF measurements with the UHF 800

Unlike standard electrical PD measurements that are supported by a host of international standards, UHF measurements are not regulated as comprehensively. UHF measurements pertain to the power of a transmitted electromagnetic signal, whereas "classical" electrical PD measurements describe wire-borne signals that are measured as currents. For that reason, UHF measurements cannot be typically expressed as a charge, and consequently the section describing IEC

60270-compliant measurement does not apply to UHF 800 devices. UHF 800 devices always use mV PD mode. Also, unlike with MPD 800 and MPD 600 devices, which exclusively use digital bandpass filters to transform the PD input signal into charge or voltage values, UHF 800 devices additionally rely on analog logarithmic amplifiers ("log-amps") to filter the wideband signal and transform it into a single value for each PD event. There are two separate log-amps, one with a bandwidth of 80 MHz (called the "mediumband" log-amp), and another that covers the entire 2 GHz bandwidth supported by the UHF 800 (known as the "wideband" log-amp). In order to select the section of the frequency spectrum that the mediumband log-amp is sensitive to, the UHF 800 is equipped with a frequency mixer that acts as a receiver for the 80 MHz-wide section of the spectrum to be measured. This mixer can be freely controlled. In the MPD Suite, these two log-amps are represented as measurement bandwidths. The 80 MHz PD measurement bandwidth setting corresponds to the mediumband log-amp, while the 2 GHz bandwidth selects the wideband log-amp for measurements. The center frequency setting corresponds to the mixer frequency when using the mediumband log-amp, but is not applicable when using the wideband log-amp. However, as the UHF 800 also supports measuring the frequency spectrum directly, independent of which PD measurement bandwidth/log-amp is used, the mixer frequency (termed f_{Rx}) can also be set while measuring in wideband mode, on the UHF 800 control panel tab.

Since version 1.40 of the MPD Suite, UHF 800 devices can also measure in "narrowband" mode. In this mode, the UHF 800 uses digital PD filters (similar to the ones used by the MPD 800) to further constrain the frequency range used for PD measurements around the f_{Rx} frequency. Thus, in narrowband mode, as in mediumband mode, the PD measurement center frequency corresponds to the f_{Rx} mixer frequency, and the spectrum view shows the frequency components that are used for the PD measurements.

The UHF 800 is equipped with a *low-noise amplifier* that amplifies the input signal by approximately 34 dB. This *LNA* is very useful for measuring very low-power signals. It is enabled by default, and can be configured on the *UHF* 800 control panel tab.

7.5.1 Using UHF frequency sweeps

To help you choose the section of the frequency spectrum to use for medium- and narrowband measurements, the UHF 800 can perform *frequency sweeps* that measure the signal across the entire supported frequency range. While sweeping, the UHF 800 cannot do any PD measurements. Generally, you will perform a sweep after setting up the measurement circuit and then select the frequency range you want to measure at. The sweep diagram will continue to show the result of the most recent sweep.



¹⁶This applies only to the digital PD filters. The analog anti-aliasing filter (with a bandwidth of about 40 MHz on the MPD 800) is still present.

¹⁷with an effective bandwidth of approx. 40 MHz on MPD 800 devices

You can configure the frequency range over which the UHF 800 device should sweep on the UHF 800 tab of the control panel, using the Sweep f_{RX} start and Sweep f_{RX} stop settings. During a frequency sweep, the UHF 800 will first set its mixer frequency to the Sweep f_{RX} start setting, and then step the mixer frequency in increments of approximately 80 MHz until the Sweep f_{RX} stop setting is reached. Then it will restart the process at the Sweep f_{RX} start setting until the sweep is disabled.

The UHF 800 supports two spectral resolutions when doing spectrum measurements (and, consequently, sweeps). The spectral resolution determines the width of spectral lines. Wider spectral lines (that have a "larger" or "coarser" spectral resolution) can be measured more quickly than narrower spectral lines (smaller or finer spectral resolutions), and as a result will better capture pulse-shaped signals that are not continuously present. On the other hand, smaller spectral lines allow better separation of different signal sources with narrow frequency bands. By default, the spectral resolution is set to 2 MHz. With this value, portions of the frequency spectrum that contain pulse-shaped signals can be easily determined by comparing the maximum and the minimum spectrum/sweep plots: When both plots are distinctly apart, it is likely that there is intermittent (pulse-shaped) signal activity present in these spectrum components. On the other hand, both plots being very close together indicates that the energy in the corresponding spectrum components stems from continuous signals, such as communication carriers. Continuous signals that cover a narrow frequency portion are better captured using the 200 kHz spectral resolution, which makes it easier to locate areas without any continuous signal activity. The spectral resolution can be configured in the *Advanced settings* section of the *UHF 800* control panel tab.

Note that each mixer frequency exhibits slightly different noise characteristics, depending on the internal configuration of the mixer. As a result, setting slightly different mixer frequencies can lead to (slightly) different spectrum diagrams, at least when measuring noise. This effect is most visible when the LNA is enabled. Sweeps are also affected by this: performing two sweeps with slightly different $Sweep f_{RX} start$ settings can lead to subtly different sweep diagrams, because the $Sweep f_{RX} start$ setting determines the set of mixer frequencies that are used during the sweep, and different settings will lead to a different set of mixer frequencies.

Note that log-amps typically only produce readings that are proportional to the pulse magnitude for pulses whose pulse width is larger than a certain value. For narrower pulses, log-amps can under-report the magnitude. The log-amps used in the UHF 800 work well with PD pulse widths of 20 ns or more, or with bursts of PD pulses of even shorter pulse widths.

7.5.2 Using spur suppression

Like many other types of equipment that measure radio-frequency signals, the UHF 800 can be subject to *self-interference*. Self-interference means that the UHF 800 device can itself produce some spurious signals (also known as "*spurs*") at some frequencies which show up in the measurements. These spurs can also be dependent on the mixer frequency. To alleviate the impact of these self-interference signals, the UHF 800 includes a functionality called *spur suppression*. When spur suppression is enabled, spurious signals that are introduced by the UHF 800 itself are removed from the spectrum measurements. To do this, the UHF 800 first performs a spectrum measurement with its UHF input turned off and stores the recorded spectrum. After turning the UHF input back on, it then effectively subtracts the "empty" measurement from the "live" measurement. Spur suppression also works for frequency sweeps.



7.6 Performing PD measurements with HVDC assets

When doing PD measurements under DC voltage, some of the most important PD analysis tools commonly used during AC testing are not available. The PRPD is not applicable, since it relies on the AC phase position of PD activity, which has no meaning during DC measurements. There are also typically far fewer PD events when testing under DC than under AC, because for partial discharges to occur, there must be free charge carriers (e.g. electrons) to "kick off" the discharge. During AC measurements, those are replenished at every cycle, and PDs can thus start anew at every cycle. In contrast, during DC tests, free electrons are much scarcer and PD events consequently happen much more rarely. Moreover, when PD does occur, the observed PD level of individual events can be much higher than during AC testing. As a result, the reading of the largest repeatedly occurring PD magnitude) is also not applicable, because PD under DC does not typically repeat.

Therefore, different analysis tools are needed for PD under DC testing. Many applicable standards define limits on the number of "relevant" PD events that may be present during a certain time interval. In this context, "relevant" applies to those PD events whose charge magnitude exceeds a certain threshold. Some of these standards define two such limits, such as that there may be no more than 30 pulses with charges ≥ 2 nC in the last 30 minutes and no more than 10 pulses with charges ≥ 2 nC in the last 10 minutes 19 . The MPD Suite supports these requirements by providing two independently configurable DC counters. These counters track the number of PD events in a sliding time window (the duration of which can be set), whose charge magnitude 20 exceeds a threshold (that can also be set). The current values of these counters, along with their parameters, are shown in the measured values display. You can also configure allowable limits for the counters, which will be used to determine a pass or fail assessment for the current values of the counters. That assessment is also shown in the measured values display.

¹⁸e.g. IEC 61378-2, "Transformers for HVDC applications"; IEC/IEEE 65700-19-03, "Bushings for DC application"; and IEC 60076-6, "Power Transformers - Part 6: Reactors"

¹⁹IEC 61378-2, section 10.4.3.4 "Acceptance criteria"

²⁰or voltage magnitude when using mV PD measurements

²¹Note though that unlike with AC-based pass/fail assessments, the fail state for DC measurements is not sticky!

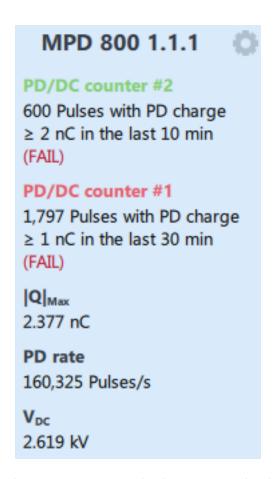


Figure 7.1: The PD/DC counters in the measured values display

Furthermore, the MPD Suite plots the historical values of the counters in a diagram called the *PD/DC* counter diagram, which is available on the PD/DC view in the upper diagram view. This diagram also optionally shows the limits for each of the counters as cursors, so you can see at one glance when the counter values exceeded their respective limits and can even change the limits by using the mouse.

Because individual PD events are so rare when measuring PD under DC, each event is much more important than during AC testing. To address this relative importance of individual PD events, the MPD Suite also provides a diagram that plots every PD event over time, along with the DC voltage measured. This diagram is called the *PD/DC pulses and voltage diagram*. For both PD pulses and the DC voltage the polarity is considered when plotting the diagram. This diagram is also available on the PD/DC view in the upper diagram view. And because generating and maintaining this diagram can take significant processing resources, there is an additional *PD/DC threshold* that can be used to limit the number of PD pulses that will be shown. Typically, you would configure the threshold to be higher than the system noise, so that only relevant pulses are recorded for the DC diagrams. Optionally, the *PD/DC pulses and voltage diagram* can also show the PD/DC threshold and the two counter thresholds as cursors, allowing you to use the mouse to change each of them.

In addition to showing the individual PD events and the DC voltage, the *PD/DC pulses and voltage diagram* can also optionally indicate periods when the PD input may have been overdriven. These periods are shown with a red shade that cover the affected PD pulses. The magnitude of pulses covered by such shades may not be correct, as they were measured while the input was (potentially) overdriven. This can happen if the PD input gain mode is set to *fully automatic* and few pulses are detected (as is typical for



DC measurements). The automatic gain adjustment performed by the MPD Suite may select a sensitive input gain setting when it has not seen any large pulses for some time. When a large pulse then comes in, it can briefly overdrive the input. Therefore, for best results, it is recommended that the PD input gain be set to *semi-automatic*. While this setting will also allow some PD pulses to overdrive the input initially, the input gain will converge on a reasonable setting over time.

PD/DC measurements must be started and stopped separately. This is done using the *Capture PD/DC* button in the *PD/DC measurement settings* section of the *PD/DC* control panel tab. When you check this button, all config-selected channel groups will begin *capturing* PD events and DC voltages for plotting in the *PD/DC pulses and voltage diagram*, and will also begin updating the PD/DC counters²². Clicking the button again will stop capturing PD pulses and DC voltages, and neither the counters nor the diagrams will be updated with any new PD pulses any longer. When you start capturing again some time later, the existing diagrams are re-used and any new pulses and voltage readings are plotted in the same diagrams (i.e. the diagrams are not cleared). However, the counters start again from 0. This procedure can be used to pause and resume DC measurements at the appropriate times, for example during polarity reversal tests.

You can select which channel group to take the DC voltage from for the *PD/DC pulses and voltage diagram* using the *DC voltage to plot* selection box located in the *Channel-specific PD/DC diagram settings* section of the *PD/DC* control panel tab. This setting can also be changed while DC capturing is in progress. In that case, the diagram will contain multiple segments, plotting the DC voltages from different channels. The color of each DC voltage segment corresponds to the color of the channel for which it was measured.

It is also possible to hover the mouse over the *PD/DC counter diagram* and see the values of both counters at the corresponding point in time, along with their parameters. When you do that, the *PD/DC pulses and voltage diagram* highlights the pulses from which the counter value under the mouse were computed, as shown in this example:

²²All config-selected channels will start capturing pulses simultaneously.

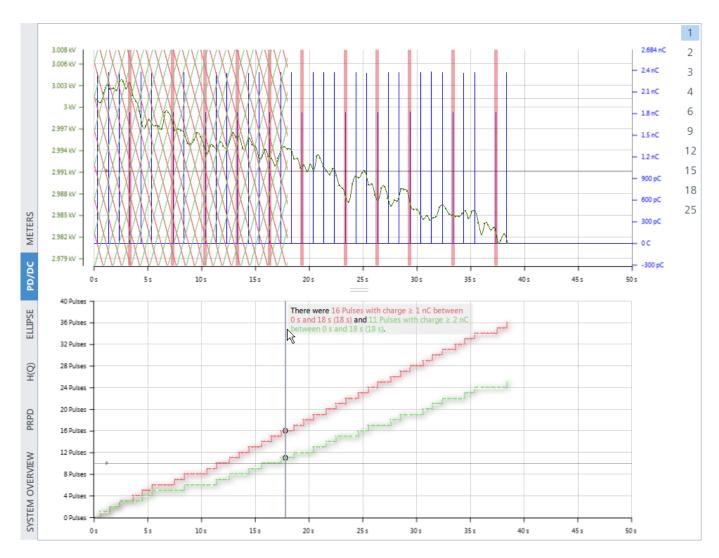


Figure 7.2: Highlighting the PD pulses from which the PD/DC counters in the PD/DC counter diagram are computed

Both of the PD/DC diagrams can be included in report files, and can also be saved to image files by using the image export functionality.

You can clear both diagrams and the counter values of all config-selected channels at any time by pressing the *Clear PD/DC diagrams* button located in the *PD/DC measurement settings* section of the *PD/DC* control panel tab. Doing so while the DC measurement is ongoing will clear all data currently visible and will start recording new data in the diagrams.

All diagrams of all channels share the same time axis. When auto-scaling is enabled, the time axis is scaled in such a way that everything from all diagrams is visible.

It is possible to change the thresholds and time window durations for each of the counters while a DC measurement is in progress, or after the measurement has been stopped and the diagrams have been filled. In either case, doing so will re-compute the counters for every point in time in the diagram and will present an updated plot that corresponds to the changed settings. This is possible because when capturing is enabled, all PD pulses that are larger than the configured PD/DC threshold are retained until the diagrams are cleared, and can be used to compute the counter values at every point in time since



starting the capture process.

Note that recording large numbers of PD events using PD/DC capturing will require large amounts of memory. When the PD/DC capture threshold is set very low, this can happen quickly (perhaps recording up to 10 million PD events within 10 seconds). Using much memory can lead to the computer becoming unresponsive or sluggish, so make sure that you configure a suitable PD/DC threshold before starting PD/DC capturing.

7.6.1 Exporting PD events and DC voltages to CSV files

You can export every detected PD event along with the currently measured DC voltage into CSV files for external analysis. The *CSV export options* section of the *PD/DC* control panel tab provides that functionality.

Once the *Start exporting* is clicked, exporting is started for all config-selected channel groups²³. For each channel group that is being exported, a new CSV file is created for the PD events from that channel, and another CSV file is created for any DC voltages that are being used as a DC voltage source. Since different channel groups may plot different DC voltages, multiple CSV files for DC voltages may be written at any time. However, when multiple channel groups use *the same* DC voltage reading in their respective *PD/DC pulses and voltage diagrams*, only a single CSV file is created for that DC voltage.

CSV files storing PD events are named according to the base file name setting, with the channel name, the string _pd, and the date and time of when the button was clicked appended to it. Conversely, The names of CSV files storing DC voltages are constructed from the base file name setting, the channel name, the string _dc, and the date and time of when the file was created. All CSV files contain two columns, with the first one containing the time of each PD pulse or DC voltage reading and the second containing the charge magnitude²⁴ of the PD pulse, or, respectively, the DC voltage reading.

7.7 Measuring PD at VLF (very low AC frequencies)

PD measurements at VLF^{25} use AC signals with frequencies below 1 Hz – it is common for VLF measurements to run at 0.1 Hz or even at 0.01 Hz (10 mHz). At 0.1 Hz, a full AC cycle takes 10 seconds, and at 0.01 Hz it takes 100 seconds. VLF measurements are commonly used to test high-load assets in the field, such as medium-voltage cable systems. Due to the low frequencies used during VLF measurements, much less apparent power is needed to energize the assets than with 50 Hz or 60 Hz. This allows for much smaller and cheaper equipment to be used during those tests.

In the default mode, the MPD Suite can only detect and measure AC signals at frequencies between 5 Hz and 1.5 kHz. In order to support VLF measurements, the MPD Suite²⁶ extends the supported AC frequency to 0.01 Hz. This support is enabled via *VLF mode*, which is available from the *VLF* control panel tab. VLF mode allows AC frequencies as low as 0.01 Hz. In VLF mode, the MPD Suite cannot detect the actual AC frequency by itself; it needs you to specify the nominal AC frequency. Based on this setting, the MPD Suite can then detect the "real" frequency, which must be within 1% of the configured setting in order for the voltage and current measurements to be accurate. When in VLF mode, the configured frequency (as specified via the *VLF frequency* setting in the *General settings* section of the *VLF*) is also used to configure certain other mechanisms in the MPD Suite to be suitable for low-frequency

OMICRON

²³You can only start exporting PD/DC measurements to CSV files once PD/DC capturing has been started.

²⁴or, in the case of mV PD measurements, the voltage magnitude

²⁵**V**ery **L**ow **F**requency

²⁶since version 1.20

measurements. Specifically, the time constants that govern when gain switching occurs with the AC and PD auto-gain modes set to *fully automatic* are adjusted to be suitable for measurements at low frequencies. Additionally, *dynamic weighting* is enabled for any PD channel for which a VLF-enabled AC channel is used as the PD/AC synchronization source. Additionally, the fallback mechanism for AC measurements is disabled, as VLF can only be used when a proper signal with a known frequency is used. The fallback mechanism would otherwise possibly interfere with the detection of the AC frequency, and would additionally extend the time needed to perform an initial measurement.

One drawback of VLF measurements is that measurements take a long time. The MPD Suite mitigates this by providing progress indicators for long-running AC measurements. For example, when initially enabling VLF mode or when changing the VLF frequency, it takes approximately 3.5x the AC cycle period²⁷ before the first VLF AC signal is available²⁸. The MPD Suite will show a message at the top of the main window that indicates how soon the first VLF AC measurement will be available. Additionally, the measured values display will also show a progress bar underneath any VLF AC measurements that indicates when the next measurement reading for those values will be available. This progress bar is shown for the RMS, peak, and DC voltage and current readings, as well as for the detected AC frequency reading. It is shown whenever the time between taking readings is 1 s or longer. For VLF measurements, readings are taken at least every 5 seconds.

7.8 Using 3FREQ to separate PD from disturbances

3FREQ is an industry-leading technology pioneered by OMICRON to differentiate between different sources of PD (and PD-like signals). Like 3PARD, it uses a star diagram to expose the relations between different measurements of the same PD event. Where 3PARD uses different physical measurement locations to detect the same PD event, 3FREQ uses different frequency components of the PD signal measured at a single measurement location.

Both the MPD 800 and the MPD 600 support 3FREQ measurements, i.e. the use of three independent frequency bands for simultaneous PD measurements. Each band uses the same bandwidth setting, but the center frequency can be configured independently for each band. 3FREQ uses the "normal" filter setting (at center frequency f_M) as one of the bands. Two additional bands (called *auxiliary measurement bands*) with center frequencies at $f_{AUX,I}$ and $f_{AUX,I}$ can be configured on the 3FREQ control panel tab.

When 3FREQ is enabled, each PD event is simultaneously measured on all three frequency bands, resulting in three different charge³⁰ values for the same event. PD events are then plotted into the 3FREQ diagram such that the charge/PD voltage values of the measurement on all three bands are used as the coordinates along the star's axes. The number of PD events at any one set of coordinates in the diagram is represented by the color of the point in the star diagram (from blue, representing few PD events, to red, representing many PD events). This way, colored clusters will form in the 3FREQ diagram, each representing a single³¹ PD source.

You can gate (filter) the PD measurement by selecting clusters in the 3FREQ diagram: Only PD events contained inside the selected clusters will be considered; all other PD events will be suppressed and will neither be shown in the PRPD nor will they contribute to any measured values. Alternatively, you can



²⁷e.g. 35 seconds for 0.1 Hz with a cycle period of 10 seconds

²⁸ and consequently, the first pulses are plotted in the PRPD

²⁹3FREQ is not currently supported for the UHF 800.

³⁰or PD voltage

³¹Note that this is an oversimplification. There may be several different propagation paths and excitation modes for a single PD source that can result in multiple clusters in the 3FREQ diagram for the same source.

choose to use *inverse* gating, such that only PD events that fall **outside** of the selected clusters will be considered, and everything within the clusters (or not contributing to any clusters) is suppressed.

You create gates by drawing rectangles in the 3FREQ diagram that cover clusters or parts thereof using the mouse. Press and hold the left mouse button and then move the mouse to create a rectangle. You can draw multiple rectangles, and move them around by dragging them with the mouse. Double-clicking into one of the selection rectangles will remove the rectangle and its associated gate filter.

When at least one such gate filter has been created, the PD measurement of the associated channel is said to be under *3FREQ back transformation*. The channel group display will indicate if a channel's PD measurement is being 3FREQ-back-transformed by showing the symbol.

By default, the PRPD view of the channel being back-transformed will show in gray the original (unfiltered) PRPD in the background, and the back-transformed PRPD in full color atop that. This is useful in seeing the effect of the 3FREQ gate filter, and can help you quickly home in on the PD source you are looking for.

You can disable the display of the unfiltered PRPD on the 3FREQ control panel tab, under the *additional* settings expander of the diagram settings section.

Chapter 8

Working with PRPDs

PD events are often visualized in diagrams called *phase-resolved PD (PRPD)* patterns. A PRPD is an important analysis tool that relies on the repetitive nature of PD¹. PRPDs can help with determining the cause and severity of PD activity. They plot PD events over the AC high-voltage signal, where each PD event is associated with a certain *phase position* of the AC signal (i.e. the position in the cycle of the AC signal where the PD event occurs). That phase position is used as the horizontal position in the plot, while the charge² of the PD event is used as the vertical position in the plot. The color of the point given by the phase position and charge of the PD events signifies the number of PD events with the same phase position and charge that have occurred so far. PRPDs give rise to characteristic patterns that may be specific to certain types of PD in certain types of assets.

In the MPD Suite, PRPDs are displayed in the PRPD view, located in the upper diagram view section of the main window. You can select in the PRPD view how many PRPD diagrams you want to see simultaneously. Available options are $\bf 1$, which shows only the primary-selected channel's PRPD, as well as $\bf 2$, $\bf 3$, $\bf 4$, $\bf 6$, $\bf 9$, $\bf 12$, $\bf 15$, $\bf 18$, and $\bf 25$. These show the primary-selected channel's PRPD as well as define a secondary selection that includes additional channels. All PRPDs of the *secondary-selected* channels are also shown. When any other option except $\bf 1$ is selected, we say that the PRPDs are shown in *overview PRPD views*. Overview PRPD views include the reading of teh charge quantity selected via the dominant charge setting (often the largest repeatedly occurring PD magnitude reading, labeled $\bf Q_{IEC}$ or $\bf Q_{WTD}$) and, if RIV measurements are enabled, also the quasi-peak voltage reading of the RIV measurement, so that the most important information can be seen at a glance. When up to 3 PRPDs are included in the overview views, they show all axes and axis labels just like a single PRPD does. For 4 to 9 PRPDs, the axes are no longer shown, but the grid lines still are. At 12 or more PRPDs, the grid lines are also hidden.

PD events that are triggered by the AC voltage as it progresses through its cycle will always appear at the same phase position. On the other hand, spurious noise and other transient signals that may look like PD, but that are not synchronous to the AC signal, will "smear" across the PRPD. Since a PRPD is a statistical diagram that aggregates the PD activity over many AC cycles, relevant correlations will become visible over time. PD events that always occur at the same AC phase position will be strongly located, forming colored points or clusters in the PRPD, whereas signals that have no relation to the AC signal's phase will be spread across the PRPD with no clear location. PRPDs thus make it relatively easy to differentiate between AC-synchronous PD and disturbance pulses that are not synchronous to the AC.



¹Note that this is only really true for AC measurements. With PD/DC measurements, PD generally does not repeat, and PRPDs are not applicable.

²or voltage, when using mV PD measurements

³In mV PD mode, the reading selected via the dominant PD voltage setting is used instead of the dominant charge.

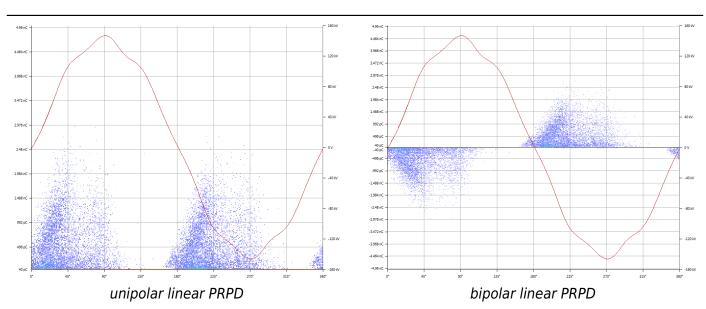
There are, however, also many sources of noise and disturbances that *are* synchronous to the AC, such as inverter noise. Those will show up on the PRPD in a localized way, much like "real" PD. However, the pattern they will form on the PRPD will be very distinct, and often clearly distinguishable from actual PD.

The coloring of PDs in the PRPD is based on a *color map*: the color map assigns colors to ranges of PD occurrences (called *color classes*). By default, a standard color map is used. The standard color map uses dark blue to represent few PD events, and then, as the number of PD events increases, progressively lighter shades of blue, then green, then yellow, and finally red for many PD events. Also by default, the color map automatically distributes the colors logarithmically across the number of PD events recorded in the PRPD, with the "lowest" color class corresponding to a single PD event, and the "highest" color class corresponding to about 85% of the maximum number of PD events seen in the PRPD thus far. This mapping is continually updated, so that the relative coloring remains the same, even as the absolute number of PD events recorded in the PRPD changes.

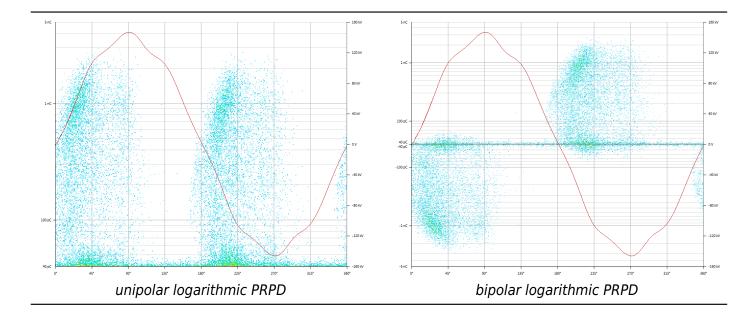
That coloring scheme can however be customized, on the *Edit PRPD color map* dialog available via the *PRPD color map* button on the control panel's *ADVANCED* tab. There you can add and remove color classes, change the colors of individual classes, and configure the mapping of colors to PD event counts manually. On the dialog, you specify a PD pulse **rate** (as opposed to an absolute number of PD event pulses), because that number will be more likely to converge on a fixed number for relatively constant PD patterns. You can manually set the PD event pulse rate associated with each color class, but for increasing color classes that number must also increase.

PRPDs can look quite different depending on how they are configured. You can use either *linear* or a *logarithmic* scaling for the charge axis, and you can plot the PRPD either in a *unipolar* or a *bipolar* fashion. Together, these two configuration options define the *view mode* of the PRPD. The view mode can be one of the following: *Unipolar linear*, *Bipolar linear*, *Unipolar logarithmic*, or *Bipolar logarithmic*. Logarithmic scaling allows you to see details at the lower charge value range that linear scaling tends to obscure. However, linear scaling may produce a more recognizable pattern overall.

The following figures show different PRPDs generated with exactly the same PD activity and diagram boundaries, but using different view modes:



44



Bipolar PRPDs, which plot negative and positive charge values in distinct areas of the diagram, focus on the relationship between the polarity of PD events and their position in the AC cycle. Unipolar PRPDs, on the other hand, ignore the polarity of individual pulses.

Much of the choice between any of these options comes down to preference or local practices. For comparability of measurements taken across many devices over a long period time, it is important to choose one representation and stick to it.

Often, the high voltage signal is overlaid over the actual PRPD. This helps with seeing at what part of the AC cycle PD activity occurs. The MPD Suite will, by default, show the AC signal of the currently selected PD/AC synchronization source atop each PRPD. If each unit triggers itself is selected as the synchronization source, this means that each PRPD will display a different AC signal. You can configure which AC plots should be shown on the PRPD on the AC plot display option section of the DISPLAY control panel tab.

A visualization related to PRPDs, called *needle plot*, is optionally shown in the same diagram as the PRPD. Needle plots visualize each individual PD event by drawing a line from 0 C to the charge of the PD event, thereby forming a "needle". Where two or more PD events occupy the same horizontal position in the needle plot, the needle shows the largest of these.

Needle plots are overlaid over the actual PRPD and show the PD activity in real time, whereas PRPDs represent the aggregate PD activity over some time range. You can enable or disable the needle plot via the PD events displayed checkbox on the PRPD diagram settings section of the PRPD & AC control panel tab. Needle plots use the same view mode and diagram boundaries as the PRPDs they are associated with.

8.1 Capturing PRPDs

PRPDs are not automatically created; you must start PRPD capturing by pressing the *Capture PRPD* button on the PRPD capture options section of the PRPD & AC control panel tab. When capturing is active, all PD event channels capture PRPDs synchronously, i.e. they begin simultaneously and capture PD events



over the same time range. The measured values display indicates the number of PD events recorded into the PRPD for each channel, as well as the total time over which PRPDs have been recorded.

Capturing can be either *timed* or *untimed*. Timed capturing specifies that PRPDs should contain a specific duration worth of PD activity, i.e. every PD event that occurred between starting the capture and the specified capture time running out. Untimed capturing means that PRPDs are captured indefinitely, i.e. until capturing is manually stopped by the user. **Note** that even for untimed capturing, the exact duration for which the PRPD has been captured is recorded and reported on the measured values display.

At any time, you can clear the PRPDs of all channels⁴ by pressing the Clear PRPD button. Clearing the PRPDs will also reset the time reported on the measured values display as the PRPD duration for all channels. If you clear PRPDs during timed capturing, the reported PRPD duration will be different from the capture duration, because only the time since (last) clearing the PRPD is reported (as only PD events are contained in the PRPD that have occurred since then).

You can also define a pre-recording time for PRPDs (on the Advanced PRPD settings section of the AD-VANCED control panel tab). The pre-recording time allows PD events to be plotted in the PRPD that were measured before capturing was started. When you start PRPD capturing with a pre-recording time set, the PRPD will instantly appear from the PD events measured during the pre-recording time immediately leading up to the moment you pressed the *Capture PRPD* button⁵. Capturing will then continue as determined by whether timed or untimed capturing is active: untimed capturing will continue indefinitely, whereas for timed capturing the total capture time (including the pre-recording time) is considered. For example, if the timed capture duration is configured as 30 s, and the pre-recording time is set to 20 s, then after pressing the *Capture PRPD* button capturing will proceed for 10 s, and the resulting PRPD will contain all PD events from 20 s **before** until 10 s after the *Capture PRPD* button was pressed.

The diagram boundaries of PRPDs are configured through the Q_{Max} and Q_{Min} settings on the PRPD diagram settings section of the PRPD & AC of the control panel. Similarly, the view mode of the PRPD can be chosen via the *View mode* setting on the same tab. While you can change the diagram boundaries and PRPD view mode at any time, the result is slightly different depending on whether PRPD capturing is currently in progress.

If you change the boundaries or the view mode of a PRPD while capturing, the PRPD will be cleared and immediately restarted with the new diagram boundaries and view mode, much as if you had pressed the *Clear PRPD* button. This affects the total time recorded in the PRPD that is reported on the measured values display.

On the other hand, if you change the diagram boundaries or view mode when capturing is not in progress, the diagram is **not** cleared, but is re-scaled to reflect the change. This re-scaling is necessarily imperfect. For example, if you specify a lower Q_{Min} or a larger Q_{Max} than was set when you captured the PRPD, nothing will be shown in the PRPD between the new and the old Q_{Min} and between the new and the old Q_{Max} , because the PRPD does not contain that data – when the PRPD was captured, only PD events with charge values between the then-current Q_{Min} and Q_{Max} settings were recorded. Likewise, changing the view mode can re-scale individual lines in the PRPD. When a PRPD was captured with logarithmic scaling, the "height" of a line in the PRPD depends on its position: lines nearer to Q_{Max} cover a much wider charge range than lines nearer to Q_{Min} . When you switch the scaling mode to linear, all lines now have the same height, but there is not enough data in the recorded PRPD to fully resolve the lines near to Q_{Max} . As a consequence, the rescaled PRPD may look "blocky". Changing between bipolar and unipolar mode does



⁴Note that there is no way to clear only a single PRPD

⁵if PD events have so far been measured for a shorter time than the configured pre-recording time, only the available PD events are shown immediately, and capturing continues for the remainder of the configured time

not introduce such artifacts; the software always records PRPDs in a bipolar manner, and transparently converts them to unipolar PRPDs if needed.

When you start capturing again after changing the diagram boundaries or view mode, the current PRPD is cleared and a new PRPD is recorded at full resolution.

PD events whose absolute charge is higher than Q_{Max} will not be shown in the PRPD. Instead, they will be "caught" by the upper edge of the PRPD⁶, i.e. the number of PD events with absolute charge values exceeding Q_{Max} will be counted and the upper edge of the PRPD will be colored based on that number, using the same color map that the interior of the PRPD uses. When the color of the edge changes, the edge will flash to make that fact more visible to the user. This feature helps alert you to the case where your PRPD does not show all data, and you can then decide to change the diagram boundaries of the PRPD if needed.

8.2 Using phase-/amplitude gating

As PRPDs can make it obvious which signals are actual PD and which should be considered noise, they allow for the possibility of *phase gating* and *phase/amplitude gating*. *Phase gating* suppresses PD activity in entire sections of the PRPD, i.e. PD events (with any charge) occurring at a certain interval of AC phase positions will be considered noise and any PD events that fall within that phase position range are disregarded for all PD measurements (and removed from the PRPD). This is very useful to, for example, suppress inverter noise, which will usually happen at fixed phase positions, but can have very large charge levels.

Phase/amplitude gating is a more selective variety of this, in that it allows the charge level of PD events to be considered in addition to its phase position when deciding whether it should be suppressed. Using phase/amplitude gating you can, for example, suppress PD events that occur between 179° and 180° of the AC signal, and have charge levels between 500 pC and 1 nC. PD events that occur between 179° and 180° of the AC but the charge levels of which are outside the 500 pC... 1 nC range will still be measured.

The MPD Suite allows you to define an arbitrary number of phase gates and phase/amplitude gates. To create a gate, you must enter *gate edit mode*. You do this by selecting the **G** button located at the right of the *PRPD* diagram view.



 $^{^{6}}$ for bipolar PRPDs, both the upper and the lower edge of the diagram catch "wayward" PDs that way; the upper edge catches PD events whose charge values are greater than Q_{Max} , while the lower edge catches PD events whose charge values are lower than $-Q_{Max}$

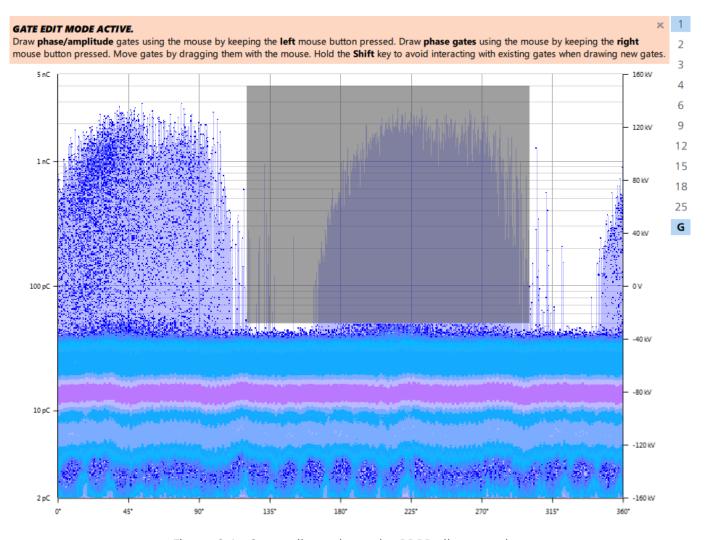


Figure 8.1: Gate edit mode on the PRPD diagram view

When gate edit mode is active, the software displays a message at the top of the PRPD indicating that you are now in gate edit mode. This message also explains how you can draw gates and move them around using the mouse. You draw *phase* gates by keeping the **right** mouse button pressed and moving the mouse. Doing so will show a shade across the PRPD, indicating the phase range to be gated. Releasing the right mouse button will commit the selected range, and a new phase gate will be created that takes effect immediately.

Likewise, to draw *phase/amplitude* gates, you keep the **left** mouse button pressed as you move the mouse. A rectangle will be shown that indicates the phase and amplitude ranges to be covered by the gate. As soon as you release the left mouse button, the newly created phase/amplitude gate will take effect.

As you draw a gate using the mouse, a tooltip window will appear next to the gate showing the range the gate will cover. A similar tooltip window will appear when you move the mouse over a previously drawn gate. This tooltip will also indicate that you can remove the gate by double-clicking on the gate rectangle.

All gate rectangles or shades can be moved by dragging them with the mouse to a new location. You do this by pointing the mouse at a previously drawn gate or shade, then pressing the **left** mouse button,

OMICRON

48

and, keeping the button pressed, moving the mouse to where the gate or shade should be moved. As you move the mouse, the gate or shade follows. Releasing the mouse button will commit the move, such that the gate or shade will begin to take effect at the new location.

You can exit gate edit mode by clicking on the **G** icon again. When not in gate edit mode, any drawn gates will be hidden, and only the effect of gating PD pulses in the PRPD will be visible.

Gates set in gate edit mode only apply to the PD channel on whose PRPD they were drawn, i.e. they never apply to more than one PD channel. You have to draw gates individually for every channel you want to apply phase-/amplitude gating to.

When at least one gate (phase or phase/amplitude) is set on a PD channel, the channel group display will indicate that fact by showing a small **G** symbol.

Gate edit mode is available for all PRPD views, not just the 1 view.

For convenience, you can quickly remove all set gates for all config-selected channels by clicking the Clear PRPD gates button on the Charge sub-tab of the SETUP & CALIBRATION tab of the control panel.



Chapter 9

Using assessments

Assessments are automatic tests that the MPD Suite can perform while measuring PD and voltages. These assessments run in parallel with all other measurements and visualizations, and are included in any report files that are generated.

There are two types of assessments: *Pass/fail* assessments and *inception/extinction voltage* assessments. You can reset pass/fail and inception/extinction voltage assessments independently, via their corresponding *Reset* button available in the *Pass/fail test* and the *Inception/Extinction voltage test* sections of the *ASSESSMENT* tab of the control panel. Resetting tests will clear any recorded states and voltages corresponding to the assessment and begin evaluating the respective assessments anew.

9.1 Working with pass/fail assessments

Pass/fail testing consists of checking whether the measured value of the *dominant charge* reaches or exceeds a configured threshold. If it does, a *FAIL* state is recorded; otherwise, the test records a *PASS*. *FAIL* states are "sticky", i.e. once a *FAIL* state has been recorded for a test, it will never switch back to *PASS* even if the measured charge value drops below the threshold. *FAIL* states are only cleared when the *Reset* button (located on the *Pass/Fail test* section on the *ASSESSMENT* tab of the *control panel*) is clicked.

Pass/fail assessments can optionally be associated with a *voltage threshold*. If one is given, the assessment is only made if the currently measured voltage reaches or exceeds the associated threshold. The voltage quantity configured via the *dominant voltage* setting derived from the signal selected as the PD/AC synchronization source is used for this determination. **Note** that tests that have recorded a *FAIL* state will stay in *FAIL* even if the voltage drops below the threshold. *FAIL* states can only be cleared by resetting the pass/fail assessments.

There are two independent pass/fail assessments available (called levels). If both are enabled, they run in parallel. Both assessments have independent PD (charge) thresholds, and can be independently configured to use a voltage threshold. Enabled pass/fail assessments are performed for every connected measurement channel.

Pass/fail assessments can only be made once a charge calibration has been performed for the corresponding channel. If a voltage threshold has been set, or a *voltage stability criterion* has been configured, a voltage calibration for the PD/AC synchronization source is also required before the pass/fail assessment can be made.



The results of the pass/fail assessments are visible in the *Assessment view*, located in the bottom left diagram section.

A pass/fail assessment can have the following outcomes:

- **PASS** The charge measurement is calibrated, and the measurement of the charge quantity selected via the *dominant charge* setting has, at no point since the last time the test was reset, reached or exceeded the configured charge threshold. If a voltage threshold has been configured, the voltage of the PD/AC synchronization source (as configured via the *dominant voltage* setting) is currently at or above the configured voltage threshold.
- **FAIL** The charge measurement is calibrated, and the measurement of the charge quantity selected via the *dominant charge* setting has reached or exceeded the configured charge threshold at least once since the last time the test was reset. If a voltage threshold has been configured, the voltage of the PD/AC synchronization source (as configured via the *dominant voltage* setting) was at or above the voltage threshold at the time the charge reading was also at or above the charge threshold.
- **No voltage measurement** A voltage threshold has been configured but no suitable PD/AC synchronization source has been set (i.e. either the internal or the line trigger options are configured).
- **Voltage below threshold** A voltage threshold has been configured, and both the charge measurement and the voltage measurements of the PD/AC synchronization source have been calibrated, but the voltage measurement of the PD/AC synchronization source (as configured via the *dominant voltage* setting) is *below* the configured voltage threshold.
- **Needs PD calibration** The charge (or mV PD) measurement is not calibrated.
- **Needs voltage calibration** A voltage threshold **or** a voltage stability criterion has been configured, and the charge measurement has been calibrated, but the voltage measurement of the PD/AC synchronization source has *not* been calibrated yet.
- **Voltage unstable** A voltage stability criterion has been defined, and both the charge measurement and voltage measurements of the PD/AC synchronization source (as configured via the *dominant voltage* setting) have been calibrated, but the voltage measurement does *not* satisfy the configured stability criterion.
- **No PD events measured** The charge measurement is calibrated, and if a voltage threshold or voltage stability criterion has been configured, the voltage measurement of the PD/AC synchronization source is also calibrated, and the voltage measurement is stable, but no PD events are currently being measured (e.g. because the PD detection threshold is higher than current PD level).
- **No voltage measured** No voltage stability criterion has been defined, but a voltage threshold has been configured and the voltage measurement is not currently available (because the fundamental frequency cannot be reliably detected).
- **Checking...** A voltage stability criterion has been defined, and both the charge measurement and voltage measurements of the PD/AC synchronization source (as configured via the *dominant voltage* setting) have been calibrated, and the voltage measurement is being analyzed for stability.

9.2 Determining the PD inception and extinction voltages

The *PD inception voltage* (PDIV) is the lowest voltage at which relevant PD activity starts to occur. As the voltage is increased beyond the inception voltage, further PD activity should be expected. Similarly, the *PD extinction voltage* (PDEV) is the voltage below which all relevant PD activity ceases.

To determine the inception and extinction voltages, the asset is subjected to increasing voltages until a designated maximum voltage is reached. If PD activity sets in at some point during that "voltage ramp", the voltage at which inception occurred is recorded. After a certain time at the maximum voltage, the



voltage is slowly decreased again, and when PD activity stops, the corresponding voltage is recorded as well.

The MPD Suite can automatically record inception and extinction voltages for two independently configurable PD thresholds. The PD measurement is based on the *dominant charge* setting as configured on the *Charge* sub-tab, or, when mV PD mode is enabled, the *dominant PD voltage* setting from the mV PD sub-tab of the *SETUP & CALIBRATION* control panel tab. If both inception/extinction voltage tests are enabled, they run in parallel. Enabled inception/extinction assessments are performed for every connected measurement channel.

Inception/extinction voltage assessments can optionally be associated with a *lock-in voltage*. If one is given, inception is locked in once the currently measured voltage reaches or exceeds the configured lock-in voltage. A locked-in inception determination can only be cleared by resetting the inception/extinction assessments. In other words, when an inception voltage has been locked in, it will never change again on its own. On the other hand, the extinction voltage may change again if, after recording extinction, PD activity sets in again (at which point the recorded extinction voltage will be cleared) and then drops below the configured PD threshold once more. When no lock-in voltage is set, seeing PD activity reach or exceed the configured threshold again after having recorded extinction will reset both the recorded inception and the extinction voltages and start a new determination cycle.

The voltage quantity configured via the *dominant voltage* setting derived from the signal selected as the PD/AC synchronization source is used for the determination of the inception and extinction voltage.

When a *voltage stability criterion* has been configured, inception/extinction assessments are only made when the voltage measurement of the PD/AC synchronization source (as configured via the *dominant voltage* setting on the *Test voltage* sub-tab of the *SETUP & CALIBRATION* control panel tab) is deemed stable according to the configured stability settings. PD activity detected during an unstable voltage measurement will not be recorded as inception. Similarly, if PD activity ceases while the voltage measurement is unstable, extinction is not recorded until the voltage measurement becomes stable again.

Inception/extinction assessments can only be made once a PD calibration has been performed for the corresponding channel. Additionally, a voltage calibration for the PD/AC synchronization source is also required before the inception/extinction assessment can be made.

The results of the inception/extinction assessments are visible in the *Assessment view*, located in the bottom left diagram section. When an inception voltage has been locked in, both it and any recorded extinction voltage is shown in bold face with a green background. Inception voltages that are not locked in are shown in italic face.

An inception/extinction assessment can have the following outcomes:

No voltage measurement No suitable PD/AC synchronization source has been set (i.e. either the internal or the line trigger options are configured).

Needs voltage calibration The charge measurement has been calibrated, but the voltage measurement of the PD/AC synchronization source has *not* been calibrated yet.

Needs PD calibration The PD measurement is not calibrated.

Voltage unstable A voltage stability criterion has been defined, and both the PD measurement and voltage measurements of the PD/AC synchronization source (as configured via the *dominant voltage* setting) have been calibrated, but the voltage measurement does *not* satisfy the configured stability criterion while waiting for inception to occur.

No PD events measured Both the PD measurement and the voltage measurement of the PD/AC synchronization source have been calibrated, and the voltage measurement is stable, but no PD events



are currently being measured (e.g. because the PD detection threshold is higher than the current PD level).

<PDIV> / <PDEV> The PD and voltage measurements have been calibrated, and the voltage measurement is stable. If inception has been recorded, <PDIV> corresponds to the recorded inception voltage, otherwise "--" is shown. If extinction has been recorded, <PDEV> corresponds to the recorded extinction voltage, otherwise "--" is shown. Note that <PDEV> will only be given if <PDIV> is also present. In other words, for extinction to occur, inception must have previously occurred.

Once inception has been recorded, the most recently recorded inception and/or extinction voltages are shown in orange if a voltage stability criterion has been defined and the current voltage measurement is deemed unstable according to the criterion.

9.2.1 Using the Q(V) diagram

As a more visual alternative to automatic inception/extinction voltage recording, the Q(V) diagram can also be used to determine the PD inception and extinction voltages of a measurement.

The Q(V) diagram plots the charge values of the PD measurements (as configured via the dominant charge setting) of each measurement channel over the values of the voltage measurement (as configured via the dominant voltage setting) of the PD/AC synchronization source. The diagram is colored in the channel's color, with the leg of the curve representing the rising voltage colored a lighter shade and the leg of the curve representing the falling voltage colored a darker shade. For stretches where the direction of the voltage change cannot (yet) be clearly determined, an intermediate shade is used.

The PD threshold can be visualized as a horizontal line in the Q(V) diagram. The inception voltage corresponds to the horizontal position where the Q(V) diagram's rising leg first intersects the PD threshold line. Likewise, the extinction voltage corresponds to the leftmost horizontal position where the Q(V) diagram's falling leg intersects the PD threshold line.



Chapter 10

Working with multiple measurement channels

For some types of PD measurements, having multiple measurement points can be important. For example, on high-voltage cable systems, it can be useful to measure at each termination and at all available joints. For transformers, one might want to do PD measurements on the primary and secondary (and tertiary, if present) windings simultaneously. Three-phase motors and generators benefit from having the ability to measure PD on all phases simultaneously. To speed up factory testing, it can also be valuable to test multiple subjects at once. There are also analysis methods that require multiple measurements to be available, such as 3PARD and time-of-flight fault localization measurements. In order to facilitate multichannel measurements, MPD 800 devices have two independent channels each for PD and AC measurements. Additionally, all MPD devices can be easily daisy-chained for simultaneous use.

Measurements done with multiple MPD devices are fully synchronous, with an accuracy of less than 1 ns. The delays introduced by using long FOs are automatically compensated for when combining measurements from multiple devices, even across FO buses. For example, you can combine measurements from MPD 800s connected to FO bus 1 of your MCU 2 with measurements made on MPD 600s connected to FO bus 3.

Support for multiple measurement channels is an integral part of the MPD Suite user interface. The central aspect of this is the concept of *channel groups*, which combines PD inputs and their associated AC inputs on MPD devices into a user interface concept.

Located at the very top of the main window, the channel group display shows all currently available measurement channels and allows you to *select* each channel. When a channel is selected, diagrams and displays (including the measured values display) generally show data from that channel, and the settings tabs on the control panel show the currently configured settings for that channel. Furthermore, changes to any of the settings will be applied to the corresponding channel.

You control which device channels are available for measurements on the system overview display. Each device is shown along with the optical fiber connecting it to the MCU or any neighboring MPD devices. Next to each device channel, there is a selection box that allows you to set the usage of the device channel to one of the following options: *Disabled, Measurement,* and *Gating*. Disabled channels will not be used for anything, and will not show up in the channel group display. In contrast, *measurement* channels are used for measuring PD and AC signals, and *gating* channels are used for channel gating¹. Depending



¹Gating channels can also be used for AC measurements.

on the licenses you have purchased, you can only assign a limited number of channels to be used as measurement and gating channels. If you have used up your licensed quota of measurement channels, you can no longer designate any additional device channels as measurement channels. Likewise, once you have expended your licensed allowance of measurement and gating channels, you can no longer mark additional device channels to be used as gating channels. However, you **can** use your licensed allotment of *measurement channels* to use a device channel as a *gating channel*.

If you need fewer measurement and gating channels than you have device channels connected (and have licensed allowances for), it can still be beneficial to disable any surplus device channels you are not using. Doing so will conserve fiber optical bandwidth for the channels you *are* using, and will improve the responsiveness of the MPD Suite.

For convenience, you can form *config groups*, which collect multiple channels for the purpose of applying settings to all members of the config group simultaneously. To apply settings to multiple channels, use the circle symbol that is located at the top of the channel representation in the channel group display. When the circle is not filled, and you click it, you *config-select* the associated channel, i.e. the channel is added to the config group that contains at least the *primary-selected* channel² and may contain additional channels. Any changes made to settings on the control panel that are marked with the config selection symbol ••• will apply to all members of the config group.

When the config group consists of more than one member and a setting differs between the members of the config group, an unequal sign (\neq) will be shown next to the setting to indicate that fact. The value that is displayed will be the one that is in effect on the primary-selected channel.

For some settings controls, such as selection boxes, changing the config group can also change the available options. With a config group, the settings control will only show any options that are available for all members of the config group. In rare cases, this can mean that there is no option that is available for all members of the config group, and the list of choices for the setting will be empty. In this case, you must remove members from the config group that do not support the desired option in order to change the setting.

You can config-select all measurement channels by clicking the three filled circles to the left of the channel group display, and clear the config group to consist only of the primary-selected channel by clicking the symbol with one filled and two unfilled circles. Note though that gating channels can never be members of a config group, and will not be added to a config group by clicking the three filled circle symbol.

There are also views that combine the data from multiple measurement channels in the same diagram. These are called *multichannel views*. For example, the PRPD, Ellipse, the H(Q), and the PD/DC views offer to show between 1 and 25 diagrams simultaneously, arranged in a grid. The Meters view always shows multiple meters – it displays all meters for all channels as a scrollable list. PD scopes, on the other hand, can show multiple PD scope plots in the same diagram.

Then there is a view that exists only with data from multiple measurement channels: the 3PARD view, which uses three independent measurement channels to allow separating different sources of PD (and PD-like signals).

10.1 Using channel gating

One common use case for using multiple measurement channels is *channel gating*. With channel gating, one or more channels are used to *gate* (i.e. filter) other channels. PD activity detected on a gating channel



²indicated by the fact that the primary-selected channel's circle symbol is always filled and cannot be de-selected

suppresses PD events that are simultaneously measured on measurement (non-gating) channels.

As described in the previous section, gating channels are designated on the system overview display. Once a channel has been marked as a gating channel, it will no longer report any PD-related measurement values. However, all AC measurements remain available. Instead of showing up in the channel group display, gating channels are shown in the *gating channel area*, which is located in the top right of the main window. Additionally, the channel will be marked with the gate symbol (1). Instead of showing the measured charge or PD voltage and RIV quasi-peak voltage, it will indicate whether the gating channel is currently enabled (by showing ON) or disabled (by showing OFF). When using any of the overview PRPD views, gating channels will also no longer show the charges or PD voltages and the RIV voltages overlaid on those. Instead, it will also indicate on the overview diagrams whether the gating channel is enabled (GC ON) or disabled (GC OFF).

You can configure the gating channel by right-clicking on the channel in the gating channel area; doing so will pop up a small settings window. Here you can enable or disable the channel as well as configure the gating window. The gating window determines for how long PD activity is suppressed for each PD-like pulse seen on the gating channel. When a pulse is detected on the gating channel while gating is enabled, all PD activity on other (non-gating) channels is suppressed from the time of the detected pulse minus half of the gating window until the time of the detected pulse plus half of the gating window, possibly offset by the gating window offset: $t_{\text{Suppress}} = [t_{\text{gating pulse}} - \frac{t_{\text{window width}}}{2} + t_{\text{offset}}, t_{\text{gating pulse}} + \frac{t_{\text{window width}}}{2} + t_{\text{offset}}].$

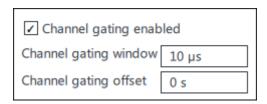


Figure 10.1: gating channel settings

Clicking away from the channel gating settings window will close it.

The selection of the PD-like activity on a gating channel that should lead to suppression of PD measurements on non-gating channels is carried out on the gating channel's PRPD. The PRPD (and its associated needle plot) of a gating channel is the only PD-related measurement that remains available for gating channels.

To select which PD-like activity seen on a gating channel should be treated as disturbance, and should thus lead to suppression of PD measurements on all non-gating channels, you draw rectangles on the gating channel's PRPD. Using the left mouse button, you can draw rectangles that cover a specific AC phase range (in the X direction) and charge range (in the Y direction). Using the right mouse button, you can draw *phase* rectangles, that cover all possible charges over a certain phase (X) range. All pulses that are contained within the drawn rectangle(s) will cause gating to occur, i.e. they will suppress measuring PD pulses on all non-gating channels. **Note** that until you have drawn at least one rectangle, no gating will occur!

The ratio of PD activity being suppressed due to channel gating is reported on the measured values display under the **Events gated** heading, in the **Channel gating:** row. This value will be continuously updated, and reflects the percentage of gated PD activity for the currently primary-selected PD channel, aggregated over approximately 300 ms.

Note that channel gating is an expensive operation, especially with large gating windows. While you

can use multiple gating channels, it is best to use those sparingly and with small gating windows.

When changing gating parameters, the software needs to reconfigure the internal processing pipeline, which necessitates briefly disabling channel gating for the channel whose parameters are changing. Gating is then re-enabled automatically once the new settings have taken effect. As a side effect of this, you will briefly see all PD activity, even such activity that would be gated by the channel. If you are recording PRPDs while changing gating parameters, those PRPDs will be affected.

10.2 Using 3PARD to separate PD from disturbances

3PARD is an exclusive technology for separating PD (and PD-like) pulses emanating from different sources. It can be used to distinguish PD activity from disturbances, and to separate activity from multiple PD sources.

3PARD stands for "three-phase amplitude relation diagram". It relies on 3 separate PD measurements running concurrently and simultaneously. A PD event detected at the same time on the three different measurement channels is plotted in the 3PARD view based on the ratios of the charge levels of the PD event. This plot is also called a *star diagram* because it arranges its three axes at 120° angles, which look like a star. Each axis is assigned to one of the three PD measurement channels.

Note that 3PARD is not currently supported for channels that are using mV PD mode. This also means that 3PARD is not currently available for UHF 800 devices.

To plot a PD event in the 3PARD diagram, the charges of all three measurements are added together vectorially, with the base vector for each measurement being the axis of the star diagram to which the measurement point is assigned. This operation yields a position in the 3PARD diagram. This is done for each PD event detected on the three measurement channels, and the number of PD events with the same coordinates is counted. The 3PARD diagram itself shows the number of PD events with the same coordinates using a color, very much like PRPDs do³. Thus, 3PARD diagrams give rise to patterns of colored clusters.

The basic insight behind 3PARD diagrams is that each cluster in the 3PARD diagram corresponds to a single source of PD (or PD-like pulses). A single source of PD will always produce signals with similar levels on a given measurement point, which is based on the coupling mode between that measurement point and the location from which the PD emanates. Different PD sources will generally have different but constant coupling modes with the three measurement points, and will thus lead to different clusters in the 3PARD diagram.



³in fact, the 3PARD diagram always uses the standard PRPD color map with automatic color classes

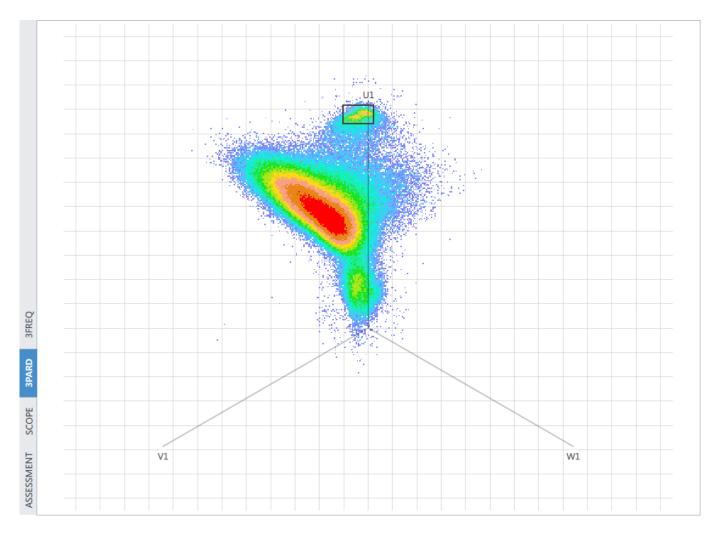


Figure 10.2: A 3PARD diagram

In the MPD Suite, 3PARD diagrams can be used to back-transform PD. This means that by selecting one or more clusters⁴ in the 3PARD diagram, you can see just the PD activity that corresponds to those clusters, as opposed to all PD activity. Back-transforming PD affects the PRPD and needle plots of the three measurement channels that participate in a 3PARD, as well as all derived measurement quantities, such as the *largest repeatedly occurring PD magnitude* (Q_{IEC} or Q_{WTD}).

Using back-transformation, you can effectively "clean up" the PD measurement so that it measures the activity from a single source only. As a result, you can generate PRPDs that are "pure" and unaffected by noise and disturbances.



⁴you select clusters by drawing rectangles in the 3PARD diagram. Those rectangles are called *gates*, like the rectangles used to define areas relevant for *channel gating* or *phase-/amplitude gating* in the PRPD.

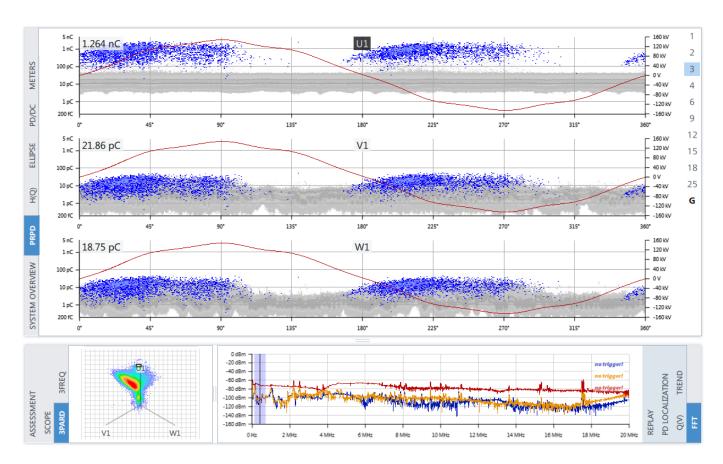


Figure 10.3: 3PARD back-transformation

In the figure above, a 3PARD diagram is generated from three PD channels named U1, V1, and W1, respectively. A cluster in the 3PARD is selected, leading to back-transformation of the three channels participating in the 3PARD. As can be seen from the figure, the original, "un-back-transformed" PRPD is shown in gray in the background behind the back-transformed PRPD⁵. Furthermore, when PD channels are subject to 3PARD back-transformation they are marked in the channel group display with the $\mbox{\ensuremath{\not{L}}}$ symbol.

With 3PARD back-transformation it becomes possible to see PD activity that would otherwise be covered by noise or disturbances. Separating the "real" PD clusters from the unwanted noise and disturbance signals in the 3PARD can reveal PD patterns hidden in an un-back-transformed PRPD.

Note that when 3FREQ is enabled, 3PARD processing takes place **after** any 3FREQ back-transformations that may be in effect. We say that 3PARD and 3FREQ are *cascaded*, with 3FREQ processing happening before 3PARD processing.



⁵This behavior can be disabled on the 3PARD control panel tab.

Chapter 11

Using dataset files

The MPD Suite can record measurement sessions to *dataset files*. Dataset files contain everything that was measured when the files were created, including all PD events (even PD events that were suppressed via channel gating, phase-/amplitude gating, 3FREQ back transformation, or 3PARD back transformation), all AC samples, all PD scope captures, all UHF spectrum captures or UHF frequency sweeps, and all RIV readings that were available during recording. Data from channels that were disabled during recording are not stored in dataset files, nor is data from disabled AC, scope, or spectrum channels.

When replaying dataset files, you can use all the features of the MPD Suite to conduct measurements, similar to what you can do during real-time measurements. One limitation is that settings that are configured on the MPD devices themselves cannot be changed during replay. This includes PD filter settings¹, as well as PD and AC gain settings, test generator settings, the PD detection threshold, PD scope trigger settings and whether the internal CPL is enabled or not. These settings will continuously reflect the state that they had during recording.

However, you can create PRPDs with different view modes and diagram settings, create XML reports, perform channel gating, perform PD localizations, or use 3FREQ and 3PARD to filter unwanted noise and disturbances.

Note that because dataset files contain a lot of information, they tend to be pretty big. It is not uncommon for a dataset file containing 10 minutes worth of measurement data to be several gigabytes in size.

11.1 Recording dataset files

Recording dataset files can be done via the Start button on the RECORD sub-tab of the RECORD/REPLAY

control panel tab, or via the hot button. Alternatively, you can press the CTRL key together with the F5 key. In any of these cases, the file is stored in the folder you configure in the target folder setting on the RECORD sub-tab of the RECORD/REPLAY control panel tab, and is given a name based on the base file name setting also configured there. The actual file name will consist of the base file name to which the date and time of when the recording was started is appended. Before starting to record a dataset file, you can enter a description of the file in the dataset description edit field².



¹such as the center frequencies, the bandwidth, time-domain integration settings, and presets

²Note that changing the dataset description once recording has begun has no effect on the dataset file being recorded.

While the recording is going on, the file name as well as the size of the file being recorded and the current recording duration all are shown in the information section of the RECORD sub-tab of the RECORD/REPLAY control panel tab, along with the remaining free space on the drive to which the file is being recorded. A message is also shown at the top of the main window area that indicates that dataset recording is in progress. This message also includes a button for stopping the recording.

By default, dataset recordings will automatically terminate after 20 minutes, unless the recording is extended by the user. This behavior can be configured under the Advanced settings section of the RECORD sub-tab of the RECORD/REPLAY control panel tab. Here you can disable and re-enable autotermination of dataset recording, and you can configure the time after which recording of dataset files should automatically stop unless extended. You can also configure the lead time of the warning message that is shown just before the dataset recording is automatically ended. By default, this time is 20 seconds. Within those last 20 seconds every 20 minutes, you can extend the dataset recording by pressing the Extend recording button in the information section of the RECORD sub-tab of the RECORD/REPLAY control panel tab or Extend recording within ... button that appears in the recording message at the top of the main window area. Failing to press either of these buttons before the auto-terminating time runs out will automatically stop dataset recording.

11.2 Loading dataset files

You can load dataset files directly from the start page, as well as from the *REPLAY* sub-tab of the *RECORD/REPLAY* control panel tab. On the start page, there is a list of recently used dataset files. This list is populated from dataset files you previously replayed as well as those that you recorded. Double-clicking on any of the entries will load the corresponding dataset file and immediately switch the software to the main window.

Alternatively, you can click the *Load other...* button above the list of recently used dataset files. Doing so will open a file selection dialog that allows you to select one or more dataset files³ to be loaded. When you click the *Open* button in the file selection dialog, all selected dataset files are loaded.

Loading multiple dataset files is called *dataset merging* and allows you to simultaneously replay several dataset files that were recorded independently but at overlapping times. This only works if all dataset files being loaded have GPS information embedded in them. In practice, this means that you can only load multiple dataset files that were recorded with MCU 2 controllers that had a GPS antenna connected to them.

Loading from the *REPLAY* sub-tab of the *RECORD/REPLAY* control panel tab involves selecting the files you want to load under the *Files to load* expander in the *Dataset files selection* section of the *REPLAY*. To do that, you can click on the + *Add files* button. Clicking that button will open a file selection dialog where you can select one or more files that should be loaded. Upon clicking the *Open* button a new row will be created in the *Files to load* section for each selected file that shows the file name and location (and allows you to edit those), as well as a remove button, which you can use to remove any file from the *Files to load* section. Once you press the *Load files* button, all files from the *Files to load* section are loaded, and will appear in the *Loaded files* section instead, along with an eject button, which allows unloading of a specific file.

If there is an error when loading a file, an error message is shown at the top of the *REPLAY* sub-tab of the *RECORD/REPLAY* control panel tab, indicating the reason for the error. In addition, the software will automatically unload all files and switch to online mode if an error occurs.



³loading more than one dataset file simultaneously only works when all files being loaded have valid GPS data.

Otherwise, the software will restore the measurement session(s) from the loaded dataset files. This includes all settings that were active when the corresponding dataset file was recorded. The *system overview* will show the MCU and MPD devices that were connected when the dataset file was recorded. When multiple dataset files are loaded, the system overview will show multiple MCUs, along with the MPDs connected to these MCUs.

At the top of the main window, you will see a message stating that one or more dataset files have been loaded. This message will also show replay controls that allow you to start, pause, and stop replaying the dataset file(s), as well as eject all loaded files.



Figure 11.1: Replay controls

Additionally, a *replay diagram* will be available. This diagram shows the values of a PD magnitude and of an AC magnitude plotted over the duration of the dataset file. You can configure the quantities to be used for this diagram in the [*Replay diagram settings*] section on the *REPLAY* sub-tab of the *RECORD/REPLAY* control panel tab. By default, Q_{IEC}^4 is used for the PD magnitude and V_{RMS} is used as the AC magnitude.

The replay diagram is available both on the *REPLAY* sub-tab of the *RECORD/REPLAY* control panel tab and on the lower-right diagram view. Using profiles, you can also enable it for the lower-left diagram view, and can disable it in the other locations. The replay diagram can also be shown as a separate resizable window, which is useful for when you have multiple screens connected to your computer. That window will also contain the replay controls that are visible at the top of the main window and on the *REPLAY* sub-tab of the *RECORD/REPLAY* control panel tab, so you can use it in place of the *REPLAY* sub-tab for most use cases.

Note that you can only load multiple dataset files simultaneously if *all* of the files you wish to load contain valid GPS information.

Starting with version 1.20 of the MPD Suite, you can also load *stream files* in the same way as dataset files. Stream files use the file extension STM⁵. Stream files contain measurement sessions created by the older *Software for MPD and MI*, which was previously used for measuring with MPD 600 devices, before the MPD Suite became available. For all practical purposes, you can treat stream files the same way as dataset files, although there are some minor differences between the two file formats. For example, stream files don't offer the same choices for the PD and AC magnitudes to be shown in the replay diagrams as dataset files. They will also never contain any GPS information, so you can only ever load a single stream file at the same time.

11.3 Replaying loaded dataset files

You start replaying dataset files by pressing the play button available in the replay controls section of the *REPLAY* sub-tab of the *RECORD/REPLAY* control panel tab. Alternatively, this button and the other replay controls are also available from the message at the top of the main window that reports the replay state, and from the separate replay window you can show by clicking on the appropriate icon in the replay diagram. When the replay is in progress, all recorded data is played back and undergoes the same processing that data from MPD devices would undergo during online ("live") measurements. However,

OMICRON

⁴or Q_{WTD}, as appropriate

⁵as opposed to dataset files, which use the PDS extension

unlike for live measurements, you can pause the replay (using the *Pause* button), to be resumed later. You can also stop replaying by clicking the *Stop* button.

Also unlike for live measurements, you can set the replay speed to something other than real-time. The replay speed can be configured in the *replay speed section* of the replay controls section of the *RECORD/REPLAY* control panel tab. The actual replay speed is also shown there, and will usually be similar to the configured speed.

When the replay speed is set to a value other than *fastest*, the MPD Suite will continually attempt to match the configured speed when replaying data by constantly monitoring the actual replay speed and slowing down or speeding up data delivery accordingly. Note that the MPD Suite attempts to match the configured replay speed one a best-effort basis. Sometimes the requested replay speed cannot be achieved, depending on the performance of the system that is replaying the dataset file. Both the speed of the storage device on which the dataset file is stored and the CPU and memory performance of the system play a role. If the actual replay speed does not match the configured speed, the actual speed reading is shown in yellow. Otherwise, it is shown in green.

You can also set the replay speed to *fastest*, which will lead the MPD Suite to load and replay data from the dataset files as quickly as possible. Note that on slower systems, it is possible for the actual replay speed to be less than real-time, even with the replay speed configured as *fastest*.

Using the replay diagram, you can also select the *replay range*, i.e. the part of the dataset file you want to replay, by using the cursors on the replay diagram. As you drag the *start cursor* (the one with the drag handle pointing to the right), the software will update the measurement readings to match the readings that were made at the corresponding position when the dataset file was being recorded.

The ability to export all measurement data for use in 3rd-party applications is only available while replaying dataset files. This is done so the considerable performance impact of exporting all data (which may be a very large amount) does not slow down the MPD Suite during online measurements.

11.4 Re-exporting dataset files

It is possible to "record" dataset files while replaying a dataset file⁶. This allows you to create dataset files that contain only a subset of the data from other dataset files. This is useful for "pruning" away uninteresting parts of a measurement and for reducing the file size of dataset files that should be archived. For example, by setting some measurement channels from the loaded dataset file to *disabled* usage, and by disabling unneeded AC and PD scope channels, as well as by setting a higher PD detection threshold than what was configured in the loaded dataset file, you can dramatically reduce the size of the reexported dataset file.

To re-export a dataset file, simply load it as usual, select the replay range and make any adjustments to your settings, and then start recording a dataset file before starting the replay.



⁶The re-exporting functionality is currently not available when replaying multiple dataset files.

Chapter 12

Exporting diagrams to image files

Most of the diagrams shown in the MPD Suite can be exported to image files. The export is configured on the *EXPORTING* tab of the control panel, where you can set the size of the exported diagrams, give a base file name (that also determines the file format), and select a folder where exported files are stored. You can also select the diagrams that should be exported when the *export selected diagrams*¹ hot button is pressed.

When diagrams are exported as image files, a *snapshot* of the current diagram is taken and then written to a file. When multiple diagrams are saved simultaneously (e.g. by using one of the hot buttons), they all represent the same point in time. Saving many diagrams to file can take fairly long, so the *EXPORTING* control panel tab shows a progress indicator once exporting has started that informs about the export progress.

The following ways exist to export diagrams to image files:

1. Use the hot button, click the *selected diagrams* button on the *EXPORTING* control panel tab or press the CTRL key together with the F4 key:

This will save all diagrams configured on the *EXPORTING* control panel tab of all config-selected channels, irrespective of which diagrams or channels are currently visible,

- 2. Use the hot button, click the *visible diagrams* button on the *EXPORTING* control panel tab or press the SHIFT key together with the F4 key:
 - This will save all diagrams that are currently visible, irrespective of which channels are currently config-selected or which diagrams are selected for exporting on the *EXPORTING* control panel tab,
- 3. Right-click the diagram view you wish to export diagrams from. This will bring up a small pop-up menu that contains an option to save the diagrams currently visible in the view. Once you click that, all currently visible diagrams from the view you clicked into will be saved:







Figure 12.1: Exporting diagram images by right-clicking into a diagram view

When you specify the base file name of the image files on the *EXPORTING* control panel tab, you can also specify a file extension that will determine the file format that is used to store the files. By default, .png is used, which will generate PNG^2 files. PNG files are highly (but losslessly) compressed, so the file sizes are comparatively small.

For screenshots of PRPD diagrams, you can optionally include the color map used to map PD rates to colors as well as the measured values display. Additionally, you can choose to disable needle plots in the exported PRPD images. Starting with version 1.30 of the MPD Suite, you can also optionally include the name of the channel group associated with a diagram in the exported image file. All of these options are configured on the *EXPORTING* tab of the control panel, under the *Additional options for per-channel screenshots* in *Diagram options* section.



²Portable Network Graphics

Part III Reference

Chapter 13

User interface concepts

This section describes some user interface concepts used throughout the OMICRON MPD Suite.

13.1 Expanders

Expanders are used to group related settings under a common heading. While the heading is always visible, the grouped settings are typically hidden ("collapsed") by default. Expanders are opened ("expanded") and closed ("collapsed") by clicking on the expander's heading or the triangular arrow next to it. The direction of the arrow indicates whether the expander is open or closed; if the arrow points towards the heading, the expander is closed. If it points downwards, it is open, and the grouped settings are revealed.

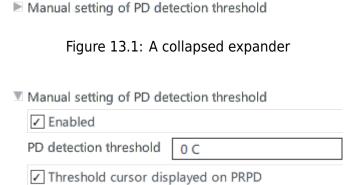


Figure 13.2: An open expander

Expanders help with keeping the user interface tidy by showing only the title of a set of related settings by default. This way, even when many settings are available on a given control panel page, the user interface is not overwhelming. Clicking on the title of an expander will reveal the grouped settings. They are used in many places on the control panel and in configuration dialogs.



13.2 Foldable panels

A foldable panel is an area in the user interface that can be optionally hidden. The control panel is a foldable panel in the MPD Suite. Foldable panels are denoted by a thin column next to the area that contains a little triangle symbol. The direction of the triangle indicates if the foldable panel is open or closed: If the triangle points towards the content area of the panel, it is open, and the content is visible. If the triangle points away from the content area, it is closed.

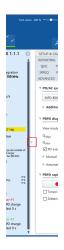


Figure 13.3: The control panel foldable panel in opened state

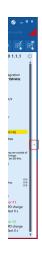


Figure 13.4: The control panel foldable panel in closed state

13.3 Splitters

Splitters sit between two adjacent user interface elements and are used to distribute space between them. A splitter has a *handle* that can be dragged by the mouse to change how much space is available to each element.





Figure 13.5: The splitter between the lower left diagram view and the lower right diagram view

Using the splitter, you can freely choose how much of the available space is given to each of the user elements. However, you cannot give an element less than its minimum required size. On the other hand, it is possible to completely hide a user interface element using a splitter: simply continue moving the splitter handle beyond the minimum required size towards the edge, and the corresponding user element will be hidden. By dragging the splitter handle back towards the middle, the user interface element is revealed again.

Double-clicking on the splitter handle resets the splitter to a default configuration for the user elements. For example, by default the splitter between the upper and lower diagram views gives 75% of the space to the upper diagram view and 25% to the lower diagram view. Double-clicking on the splitter handle between the two will reset the arrangement to that configuration.

13.4 Channel groups

You will find the term *channel groups* used throughout this documentation. Channel groups abstract measurement channels that are provided by MPD devices into a user interface concept. MPD devices have one or more PD inputs and an equal number of AC inputs. For each PD input on an MPD device, there is a corresponding AC input. Together, the PD input and its associated AC input form a channel group.

Each MPD 800 device has two channel groups, while each MPD 600 and UHF 800 has a single channel group.

13.5 Selection states



Figure 13.6: Selection states

The MPD Suite differentiates between multiple types of channel selection. Channels are selected via the channel group display. The simplest of these types is **primary selection**, which always consists of a single channel group. A channel group is usually *primary-selected* by clicking on its icon in the channel group display. Alternatively, you can primary-select a channel group by clicking on its name in the System overview, or by clicking on the channel group's diagram when any of the multichannel views are open



(PRPD, Ellipse, H(Q), Meters, or PD/DC). Primary selection determines which diagrams are visible, and which settings are displayed and configured in the control panel. The channel group display highlights primary-selected channels as shown by the channel group marked (1).

Another type of channel selection is **secondary selection**, which is only relevant when any of the multichannel views are selected. The secondary selection comprises all the channel groups adjacent to the primary-selected channel group whose diagrams are visible in the multichannel view. The secondary selection state of a channel group cannot be directly changed by the user; it always follows from the primary selection. When possible, the channels that immediately follow the *primary-selected* channel are secondary-selected. However, if that is not possible, for example when the last channel group is primary-selected, additional channels that precede the primary-selected channel will also be secondary-selected. In the channel group display, secondary-selected channel groups are highlighted as shown by (2). The channel group marked (3) is neither primary- nor secondary-selected.

Lastly, there is **config selection**. This determines which channel groups are affected by changes to control panel settings and mouse interactions on diagrams. On a control panel tab, the settings shown always correspond to the currently active settings on the primary-selected channel group. However, if multiple channel groups are *config-selected*, changing any of these settings will apply not only to the primary-selected channel group, but to all channel groups that have been config-selected. Further, if the current settings are not the same across all config-selected channel groups, the corresponding option will have an unequal sign (\neq) next to it to indicate that the value shown is *not* currently in effect for all config-selected channel groups. Settings that are subject to config-selection are indicated by the **config-selection symbol**

Channel groups can be config-selected via the circle symbols on the channel group display as indicated by **(4)**. Every channel group (except for gating channels) has one of these. A filled circle indicates that the corresponding channel group is config-selected, i.e. changes to settings will affect that channel group. An empty circle indicates that the corresponding channel group is not currently config-selected.

There are two additional shortcut icons next to the first channel group: the three filled circles (5) can be used to config-select all channel groups (except for those channel groups that are designated as gating channels), and the single filled circle and two empty circles (6) can be used to remove from the config-selection all but the primary-selected channel group.

Note that the primary-selected channel group is *always* config-selected. If you primary-select a channel that was *not* config-selected, the config-selection is cleared and reset to the newly primary-selected channel.

Also **note** that *gating channels* can never be part of a config selection, and can only ever be configured individually. You can primary-select a gating channel, but you won't be able to add a gating channel to a config selection or to add *any* channel to the config selection when a gating channel is primary-selected.

13.6 Value edits

550 kHz

Figure 13.7: A value edit

Value edits are text input fields that accept any numeric value for the corresponding setting, along with suitable units and prefixes. These are primarily used on the control panel tabs. For example, the value

70 OMICRON

edit for the center frequency of the PD measurement filter (on the SETUP & CALIBRATION tab of the control panel) accepts any of the following equivalent inputs: 1e6, 1 M, 1 MHz, 1MHz, 1000kHz, 1000000, 0.001G, etc. All of them mean "1 MHz", and this is also what the value edit will display once you press Enter after typing any of the above examples. **Note** that you *must* press the Enter key after typing a value in order for the new value to take effect. Otherwise, the previous value will continue to be used.

Some value edits accept multiple different units. For example, when the underlying setting is a time duration, you can enter the time in seconds, minutes, hours, or days. You can also enter it in milliseconds, microseconds, etc. You can even combine the use of different units (e.g. 2 h 3 min 12.3 s). As another example, value edits associated with distances can accept SI units (meters, kilometers, etc.) as well as US-Imperial units (inches, foot, yards, etc.) By default, such values are always displayed in their base unit, in this case meters, but that can be customized.

Value edits also support changing the currently selected value by using the cursor up (\uparrow) and cursor down (\downarrow) keys, and by using the mouse wheel while the value edit has the active focus. Depending on the associated setting, this will either change the current value by going to the next highest (or lowest) decade (e.g. 1, 2, 5, 10), or will add or subtract a certain amount from the current value. Often the amount that is added or subtracted depends on some other setting. For example, when changing the horizontal offset for a diagram, the change is equal to the configured horizontal scale for that diagram.



Chapter 14

Main window user interface elements

14.1 The channel group display

The channel group display, located at the top of the main window, visualizes all available channel groups as boxes. The color of the channel group's box depends on its selection state. For each channel group, the box shows the following information:

- the name of the channel group,
- the channel group's color,
- · various status indicators of the channel group,
- the largest repeatedly occurring PD magnitude measured on the channel group's PD input, or, when mV PD mode is enabled, the weighted PD voltage
- when RIV measurements are enabled for the channel group, the RIV guasi-peak voltage.

Additionally, when you hover the mouse over the channel group's box, it shows a tooltip with additional information:

- a description of each of the active status indicators of the channel group,
- the serial number of the device to which the channel group belongs,
- the current voltage of the power supply attached to the channel group's device,
- (for MPD 800 and UHF 800 only) the current temperature of the channel group's device, and an indication if the device has been overheated,
- (for MPD 800 and UHF 800 only) if one or more RPB 1 batteries are attached to the MPD 800 or UHF 800, the current charge level of the battery, the battery temperature as well as the estimated remaining operating time. Additionally, the total estimated remaining operating time is shown along with the battery charge level across all connected batteries.

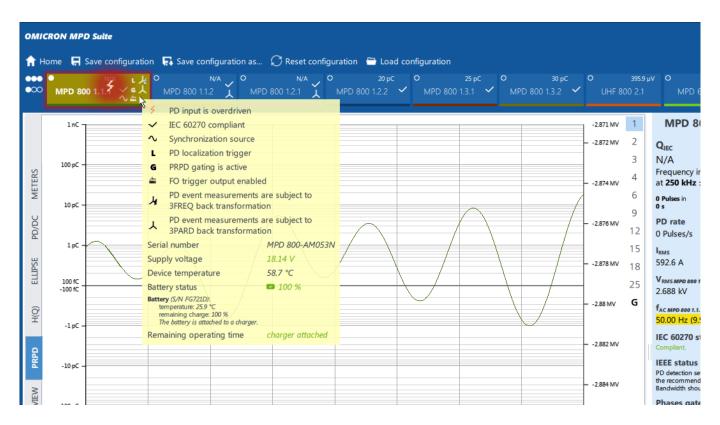


Figure 14.1: Hovering the mouse over a channel group

The following status indicators might appear on the channel group's box:

- The *low battery* symbol () indicates that the channel group's device is powered by a battery whose capacity is getting low. When the symbol blinks, the remaining battery capacity is critical, meaning that the device may power off very soon. When you hover the mouse over the channel group's box, the remaining capacity of the battery is visualized with different symbols: for high remaining capacity, for low remaining capacity, and for when the remaining battery capacity is critically low.
- The *input overdriven* symbol (∮) indicates that either the channel group's AC or PD input¹ is being overdriven, i.e. the voltage or current applied to the input is too high for the current gain setting. You can adjust the input's gain setting on the *ADVANCED* control panel tab, under the AC level and gain settings or PD level and gain settings sections, respectively. When the mouse is hovered over the channel group's box, the overdriven state for the AC and PD inputs is indicated separately.
- The compliant with IEC 60270 symbol (✓) indicates that the PD measurement of the channel group uses PD measurement settings that are compliant with IEC 60270 and that the PD measurement has been calibrated.
- The PD/AC synchronization source symbol () indicates that the channel group's AC input is being used as the PD/AC synchronization source. If this symbol is shown on only one channel group's box it means that the corresponding channel group is used as the PD/AC synchronization source for all PRPDs, otherwise the symbol will be shown on all (non-gating) channel groups, and indicates that the Each unit triggers itself option is enabled.
- **The** *localization source* **symbol (L)** indicates that the channel group is being used as the trigger source for PD source localization.



¹for UHF 800 devices, the UHF or SYNC inputs

- **The PRPD gating active symbol (G)** indicates that some phase or phase/amplitude gates have been defined on the channel group's PRPD.
- The trigger output enabled symbol () indicates that the channel group is being used to drive the MPD's or UHF's optical trigger output. When this symbol is shown, PD events detected by the channel group, optionally constrained by a PD event trigger window as configured on the SCOPE & FFT control panel tab, will lead to a pulse on the optical trigger output of the MPD or UHF device.
- The under 3PARD back-transformation symbol (人) indicates that the channel group participates in a 3PARD diagram in which clusters are selected, leading to back-transformation such that only a subset of PD events detected by the channel group contributes to any PD measurements.
- **The under 3FREQ back-transformation symbol** (*) likewise indicates that the channel group has 3FREQ enabled, and clusters are selected on the 3FREQ diagram, leading to back-transformation. Here, too, some PD activity seen by this channel group is suppressed and does not take part in PD measurements.
- The device overheated symbol () warns about the temperature of the channel group's MPD or UHF device being too high. Note that when this happens, there is a risk of damaging the device if you continue using it. You should try to cool down the device until the warning message disappears.

You can change the channel group's name by double-clicking the displayed name in the channel group box. Doing so will change the name into an edit field and select the name. You can then type a new name and press the Enter key to accept it. **Note** that you cannot use the same name for different channel groups, and you cannot use the < and > symbols in a channel group name. If you want to restore the original name², simply type an empty name (by pressing the Del key and then accepting the empty text by pressing the Enter key after double-clicking the channel group name).

The channel group box also lets you change the color of the channel group. The channel group's color is used as the plot color in several diagrams, including the *scope* diagram, the *FFT* diagram, the Q(V) diagram, the *trend* diagram, the *UHF* spectrum diagram, the *UHF* sweep diagram and the AC plot on the PRPD. The channel group's current color is indicated by a narrow strip at the bottom of the channel group's box. Hovering the mouse over that strip enlarges it somewhat, and double-clicking it opens a color selection window. In that window, you can choose a different color for the channel group, and clicking the OK button will activate the new color.

The channel group display is also the place where you can config-select channel groups in order to form config groups. The *three filled circles* ($\bullet \bullet \bullet$) symbol at the top left of the channel group display will add all measurement channel groups to the current config group, while the *single filled circle* ($\bullet \bigcirc \bigcirc$) symbol removes all but the currently primary-selected channel group from the config group. There is also a circle symbol on each channel group box. When filled, it indicates that the channel group is a member of the current config group. Empty circles indicate that the channel group is not a member of the current config group. You can add and remove a channel group to the current config group by clicking that circle symbol.

14.2 The channel gating area

Similar to the channel group display, the channel gating area shows boxes for any channel groups that are designated as gating channels. It is located to the right of the channel group display. Unlike on the channel group display, channel group boxes for gating channels do not show any measurement readings.



²which is derived from the channel group's device type and its position in the measurement setup, e.g. MPD 800 1.1.1 means the first channel group of the first MPD 800 device on the first FO bus of the MCU.

Instead, they show the gating symbol () to clearly distinguish them from "regular" measurement channel groups.

Additionally, they indicate whether the gating channel is enabled, by showing **ON** or **OFF**. Also, not all channel group status indications apply to gating channels. They never show the *compliant with IEC 60270*, *localization source*, *PRPD gating active*, *under 3PARD back-transformation*, or *under 3FREQ back-transformation* symbols.

Gating channels also cannot be a member of a config group; therefore, they don't show the circle symbol. Primary-selecting a gating channel will reset the current config group, and all configuration changes will only be applied to the selected gating channel.

14.3 The upper diagram view

The upper diagram view takes up most of the space on the main measurement window by default. It is located at the top left of the window, and contains the $System\ overview$, PRPD, H(Q), Ellipse, PD/DC and $Meter\ views$. Only one of these diagrams can be visible at any time; you select the visible diagram by clicking on the title to the left of the upper diagram view.

The upper diagram view also shows important messages above the diagram(s) that are currently selected, such as when dataset files are being recorded or replayed, when an XML report file is being written, when the GPS signal has been lost or the MCU system clock is not fully synchronized with the GPS clock, or when a UHF frequency sweep is in progress on a connected UHF 800 device.

14.3.1 The system overview display

The system overview display shows all connected MPD and UHF devices along with some fundamental measurement results and some important settings. The MPD and UHF devices are represented by images of the physical units which are arranged according to how they are connected to the MCU (which is also shown). Devices that are daisy-chained on a single bus appear next to each other, with the fiber optical link between them (and between the first device on a bus and the MCU) depicted as an orange line. Devices from different buses are shown atop each other. This arrangement makes it easy to see which devices are connected where. Hovering the mouse over any device image will highlight the device, and will also highlight all channel groups belonging to the device in the channel group display.



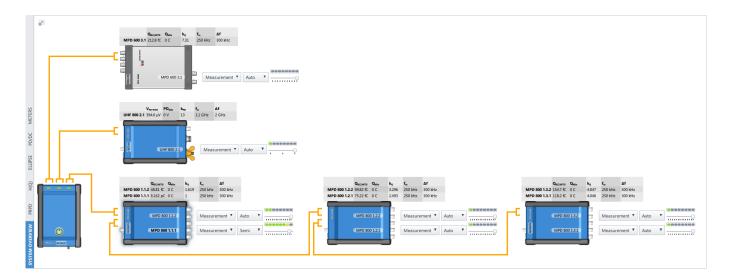


Figure 14.2: The system overview display

Above each device image there is a table that shows a set of fundamental measurement readings as well as some basic settings for the channel groups belonging to the MPD or UHF device. Depending on the current configuration, the table shows the following entries:

- the largest repeatedly occurring PD magnitude, labeled Q_{IEC/WTD},
- the PD detection threshold, labeled Q_{Min} when not using mV PD mode and PD_{Min} when using mV PD mode,
- the charge calibration factor, labeled k_O,
- the weighted PD voltage, labeled V_{PD WTD} (only available in mV PD mode)
- the PD voltage normalization factor, labeled k_{PD} (only available in mV PD mode)
- the center frequencies of the PD measurement filter, labeled f_m, f_{AUX I}, and f_{AUX II}, respectively,
- the bandwidth of the PD measurement filter, labeled Δf,
- the quasi-peak voltage of the RIV measurement, labeled V_{RIV},
- the RIV calibration factor, labeled k_{RIV},
- the center frequency of the RIV measurement filter, labeled f_{RIV}, and
- the bandwidth of the RIV measurement filter, labeled Δf_{RIV} .
- the t₁ and t₂ settings when time-domain integration is enabled.

The device image also directly shows the channel groups belonging to it, with the channel group name displayed next to the (PD and AC) inputs that constitute the channel group. Similar to the channel group display, you can change the name of the channel groups by double-clicking the name text and entering a new name. The name of the primary-selected channel group is shown in bold typeface. You can also primary-select a channel group directly from the system overview display by single-clicking its channel name.

Next to the device image, aligned to the inputs that make up the channel group, you can set the usage of the channel group from a selection box. Depending on your licensed number of measurement channels, you can mark a channel group for *measurement* usage. This unlocks all measurement functionalities for the channel group, including charge, RIV³ and AC measurements, and makes the channel group appear in the channel group display.

You can also designate a channel group for gating usage, which enables AC measurements and the PRPD



³RIV measurements are separately licensed, but are never available for gating channels.

for the channel group's PD channel while disabling all other PD and RIV measurements. Channel groups marked as *gating* will appear in the channel gating area. The channel group's PD channel is said to be a *gating channel* in this case.

Finally, you can also disable a channel group by specifying *disabled* usage. Disabled channels do not show up in either the channel group display or the channel gating area, and consume far fewer resources⁴ than channel groups marked for a different usage.

Next to the usage selection, you can set the auto-gain mode for the PD input of the channel group. This setting is duplicated from the PD level and gain settings section of the ADVANCED control panel tab. Setting it to Auto will automatically select the most suitable gain setting for the signal applied to the channel group's PD input. The Semi (for semi-automatic) option allows the MPD Suite to automatically reduce the gain setting (i.e. set to a less sensitive setting) in order to avoid overdriving the PD input, but not increase it (i.e. set to a more sensitive setting). Both of these options can lead to the gain setting changing during the measurement. The Manual setting completely disables automatic gain control, and the software will never change the gain setting by itself.

Next to the auto-gain setting you see the current PD input level and can also manually set the PD gain setting via a slider. Both the PD input level indicator and the PD gain setting slider are duplicated from the PD level and gain settings section of the ADVANCED control panel tab.

On the image representing the MCU there is a LED indicator for each fiber optical bus available on the MCU. This indicator shows the current state of the bus. When the indicator is green, the bus is connected to at least one device, and the connection is error-free. Yellow indicates that while the bus is connected to at least one device, there are intermittent errors in the communication. This can happen while a device is being connected or detected by the MPD Suite, but it can also indicate faulty FO cables or bad connections. A red LED indicator means that nothing is connected to the FO bus, or that the connection is interrupted. Finally, a gray LED indicates that the bus is disabled. When you hover the mouse over each bus' LED indicator, a tool-tip message will show that explains what each color means. You can disable and re-enable individual FO buses by right-clicking on the bus' LED indicator. Alternatively, there is a power button () on the image of the MCU itself, which you can use to disable and re-enable all buses simultaneously. To disable all buses, you must press this button using the mouse for at least 3 seconds. After that, the button turns red, and all buses are disabled. To re-enable all buses, just press the button once.

For MCU 2 devices, the image will also show a GPS indication when a GPS antenna is connected and the built-in GPS receiver has acquired a position fix. Once a GPS fix has been established, the MCU 2 will use the timing data from the GPS satellites to continuously synchronize itself with the GPS satellites' atomic clock. **Note** that this process can take several minutes. While the MCU 2 has a GPS fix but is not yet fully synchronized to the satellites' clock, the GPS indicator is shown with a yellow background. As soon as the MCU has achieved clock synchronization with the satellites⁵, the GPS indicator will be shown with a green background. Additionally, while there is a GPS connection but the MCU clock is not fully synchronized with the GPS time, a warning message will be shown above the large diagram view, alerting you to that fact. Similarly, if the MCU 2 loses the connection to the GPS satellites, e.g. because the antenna is disconnected or because of poor reception conditions, another message is shown, indicating that fact.



⁴communication bandwidth on the fiber optics links as well as CPU and graphics usage on the PC running the MPD Suite ⁵currently, this occurs when the time difference between the MCU 2's clock and the GPS clock is less than 100 ns



Figure 14.3: MCU 2 with GPS fix and no synchronization



Figure 14.4: MCU 2 with GPS fix and synchronization

The ability to synchronize the MCU 2's clock to the GPS signal comes into play when merging multiple dataset files, which only works for GPS-synchronized dataset files. With GPS synchronization, multiple dataset files can be loaded simultaneously and can be replayed in unison, such that all MPD and UHF devices that are contained in any of the dataset files can be used as if all devices were connected to a single MCU.

At the top of the system overview display, a message informs you about how many MPD 800 and UHF 800 channels you can still assign for measurement and gating usage. This number depends on how many channel licenses you have purchased.

The system overview display can be *detached* into its own window from the upper diagram view. To do this, you click the button located at the top left of the system overview display. When detached, the system overview display is no longer available on the upper diagram view and stays visible until you close the detached window.

Detaching the system overview display is equivalent to clicking the *View system overview* button on the start page.

Regardless of whether the system overview display is detached, you can save the system overview



display to an image file by right-clicking into the system overview image and selecting *Save system* overview as image. This will store the image in the folder and with the file name as configured on the *EXPORTING* control panel tab.

You can zoom into and out of the system overview display by keeping the CTRL key pressed while moving the mouse wheel when the mouse pointer is hovering over the system overview display. You can also use the left mouse button to drag the view around. Alternatively, you can use the scroll bars to change the view.

14.3.2 The PRPD view

The PRPD view displays the PRPDs of the primary-selected channel group as well as of additional channel groups depending on the current secondary selection. When some channel-groups are secondary-selected, the PRPD view shows PRPD overview diagrams, which include the current value of the largest repeatedly occurring PD magnitude and RIV quasi-peak voltage readings for the channel groups whose PRPDs are shown.

PRPDs are generated from two-dimensional matrices that contain a number of "bins". Each PD event is assigned to a bin based on its phase position in the AC signal of the PD/AC synchronization source and its apparent charge. Currently, the MPD Suite uses 500×400 matrices, i.e. there are 500 bins in phase direction (approximately 1.4 bins per degree) and 400 bins in charge direction (i.e. the charge range between Q_{Max} and Q_{Min} as configured on the PRPD & AC tab of the control panel is divided into 400 bins, either in a linear or logarithmic fashion, depending on the view mode of the PRPD). Each bin counts the number of PD events that have the same horizontal (between 0 and 499) and vertical (between 0 and 399) "bin position".

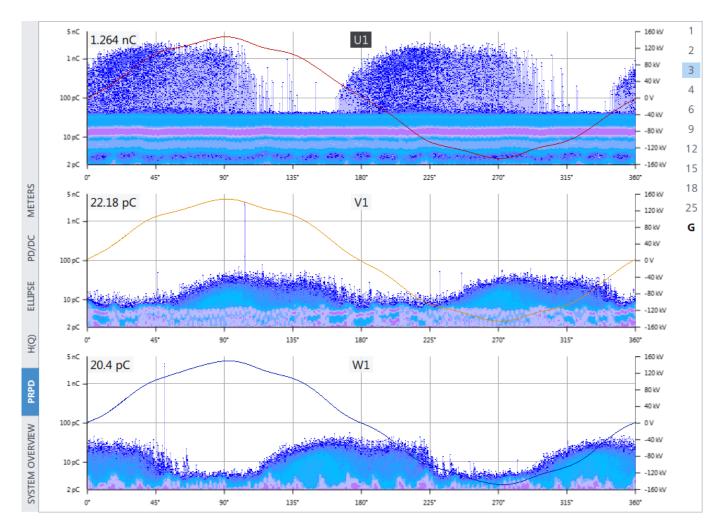


Figure 14.5: The PRPD view

You also interact with the PRPD on this view to do other things, including:

- · defining phase and phase/amplitude gates on measurement channels,
- defining areas of interest on gating channels,
- defining conditions for the PD event window scope trigger,
- selecting trigger pulses for sTDR and sTOF-based PD localization

While the diagram settings for the PRPD are available on the PRPD & AC control panel tab, you can also change the scaling of the charge axis of the PRPD using the mouse, directly from the PRPD view. This works on any view where the charge axis is visible (i.e. the $\bf 1$, $\bf 2$ and $\bf 3$ views). To change the scaling of the PRPD, keep the SHIFT key pressed as you drag the mouse across the charge axis (using the left mouse button). Doing so will change the upper diagram boundary of the PRPD while keeping the lower diagram boundary fixed. You can also change both the lower and upper boundary of the diagram by dragging the mouse across the charge axis without holding the SHIFT key.



14.3.3 The $H(Q)/H(V_{PD})$ view

The H(Q) view provides an alternative view on the data underlying the PRPD view. It ignores the phase position of PD and counts the number of PD events with a certain apparent charge⁶. Using the same data representation as PRPDs, the bins along the phase direction are accumulated to produce a final count of PD events with a certain apparent charge. Note that this means that the "bin size" of the H(Q) diagram affects the total number of PD events with a certain apparent charge: The charge range between Q_{Min} and Q_{Max} as configured on the PRPD & AC tab of the control panel is divided into 400 bins, either in a linear or logarithmic fashion, depending on the view mode of the PRPD. A larger charge range makes each bin bigger, and thus has the potential for counting more PD events.

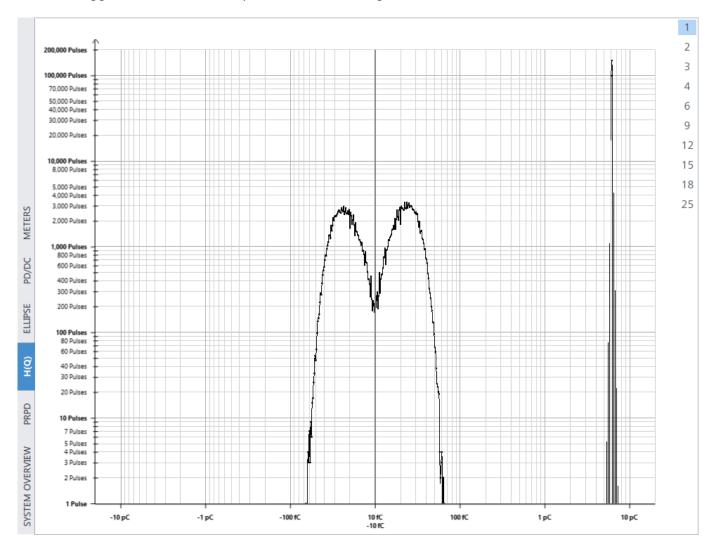


Figure 14.6: The H(Q) diagram

You configure the H(Q) diagram from the H(Q) control panel tab. This includes setting the scale mode for the count (vertical) axis (*linear* or *logarithmic*), enabling or disabling auto-scaling for the count axis, and setting the maximum value to use for the count axis if auto-scaling is disabled. It also allows you to start and stop capturing the H(Q) diagram, including setting a time to capture the diagram for. However, be aware that since H(Q) diagrams and PRPDs are tied together, you also start building an H(Q) diagram



⁶in mV PD mode, the diagram is called $H(V_{PD})$ and counts the number of PD events with a certain PD voltage.

when you start a capturing PRPD and vice versa. Thus, clicking the Capture H(Q) button on the H(Q) control panel tab has the same effect as clicking the Capture PRPD on the PRPD & AC control panel tab.

The H(Q) diagram supports auto-scaling its count (vertical) axis. Alternatively, when auto-scaling is disabled, you can also change the scaling of both the charge and the count axis of the H(Q) diagram using the mouse, directly from the H(Q) view. This works on any view where the axes are visible (i.e. the **1**, **2** and **3** views). To change the scaling of the H(Q) diagram, keep the SHIFT key pressed as you drag the mouse across the count axis (using the left mouse button). In the same way, you can also change the scaling of the charge axis. **Note** however that doing so will also change the scaling of the PRPD's charge axis, as the two diagrams share the same data back-end.

14.3.4 The Ellipse view

The *ellipse view*, also known as the *Lissajous view*, is yet another view on the PD activity. This diagram shows individual PD events as "needles" (similar to the ones that you can optionally view on top of PRPDs) arranged on an ellipse that represents the phase position of the PD/AC synchronization source. The needles are drawn vertically from the ellipse to a point that corresponds to the PD event's apparent charge.

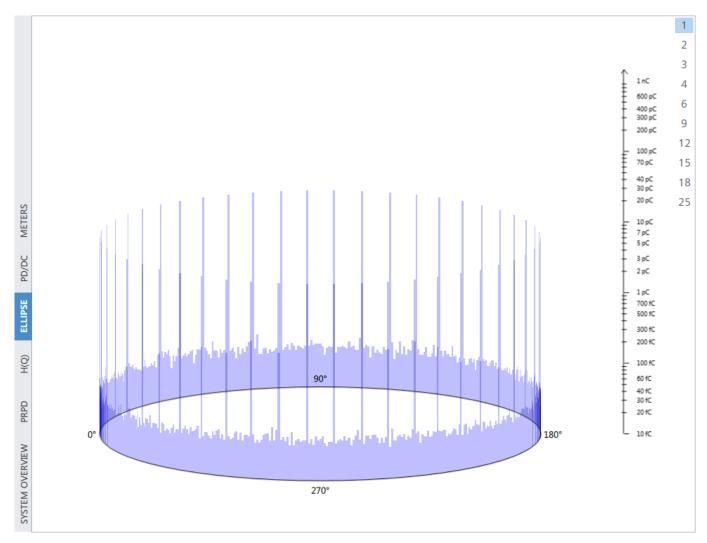


Figure 14.7: The Ellipse (Lissjaous) diagram



The ellipse diagram is a well-known feature of early PD measurement devices that were based around an oscilloscope. In the MPD Suite, a (charge) axis showing the effect of offset, scale and view mode is shown next to the ellipse. It is based on the 0° and 180° position of the diagram.

The ellipse view is bound to the PRPD view such that it uses the same view mode and diagram boundaries as the PRPD, so there is no special control panel tab for it. However, like with the PRPD and H(Q) view, you can use the mouse to shift and scale the diagram by dragging the mouse across the axis. When you press and hold the SHIFT key while dragging the mouse, you change the scaling of the ellipse view, while you can change the charge offset of the ellipse view by dragging the mouse over the axis without the SHIFT key held. **Note** that when you interact with the axis this way, you are also changing the PRPD's charge axis as configured on the *PRPD & AC* control panel tab.

14.3.5 The PD/DC view

The *PD/DC view* contains two diagrams that are used during PD/DC measurements: The *PD/DC pulses* and voltage diagram shows individual PD events and the DC voltage over time, and the *PD/DC counter* diagram shows the values of the two PD/DC counters as they change over time. The diagrams are arranged using a splitter. You can change the height of either diagram by dragging the splitter, and can even hide one of the diagrams by dragging the splitter all the way up or down.

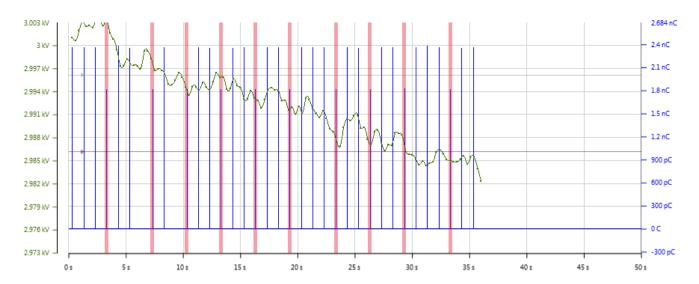


Figure 14.8: The PD/DC pulses and voltage diagram

The left vertical axis of the *PD/DC pulses and voltage diagram* applies to the DC voltage plotted and is given in V, while the right vertical axis applies to the PD events (and is given in either C or V, depending on whether mV PD mode is used or not). The DC voltage is plotted in the color of the channel from which it is taken, as configured via the *DC voltage to plot* setting from the *Channel-specific PD/DC diagram settings* section of the *PD/DC* control panel tab. **Note** that because this setting can be changed while a DC measurement is in progress, the DC voltage plot may consist of multiple non-contiguous segments that are of a different color, each reflecting the channel from which the segment was taken.

The color of the PD pulses in the PD/DC pulses and voltage diagram, which are also called "needles", can be configured via the Needle plot color setting from the PD/DC diagram settings section of the PD/DC control panel tab.

The *PD/DC pulses and voltage diagram* can also show periods where the PD input may have been over-driven, using red translucent shades that cover the possibly affected PD pulses. This functionality can be enabled or disabled via the *Overdrive warning visualization enabled* setting from the *PD/DC diagram settings* section of the *PD/DC* control panel tab.

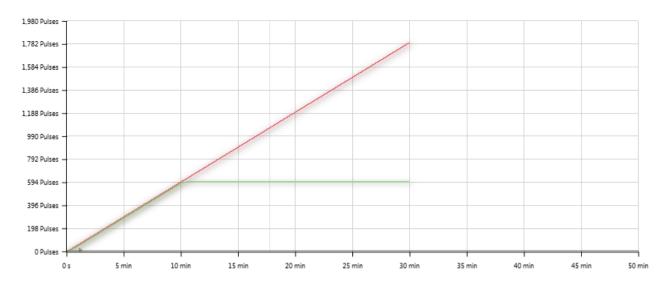


Figure 14.9: The PD/DC counter diagram

The color of the counter values shown in the *PD/DC counter diagram* can be configured in the *PD/DC diagram settings* section of the *PD/DC* control panel tab.

You can view PD/DC diagrams for multiple channels by choosing the desired number of channels on the right-hand side of the PD/DC view. This works in exactly the same way as when you view multiple PRPDs, Lissajous diagrams and H(Q) diagrams.



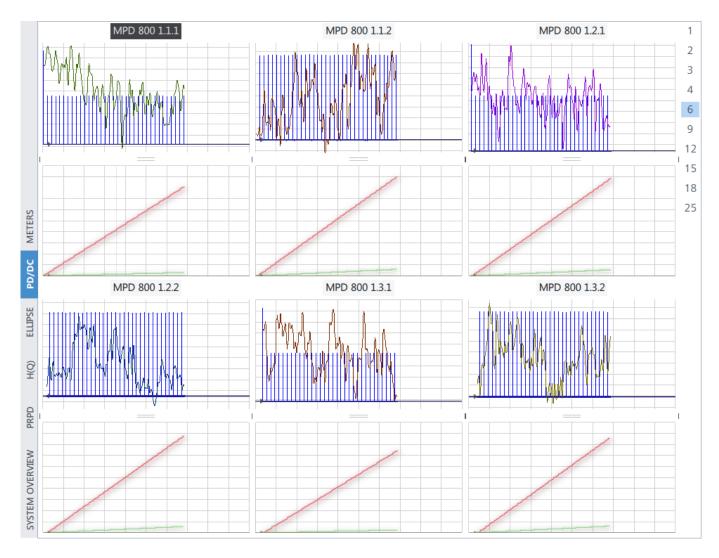


Figure 14.10: Viewing PD/DC views from multiple channels

14.3.6 The Meters view

The *meters view* shows a set of displays for each channel group, arranged in a row. The first display simply shows the reading of the dominant charge of the channel group as a numeric value (in *mV PD mode*, the reading of the dominant PD voltage is used instead).

The second display also shows the reading of the dominant charge or PD voltage, but it displays it in the form of a needle instrument along with the numeric value. It also colors the labels in the needle instrument based on the smallest of the enabled pass/fail levels: Green indicates that PD levels up to this value pass the assessment, while red indicates that these PD levels exceed the pass/fail threshold. The needle display's range coincides with the diagram boundaries from the PRPD view.

The third display shows the dominant voltage reading of the channel group that acts as the PD/AC synchronization source for the meter row's channel group. If the *each unit triggers itself* option is enabled, the channel group uses its own AC input for PD/AC synchronization. If a specific AC or V input is selected as the PD/AC synchronization, its reading is shown for all meter rows. For the *line trigger* or *internal trigger* options, no third display is shown.



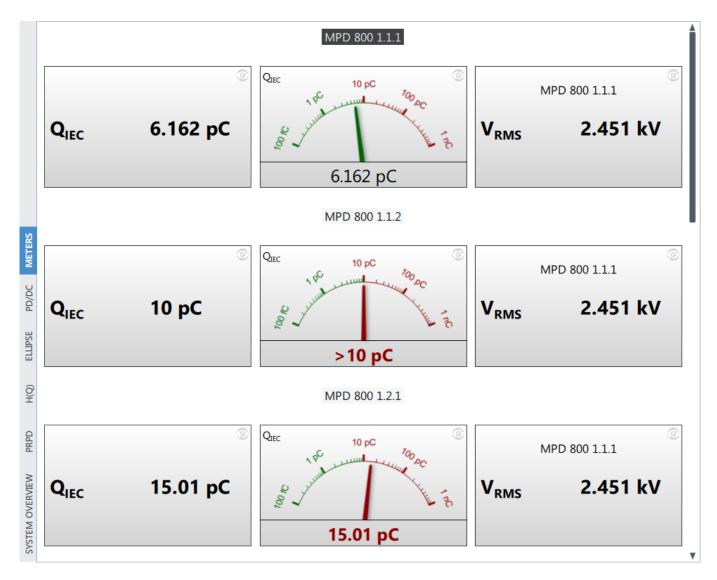


Figure 14.11: The meters view

You can hide each of the three display for each row by clicking the \mathfrak{P} icon located at the top right of each display.

The meters view always shows three channel groups at the same time in a scrollable view. To see other channel groups, scroll the view down.

14.4 The lower diagram view

14.4.1 The assessment view

The assessment view displays the result of pass/fail and inception/extinction voltage for all channel groups designated for measurement usage. The results are presented in a table, with one row used for each channel group. There is one column for each enabled level of the pass/fail and inception/extinction voltage assessment, respectively.

Refer to the sections on the pass/fail and inception/extinction voltage assessments for a description of



the possible results.

When no measurement channels are enabled for measurement usage, the assessment view shows a message to that effect.

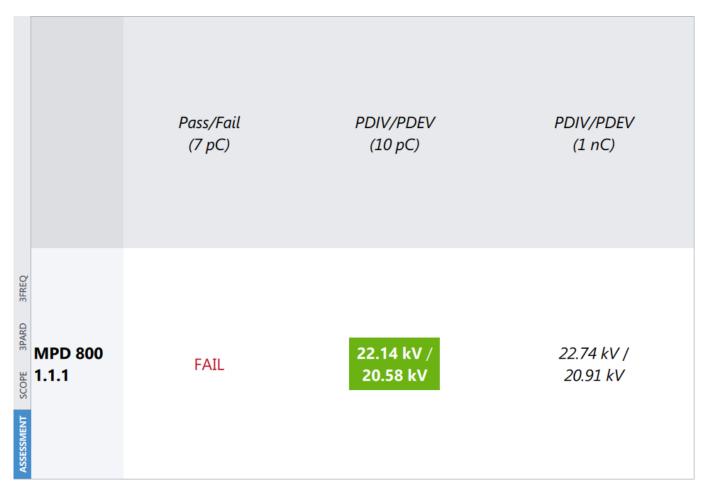


Figure 14.12: The assessment view

14.4.2 The PD scope view

The *PD scope view* shows the signal applied to the PD input of the primary-selected channel group, plotted as voltage over time. The PD scope view works much like a regular oscilloscope. A *trigger condition* is defined on the *SCOPE & FFT* control panel tab, and when that trigger is satisfied, a snapshot of the continuous signal applied to the PD input (known as a *trigger shot*) is transmitted to the PC and displayed in the PD scope view. The time designated as 0 s corresponds to the moment that the trigger condition was satisfied. Depending on the pre-trigger time setting and the available *scope depth*⁷, the trigger shot starts some time before the trigger time and extends for a time after it. A *trigger indicator* (a small triangle) is shown at the top of the diagram when the PD input is currently triggering. It will fade if no trigger events are detected, and after approximately 2 s of no trigger events a *no trigger!* warning will be shown at the top right of the view. The trigger indicator and the no trigger warning can be disabled from the *SCOPE & FFT* control panel tab.

The PD scope view can contain multiple cursors: By default, scope markers are shown which allow you



 $^{^{7}}$ up to 132 μ s for MPD 800 and UHF 800, and 32 μ s for MPD 600

to measure time differences and – if a suitable propagation speed has been configured – also spatial distances. The distance between the scope markers is shown on the PD scope view. Alternatively, the PD scope view can also show the *time integration boundaries* when time integration is enabled for the PD measurement on the primary-selected channel group. The t_1 and t_2 cursors are only shown when the scope markers are disabled on the *SCOPE & FFT* control panel tab and time domain integration has been enabled.

If the *edge* or *peak* trigger mode has been configured for the primary-selected channel group, you can also set the trigger threshold via a cursor.

Furthermore, the PD scope view can show the trigger shots of multiple channels, not just the primary-selected one. You can choose the other channel groups to show in the PD scope view along with the current primary-selected channel from the *SCOPE & FFT* control panel tab. Note that this setting is attached to the primary-selected channel group, so that you can select different sets of scopes to view for different primary-selected channel groups.

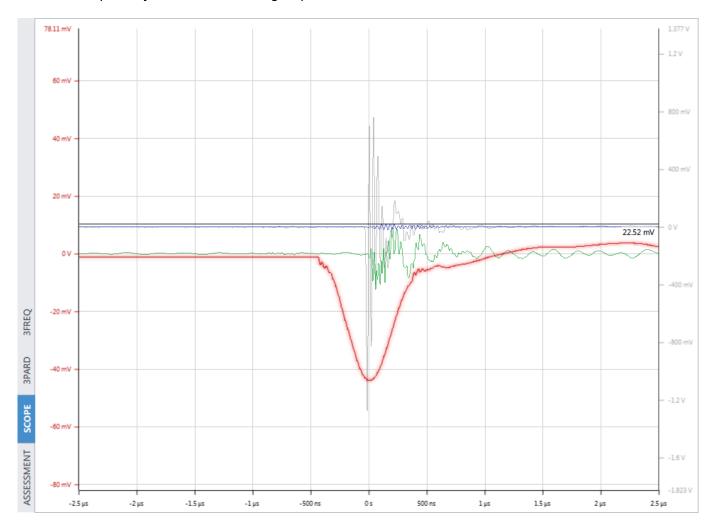


Figure 14.13: The PD scope view with multiple trigger shots

Since version 1.40 of the MPD Suite, trigger shots from other channels selected to be shown along with the trigger shots from the primary-selected channel in this way can also be plotted using a *secondary* vertical axis. This is helpful when comparing signals of vastly different magnitudes. To select which



vertical axis a scope plot should use, you use the *axis indicator* on the channel selection box. This indicator will show **1** when the primary vertical axis is selected for trigger shots from the corresponding channel, and **2** when the secondary vertical axis is selected. The primary-selected channel will always use the primary axis, and thus does not show the axis indicator.

The primary axis is shown on the left of the PD scope diagram, using the channel color of the primary-selected channel group. When using a secondary axis, it is shown on the right of the PD scope diagram, and uses the channel color of the first channel that is assigned to the secondary axis.

While you can control the scaling of the PD scope view from the SCOPE & FFT control panel tab, including enabling auto-scaling for the vertical (primary and secondary) and horizontal (time) axes, you can also use the mouse to change the scale. By dragging the mouse across the time or voltage axis, you can shift that axis. By dragging the mouse across the axis with the SHIFT key held, you can re-scale the axis (i.e. change the time base or voltage scale of the corresponding axis).

You can also enable an "afterglow" effect on the scope plot. This setting is located on the *DISPLAY* control panel tab. When enabled, each newly shown plot will "glow" and slowly fade out, mimicking the effect of phosphor screens. The strength of the afterglow effect is controlled via the half-life setting. By default, the afterglow effect is enabled with an 80 ms half-life.

14.4.2.1 Analysis filters for scope and FFT

Since version 1.40, the MPD Suite supports analysis filters for scope and FFT. Using this feature, trigger shots can be post-processed in software in various ways. For one thing, you can average multiple trigger shots to reduce noise. Unlike hardware averaging, which is subject to trigger-time jitter of approximately ±2 ns⁸, this software-based averaging is applied to the exact trigger time. Furthermore, you can apply software-based digital filters⁹ to the trigger shot. The software offers low-pass, high-pass, and band-pass filters. For low-pass filters you choose the upper cut-off frequency of the filter. Similarly, for high-pass filter you choose the lower cut-off frequency. For band-pass filters you must choose both the lower and the upper cut-off frequencies. Regardless of the chosen filter type, you also choose a filter order, which determines the steepness of the filter. The default filter order is 30, which gives a filter with relatively low steepness. The filter order is an important parameter, whose effect is particularly important with low-pass filters using a low cut-off frequency. The cut-off frequencies of the filters are specified as 6 dB limits, i.e. at the specified frequencies the signal is attenuated by 6 dB. However, with low-order filters that have a relatively flat (non-steep) filter response, the attenuation increases slowly with the frequency as it approaches the cut-off frequency and then keeps increasing slowly as it moves further into the supposed blocking range. With very low cut-off frequencies (below 1 MHz) a filter with low steepness does not "manage" to sufficiently attenuate the signal by 6 dB at the configured cut-off frequencies due to its flat response. In those case, you need to use a higher filter order. For example, to achieve a 6 dB cut-off at 500 kHz, you should use a filter order of 300 or more. For other desired cut-off frequencies, refer to the table below for suitable filter order settings.

Desired low-pass cut-off frequency	Recommended filter order setting
5 MHz	30
4 MHz	40
3 MHz	50
2 MHz	70

⁸ for MPD 800; ±8 ns for MPD 600

OMICRON

90

⁹the MPD Suite uses FIR (finite impulse response) filters for this

Desired low-pass cut-off frequency	Recommended filter order setting
1 MHz	150
500 kHz	300
200 kHz	700
100 kHz	2000
50 kHz	4000
30 kHz	5000

The maximum filter order is 5000. Please note that using high filter orders consumes a large amount of processing power and should only be configured for those channels that need to use a low-pass cut-off frequency.

The effect of the analysis filter is shown both in the FFT diagram and the PD scope diagram. In the PD scope diagram, the plot of the primary-selected channel group shows the filtered signal. Optionally, the software can also plot the unfiltered signal in the background of the PD scope view¹⁰. This can be enabled from the *Analysis filter for scope and FFT* section on the *SCOPE & FFT* tab of the control panel. When enabled, the unfiltered signal is shown in a light-gray color behind the filtered signal¹¹, using the secondary axis. In that case, the secondary axis on the right of the PD scope diagram is always shown in light-gray, independent of any plot from other channel groups that may be also assigned to the secondary axis. Unlike with the secondary plots (from other channel groups that are not primary-selected), you cannot choose to plot the unfiltered signal on the primary axis. When the unfiltered signal is shown, the trigger threshold cursor (if applicable) is bound to the unfiltered signal. This is helpful in seeing and configuring the trigger threshold, which applies to the unfiltered signal.

14.4.3 The 3PARD view

The 3PARD view shows the 3PARD diagram that is generated as a result of 3PARD processing, if enabled. When 3PARD processing is not currently enabled, the diagram will show a message to that effect, along with a link to the 3PARD control panel tab, where you can control 3PARD processing.

When enabled, the diagram shows the 3PARD "star diagram". By default, the 3PARD axes (the "star" itself) are shown and labeled with the names of the channel groups that participate in the 3PARD. Also by default, a grid is enabled. All of these things can be disabled on the 3PARD control panel tab.

The 3PARD diagram itself is a histogram that uses the default color map also used for PRPDs. Unlike with PRPDs, you cannot currently change the color map used for the 3PARD.

When PD events would appear in the 3PARD, but would be located outside the currently visible part of it, the PD event is counted on the edge or corner beyond which it would appear in the diagram. This is similar to how the PRPD tracks PD events that fall outside its visible area. The color of the edges and corners depends on the number of PD events that would appear beyond it, and uses the same color map as the interior of the 3PARD diagram. When the color of an edge or corner changes, it briefly flashes, to bring that change to your attention.

While you can control the visible area of the 3PARD diagram from the 3PARD control panel tab, you can also use the mouse to change the view area. Keeping the CTRL key pressed while dragging the mouse over the 3PARD diagram will move the center of the diagram. If you move the mouse wheel while the



¹⁰Plotting the unfiltered signal in the FFT view when using analysis filters is not supported.

¹¹which is plotted using the primary-selected channel's color

mouse hovers over the 3PARD diagram, and you have the CTRL key held, you can zoom into or out of the diagram. **Note** that changing the visible area of the diagram will clear it.

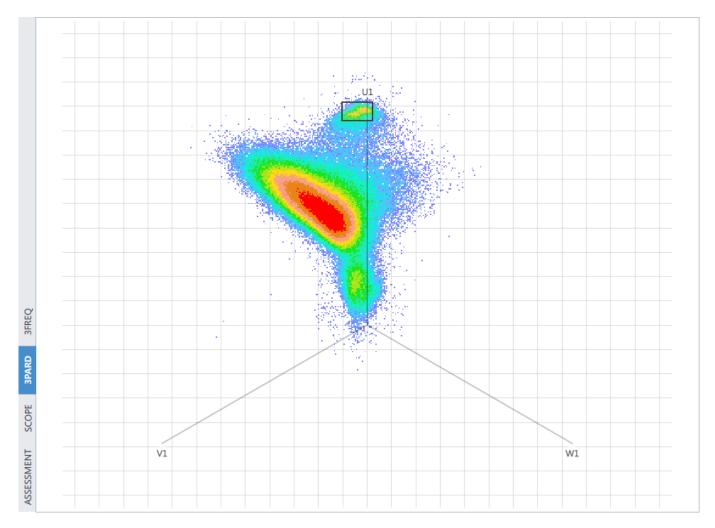


Figure 14.14: The 3PARD diagram

You also control 3PARD back transformations from the 3PARD diagram, by drawing rectangles over the clusters in the 3PARD diagram that you want to back-transform. You can draw multiple rectangles using the left mouse button. You can also move rectangles you have drawn, by clicking inside them and dragging them around. To remove a rectangle, simply double-click it.

Note that 3PARD is not currently supported for any channels that use *mV PD* mode, which includes UHF 800 devices.

14.4.4 The 3FREQ view

The *3FREQ view* shows the 3FREQ diagram for the currently primary-selected channel group, if 3FREQ processing has been enabled for it. It will show a message if 3FREQ processing is not enabled, and may indicate that 3FREQ processing is not currently available for the primary-selected channel group. This can happen for MPD 600 channels if RIV measurements are enabled, or if high bandwidth mode is enabled for the channel. 3FREQ processing is also never available for gating channels. When 3FREQ



processing is disabled but is available, the message will include a link to the 3FREQ control panel tab, where you can control 3FREQ processing.

The 3FREQ diagram is very similar to the 3PARD diagram. As with 3PARD, by default the 3FREQ view will show the axes (the "star" itself) and label them with the center frequencies used to construct the 3FREQ diagram. Also like with 3PARD, by default the grid is also enabled. All of these things can be disabled on the 3FREQ control panel tab.

Like the 3PARD diagram, the 3FREQ diagram is also a histogram that uses the default color map also used for PRPDs, which you cannot currently change.

The 3FREQ diagram also visualizes PD events that fall outside the visible area by coloring its edges and corners, like the 3PARD diagram does.

While you can control the visible area of the 3FREQ diagram from the 3FREQ control panel tab, you can also use the mouse to change the view area. This works exactly as with the 3PARD view: keeping the CTRL key pressed while dragging the mouse over the 3FREQ diagram will move the center of the diagram. If you move the mouse wheel while the mouse hovers over the 3FREQ diagram, and you have the CTRL key held, you can zoom into or out of the diagram. **Note** that changing the visible area of the diagram will clear it.

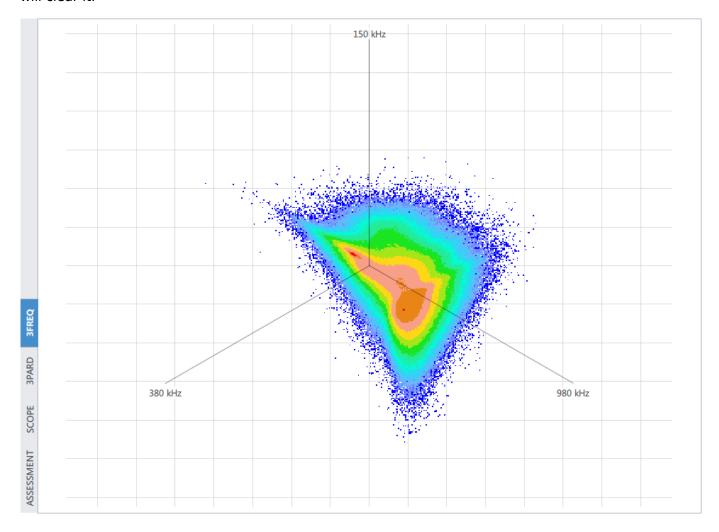


Figure 14.15: The 3FREQ diagram



You also control 3FREQ back transformations from the 3FREQ diagram, just like you do with 3PARD diagrams. By drawing rectangles over the clusters in the 3FREQ diagram that you want to back-transform. You can draw multiple rectangles using the left mouse button. You can also move rectangles you have drawn, by clicking inside them and dragging them around. To remove a rectangle, simply double-click it.

Note that like 3PARD, 3FREQ is also not currently supported for any channels that use mV PD mode, which includes UHF 800 devices.

14.4.5 The trend view

The trend view can plot the readings of various measurements over time, allowing you to see trends in the measurements. Prior to version 1.40 of the MPD Suite, the trend view always showed a single measurement quantity over time, from the primary-selected channel group. Since version 1.40 of the MPD Suite, you can view a single quantity from any number of channel groups, and the view is no longer bound to the primary-selected channel group. Instead, there is a global selection of channels to plot trend data from.

The following measurements can be trended:

- the largest repeatedly occurring PD magnitude, designated as Q_{IEC} / Q_{WTD},
- the number of PD pulses per second that contributes to the largest repeatedly occurring PD magnitude, designated as for IEC,
- the total PD rate,
- the minimum absolute apparent charge of all detected PD events, measured over the reference time t_{Ref} , designated as $|Q|_{Min}$,
- the average absolute value of the largest repeatedly occurring PD magnitude, measured over the reference time t_{Ref} , designated as $|\mathbf{Q}|_{Avg\ IEC}$,
- the average absolute apparent charge of all detected PD events, measured over the reference time t_{Ref} , designated as $|\mathbf{Q}|_{\mathbf{Avg}\ \mathbf{PD}}$,
- the maximum absolute apparent charge of all detected PD events, measured over the reference time t_{Ref} , designated as $|Q|_{Max}$,
- the quadratic rate, designated as **D**,
- the discharge power, designated as P_{Dis},
- the average discharge current, designated as I_{Dis},
- the weighted PD voltage during mV PD measurements, designated as $V_{PD\ WTD}$,
- the peak PD voltage during mV PD measurements, designated as $\hat{\mathbf{V}}_{PD}$,
- the average PD voltage during mV PD measurements, designated as V_{PD},
- the average absolute value of the weighted PD voltage, measured over the reference time t_{Ref} during mV PD measurements, designated as $V_{PD\ Avg\ WTD}$,
 • the maximum recurring PD voltage during mV PD measurements, designated as $V_{PD\ MRP}$,
- the number of PD pulses per second that contribute to the weighted PD voltage during mV PD measurements, designated as f_{V PD WTD},
- the dominant frequency of the signal at the AC/V input, designated as f_{AC},
- the RMS voltage of the signal at the AC/V input, designated as V_{RMS},
- the peak voltage of the signal at the AC/V input, designated as $\hat{\mathbf{V}}/\sqrt{2}$,
- the DC component of the voltage at the AC/V input, designated as V_{DC},
- the RMS current of the signal at the AC/V input, designated as I_{RMS},
- the peak current of the signal at the AC/V input, designated as $\hat{\mathbf{I}}/\sqrt{2}$,
- the DC component of the current at the AC/V input, designated as I_{DC},



¹²as in, it applies independent of the channel group selection

- ullet the RMS voltage of the RIV measurement, designated as $oldsymbol{V_{RMS_filtered}}$,
- the peak voltage of the RIV measurement, designated as $\hat{V}_{filtered}/\sqrt{2}$, and
- the quasi-peak voltage of the RIV measurement, designated as RIV,
- the pulse rate of pulses that contribute to the RIV quasi-peak voltage, designated as RIV pulse rate.

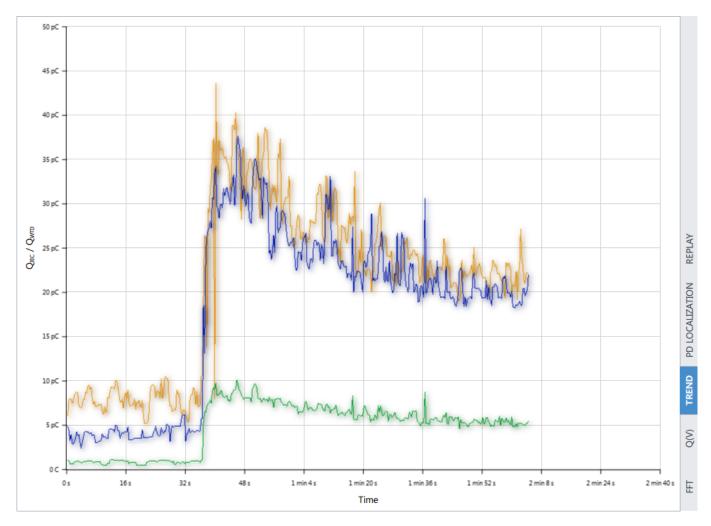


Figure 14.16: The trend diagram

You configure trending on the *Trend* control panel tab. Independent of what you select there as the measurement to be plotted in the trend view, all values are recorded when trend capturing is enabled. You can switch between different measurements and view their history at any time.

Trending works by recording a single data point for each measurement at a configurable interval 13 . The decimation policy controls how the data point is generated at each interval:

- The average setting will take the average of all measurement readings over the interval,
- the *minimum* setting will use the smallest value of all measurement readings taken within the interval,
- the *maximum* setting will use the largest value of all measurement readings taken within the interval,



 $^{^{\}rm 13} the$ interval can be configured between 300 ms and 1 h

- the *median* setting will use the median¹⁴ value of all measurement readings taken within the interval,
- the single sample setting will take the very last reading taken during the interval.

You can enable auto-scaling for both the horizontal and the vertical axes on the control panel tab. However, when auto-scaling is disabled, you can use the mouse to change the scaling and position of the plot. To move the plot, you drag the mouse over the axis (horizontal or vertical) using the left mouse button. To re-scale the plot, you drag the mouse over the axis with the SHIFT key held.

The trend diagram uses the channel group colors for the plots it displays.

Since version 1.40 of the MPD Suite, you also select the channels whose data should be trended in the trend plot in the *Channels to show trend data for* section of the *Trend* control panel tab. You need to select at least one channel for the diagram to show any plots. If no channel is selected, a warning message is shown in the trend diagram area alerting you to that fact.

14.4.6 The FFT view

The FFT view shows the frequency spectrum of trigger shots. As such, it is tied to the PD scope view, and will only contain any data when the PD scope view has triggered. As of version 1.40 of the MPD Suite, this includes the trigger shots from the primary-selected channel as well as the trigger shots from any channels that have been additionally enabled to be shown in the scope and FFT diagram. The horizontal axis represents the frequency of the spectrum, while the vertical axis represents the spectral energy of the signal, given in dBmV (a voltage relative to 1 mV).

You control the FFT view from the SCOPE & FFT control panel tab, including enabling or disabling autoscaling for the dBmV (vertical) axis. If auto-scaling is not enabled, you can also use the mouse to reposition and re-scale the dBmV axis. This is always possible for the frequency axis. To re-position the plot along the axis, you drag the mouse across the axis with the left button. To re-scale the plot along the axis, you keep the SHIFT key held while you drag the mouse across the axis.

The FFT view also supports taking *snapshots*. Up to 5 snapshots of the FFT signal can be captured from the *SCOPE* & *FFT* control panel tab's FFT diagram settings section. Captured snapshots are displayed in the FFT view behind the "live" plot, in progressively lighter shades of gray. This facility can help with finding the SNR^{15} of the PD input signal, when capturing a noise signal and a PD signal as a snapshot, respectively. Captured snapshots are cleared by pressing the *clear FFT snapshots* button on the *SCOPE* & *FFT* control panel tab.



¹⁴if all readings taken over the interval are sorted by value, the median is the central value

¹⁵Signal-to-Noise Ratio

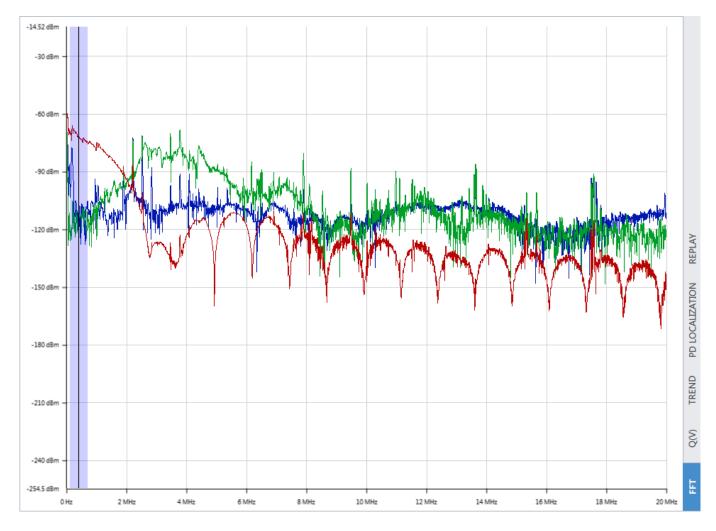


Figure 14.17: The FFT view

Like the PD scope view, the FFT shows a *no trigger!* warning when the PD scope has not triggered for about 2 s. It also shows a *triggered* notification when the PD scope has triggered. These notifications can also be disabled on the control panel tab.

When time-domain integration is disabled, the FFT view shows the PD filter frequency bands that are currently in use. This applies to the f_m filter as well as the $f_{AUX\,I}$ and $f_{AUX\,II}$ filters when 3FREQ is enabled. The center frequencies are represented by cursors, that can also be dragged with the mouse to change the frequencies, and the bandwidths are visualized as shaded areas around the cursors. Any filter band that contributes to the PD measurements (PRPDs, largest repeatedly occurring PD magnitude, etc.) is shaded in blue; other filter bands are shown in gray. Note that this means that the Combined 3FREQ filter for PRPD and PD measurements setting must be enabled for all three frequency bands to be shaded in blue.

Note that the FFT view is only available for MPD 800 and MPD 600 devices, but not for UHF 800 devices. UHF 800 devices supply the *spectrum* and *sweep* views instead.



14.4.7 The $Q(V)/V_{PD}(V_{AC})$ view

The Q(V) view allows plotting the charge measurement of the primary-selected channel group over the voltage of the PD/AC synchronization source. This can be used to determine the PD inception and extinction voltage of a test subject during a high-voltage test. In mV PD mode, the diagram is called $V_{PD}(V_{AC})$ instead and plots the PD voltage over the configured PD/AC synchronization voltage.

With some types of PD you expect a hysteresis between inception and extinction of PD as you perform a voltage test: PD will usually set in at a higher voltage level than it will cease at. This will be very clearly seen in the Q(V) diagram, and can be used to verify that PD activity actually originates within the test subject (rather than being caused by some other, outside effect).

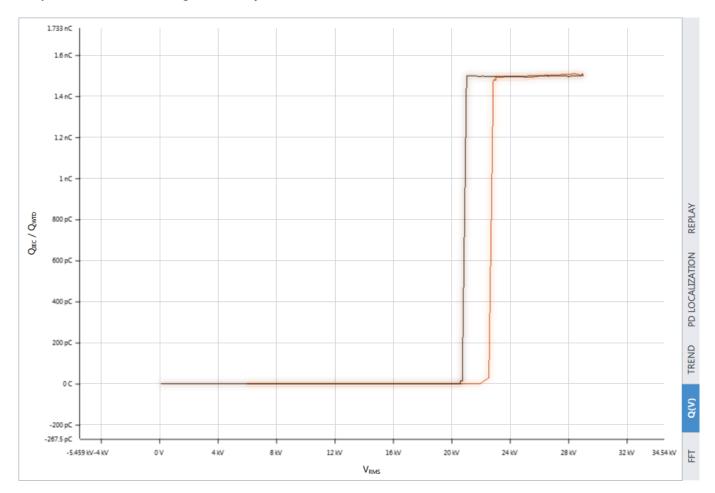


Figure 14.18: The Q(V) view

Plots in the Q(V) diagram will look different depending on whether the voltage signal was increasing or decreasing when the diagram was plotted. The leg of the plot generated when the voltage was rising will be drawn in a lighter shade of the channel group color, while the falling voltage section will be drawn in a darker shade of the same color. When it is not clear yet to the software whether the measurement is on a rising or falling voltage branch, the plot will be drawn in a medium shade of the channel group color; however, as soon as a direction has been reliably detected, the color will be updated to match that detection result.

You control the Q(V) diagram from the Q(V) control panel tab. This is also where you enable capturing of

OMICRON

a Q(V) diagram for all config-selected channel groups. You can also configure the charge quantity (one of largest repeatedly occurring PD magnitude, denoted as Q_{IEC} / Q_{WTD} , the average absolute apparent charge, denoted as $|Q|_{Avg}$, or the maximum absolute apparent charge, denoted as $|Q|_{Max}$) and the voltage quantity (one of RMS voltage, denoted as V_{RMS} , peak voltage, denoted as V_{DC}) to plot.

You can also configure the scale and offset for each of the axes of the plot there, or enable auto-scaling for either or both axes. However, when auto-scaling is disabled for any axis, you can also use the mouse to re-position or re-scale the plot directly from the Q(V) view. To re-position the plot, simply drag the mouse across the corresponding axis (using the left mouse button). To re-scale the plot, drag the mouse with the left button across the axis while holding the SHIFT key.

14.4.8 The UHF sweep diagram

When measuring with a UHF 800 device during UHF measurements, it is often useful to get an overview over the frequency spectrum that is supported by the UHF measurement. To do this, you can perform a UHF frequency sweep. The result of the sweep is shown in the UHF sweep diagram.

The sweep diagram shows the minimum and the maximum energy of the signal picked up by the UHF 800's UHF input as the mixer frequency is swept across the configured frequency range. The diagram helps with selecting suitable frequency ranges for the PD measurement, while avoiding parts of the frequency spectrum that are affected by radio frequency sources. At points in the spectrum where the minimum and the maximum of the sweep view have a similar value, it is likely that there is a continuous signal at that frequency, such as a radio carrier. Pulse-shaped signals typically exhibit different minimum and maximum peak values. Since PD is a transient (pulse-shaped) phenomenon, it should be distinguishable from continuous signals in the spectrum.

Optionally, the sweep diagram can show the absolute peak value across the entire frequency sweep. This is configured on the UHF 800 tab of the control panel, under the *Advanced settings* section.



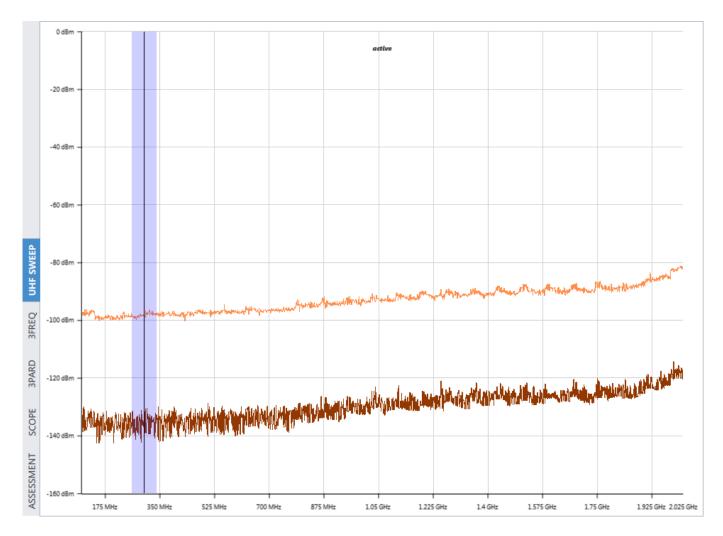


Figure 14.19: The UHF sweep diagram

Since version 1.40 of the MPD Suite, the sweep diagram also indicates the 80-MHz wide frequency range that is shown in the spectrum diagram using a light-blue shade (similar to how the FFT view indicates the PD measurement range on the MPD 800 and MPD 600.), as well as the frequency range used for PD measurements (as a light-gray shade).

Note that the UHF sweep diagram is only available when a UHF 800 device is primary-selected.

14.4.9 The UHF spectrum diagram

The UHF spectrum diagram shows the frequency signal around the current mixer frequency during UHF PD measurements. The UHF 800 is capable of showing approximately 80 MHz worth of frequency data around the configured mixer setting. Note that this applies also when wideband mode is enabled, because the spectrum has an independent signal path from the PD signal.

The spectrum view can give a good detail view on the frequency range that you are currently measuring PD at. When a UHF frequency sweep is *not* in progress, it continuously shows the spectrum of the 80 MHz range around the mixer frequency. On the other hand, when sweeping, it is essentially a "zoom" view into the sweep diagram, and is updated along with that. Together, both diagrams make it convenient to

OMICRON

investigate different parts of the frequency spectrum and select the most appropriate frequency range for the PD measurement.

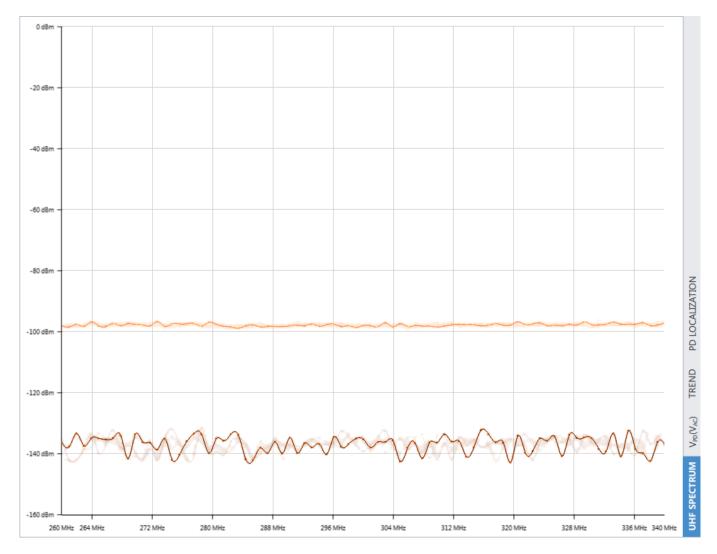


Figure 14.20: The UHF spectrum diagram

Since version 1.40 of the MPD Suite, the spectrum diagram also indicates the frequency range used for PD measurements if narrowband measurements are enabled. To this effect, a light-gray shade is shown in the spectrum diagram around the PD measurement center frequency, with a width that corresponds to the configured measurement bandwidth.

Note that the UHF spectrum diagram is only available when a UHF 800 device is primary-selected.

14.4.10 The replay diagram

The replay diagram is only available when a dataset file has been loaded. In that case, it is by default available in the lower-right diagram section. Additionally, it is also visible in the *REPLAY* sub-tab of *RECORD/REPLAY* control panel tab. Using profiles, it can also be enabled for the lower-left diagram section.





Figure 14.21: The replay diagram

The replay diagram plots the readings of a *PD magnitude* and an *AC magnitude* from the loaded dataset file over time, similar to a trend diagram that contains two different quantities. By default, the PD magnitude is set to the Q_{IEC} reading (or Q_{WTD} if the measurement settings were not compliant with the recommendations from the IEC 60270 standard at the time the reading was made), and the AC magnitude is set to the V_{RMS} reading for the primary-selected channel group. You can change the PD and AC magnitudes to be plotted in the *Replay diagram settings* section on the *REPLAY* sub-tab of the *RECORD/REPLAY* control panel tab. Since version 1.30 of the MPD Suite, you can also disable plotting either quantity by selecting *disabled*.

The replay diagram features two cursors that allow you to configure the replay range. The *replay start* cursor on the left has a handle that points to the right, while the *replay end* cursor on the right has a handle that points to the left. Dragging the replay start cursor will also automatically apply all settings that were in effect at the selected time during recording, and will update the *measured values display* to show the measurement readings reported at the selected time.

Since version 1.30 of the MPD Suite you can move both cursors simultaneously by holding the SHIFT key pressed while dragging either cursor. Note though that if you reach the beginning or the end of the dataset file with either cursor while dragging both cursors, the replay range will be adjusted accordingly (i.e. you are not prevented from moving further towards the end of the file; instead, the replay range will

be shortened).

When a replay is in progress, the replay diagram will shade the area that was selected as the replay range when the replay was started. You are free to change the start and stop cursors during replay, but those changes will not take effect until you stop replay and restart again. Additionally, a cursor will show the current position in the file as it is being replayed. While you cannot move this cursor with the mouse, hovering over it will show you the current readings of the configured PD and AC magnitudes that were recorded with the dataset file at the current replay position. It will also show you the current replay time offset in the file, as well as the absolute date and time of the current replay position.

On the top-right of the replay diagram there is a small icon (). Clicking this button will open a separate window that contains the replay diagram along with the replay controls also visible at the top of the main diagram area and in the *REPLAY* sub-tab of the *RECORD/REPLAY* control panel tab.

14.5 The measured values display

The measured values display is the area of the main window that is located between the upper and lower diagram views to the left and the control panel to the right. It shows measurement readings and status information. You can customize the measured values display extensively, including by re-ordering displayed elements, hiding elements, and resizing the elements.

The measured values display can show the following elements:

- The largest repeatedly occurring PD magnitude value, specified as Q_{IEC} or Q_{WTD}, depending on whether the PD measurement settings follow the recommendations from the IEC 60270 standard, along with the configured center frequency and bandwidth of the primary-selected channel group,
- The number of PD events that are contributing to the PRPD of the primary-selected channel group, and the duration over which the PRPD has been constructed thus far,
- The total *PD rate* of the primary-selected channel group, i.e. the total number of PD pulses seen per second,
- The RMS voltage and current (V_{RMS} and I_{RMS}), the peak voltage and current ($\frac{\hat{V}}{\sqrt{2}}$ and $\frac{\hat{I}}{\sqrt{2}}$), the DC voltage and current (V_{DC} and I_{DC}), and the dominant frequency (f_{AC}) of the signal at the primary-selected channel group's AC input,
- The RMS voltage and current (V_{RMS} and I_{RMS}), the peak voltage and current ($\frac{\hat{V}}{\sqrt{2}}$ and $\frac{\hat{I}}{\sqrt{2}}$), the DC voltage and current (V_{DC} and I_{DC}), and the dominant frequency (f_{AC}) of the current channel group's PD/AC synchronization source,
- The RIV quasi-peak voltage, RIV peak voltage, and RIV RMS voltage, as well as the RIV pulse rate of the primary-selected channel group,
- the *current compliance status* of the primary-selected channel group's PD measurement with the IEC 60270 and IEEE C.57.113 standards,
- The percentage of AC phases gated via phase gates on the primary-selected channel group's PRPD, i.e. the portion of an AC cycle where PD measurement is suppressed due to phase gates.
- The percentage of PD activity suppressed on the primary-selected channel group due to channel gating, 3PARD back transformation, 3FREQ back transformation, and phase/amplitude gating on PRPDs,
- The average value of the largest repeatedly occurring PD magnitude, over the reference time, designated as $|Q|_{Avg\ IEC}$,
- The average absolute charge value of all PD events measured on the primary-selected channel group over the reference time, designated as |Q|_{Avg PD},



- The maximum absolute charge value of all PD events measured on the primary-selected channel group over the reference time, designated as $|Q|_{Max}$,
- The *minimum absolute charge* value of all PD events measured on the primary-selected channel group over the *reference time*, designated as $|Q|_{Min}$,
- The average discharge current resulting from the PD activity on the primary-selected channel group, measured over the reference time, designated as I_{Dis},
- The *quadratic rate* of the PD activity on the primary-selected channel group, measured over the *reference time*, designated as D,
- The *discharge power* of the PD activity on the primary-selected channel group, measured over the *reference time*, designated as P_{Dis},
- The *IEC-relevant PD event rate* of the primary-selected channel group, i.e. the number of PD pulses per second that contribute to the largest repeatedly occurring PD magnitude reading, designated as $f_{O\ IFC}$,
- the value of the two PD/DC counters, along with a description of each of the counter's parameters,
- the peak PD voltage (available only during mV PD measurements), designated as \hat{V}_{PD} ,
- \bullet the average PD voltage (available only during mV PD measurements), designated as $\overline{V_{PD}}$, and
- The RMS voltage of the PD filter output of the primary-selected channel group, designated as $V_{PD\;filter\;(RMS)}$ (useful for type-testing).

By default, a subset of these elements is shown, but you can control which you want to see by entering *edit mode*. You do this by clicking the cogwheel symbol at the top right of the measured values display. Once in edit mode, all entries appear, even those that were hidden previously, and there is a checkbox next to each entry that controls whether the entry is shown in normal mode. Additionally, you can reposition the elements by dragging them with the mouse.

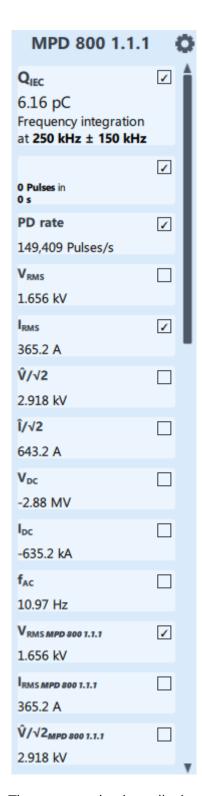


Figure 14.22: The measured values display, in edit mode

It is also possible to resize every text within each element (including the title), by holding the CTRL key while moving the mouse wheel when the mouse is hovered over the text you want to resize. When you press and hold the CTRL key, the text element that will be resized is shaded in yellow. You can restore the default size of the text element by double-clicking the text element with the CTRL key held. You can also



reset the sizes of all texts in all elements by double-clicking the heading of the measured values display (at the top, which shows the name of the primary-selected channel group) with the CTRL key held.

Finally, it is possible to change the width of the measured values display by dragging the splitter that separates it from the upper and lower diagram views. Using the same splitter, you can also hide the measured values display altogether, by dragging the splitter further, beyond the minimum size of the view, and keeping dragging until you reach the middle of the view. The view will then disappear. In order to make it visible again, you have to drag the splitter to the left by about half the minimum width of the view.

Chapter 15

The control panel

The control panel is the area of the main measurement window where the behavior of the software and of the connected MPD devices is configured. It consists of a number of tabs, which each correspond to a group of related settings.

Each of these tabs is described in detail in the following sections.

15.1 The SETUP & CALIBRATION tab

The Setup & calibration tab allows you to configure the current measurement setup, which consists of describing the measurement setup and calibrating it for charge, RIV, and AC measurements. Calibration is necessary to ensure that measurements produce the correct physical values.



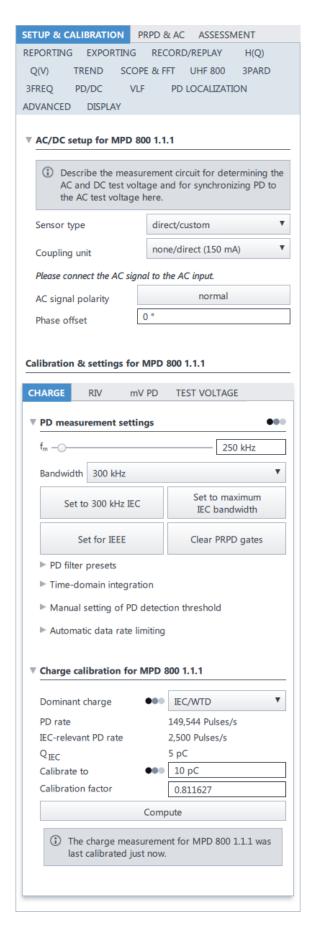


Figure 15.1: The SETUP & CALIBRATION tab of the control panel

15.1.1 AC/DC setup

The AC/DC section provides a facility to describe to the MPD Suite the measurement setup that is currently in use for AC/DC measurements. This description is made per channel and defines where in the measurement circuit the corresponding channel is connected. With MPD 800 and UHF 800 devices, you configure the *type* of sensor at which the MPD channel measures, the actual sensor *device*, and the *coupling unit* used to connect the MPD's input channel to the sensor. With MPD 600 devices, only the coupling unit can be configured.

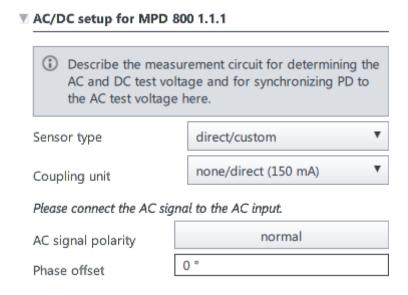


Figure 15.2: The AC/DC setup section

15.1.1.1 AC/DC setup for MPD 800 and UHF 800 devices

The Sensor type selection box offers the options direct/custom, Coupling Capacitor, $HFCT^1$, VT and Rogowski coil. Direct/custom is used when the MPD 800 or UHF 800 device is connected to a type of sensor not listed here, or if there is no sensor in the test circuit. Depending on the chosen sensor type, the Device selection box offers specific devices that are known to the MPD Suite.

For coupling capacitors, these include OMICRON's *MCC 112-A*, *MCC 117-C*, *MCC 124-A*, *MCC 124-C*, *MCC 205*, *MCC 205-L*, *MCC 210*, and *MCC 210-L*. You can also indicate that a bushing measurement tap is used as the coupling capacitor, or that a custom capacitor is used. In both of the latter cases, you must specify the series capacitance of the actual capacitor being used. The parallel capacitance is always assumed to be 0.

For HFCTs, the list of known devices include OMICRON's MCT 120 and MCT 100. You must specify the capacitance of the test object in the Test object capacitance (estimated or actual) field. Use an estimated value if you don't know the exact capacitance. If you specify 0 here, the test object capacitance is assumed to be ∞ (infinity).

No actual devices are offered when VT is selected. You need to enter the turn ratio of the VT you use in the *Ratio* field.



¹High-Frequency Current Transformer

For Rogowski coils, the list of devices offered include the *RT2000*, and the *ACP3005* for 30 A, 300 A, and 3000 A, respectively.

For the *direct/custom*, *Coupling capacitor*, and *HFCT* sensor types you must also specify the coupling unit used to connect the MPD 800 or UHF 800 device to the sensor. The units offered for the *direct/custom* and *Coupling capacitor* sensor types include OMICRON's *CPL 1*, *CPL 2*, *CPL 542* for 500 mA, 1.2 A, and 2 A, respectively, and *CPL 543*. When the sensor type is *Coupling capacitor* and the device is *Bushing tap*, you can additionally choose OMICRON's *OMS 844* coupling device. For the *direct/custom*, *Coupling capacitor* and *HFCT* sensor types you can also choose the *internal CPL (150 mA)*, which enables the quadripole built into the MPD 800 and UHF 800 devices. Also offered are the *none/direct (150 mA)* and *custom* options. Both configure the model to not use a quadripole. The *none/direct (150 mA)* option should be used when connecting the MPD directly to the test circuit. The *custom* option should be used when connecting a different coupling unit that is not listed in the options. In this case, because the coupling unit is not modeled, the MPD Suite cannot account for any phase shift introduced by the coupling unit, and will report that fact below the *Coupling unit* section. When using either of these coupling options, you must make sure that the measurement current applied to the AC input will never exceed 150 mA, and that the signal applied to the PD input never exceeds a power of 0.5 W, otherwise the MPD device may be damaged.

15.1.1.2 Measurement setup for MPD 600 devices

Only the *Coupling unit* selection box is available and allows you to choose whether the internal CPL is enabled or not. The internal CPL is the quadripole built into the MPD 600. Select *none* if you are using an external coupling device such as the OMICRON *CPL 542*.

15.1.1.3 Advanced measurement setup options

For both MPD 800 and MPD 600 devices, a *connection message* below the selection options indicates how the MPD channel must be connected to the test circuit. The message depends on the actual configured setup and may indicate that the *OMICRON 100 k\Omega V-to-AC adapter* must be used to connect your MPD's AC channel to the test circuit. In order to ensure accurate measurements, it is important that you follow the instructions from the message exactly.

When sensor and coupling device are configured, you can additionally choose to invert the AC signal for measurement purposes, for example if the connections of a sensor or coupling device are inverted (high-voltage on ground input and vice versa). This setting is named AC signal polarity and offers the choices normal and inverted. The effect of choosing inverted is that the polarity of the AC signal is inverted in the AC plots shown in the PRPD.

Finally, the measurement setup control allows you to specify an arbitrary *phase offset* that should be applied to AC measurements. This can be used to express more complicated setups that introduce a known phase shift (such as custom CTs or CVTs). When the phase offset is given here, the AC signal is shifted accordingly, such that the AC plot in the PRPD appears correct, and PD events are attributed to the correct phase positions in the PRPD.

Below the measurement setup section, four sub-tabs are available that allow you to perform calibrations of all PD (charge or voltage), AC (test voltage and current) and RIV (voltage) measurements made with this device.



15.1.1.4 Additional note about quadripoles

For MPD 600 devices, which have a voltage input, the input signal must not exceed 50 V RMS, independent of whether the internal quadripole is enabled or not. On the other hand, MPD 800 devices nominally support input currents of up to 150 mA on their AC inputs, but with the internal quadripole enabled, they can be operated up to 250 mA. This opens a window for a possible issue: If you use the MPD 800's internal quadripole and run a test that results in a measurement current in excess of 150 mA, and you turn off the internal quadripole in the MPD Suite while the measurement current is applied to the MPD 800's PD input, you risk damaging the device. Therefore, the MPD Suite will issue a warning message whenever any configuration change you made would lead to the internal quadripole being disabled on any MPD 800. The warning message will give you the option to skip disabling the internal quadripole, so that the MPD 800 device will not be subjected to possibly damaging overcurrents.

In addition to the obvious case of selecting any option from the *Coupling unit* selection box other than *internal CPL (150 mA)*, the internal quadripole will also be disabled when you choose *VT* or *Rogowski coil* as the sensor type. Bear in mind that resetting the configuration will also disable the internal quadripole, and loading a previously saved configuration or switching to a different profile (with different settings) may also disable the internal quadripole. The MPD Suite will detect when the internal quadripole would be disabled by *any* action and will show the warning message before actually performing the action, allowing you to intercede and avoid disabling the internal quadripole.

15.1.2 Charge sub-tab

The sub-tab named *Charge* allows you to configure the PD measurement settings as well as perform charge calibrations.



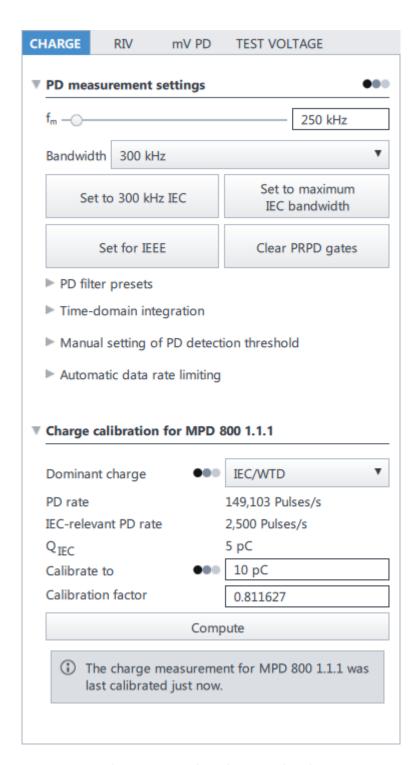


Figure 15.3: The Charge sub-tab

15.1.2.1 PD measurement settings

This section controls how PD events are measured. These settings apply to all *config-selected* channel groups.

PD measurement settings determine which parts of the PD input signal are used to compute the apparent charge of the PD event. This affects all charge-related measured quantities (such as the Q_{IFC} value) as

well as the PRPD.

In most cases, this will simply show the PD filter's center frequency (f_m) and bandwidth (Δf). However, if 3FREQ processing is enabled on the 3FREQ tab, and the combined filter is enabled, this will also allow you to change the two auxiliary filters' center frequencies f_{AUX} and f_{AUX} .

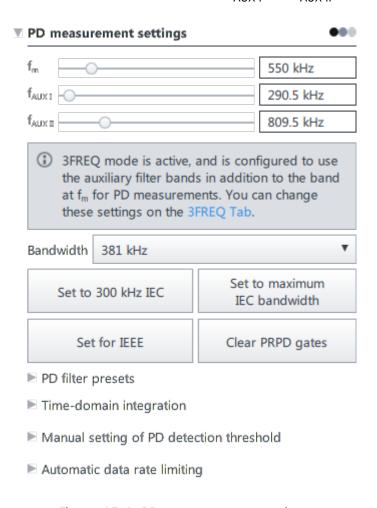


Figure 15.4: PD measurement settings

Center frequencies can be chosen via slider and through a value edit. Both controls are bound to each other; when one is changed the other is updated accordingly. The slider can be dragged with the mouse from the minimum possible setting for a certain selected bandwidth to the maximum possible setting, which varies by device type (20 MHz for MPD 600 and 62.5 MHz for MPD 800). The value edit allows entering the frequency directly, including the use of units and prefixes. Additionally, center frequencies can be chosen via cursors on the FFT plot. **Note** that the sliders use logarithmic scaling, i.e. there is more space available to select lower frequencies than higher frequencies.

For MPD 600 devices, the high bandwidth mode setting controls which PD filters are used to measure PD. When this setting is enabled, the MPD 600 device will use a different set of PD filters that allow up to 3 MHz of bandwidth, but do not support 3FREQ processing and will also not work with any devices connected to the MPD 600's AUX ports. When disabled, the newer PD filters will be used, and no such restrictions apply. This setting is not needed for MPD 800 devices and will not appear when an MPD 800's channel group is primary-selected.



Bandwidths are presented via a drop-down selection box. The drop-down box contains a list of the measurement bandwidths supported by all config-selected channel groups. Choosing a bandwidth may change the center frequency settings as well: if the current center frequency setting is less than the allowed minimum setting for the newly selected bandwidth, the center frequency setting is adjusted accordingly. **Note** that when multiple different types of MPD channel groups are *config-selected*, such as one MPD 800 and one MPD 600, the list of bandwidths shown in the drop-down selection box will represent the *intersection* of the available bandwidths for all config-selected channel groups. In some cases, that intersection can be empty, in which case no selection is possible until the config-selection is changed.

Below the actual measurement settings there is a row of buttons that allow configuration of the PD measurement filters for some standard use cases.

The Set to 300 kHz IEC button configures the measurement on all config-selected channel groups to be compliant with IEC 60270. To this effect, it selects a center frequency of 250 kHz and a bandwidth of 300 kHz, and turns 3FREQ processing off.

The Set to maximum IEC bandwidth button also configures all config-selected channel groups for IEC 60270 compliance, but it uses the entire bandwidth allowed by the IEC 60270. It sets the lower frequency limit f_1 to 100 kHz and the upper frequency limit f_2 to 1 MHz², resulting in a PD filter with an effective bandwidth of 900 kHz.

The Set for RIV button (available only when an MPD 600 is currently primary-selected) 3 chooses settings that are compatible with CISPR 16-1-1 and NEMA 107. It selects a center frequency of 1 MHz and a bandwidth of 9 kHz, and also turns off 3FREQ processing.

The Set for IEEE button (available only when an MPD 800 is currently primary-selected) chooses settings that are compatible with the IEEE C.57.113 standard. It selects a center frequency of 200 kHz and a bandwidth of 200 kHz. **Note** that this setting is also compatible with IEC 60270.

The Clear PRPD gates button will remove any phase-/amplitude gates for the config-selected channels.

Instead of manually configuring PD event detection, you can also select predefined *PD filter presets* from the drop-down selection box under the *PD filter presets* expander. When a preset is selected, all other PD filter controls are disabled, including center frequency and bandwidth controls, time-domain integration settings and the 3FREQ settings on the 3FREQ tab. The available presets vary by device type, and include a setting amounting to the equivalent of a 900 kHz filter which enables the use of the maximum frequency range allowed under IEC 60270⁴, and a number of settings with different effective bandwidths that prevent negative superposition when doing double-pulse testing (for example on cables).

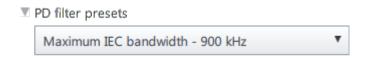


Figure 15.5: PD filter presets

The *Enable time-domain integration* expander allows switching the PD detection to time-domain integration, as opposed to *frequency-domain integration*, which is the default. With frequency-domain integration, the PD input signal is filtered through a band-pass filter described by a center frequency and a



 $^{^{2}}$ equivalently, f_{M} is set to 550 kHz and the bandwidth is set to 900 kHz

³The MPD 800 allows simultaneously measuring RIV and IEC 60270-compliant PD with independent parameters.

⁴this preset is the same as the settings configured by the *Set to maximum IEC bandwidth* button

bandwidth. Only the frequency components spanning the configured bandwidth around the configured center frequency of the original signal are used to compute the magnitude (charge) of any detected PD events. With time-domain integration, the entire input signal is used to compute the magnitude of PD events. Instead of specifying a center frequency and bandwidth, you specify a *start time* ($\mathbf{t_1}$) and an *end time* ($\mathbf{t_2}$) which define the duration of the signal around the PD event detection time that should be used to compute the PD event's magnitude.

Enabling time-domain integration will disable the controls dedicated to configuring frequency-domain integration, including the center frequency sliders and value edits, the bandwidth selection box and the 3FREQ processing options on the 3FREQ tab. Presets, however, are still available, and take precedence when selected.

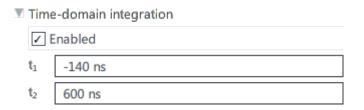


Figure 15.6: Time domain integration settings

The Manual setting of PD detection threshold expander allows manual configuration of the PD detection threshold set on the MPD device. If this option is disabled, the PD detection threshold for the config-selected channel groups is set to coincide with the lower edge of the channel group's PRPD (as configured via the PRPD and PD event display settings section). If it is enabled, the user can specify the detection threshold via the value edit contained in the expander. The expander also contains an option to show a threshold cursor when the threshold is set manually. This cursor will appear in the corresponding channel group's PRPD diagram and is visible if the threshold is higher than the PRPD's lower edge and lower than the PRPDs upper edge. The threshold cursor can be used to adjust the PD threshold setting via the mouse, directly from the PRPD.

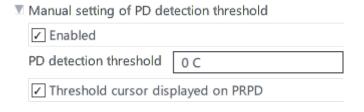


Figure 15.7: Manual PD threshold setting

The Automatic data rate limiting expander controls the behavior of the automatic data-rate limiter built into MPD 800 and UHF 800 devices. This feature is not available on MPD 600 devices. When enabled, the device will automatically limit the data rate of PD events it transmits to the PC if the available bandwidth on the FO link is not enough to transmit every detected PD pulse, but in a way that prioritizes relevant PD pulses. The limiter works by estimating the entropy of the PD data stream and adjusting an internal "hidden" PD threshold such that the most relevant pulses can all be transmitted, at the expense of less relevant pulses such as noise, which will be partially suppressed. In contrast, when this option is disabled, the device will attempt to transmit every PD event to the PC, and will stochastically drop PD events when that is not possible due to limited FO link bandwidth. As a result, it will faithfully reproduce the statistical



distribution of PD pulses, including noise, but may fail to transmit some relevant PD pulses (such as calibrator pulses or Corona PD).



Figure 15.8: Automatic data rate limiting setting

15.1.2.2 Charge calibration settings

The charge calibration section allows you to calibrate charge-based PD measurements and provides access to some configuration options pertaining to charge calibration:

- The Dominant charge setting selects which charge quantity should be calibrated. The following options are available: IEC/WTD (largest repeatedly occurring PD magnitude), AVG IEC (average of the largest repeatedly occurring PD magnitude), and MAX (maximum absolute charge of PD events). AVG IEC and MAX consider the most recent t_{Ref} time interval as configurable via the Miscellaneous settings section on the Advanced control panel tab.
- The *PD rate* indicates the total number of PD pulses per second that are detected on the channel being calibrated.
- The IEC-relevant PD rate shows the rate of those PD events that are considered for the Q_{IEC} reading
 (the largest repeatedly occurring PD magnitude)⁵. This rate should be equal to the rate of pulses
 injected by the charge calibrator, indicating that calibration occurs on the calibrator pulses and not
 on some unrelated noise or disturbances. This value is visible only if the IEC/WTD options has been
 selected as the dominant charge.
- Depending on the *dominant charge* setting, either Q_{IEC} , Q_{AVG} , or Q_{Max} displays the current *measurement reading* of the quantity being calibrated.
- The *Calibrate to* field should be set to the charge that the charge calibrator is configured to inject. This is the charge value that, after calibration, should be measured.
- The Calibration factor field contains the current calibration factor, and can be directly adjusted by the user. This is the factor that is multiplied with the raw charge measurement to arrive at the measurement reading.
- Pressing the *Compute* button will also update the *Calibration factor* field such that the measurement reading matches the target value.

Below the *Compute* button, a message indicates when the channel was last calibrated. Changing relevant PD settings (such as the bandwidth or center frequency) resets this time, and the message will indicate that the channel is not currently calibrated.

If no PD events are being measured, the *Compute* button will be disabled, and an additional message will appear below the calibration time message, explaining that calibration cannot be done until PD events are measured again, and pointing out some measures that can achieve that.



 $[\]overline{\ }^{5}$ When the current measurement is not deemed to be fully compliant with IEC 60270, WTD-relevant PD rate and Q_{WTD} are shown instead.

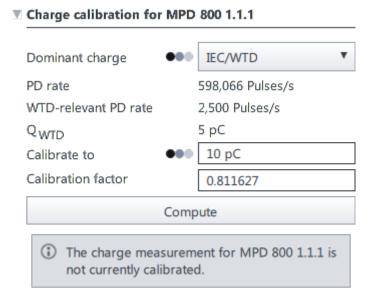


Figure 15.9: charge calibration settings

15.1.3 RIV sub-tab

The sub-tab named *RIV* provides access to RIV measurement settings and to the functionality used for calibrating RIV measurements.



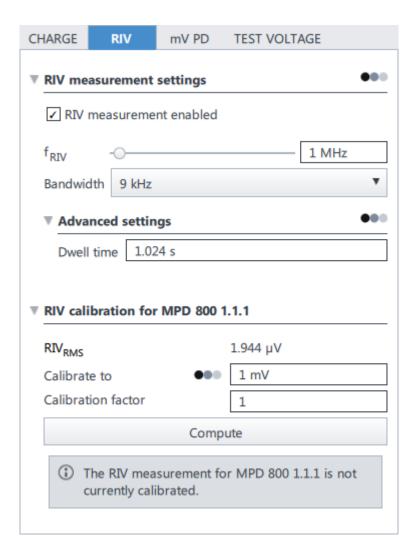


Figure 15.10: The RIV sub-tab

15.1.3.1 RIV measurement settings

This section contains settings that control RIV measurements. These settings apply to all *config-selected* channel groups.

The *RIV measurement enabled* checkbox is used to enable or disable RIV measurements for the configselected channel groups. When RIV measurements are disabled, the corresponding measured quantities are not available for display (in the measured values display, on the channel group display, and on PRPDs when multiple channels are visible), for trending, or when recording XML files.

The f_{RIV} and Bandwidth settings configure the center frequency and bandwidth of the measurement filter used to perform RIV measurements. On MPD 800 devices, those settings are independent form the PD measurement filter used for charge-based, IEC 60270-compliant measurements. On the MPD 600, RIV and charge-based measurements are not independent, and configuring the filter here will also change the PD measurement settings accordingly.

The center frequency and bandwidth settings work exactly like those that configure the PD measurement settings, except that only the 4.5 kHz and 9 kHz bandwidths are available.

There is an additional *Advanced settings* expander which contains the *Dwell time* value edit. This allows setting the *dwell time*⁶ for the RIV measurement. The dwell time controls the time over which pulses are aggregated to measure the pulse rate, as well as the peak, quasi-peak, and RMS voltages. This value defaults to approximately 300 ms[^327.68 ms for the MPD 800 and 328.32 ms for the MPD 600] and can be set to values between 300 ms and 5 minutes.

15.1.3.2 RIV calibration settings

This section allows you to calibrate RIV measurements. With RIV, you always calibrate the RMS voltage, by using a dedicated RIV calibrator such as the OMICRON RIV 1 or a frequency generator.

It includes the following controls:

- The *current measurement reading* of the RIV RMS voltage (V_{RIV_{RMS}}) shows the currently measured RIV RMS voltage, with the current calibration factor applied.
- The *Calibrate to* field should be set to the voltage that the RIV calibrator or frequency generator is configured to inject. This is the voltage value that, after calibration, should be measured.
- The *Calibration factor* field contains the current calibration factor, and can be directly adjusted by the user. This is the factor that is multiplied with the raw RIV RMS measurement to arrive at the measurement reading.
- Pressing the *Compute* button will also update the *Calibration factor* field such that the measurement reading matches the target value.

15.1.4 mV PD sub-tab

The mV PD sub-tab allows you to configure PD measurements using mV values rather than charge values and provides the functionality for $normalization^7$ of such measurements. mV PD measurements are only supported on MPD 800 devices.



⁶also referred to as measurement time in the CISPR 16-1-1 standard

⁷We speak of *normalization* instead of *calibration* in the context of mV PD measurements because *calibration* requires that there is a standard that defines the calibration procedure. mV PD measurements are not standardized, and can thus not be calibrated. But using the same procedure as we do during *charge calibration*, we can normalize mV PD measurements.

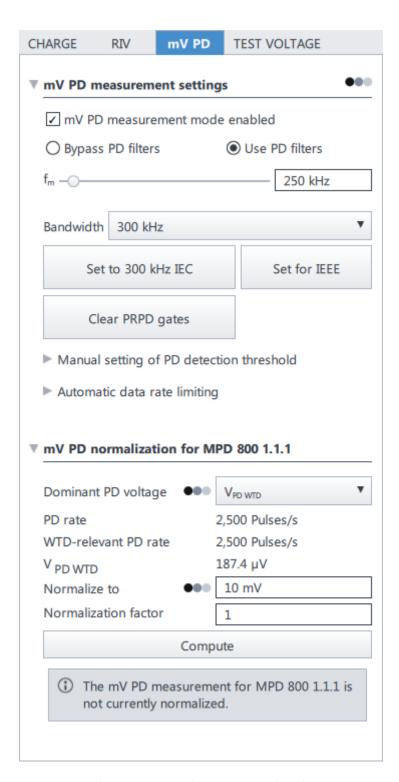


Figure 15.11: The mV PD sub-tab

The *mV PD measurement settings* section contains the settings that control mV PD measurement mode. The *mV PD measurement mode enabled* checkbox enables or disables mV PD mode. When enabled, time-domain integration is automatically disabled.

When mV PD measurements are enabled, all PD-related measurements use voltage quantities (mV, V,

etc.), as opposed to charge quantities (pC, nC, etc.) This affects PRPDs, PD count histograms (H(Q)), and PD-over-voltage diagrams (Q(V)). Also, the largest repeatedly occurring PD magnitude reading is not available during mV PD measurements. Instead, the *peak PD voltage* (\hat{V}_{PD}) and *average PD voltage* (V_{PD}) are used as the readings for the PD activity.

You can configure mV PD measurements to bypass the PD filters, using the *Bypass PD filters* radio button, in which case the entire analog input bandwidth of the MPD 800⁸ is used for PD measurements. Alternatively, you can choose to use the PD filters, by selecting the *Use PD filters* radio button. When using PD filters you can configure the center frequency and bandwidth of the PD filters directly on the mV PD sub-tab. **Note** that 3FREQ measurements are not currently supported in conjunction with mV PD measurements. The *Set to 300 kHz IEC*, *Set for IEEE* and *Clear PRPD gates* buttons are also available in the mV PD sub-tab when the *Use PD filters* option is selected. Finally, the *Manual setting of PD detection threshold* and *Automatic data rate limiting* settings have the same meaning as the ones on the charge sub-tab.

The *mV PD normalization for ...* section contains the controls to normalize mV PD measurements. The section hosts the following controls:

- The Dominant PD voltage setting selects which PD voltage quantity should be calibrated. The following options are available: \hat{V}_{PD} (the maximum peak voltage of detected PD pulses), and V_{PD} (the average peak voltage of detected PD pulses), using pulses from the most recent t_{Ref} time interval as configurable via the Miscellaneous settings section on the Advanced control panel tab.
- The *PD rate* indicates the total number of PD pulses per second that are detected on the channel being calibrated.
- Depending on the dominant PD voltage setting, either \hat{V}_{PD} , or V_{PD} displays the current measurement reading of the quantity being calibrated.
- The *Normalize to* field should be set to the PD voltage that you are applying to the test circuit. This is the PD voltage value that, after normalization, should be measured.
- The Normalization factor field contains the current normalization factor, and can be directly adjusted by the user. This is the factor that is multiplied with the raw PD voltage measurement to arrive at the measurement reading.
- Pressing the *Compute* button will also update the *Normalization factor* field such that the measurement reading matches the target value.

15.1.5 Test voltage sub-tab

The test voltage sub-tab allows enabling and disabling the AC measurement and provides access to the calibration functionality for the test voltage.



⁸approximately 40 MHz

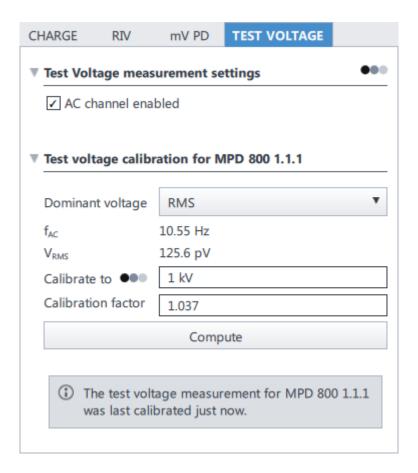


Figure 15.12: The Test-voltage sub-tab

15.1.5.1 Test voltage measurement settings

This section allows you to enable or disable the AC channel for the currently *primary-selected* channel group. Disabling the AC channel removes the corresponding entry from the list of synchronization sources on the *PRPD & AC*. When an AC channel is disabled, no voltage and current measurements are performed on that channel; i.e. the following measurement readings will not be available for the primary-selected channel: V_{RMS} , V_{DC} , $\frac{\hat{V}}{\sqrt{2}}$, I_{RMS} , I_{DC} , $\frac{\hat{I}}{\sqrt{2}}$, f_{AC} (for MPD 800 channels), and f_V (for MPD 600 channels).

However, disabling the AC channel has one benefit: The device no longer needs to transmit the AC signal to the PC, thus leaving additional bandwidth available on the fiber link for other measurements, such as PD events. When multiple⁹ MPD devices are connected in a fiber daisy chain, this effect can be significant, i.e. the total PD rate can be significantly higher on all connected MPD devices.

15.1.5.2 Test voltage calibration settings

This section allows you to calibrate AC measurements, and contains settings that affect AC calibrations for the currently *primary-selected* channel group:

• The *Dominant voltage* setting determines which voltage quantity is used for calibration. It can be one of the following: RMS, $\frac{\hat{V}}{\sqrt{2}}$, and DC.

⁹≥ 5

- The currently detected frequency (f_{AC}) of the measured AC signal as applied to the AC input of the primary-selected channel group.
- Depending on the selected dominant voltage setting, either V_{RMS} , $\frac{\hat{V}}{\sqrt{2}}$, or V_{DC} displays the current measurement reading of the quantity being calibrated.
- The *Calibrate to* field should be set to the voltage that the high voltage is currently set to. This is the voltage value that, after calibration, should be measured.
- The *Calibration factor* field contains the current calibration factor, and can be directly adjusted by the user. This is the factor that is multiplied with the raw voltage measurement to arrive at the measurement reading.
- Pressing the *Compute* button will also update the *Calibration factor* field such that the measurement reading matches the target value.



15.2 The PRPD & AC tab

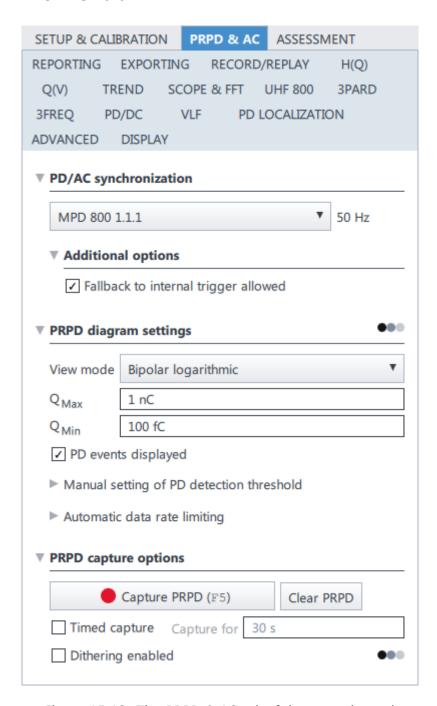


Figure 15.13: The PRPD & AC tab of the control panel

The *PRPD & AC tab* contains settings that pertain to PRPDs and related features, such as the synchronization source used to map PD events to AC phase positions. The tab contains the following sections:

15.2.1 PD/AC synchronization

This determines which synchronization source is used to assign phase information to PD events such that they can be plotted in a PRPD. The synchronization source can be the signal of an AC or V input of



a connected MPD channel, the *Line Trigger*, or the *Internal Trigger*. It can also be set to the *Each unit triggers itself* option. The current frequency of the selected synchronization signal is displayed next to the selection box. This setting is global, i.e. it always applies to all channel groups.

In general, a synchronization source provides a periodical signal (such as a sinusoidal wave). Each period of the signal can be divided into *phase positions*, typically expressed in degrees (°). To synchronize PD events with such a source for the purposes of generating PRPDs, the timestamp of each PD event is mapped to a phase position of the synchronization signal, which is then used as the PD event's horizontal position in the PRPD.

The options listing a channel name use the signal applied to the corresponding MPD channel's AC or V input for synchronization.

The Each unit triggers itself option uses the associated AC input (for MPD 800) or V input (for MPD 600) as the synchronization source. The associated AC or V input is the input that is physically next to the channel's PD input and together with that PD input forms a channel group. **Note:** With this option, every PRPD is synchronized using a different signal. The other options synchronize all PRPDs to the same signal.

In contrast, the *Line Trigger* option uses the light-sensitive sensor built into OMICRON MCUs for synchronization. The sensor responds to oscillations in the light emitted from light bulbs connected to line power. The sensor signal is thus synchronous to the line voltage. **Note** that the line trigger is sensitive to oscillations with frequencies between 50 and 60 Hz, so it will not work with switched-power lights that use higher frequencies, such as compact fluorescent lights (CFLs).

The *Internal Trigger* option generates an artificial signal with a configurable period for synchronization. It can be used if no other synchronization source is available. The frequency of the internal trigger can be set on the advanced tab of the control panel, or via the *Internal trigger frequency* value edit that is available under the *Additional options* expander when the internal trigger is selected.

When any option other than *Internal Trigger* is used, the *Additional options* expander duplicates the *Fallback to internal trigger allowed* option, that is otherwise available under the *Internal trigger settings* section of the *ADVANCED* control panel tab.

15.2.2 PRPD diagram settings

This section contains settings that configure the display of PD activity in the channel group's PRPD, Ellipse (Lissajous) and H(Q) views. These settings apply to all config-selected channel groups.

The *View mode* drop-down box configures how PRPDs, needle plots and H(Q) diagrams are displayed. The *view mode* comprises two dimensions: the *polarity* of PD events and the *scaling* of the charge¹⁰(Y) axis. *Bipolar* view modes display PD events with positive charge or voltage values in the top half of the diagram, and PD events with negative charge or voltage values in the bottom half. In contrast, *unipolar* view modes disregard the polarity of the PD events' charge or voltage values when plotting PRPDs and needles.

Linear scaling uses a linear charge axis, i.e. every vertical division in the diagram covers the same charge or voltage value range. Logarithmic scaling, on the other hand, scales the charge or voltage axis logarithmically, so that every decade takes the same amount of space in the diagram. **Note** that when logarithmic scaling is active, a charge or voltage value of 0 cannot be plotted (the logarithm of 0 is $-\infty$!).



¹⁰or voltage, in mV PD mode

The Q_{Max} and Q_{Min} value edits set the top and bottom edge, respectively, of the PRPD diagram when using charge-based measurements (as opposed to mV PD measurements). Put another way, Q_{Max} determines the largest (absolute) charge value that can still be shown in the diagram, while Q_{Min} corresponds to the smallest (absolute) charge value that can be shown. Any PD events with charge values outside the $[Q_{Min}, Q_{Max}]$ range will not appear in the diagram. In bipolar mode, the "bottom edge" actually refers to the middle of the diagram. **Note** that in the bipolar case, the diagram contains a discontinuity between the top and bottom halves, each of which shows PD events with a certain polarity. The discontinuity arises because each half of the diagram plots values between Q_{Min} and Q_{Max} for the two polarities, so the line between the positive and the negative halves of the diagram actually contains all charge values between Q_{Min} and Q_{Min} . There are several reasons for choosing this representation. One reason is that there is no way to logarithmically plot the value 0 (the logarithm of 0 is - ∞). Another is that by default Q_{Min} is also used as the detection threshold for PD events, so that no PD activity with absolute charge values below Q_{Min} is actually even measured 12.

When using mV PD mode, the Q_{Max} and Q_{Min} settings are replaced by \hat{V}_{Max} and \hat{V}_{Min} settings that configure the PRPD boundaries as a PD voltage. These settings are independent of the charge-based settings, so switching between charge-based and mV PD mode will apply the values that were most recently used in the corresponding mode. When multiple channels are config-selected and the config-selected channels use a different mode (charge-based or mV PD), then changing PRPD boundaries of the primary-selected channel will only apply to channels that use the same PD mode.

The PD events displayed checkbox controls whether individual PD events are displayed in the PRPD diagrams in addition to being plotted in the histogram. When enabled, each PD event is plotted as a "needle", a line going from charge (or voltage) 0 to the charge (or voltage) of the PD event. PD events that occur at the same horizontal position are combined into single needles with the tip ending at the largest absolute charge/voltage. Needles are cleared the next time the diagram is drawn.

The Manual setting of PD detection threshold option is duplicated from the PD measurement settings section of the charge and mV PD sub-tabs on the SETUP & CALIBRATION control panel tab. It allows you to specify a PD event detection threshold directly, instead of using the Q_{Min} or \hat{V}_{Min} value from the PRPD diagram settings.

Likewise, the *Automatic data rate limiting* option shown here is the same as the one on the PD measurement settings section of the charge and mV PD sub-tabs on the SETUP & CALIBRATION control panel tab. It controls the behavior of the automatic data rate limiting feature.

15.2.3 PRPD capture options

This section contains settings that control capturing of PRPDs. These settings apply to all PRPDs, not just the *config-selected* channel groups.

The Capture PRPD button starts or stops capturing of PRPDs. When capturing is in progress, the button is shaded in blue to indicate that it is active. When timed capturing is enabled, the button also shows the remaining capture time when capturing is active (e.g. "Capture PRPD (27 s)").

The *Clear PRPD* button clears all PRPDs of all channel groups, but does not stop capturing. Importantly, it also does **not** restart capturing when timed capturing is enabled.



 $[\]overline{^{11}}$ However, the PRPD will track the number of events with absolute charges greater than Q_{Max} and color the upper (and, for bipolar views, lower) edge of the diagram using the same color map as the inside of the PRPD.

¹²This behavior can be changed via the *Manual setting of PD detection threshold* option

The *Timed capture* checkbox enables timed capturing. With timed capturing, PRPDs are recorded for the specified time. All PRPDs from all PD inputs are started simultaneously, and capture for exactly the time configured in the *Capture for* value edit. Once capturing is complete, the *Capture PRPD* button returns to its normal non-active state (shaded in gray rather than blue).

It is possible to change from timed capturing to untimed capturing, or vice versa, while capturing is in progress. When switching from timed capturing to untimed capturing while capturing is in progress, the capture will simply continue until the *Capture PRPD* button is pressed again (and the button will no longer show the remaining capture time). When switching from untimed capturing to timed capturing while capturing is in progress, the behavior depends on the capture duration that has already elapsed. If the time given in the *Capture for* value edit is *larger* than the currently elapsed capture duration (i.e. the time since capturing was started), capturing will continue for the remaining duration (i.e. the time given by *Capture for* minus the current capture duration), with the *Capture PRPD* button showing the remaining time. If the *Capture for* time is *equal to or smaller* than the currently elapsed capture duration, capturing will stop immediately, because the given capture time has already been reached or exceeded.

The *Dithering enabled* checkbox enables dithering on the PRPD. When dithering is enabled, instead of counting an event once in its associated bin, the event leads to multiple bins being counted. The bin it is associated with is counted 4 times for each PD event, direct neighbors of the bin are counted twice, and diagonal neighbors are counted once. This has the effect of "smearing" the PRPD somewhat, i.e. comes at the expense of the resolution of the PRPD histogram, but it will lead to a clear PRPD sooner with fewer PD events. Dithering is best used if there is little PD activity or the available time for capturing PRPDs is limited.



15.3 The ASSESSMENT tab

SETUP & CALIBRATION PRPD	& AC ASSESSMENT	
REPORTING EXPORTING RECORD/REPLAY H(Q)		
Q(V) TREND SCOPE &	FFT UHF 800 3PARD	
3FREQ PD/DC VLF	PD LOCALIZATION	
ADVANCED DISPLAY		
▼ Pass/Fail test	Reset	
✓ Level 1	Level 2	
PD threshold	PD threshold	
10 pC	1 nC	
☐ Test voltage threshold	☐ Test voltage threshold	
1 kV	1 kV	
▼ Inception/Extinction voltage test Reset		
✓ Level 1	✓ Level 2	
PD threshold	PD threshold	
10 pC	1 nC	
✓ Lock-in voltage	Lock-in voltage	
2 kV	1 kV	
▼ Test voltage stability criteria		
☐ Enabled		
Voltage change tolerance 5	%	
Assessment time 1	S	
Suppression time 1	s	
▼ Standard compliance options		
✓ IEC 60270 compliance indicated		
✓ IEEE compliance indicated		

Figure 15.14: The ASSESSMENT tab of the control panel

The ASSESSMENT tab contains settings that control pass/fail and inception/extinction voltage assessments as shown on the Assessment view. It also allows you to configure whether the MPD Suite indicates if measurement parameters satisfy recommendations by various standards.

These settings always apply to all channel groups.

15.3.1 Pass/Fail test

The *Reset* button discards any existing pass/fail assessments and restarts the enabled tests. Any *FAIL* states are cleared.

Two levels can be configured (Level 1 and Level 2). Both levels can be independently enabled or disabled via the associated checkboxes. For each level, the following settings are available:

- the *PD threshold* value edit controls the PD level (expressed in Coulomb for charge-based measurements and in Volt for mV PD measurements), that must be reached or exceeded for the pass/fail test to **fail**, i.e. is the minimum non-acceptable PD level.
- the voltage threshold value edit sets a voltage level on the PD/AC synchronization source that must be reached or exceeded for the pass/fail test to be active. The PD level is only compared against the threshold when the voltage of the synchronization source is equal to or higher than this setting. The voltage threshold is only considered if the voltage threshold checkbox is checked, otherwise the pass/fail test is evaluated independent of the measured voltage.

15.3.2 Inception/Extinction voltage test

The *Reset* button discards any existing inception/extinction voltage assessments and restarts the enabled tests. Any recorded inception and extinction voltages are cleared.

Two levels can be configured (Level 1 and Level 2). Both levels can be independently enabled or disabled via the associated checkboxes. For each level, the following settings are available:

- the PD threshold value edit controls the PD level (expressed in Coulomb for charge-based measurements and in Volt for mV PD measurements) that should be considered actual PD (as opposed to system noise). When the measured PD level (as configured by the dominant charge setting on the Charge sub-tab or the dominant PD voltage on the mV PD sub-tab of the SETUP & CALIBRATION control panel tab) first reaches or exceeds the PD threshold, PD inception occurs, and the voltage measured on the PD/AC synchronization source (as configured by the dominant voltage setting on the Test voltage sub-tab on the SETUP & CALIBRATION control panel tab) is recorded as the inception voltage. When the measured PD level last drops below the PD threshold, PD extinction occurs, and the corresponding voltage is recorded as the extinction voltage.
- If the Lock-in voltage setting is enabled, the corresponding value edit controls when measured inception voltages are locked in. Locked-in inception voltage readings will not be automatically cleared, even if, after recording extinction, PD sets in again. You need to reset the inception/extinction voltage assessment in order for a locked-in inception reading to be cleared. Inception voltages lock in once the measured AC voltage (as configured by the dominant voltage setting on the Test voltage sub-tab on the SETUP & CALIBRATION control panel tab) reaches or exceeds the configured lock-in voltage.



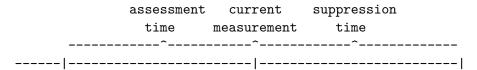
15.3.3 Voltage stability criteria

You can optionally enable tests on the voltage measurement of the PD/AC synchronization source (as configured by the dominant voltage setting on the *Test voltage* sub-tab on the *SETUP & CALIBRATION* control panel tab) that ascertain if the voltage measurement is *stable*, i.e. does not change "too much". The result of this evaluation affects both the pass/fail and the inception/extinction voltage assessments. At times when the voltage measurement is deemed unstable, no pass/fail or inception/extinction voltage assessment will be made, and the outcome of the corresponding test will be *Voltage unstable*.

When enabled, the following settings can be configured:

- the *Voltage change tolerance* value edit configures the maximum amount by which the voltage measurement can change for it to be considered stable. It is given in percent (%). This evaluation is made independently for the assessment time and suppression time, i.e. the voltage reading must not have changed by more than the *voltage change tolerance* during either the assessment time or the suppression time.
- the assessment time value edit configures the time range *prior* to the current measurement for which the stability assessment is made.
- the *suppression time* value edit configures the time range *after* the current measurement for which the stability assessment is made.

When voltage stability tests are enabled, pass/fail and inception/extinction voltage assessments are made only if the voltage was stable both for the assessment time **preceding** the current PD and voltage measurement as well as for the suppression time **following** the current PD and voltage measurement. Note that this means that the current measurement is delayed by the suppression time so that a statement about the stability of the voltage after the current measurement can be made. The following figure illustrates the relationship between measurement time, assessment time and suppression time:



Voltage stability checking only takes effect when the currently configured PD/AC synchronization source provides a voltage measurement. This means that neither the internal nor the line trigger options may be selected as the PD/AC synchronization source for voltage stability checking to occur.

The voltage stability criteria always apply to all measurement channels and to all enabled pass/fail and inception/extinction voltage tests.

15.3.4 Standard compliance options

When the *IEC 60270 compliance indicated* checkbox is enabled, the *measured values display* indicates whether the PD measurement for the primary-selected measurement channel conforms to the recommendations from the IEC 60270 standard. This evaluation is affected by the channel's PD measurement settings and whether the channel's PD measurement has been calibrated. When enabled, the measured values display will show a text describing if the measurement is considered conforming, and if not, what recommendations are not satisfied. When the checkbox is disabled, the corresponding entry in the measured values display is hidden. When disabled, the channel group display will also no longer show a check mark symbol (<) if the corresponding channel conforms to IEC 60270 and has been calibrated.

Similarly, the *IEEE compliance indicated* checkbox controls whether compatibility of the primary-selected measurement channel with the IEEE C.57.113 recommendations should be reported in the *measured val-*



ues display. Again, the measured values display will show a descriptive text about the compatibility of the primary-selected channel's PD measurement with the recommendations from IEEE C.57.113, including details about why the measurement should not be considered conforming if necessary. Disabling the checkbox will completely hide the corresponding entry in the measured values display.

The standard compliance options always apply to all measurement channels.

15.4 The REPORTING tab

The *Reporting* tab allows you to configure the XML reporting functionality built into the MPD Suite. XML reports are similar to dataset files, but instead of containing every PD event, scope and AC sample, they contain derived quantities such as the largest repeatedly occurring PD magnitude, AC RMS voltage, diagram screenshots, as well as settings. XML reports can be viewed in the *report viewer* tool that is bundled with the MPD Suite.



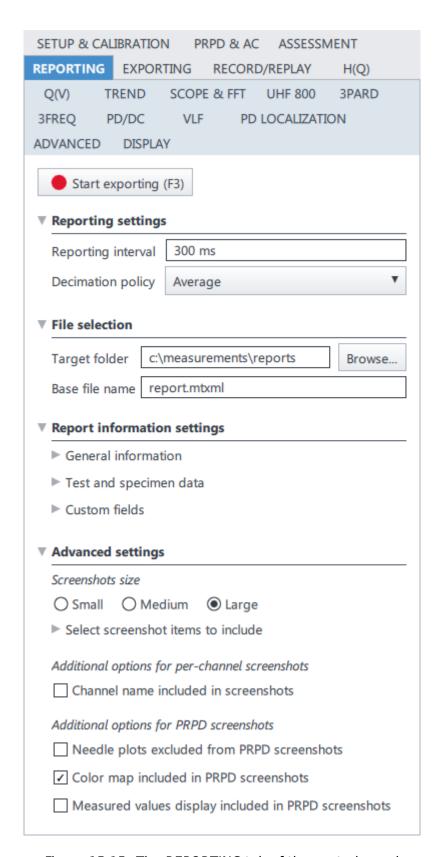


Figure 15.15: The REPORTING tab of the control panel

The Start exporting button begins exporting an XML report file, using the settings configured on this

page. Once clicked, it turns blue to indicate that exporting is in progress, and its texts changes to *Stop exporting*. As indicated on the button, pressing the F3 key has the same effect as clicking this button.

While exporting, the *Save screenshot* button is visible, and allows creating screenshots of the various diagrams in the MPD Suite, which are then stored in the XML report file being created. Pressing F4 achieves the same effect as clicking this button. When a diagram screenshot is started, a progress bar will be shown that indicates the progress of the screenshot operation.



Figure 15.16: XML export is in progress

15.4.1 Reporting settings

In this section, you can configure the *Reporting interval*, which determines how often measurement readings are stored in the XML file. The value edit can take values between 300 ms and 1 h. Its companion setting, the *Decimation policy*, configures *how* that measurement reading is taken. You have the following options:

Average The reading stored in the XML file is computed as the average of all readings produced during the decimation period.

Minimum The reading stored in the XML file is the minimum of all readings produced during the decimation period.

Maximum The reading stored in the XML file is the maximum of all readings produced during the decimation period.

Median The reading stored in the XML file is computed as the arithmetic median of all readings produced during the decimation period, i.e. the value that occurred "in the middle" of the decimation period.

Single sample The reading stored in the XML file is the last reading produced within the decimation period.

15.4.2 File selection settings

This section configures the file name and storage location of XML report files. The *Target folder* setting accepts the folder into which report files are stored. You can enter the location manually in the edit field, or use the *Browse* button to use a file dialog to select the folder.

The Base file name setting controls the naming of the report file. When a report is started, the file name entered here is extended with the date and time of the moment reporting was started 13 . As a result, a configured base name of report.mtxml will turn to an actual file name such as report-2022-10-24-17h07m50s.mtxml.

15.4.3 Report information settings

In this section, you configure meta information that will be included in the report file. This information is passed through to the report file as is, and is not interpreted further by the MPD Suite. Any of these settings can be left blank. In that case, the report viewer will simply omit the corresponding information from the report.



¹³Using local time (as opposed to UTC).

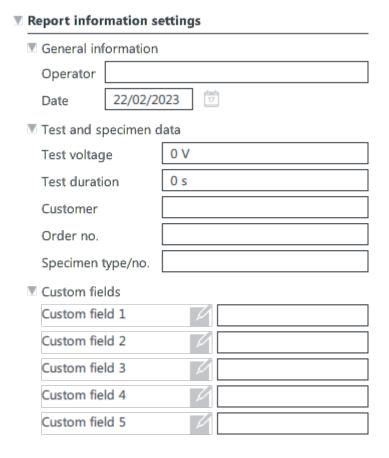


Figure 15.17: Report information settings

15.4.3.1 General information

This subsection allows you to set the name of the person performing the measurement in the *Operator* edit field, as well as the date of the measurement in the *Date* edit field. The latter field is initialized to the current date, but can be changed by the user by typing a date into the field, or by clicking the calendar icon (\square) and choosing the date interactively.

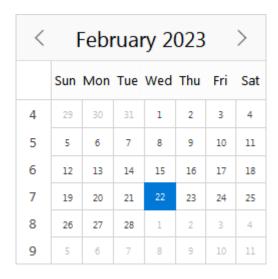


Figure 15.18: Picking a date via the calendar

15.4.3.2 Test and specimen data

In this subsection, you can describe the test and the specimen being tested. The nominal test voltage can be entered in the *Test voltage* edit field, while the duration of the test can be set via the *Test duration* edit field. You can also name the customer in the *Customer* edit field, as well as the order number by way of the *Order no.* edit field. Finally, this section allows you to set a specimen type or code in the *Specimen type/no.* edit field.

15.4.3.3 Custom fields

If you need to store more meta information, or other things that are not covered by the above fields, you can define up to 5 custom fields that will also be included in the report. These fields are configured in this section, in the *Custom field 1*, *Custom field 2*, *Custom field 3*, *Custom field 4*, and *Custom field 5*, controls. For each field, you can set a name by clicking the button, and you can type the value of the field in the corresponding edit field.

15.4.4 Advanced settings

This section allows you to control which diagram screenshots are included in XML report files, and configures how they are generated.



Advanced settings	
Screenshots size	
○ Small ○ Medium	Large
▼ Select screenshot items to	include
✓ System overview	✓ 3PARD
✓ Trend	✓ PRPD
	✓ Ellipse
✓ Replay	✓ PD/DC
✓ PD/DC counter	✓ Meters
✓ Scope	✓ 3FREQ
✓ FFT	
✓ PD localization	✓ UHF Spectrum
✓ UHF Sweep	
Additional options for per-cho	annel screenshots
Channel name included i	n screenshots
Additional options for PRPD s	creenshots
☐ Needle plots excluded fr	om PRPD screenshots
✓ Color map included in Pf	RPD screenshots
Measured values display screenshots	included in PRPD

Figure 15.19: Advanced settings

The *Screenshots size* setting controls the size of exported diagram screenshots. You can choose between *Small* (400x300 Pixels), *Medium* (800x600 Pixels), and *Large* (1600x1200 Pixels). Note that these sizes are guidelines; depending on the configured screenshot options, the diagram may be larger than those values. For example, when the *Measured values display included in PRPD screenshots* option is enabled, the PRPD itself is sized according to this setting, and the measured values display is then added to the diagram with a suitable size.

The Select screenshot items to include setting configures which diagrams are included in the XML report file when screenshots are triggered. You can select all diagrams available in the software. Most diagrams will be generated separately for each measurement channel, with the exception of the System overview, 3PARD, and (since version 1.40 of the MPD Suite) the Trend diagrams, which are global and are generated only once.

The Additional options for per-channel screenshots option allows configuration of additional options for

the diagram screenshots that are generated separately for each channel. Currently, the only option is *Channel name included in screenshots*, which, when enabled, will annotate diagram screenshots with the name of the channel to which they belong.

The Additional options for PRPD screenshots contains options that only apply to PRPD diagram screenshots. When the Needle plot excluded from PRPD screenshots option is enabled, the PRPD diagram exported to the XML report does not show the PRPD "needles" view, independent of whether it is enabled in the PRPD options. When disabled, the needles will be visible in the exported diagram if they are enabled in the PRPD options.

The Color map included in PRPD screenshots controls whether the color map used to generate the PRPD is also included in the PRPD screenshots exported to the XML report file. When enabled, the color map is shown next to the PRPD in the exported screenshot, otherwise no color map is added.

Similarly, the *Measured values display included in PRPD screenshots* option controls if the measured values display is included in the PRPD screenshot exported to the XML report file. If enabled, the measured values display with all measured values at the time of the screenshot is shown next to the PRPD (potentially along with the color map).

Note that these options may make the generated screenshot file larger than the noinal size selected in the *Screenshots size* setting.



15.5 The EXPORTING tab

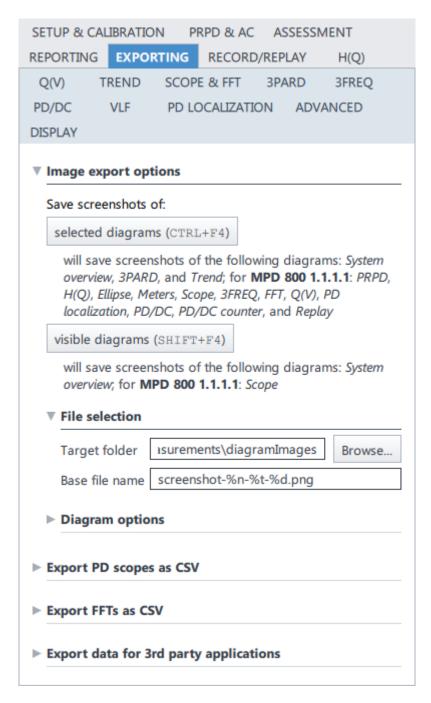


Figure 15.20: The EXPORTING tab of the control panel

The *EXPORTING* tab contains settings that configure how diagrams are saved to image files when the appropriate buttons or keyboard shortcuts are pressed, as well as allows exporting the data underlying the PD scope and FFT diagrams to CSV files.

15.5.1 Image export options

The *Image export options* section contains two buttons that can trigger exporting diagrams as images. Clicking the *selected diagrams* button, or, equivalently, pressing the CTRL+F4 keyboard shortcut, will save all diagrams selected for exporting of all config-selected as image files. Clicking the *visible diagrams* or pressing the SHIFT+F4 keyboard shortcut will save all currently visible diagrams as image files, independent of which diagrams are selected. Next to the buttons there is a text that describes which diagrams will be saved to image files when the buttons are clicked, depending on the currently visible diagrams, the config-selection, and the export selection.

When saving diagrams to files, a progress bar will appear in this section indicating how many of the requested files have been saved. Next to the progress bar will be an indication how many total files need to be written, and how many files have already been saved. This information will continue to be shown for a short time¹⁴ after saving is complete, and will then disappear again.

The *File selection* section contains settings that control where images files will be saved and how the file names will be constructed. The *Target folder* field determines the folder into which images files will be saved once one of the export buttons is clicked. You can use the *Browse* button to browse for the folder, allowing you also to create a new folder in the process.

The Base file name setting controls how file names for image files are constructed. The base file name sets a name component and an extension component. The name component of the base file name can include one or more placeholders, which will be replaced by information about the image being written. The supported placeholders are:

- %t represents the *type* of the diagram that is being saved as an image file. This will be replaced with a suitable text, such as *PRPD*, *HQ* or *3PARD*.
- %d represents the *date and time* of the moment when the file is created.
- %n represents the name of the channel to which the diagram belongs that is being saved to a file. This placeholder will be replaced with an empty string if the diagram being saved is not associated with a specific channel (such as a 3PARD diagram).

The extension component determines the file format of the image files to be saved. Supported extensions include PNG^{15} , JPG, $WEBP^{16}$, BMP^{17} , and TIFF, among others. Not specifying an extension will default to .png, which represents the PNG file format. You can hover the mouse over the base file name edit field to see all file formats that are supported on your system as well as the supported placeholders and their meaning.

When a file is saved, the file name is constructed from the *base file name*, replacing any placeholders if present. If the resulting file name already exists, a running number is appended to the file name such that a file can always be saved without overwriting any existing files.



¹⁴approximately 10 s

¹⁵Portable Network Graphics

¹⁶Webpack format

¹⁷Windows bitmap format

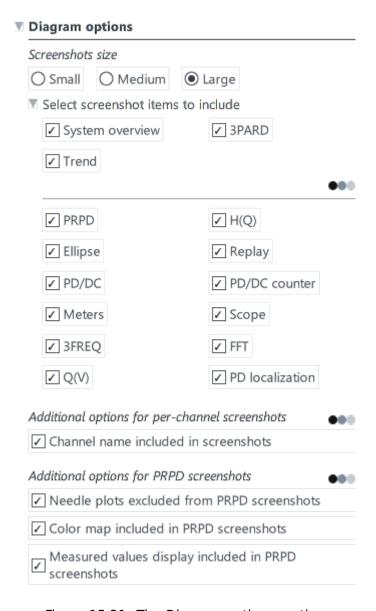


Figure 15.21: The *Diagram options* section

The *Diagram options* section controls how diagrams are saved to image files. The *Screenshots size* section determines the dimensions of the saved image files. You can choose between *Small* (nominally 400 by 300 pixels), *Medium* (nominally 800 by 600 pixels), and *Large* (nominally 1600 by 1200 pixels). By default, *Large* is selected. **Note** that these sizes are guidelines only. Some of the options that can be configured on this page can lead to the files having bigger dimensions than those listed here. For example, when the *Color map included in PRPD screenshots* option is selected, the PRPD itself is sized according to the *screenshot size* setting, and the color map is then placed next to it, so the resulting file will be bigger.

The Select screenshot items to include section configures which diagram types should be saved to image files ("screenshots") when the selected diagrams button is pressed. The System overview, and 3PARD diagram settings are "global", since the corresponding diagrams are not specific to a certain channel. All other diagrams can be independently enabled and disabled for each channel group, as indicated by the symbol. Checking or unchecking any of these diagram types will apply to all config-selected

channels.

The Additional options for per-channel screenshots section contains an option that applies only to screenshots that are specific to channels, such as PRPDs or PD scope diagrams. Screenshots of "global" diagrams such as the system overview diagram or the 3PARD are not affected by this setting. If the Channel name included in screenshots option is enabled, per-channel screenshots are annotated with the name of the channel to which they belong. The channel is added to the bottom of the diagram. **Note** that the channel name is not included in the size guideline, so images will be somewhat longer than what the screenshot size setting implies when this option is enabled, to accommodate the additional space needed for the channel name text.

The Additional options for PRPD screenshots section contains some additional options that apply only to PRPD diagrams. Changes to these options apply to all config-selected channels as well. The Needle plots excluded from PRPD screenshots option controls whether image files saved from PRPD diagrams will show the individual PD events ("needles"). This setting is independent of the PD events displayed setting on the PRPD & AC control panel tab. Enabling the Color map included in PRPD screenshots options will show the color map used to assign colors in the PRPD next to the PRPD diagram in the saved image file. This color map associates a color with a certain number of PD pulses per second. Finally, the Measured values display included in PRPD screenshots can be enabled to also include a screenshot of the measured values display for the channel from which the PRPD diagram is exported in the image file.

15.5.2 Export PD scopes as CSV

The Export PD scopes as CSV section allows exporting PD scope trigger shots to CSV files, and configures the options pertaining to that export functionality. The Export current plots button exports the most recent trigger shot(s) of the config-selected PD scope channels to files. If the New data for current channel continuously exported option is enabled, new trigger shots are also saved to a file automatically as they trigger.

The *File selection* section contains controls to configure the folder into which CSV files are exported, as well as how they are named. The *Target folder* edit field allows you to type in the folder you wish to export scope CSV files to. Alternatively, you can also click on the *Browse* button to locate the folder interactively. Below that, the *Base file name* control configures how the CSV files will be named. In this file, you specify a *base file name* including the extension of the file. When a file is created, the base file name is extended with the date and time of the moment the file is created. So, for a base file name of pd-scope.csv, an actual file named pd-scope-2022-12-15_14h24m12s534ms.csv might be created.

Further below, you can configure the column separator to use in the exported files, using the *Column separator* selection box. By default, this is set to the semicolon (;), but it can also be set to the tabulator (tab) character, a comma (,), the pipe symbol (|), the tilde symbol (~) or the caret symbol (^).

The *Advanced options* section contains further options to customize the generated CSV files. The *Time format* selection box lets you choose how time points are represented in the CSV file. You can choose between the following options:

- Default: Times will be reported as day-month-year hour:minute:second.milliseond (UTC), e.g. 16-DEC-2022 14:30:01.443 (UTC)
- ISO 8601: Times will be reported in ISO 8601 format. e.g. 2022-12-16T14:30:01.443
- Start time and offset: Times will be reported as fractions of seconds with respect to a start time. The start time will be contained in the header, and will be given as 16-DEC-2022 14:30:01.443



¹⁸by default, the extension is CSV, but other extension can be used.

(UTC).

• Compatible with Microsoft Excel: Times will be reported as year-month-day hour:minute:second.millisecond, e.g. 2022–12–16 13:30:01.443

Below that, using the *Decimal point symbol* selection box, you can choose what symbol should be used to separate the fractional part from the whole part in numbers. Here, the available options are the period (.) or the comma (,).

The *New data for current channel continuously exported* option controls whether files are continuously exported when new trigger shots are reported. When disabled, pressing the *Export current plots* button will only create a single file for each config-selected scope channel. On the other hand, when that option is enabled, new files will automatically be created when a new trigger shot comes in.

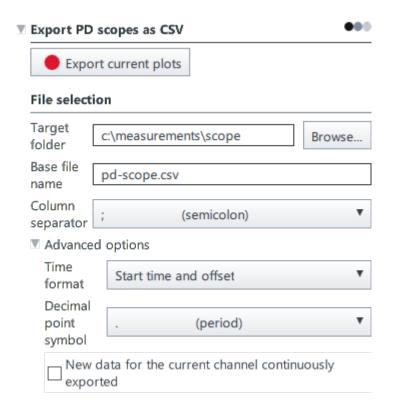


Figure 15.22: The Export PD scopes as CSV section

15.5.3 Export FFTs as CSV

The *Export FFTs* as *CSV* section allows exporting the frequency spectra of PD scope trigger shots¹⁹ to CSV files, and configures the options pertaining to that export functionality. The *Export current plots* button exports the FFTs of the most recent trigger shot(s) of the config-selected PD scope channels to files. If the *New data for current channel continuously exported* option is enabled, FFTs of new trigger shots are also saved to a file automatically as they trigger.

The *File selection* section contains controls to configure the folder into which CSV files are exported, as well as how they are named. The *Target folder* edit field allows you to type in the folder you wish to export scope CSV files to. Alternatively, you can also click on the *Browse* button to locate the folder



¹⁹as displayed in the FFT view

interactively. Below that, the *Base file name* control configures how the CSV files will be named. In this file, you specify a *base file name* including the extension 20 of the file. When a file is created, the base file name is extended with the date and time of the moment the file is created. So, for a base file name of pd-fft.csv, an actual file named pd-fft-2022-12-15_14h24m12s534ms.csv might be created.

Further below, you can configure the column separator to use in the exported files, using the *Column separator* selection box. By default, this is set to the semicolon (;), but it can also be set to the tabulator (tab) character, a comma (,), the pipe symbol (|), the tilde symbol (~) or the caret symbol (^).

The Advanced options section contains further options to customize the generated CSV files. The Decimal point symbol selection box allows you to choose what symbol should be used to separate the fractional part from the whole part in numbers. Here, the available options are the period (.) or the comma (,).

The New data for current channel continuously exported option controls whether files are continuously exported when new trigger shots are reported. When disabled, pressing the Export current plots button will only create a single file for each config-selected scope channel. On the other hand, when that option is enabled, new files will automatically be created when a new trigger shot comes in.

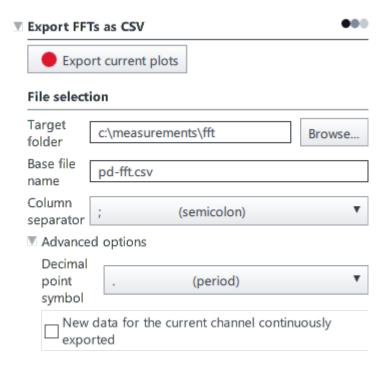


Figure 15.23: The Export FFTs as CSV section

15.5.4 Export data for 3rd party applications

This section is only available when one or more dataset files have been loaded. It allows configuring of export of "low-level" data to files that can be loaded into 3rd-party applications or tools, such as Matlab®, Octave, or custom tools. Data that can be exported include every PD event, including its AC-phase position, coefficients describing the AC signal, and line trigger signals.



²⁰by default, the extension is CSV, but other extension can be used.

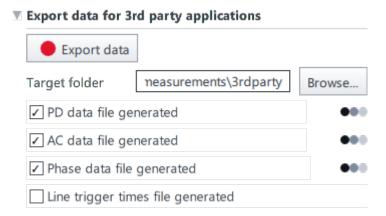


Figure 15.24: The Export data for 3rd party applications section

The Export data button enables exporting of the configured data. When the loaded dataset files are replayed next, the configured data is exported. Clicking the button enabled while a replay is in progress will start exporting the data from the moment the button was clicked. Exporting will occur for every enabled channel, but the content of the data being exported can be customized for each channel.

The *Target folder* control edit field allows you to type in the folder you wish to export the data to. Alternatively, you can also click on the *Browse* button to locate the folder interactively. When an export is started, a new folder is created within the folder selected here that is named according to the date and time of when the export was started. For example, when starting an export on December 19th, 2022, at 12:34 and 17 seconds, the folder being created would be named 20221219 12h34m17s.

The *PD data file generated* option controls whether PD events are exported for the config-selected channels. When checked, a file with the .PD extension is created for each config-selected channel that contains the time stamp and PD magnitude level (charge or, for mV PD measurements, voltage) for every PD event that is reported by that channel during replay. The name of this file is constructed from the name of the channel group, extended with the date and time of the first data point in that file. Note that this date and time corresponds to the point in time at which that channel originally produced data, i.e. when the file was recorded. For example, such a file could be named V1-20191021_11h06m48s970ms.PD for a channel named "V1" that originally produced data on October 21st, 2019, at 11:06:48 (and 970 ms).

Below that, the *AC data file generated* option likewise controls whether AC signals are exported for the config-selected channels. When checked, a file with the .AC extension is created for each config-selected channel that contains a timestamp, a fundamental frequency, and a set of coefficients that describe the AC signal of the corresponding channel at that moment. The name of this file is constructed from the name of the channel group, extended with the date and time of the first data point in that file. Note that this date and time corresponds to the point in time at which that channel originally produced data, i.e. when the file was recorded. For example, such a file could be named V1-20191021_11h06m48s970ms.AC for a channel named "V1" that originally produced data on October 21st, 2019, at 11:06:48 (and 970 ms).

Further below, the *Phase data file generated* option controls whether an additional file is generated that describes the AC phase position of each PD event. If enabled, a file with the .PH extension is generated for each

config-selected channel that contains one entry for each PD event that would be stored in a corresponding .PD file that indicates the position on the AC cycle for the corresponding PD event. The name of this file

is constructed from the name of the channel group, extended with the date and time of the first data point in that file. Note that this date and time corresponds to the point in time at which that channel originally produced data, i.e. when the file was recorded. For example, such a file could be named $V1-20191021_11h06m48s970ms.PH$ for a channel named "V1" that originally produced data on October 21^{st} , 2019, at 11:06:48 (and 970 ms).

Finally, the *Line trigger times file generated* option controls whether an additional file with the .TM extension is created that contains the timestamps of the moments the line trigger fired. The name of the file is constructed from the serial number of the MCU hosting the line trigger, extended with the text "-lineTrigger" and the date and time of the first data point in that file. Note that this date and time corresponds to the point in time at which that channel originally produced data, i.e. when the file was recorded. For example, such a file could be named MCU2-BD035B-lineTrigger-20191021_11h06m48s970ms.TM, if the serial number of the MCU that hosted the line trigger was MCU2-BD035B and the dataset file contained data starting at 11:06:48 (and 970 ms) on October 21st, 2019.



15.6 The RECORD/REPLAY tab

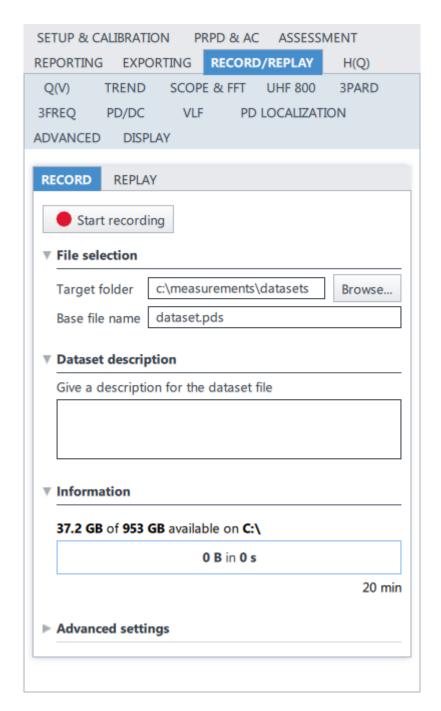


Figure 15.25: The RECORD/REPLAY tab of the control panel

The RECORD/REPLAY tab contains the controls that allow you to record measurement sessions to dataset files, and to replay previously recorded dataset files. It consists of two sub-tabs, the RECORD tab, which configures recording of measurement sessions to dataset files, and the REPLAY, which controls replaying of dataset files.



15.6.1 The RECORD sub-tab

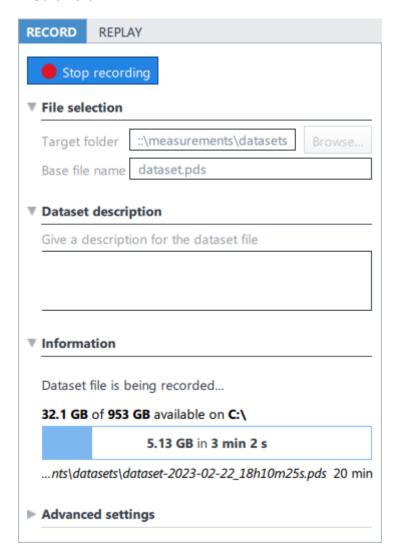


Figure 15.26: The RECORD subtab

The recording sub-tab hosts the controls needed to configure dataset file recording and to start and stop the recording process. The *Start recording* button is used to begin recording datasets. While a dataset is being recorded, the button changes to read *Stop recording*, and when pressed will stop recording the dataset.

Below that, the *File selection* section allows configuring the location and name of dataset files. Within it, the *Target folder* edit field can be used to type in the folder into which dataset files should be stored, or the [*Browse*]{record-subtab-file-target-folder-browse} button can be used to browse for the folder to be used. The *Base file name* edit field controls the base file name of dataset files. When a dataset file is created, the base file name configured here is extended with the current date and time to produce the actual file name of the dataset. For example, a base file name of dataset.pds would lead to a file named dataset-2022-09-21_13'h'19'm'25'ss.pds when a dataset recording is started on September 21st, 2022 at 1:19:25 pm.

The *Dataset description* section further down on the tab allows you to enter a description for dataset files. This description will be included in any dataset files you record. While a dataset is being recorded,



the file selection and dataset description controls are disabled.

In the *Information* section, the MPD Suite reports information about the currently recorded dataset file. It also shows the currently available space on the device upon which the selected target folder is located. This information is continually updated. Below the information about the currently available space, a progress indicator is displayed that shows the amount of data written to the dataset file being recorded as well as the running time of the recording. The progress indicator is scaled to the recording duration configured in the *Advanced settings* section, independent of whether automatic termination is enabled. When ending a recording, this section will continue to show some information about the most recently recorded dataset file. Below the progress indicator, the full path of the dataset file being recorded is also shown. If an error occurs while recording a dataset file, this section will also show a suitable error message. Additionally, when automatic termination of datasets is enabled, and the recording is about to be automatically ended, a warning message is shown in this section along with an *Extend recording* button. Pressing the button will continue recording the dataset file for the configured automatic # recording duration before showing the message and extend button again.

At the bottom of the control panel tab, the *Advanced settings* section contains controls to configure automatic termination of dataset recordings. The *Automatic termination of recording enabled* checkbox controls whether recording of dataset files are automatically stopped after a certain time period. This time period is configured via the *Recording duration* value edit. By default, it is set to 20 minutes. When automatic termination of dataset recording is enabled, the MPD Suite will show a warning message a short time before the recording duration configured here runs out, allowing you to extend the recording for another stint of the same length. The time at which to show this warning message is also configured in this section, using the *Auto-termination warning lead time* value edit.

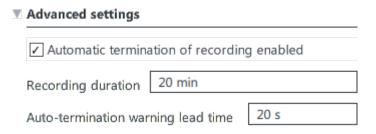


Figure 15.27: The Advanced settings section



15.6.2 The REPLAY sub-tab



Figure 15.28: The REPLAY subtab



The REPLAY sub-tab is used to load dataset files for replay, and for configuring the replay process.

The *Replay controls* section allows you to interact with loaded dataset files and provides information about the datasets as they are replayed. The Play (\triangleright) button starts or resumes playback. When dataset files are first loaded, replay is stopped, and pressing the play button will start the playback. Once playback has been started, you can press the Pause (||) button

to pause the replay at the current time position. Pressing the pause button again will resume playback. In contrast, the *Stop* button (\blacksquare), will stop playback. When you start playback after having stopped the playback, the MPD Suite will restart the playback from the configured replay start position. Finally, the *Eject* (\triangleq) will unload all currently loaded dataset files and return to online operation²¹. **Note** that this is different from pressing the eject symbol next to the file name of the individual loaded files. That button will only unload one specific dataset file, whereas the eject button in the replay controls section will unload **all** dataset files at once.

The *Replay speed* allows you to configure the speed at which datasets should be replayed, and will also show the actual replay speed that is currently being achieved. You can set specific replay speeds (0.25x, 0.5x, 1x, 2x,and 4x), which are given as multiples of the real-time (recording) speed of the dataset files. You can also set the *fastest* option, in which case the software will replay the datasets as fast as possible on the current machine. In any case, the actual replay speed that is currently being achieved is displayed underneath the replay speed selection slider. The maximum speed that can be achieved depends on a number of factors, including the CPU and I/O performance of the computer on which the replay takes place as well as the type and amount of data present in the dataset files.

When an override calibration is currently active, a message indicating that fact will also be shown here.

The Dataset files selection section is where you select and load the dataset files to replay. All dataset files that are currently loaded into the MPD Suite are shown in the Loaded files section. Each file has an eject symbol (\triangleq) next to it, that you can click with the mouse to unload the corresponding dataset file. Any other dataset files will be reloaded, so that only the file you clicked the symbol for will be unloaded.

The *Files to load* section, on the other hand, allows you to select the files you wish to load. When you click the + *Add files* button, the software opens a dialog that allows you to browse a dataset file²². Once selected, the file is shown under the files to load section, along with a *remove* (-) button. Pressing that button will remove the corresponding file from the list of files to be loaded. When there is at lease one file in the files to load section, the *Load files* button will be visible. When you click this button, all files selected in the files to load section will be loaded (in addition to any files that are already loaded into the software) and will from then on be shown in the loaded file section.

Note that it is only possible to load files that were recorded on a different MCU, and that have some overlap in the time range they cover. If you load multiple files, they also all need to have been recorded while a valid GPS signal was detected.

The *Dataset description* section shows the descriptions of all loaded dataset files. Note that this may be empty if no description was given when the loaded dataset file(s) where recorded.

Further below, the *Replay range* section allows you to configure the time range that should be replayed when the play button is pressed. The replay range by default covers the entire time range contained in the loaded dataset files. You can change both the start and the end of the range in the value edits titled



²¹Online here means that the MPD Suite will use any connected MCUs and acqusition units connected to that for PD measurements.

²²Note that you can also select so-called "stream" files (using the .STM file extension), which were recorded using the older *Software for MPD and MI*. This software was previously used to control and perform measurements on MPD 600 devices.

Replay from and Replay through, respectively. The replay range can also be configured by dragging the replay cursors in any of the replay diagrams²³.

Below the replay range, you can configure the replay diagrams in the *Replay diagram settings* section. You can set the time base and horizontal offset of the replay diagram, as well as the scale and offset of the AC plot in the replay diagram. Further, you can also configure which AC quantity is plotted in the replay diagram. Which quantities are available vary between dataset files, but generally include the RMS voltage and frequency of the AC signal at the time of the recording.

Likewise, you can also configure the scale and offset of the PD plot in the replay diagram. Here as well you can choose the PD quantity to be plotted in the replay diagram. Available options vary between dataset files, but usually include the largest repeatedly occurring PD magnitude (the Q_{IEC} reading).

Below the replay diagram settings section, the replay diagram is always available on the *REPLAY* sub-tab of the *RECORD/REPLAY* control panel tab.

²³By default, a replay diagram is available in the small right diagram view as well as on the replay sub-tab of the RECORD/REPLAY control panel tab, but it can also be enabled for the small left diagram view and can be shown as a separate window.



15.7 The UHF 800 tab

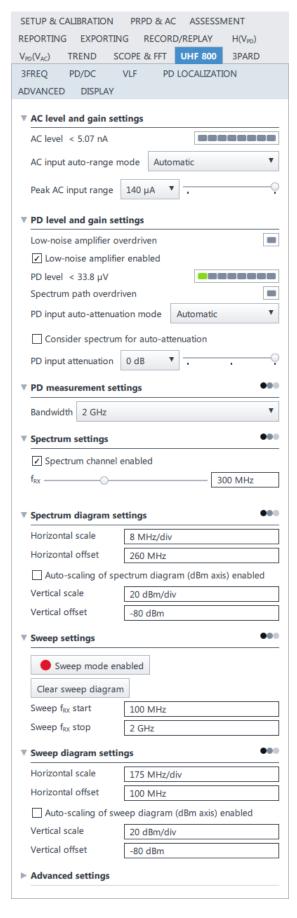


Figure 15.29: The UHF 800 tab of the control panel



The *UHF 800* tab contains settings that control how UHF/PD measurements are made with UHF 800 devices. It aggregates a few settings from other tabs, but also holds specific settings not found anywhere else. The goal is to avoid having to switch tabs when performing the most common measurements.

The UHF 800 tab is only visible when at least one UHF 800 device is connected and has its usage set to *measurement*. It can only be interacted with if the primary-selected channel is a UHF 800. Otherwise, all controls and displays on the tab are grayed out.

15.7.1 AC level and gain settings

This section contains controls that allow configuring the SYNC 24 input of the current primary-selected UHF 800 device which is used to measure the AC signal. The AC level display shows the signal level measured on the SYNC input, both as a current 25 and as a fraction of the maximum level supported by the current range setting. The latter is displayed as LED bar, with green and yellow "lit" LEDs indicating the fraction of the maximum level that is applied to the SYNC input. A red "lit" LED signifies that the SYNC 26 input is being overdriven.

The AC input auto-range setting configures how the MPD Suite automatically adjusts the input range in order to achieve the best signal level. Setting the auto-range mode to Automatic will allow the MPD Suite to set both more and less sensitive input ranges, while Semi-automatic only allows the MPD Suite to set less sensitive input ranges to avoid the input from being overdriven. Finally, the Manual option disables automatic auto-ranging completely. The user must then manually set the desired input range.

The *Peak AC input range* setting allows you to configure the input range that is used for the UHF 800's SYNC²⁷ input. The input range can be chosen either via the selection box or the slider next to it. When a VT sensor is configured in the AC/DC setup section of the SETUP & CALIBRATION control panel tab, there is only a single available input range, and the AC input range controls are hidden.

15.7.2 PD level and gain settings

This section configures the input range and auto-ranging mode of the primary-selected UHF 800's UHF input. It also shows the signal level at the UHF input, given as a current. The *Low-noise amplifier overdriven* display indicates if the low-noise amplifier (LNA) built into the UHF 800 is being overdriven. If that is the case, the LED will turn red; otherwise it will be "off" (as visualized by a dark-gray color). Below the LNA overdrive indication, the *Low-noise amplifier enabled* checkbox can be used to turn the LNA or off. When the LNA is enabled, it will amplify the input signal by approximately 34 dB compared to the LNA-off setting. Further below, the *PD level indication* shows the current level of the high-frequency signal applied at the UHF 800's UHF input. It is given both as a voltage and as a LED "bar", with "lit" LEDs (green or yellow) showing the fraction of the input range that the signal level corresponds to. A "lit" red LED indicates that the UHF input is being overdriven, leading to incorrect measurement readings and clipped waveforms.

A separate indicator visualizes the overdrive state of the spectrum signal path. A red "lit" LED represents the spectrum signal path being overdriven, while a dark-grey ("unlit") LED means that the spectrum path



²⁴**Note** that this only true if the *coupling unit setting* in the AC/DC setup section of the SETUP & CALIBRATION control panel tab is set to a value other than *internal*. If it is set to *internal*, the AC level and range settings apply to the low-frequency signal portion of the **UHF** input instead.

²⁵unless a VT sensor is configured in the AC/DC setup section of the SETUP & CALIBRATION control panel tab, in which case the level is shown as a voltage.

²⁶resp. the low-frequency portion of the UHF input

²⁷except when the *coupling unit setting* in the AC/DC setup section of the SETUP & CALIBRATION control panel tab is set to *internal*, in which case the AC input range settings apply to the low-frequency signal portion of the **UHF** input instead.

is not overdriven. The reason for having separate overdrive indicators is that the different components (LNA, spectrum signal path, PD signal path) can be overdriven at different signal levels depending on the signal waveforms.

The *PD input auto-attenuation mode setting* selects if and how the MPD Suite automatically adjusts the input range in order to achieve the best signal level on its UHF input. Setting the auto-attenuation mode to *Automatic* will allow the MPD Suite to set both more and less sensitive input ranges, while *Semi-automatic* only allows the MPD Suite to set less sensitive input ranges to avoid the input from being overdriven. Finally, the *Manual* option disables automatic auto-ranging completely. The user must then manually set the desired input range. The *Consider spectrum for auto-attenuation* checkbox controls whether the MPD Suite will consider the spectrum signal path when making input range choices. When disabled, the MPD Suite will choose a less sensitive input range only when the PD input signal path is overdriven, but not when the spectrum signal path is overdriven. On the other hand, when the checkbox is enabled, the MPD Suite will also select a less sensitive input range when the spectrum signal path is overdriven.

The *PD input attenuation setting* controls the input range for the UHF input. Unlike with the *AC input range*, where you select the maximum current or voltage when choosing a range, for the UHF input you can select an additional attenuation to apply to the input signal. You can choose 6 settings between 0 and 30 dB, either by selecting the desired setting from the selection box or via the slider to the right of the selection box.

15.7.3 PD measurement settings

This section contains the *bandwidth selection* control, which allows you to switch between the mediumband, the wideband and the narrowband measuring modes. These modes are characterized by their effective bandwidths; mediumband mode has an effective bandwidth of 80 MHz, while wideband mode covers 2 GHz. Narrowband mode provides bandwidths between 9 kHz and 20 MHz. By selecting the *80 MHz* entry in the bandwidth selection box, you configure the UHF PD measurement for mediumband mode, while the *2 GHz* entry selects the wideband mode. All other bandwidth settings enable narrowband mode. **Note** that the bandwidth selection is also available in the mV PD measurement settings section of mV PD on the SETUP & CALIBRATION control panel tab.

When in mediumband and narrowband mode, the f_{RX} setting also affects the PD measurement, as it also acts as the center frequency for the PD measurement. This setting applies to all config-selected UHF 800 devices.

15.7.4 Spectrum settings

These settings configure the spectrum signal path for the UHF inputs of all config-selected UHF 800 devices. The *Spectrum channel enabled* checkbox controls whether measurements on the spectrum signal path are transmitted to the PC. When checked, the spectrum is visualized in the UHF spectrum diagram, or the UHF sweep diagram when a UHF sweep is in progress. When unchecked, these diagrams remain empty.

Below that you find the f_{RX} setting, which configures the mixer frequency of the UHF 800's RF mixer. This setting selects the portion of the spectrum that the UHF 800 will constantly measure, which is approximately 80 MHz wide. The f_{RX} setting is not available while frequency sweeping is enabled, because during frequency sweeps the f_{RX} frequency is constantly stepped across the sweep range.

When the UHF 800 is configured for mediumband or narrowband mode, a message below the f_{RX} control



reminds you that the f_{RX} setting doubles as the f_{M} (center frequency) setting from the mV PD on the SETUP & CALIBRATION control panel tab. **Note** that when the f_{RX} settings are changed, the horizontal offset of the spectrum diagram as configured in the spectrum diagram settings section is automatically updated such that the spectrum around the new f_{RX} setting is centered in the spectrum diagram.

15.7.5 Spectrum diagram settings

This section contains settings that control the spectrum diagram. The *Horizontal scale* value edit sets the scaling of the spectrum diagram along the x (frequency) axis. Below it, the *Horizontal offset* value edit configures the frequency that corresponds to the left boundary of the spectrum diagram. The *Autoscaling of spectrum diagram (dBm axis) enabled* checkbox determines whether the vertical axis of the spectrum diagram is automatically scaled and positioned such that all data is visible. If checked, the vertical scale and vertical offset settings are automatically configured by the MPD Suite, and their corresponding value edits are disabled. When the checkbox is not checked, you must set the vertical scale and offset yourself.

The *vertical scale* and *vertical offset* value edits configure the scaling and positioning of the spectrum diagram along its y (dBm) axis. The vertical offset setting corresponds to the middle of the spectrum diagram along the y-axis.

These settings also apply to all config-selected UHF 800s.

15.7.6 Sweep settings

This section configures UHF frequency sweeps. The *Sweep mode enabled* checkable button determines whether sweeping is enabled. While sweeping, the UHF 800's mixer is quickly stepped through the frequency range and the spectra from each step are combined into a diagram that covers the entire sweep range. Clicking the *Clear sweep diagram* button will clear the current sweep diagram.

Below these two buttons, you can configure the sweep range. The *Sweep* f_{RX} *start* value edit configures the beginning of the sweep range. This setting represents the *first* mixer frequency that will be set when starting a sweep. The *Sweep f_{RX} stop setting, on the other hand, determines the end of the sweep range, i.e. the *last* mixer frequency that will be set during a sweep cycle. **Note** that because the spectrum collected at each mixer frequency actually spans the 80 MHz range *around* the mixer frequency, this means that the resulting sweep diagram will actually show data from approximately 40 MHz *before* the *Sweep* f_{RX} *start* setting until 40 MHz *after* the *Sweep* f_{RX} *stop* setting.

15.7.7 Sweep diagram settings

This section contains settings that control the sweep diagram. The *Horizontal scale* value edit sets the scaling of the sweep diagram along the x (frequency) axis. Below it, the *Horizontal offset* value edit configures the frequency that corresponds to the left boundary of the sweep diagram. The *Auto-scaling of sweep diagram (dBm axis) enabled* checkbox determines whether the vertical axis of the sweep diagram is automatically scaled and positioned such that all data is visible. If checked, the vertical scale and vertical offset settings are automatically configured by the MPD Suite, and their corresponding value edits are disabled. When the checkbox is not checked, you must set the vertical scale and offset yourself.

The *vertical scale* and *vertical offset* value edits configure the scaling and positioning of the sweep diagram along its y (dBm) axis. The vertical offset setting corresponds to the middle of the sweep diagram along the y-axis.



These settings also apply to all config-selected UHF 800s.

15.7.8 Advanced settings

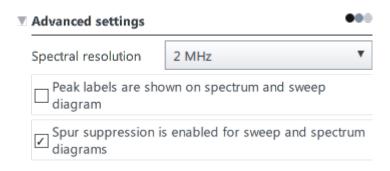


Figure 15.30: The Advanced settings section

This section contains settings that are not as commonly used as the ones described in the previous sections. Changes made here apply to all config-selected UHF 800 devices.

The *Spectral resolution* selection box allows you to configure the spectral resolution of the spectrum and sweep diagrams. You can choose between *2 MHz*, and *200 kHz*, with 2 MHz being the default. The coarser setting makes it easier to see where pulse-shaped signals are present in the diagrams²⁸. The finer resolution, on the other hand, makes it easy to determine with greater accuracy the bandwidth of continuous signals.

The Peak labels are shown on spectrum and sweep diagram checkbox controls whether the spectrum and sweep diagrams show the maximum dBm reading of the spectrum as a separate label. When checked, these labels are visible and display the reading from the currently primary-selected UHF 800. When unchecked, no such labels are shown.

The Spur suppression is enabled for sweep and spectrum diagrams checkbox configures spur suppression. When enabled, spurious signals that are introduced by the UHF 800's device circuitry itself and are not physically present in the input signal are measured and removed from the displayed spectrum and sweep signal.



²⁸Typically, pulse-shaped signals are indicated by the minimum and the maximum plot of the spectrum and sweep diagrams being clearly different from one another, whereas continuous signals are characterized by the maximum and minimum plots converging.



15.8 The PD/DC tab

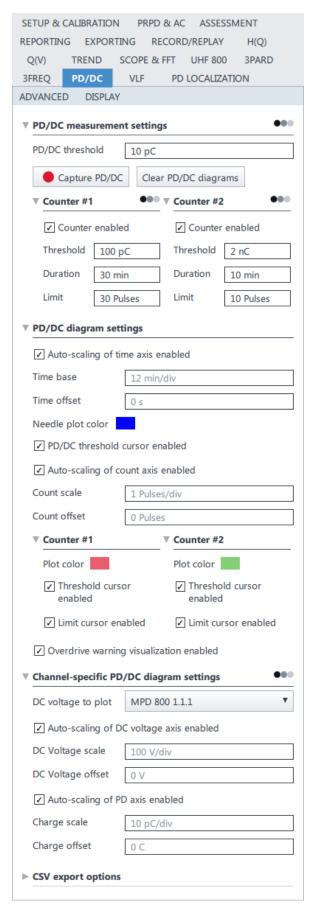


Figure 15.31: The *PD/DC tab* of the control panel



The *PD/DC* tab contains the settings that configure and control *PD/DC* measurements with the MPD Suite. It consists of the following sections:

15.8.1 PD/DC measurement settings

This section contains settings that configure the DC measurement. The *PD/DC threshold* setting controls the minimum charge²⁹ a PD event must have in order to be captured during PD/DC measurements.

The Capture PD/DC button is used to start and stop capturing of PD pulses and DC voltages on all configselected channels. The PD/DC pulses and voltage diagram and the PD/DC counter diagram are only updated when capturing is active. Also, the DC counters are only updated when capturing is active.

The Clear PD/DC diagrams button will clear both the PD/DC pulses and voltage diagram and the PD/DC counter diagram for all config-selected channel groups.

The Counter #1 and Counter #2 sections allow configuring the DC counters. The Counter enabled checkbox controls whether the corresponding counter is enabled. When a counter is disabled, it is not shown in the measured values display and is not included in the PD/DC counter diagram. Also, none of the counter's associated cursors are visible when the counter is disabled. The Threshold and Duration value edits configure the counters' charge threshold³⁰ and duration, respectively. The charge/voltage threshold determines the magnitude that a PD pulse must have or exceed in order for the counter to track it, and the duration sets the length of time for which pulses are tracked. This establishes a sliding time window of length Δt that, for any given point in time t, considers the PD pulses within the time Δt leading up to t for the counter value at time t. Changing these values will re-compute not only the current counter value but also the PD/DC counter diagram. The Limit value edit configures the maximum permissible value for the counter. When the counter value exceeds the limit, the PD/DC test is assessed to be failed.

15.8.2 PD/DC diagram settings

This section contains settings that configure the *PD/DC pulses and voltage* and *PD/DC counter* diagrams. The *Auto-scaling of time axis enabled* setting enables or disables auto-scaling for the time axis that is shared by all PD/DC diagrams. When enabled, the *time base* and *time offset* settings are continuously automatically set such that all time points from all diagrams are visible. When auto-scaling is disabled, the *Time base* value edit can be used to set the time base of all diagrams manually, and the *Time offset* value edit can be used to set the time offset for the diagrams, i.e. the time point at the left diagram boundary.

The Needle plot color configures the color of the individual PD pulses plotted in the PD/DC pulses and voltage diagram. With the PD/DC threshold cursor enabled checkbox you can control whether the PD/DC pulses and voltage diagram shows a cursor indicating the PD/DC threshold. When the cursor is enabled, you can use the mouse to change the threshold directly within the diagram.

The Auto-scaling of count axis enabled setting enables or disables auto-scaling of the count axis that is shared for all PD/DC counter diagrams. When enabled, the MPD Suite will automatically keep the count scale and count offset settings updated such that all counter diagrams show the maximum count across all channels. When count axis auto-scaling is disabled, the Count scale value edit is enabled and controls the vertical scaling of the shared count axis, while the Count offset value edit controls the vertical offset of the count axis.



²⁹or voltage, if mV PD mode is enabled for a channel

³⁰or voltage threshold, when using mV PD mode

Like in the *PD/DC measurement settings* section, the *PD/DC diagram settings* section also has a *Counter* #1 and a *Counter* #2 section. These sections allow you to configure the plot colors of the counters and control whether the counters' threshold cursors and limit cursors are visible in the PD/DC diagrams.

The *Overdrive warning visualization enabled* setting controls whether the *PD/DC pulses and voltages diagram* shows time periods where the PD input may have been overdriven using red shades.

15.8.3 Channel-specific PD/DC diagram settings

This section configures settings that are specific to individual channel groups' *PD/DC diagrams*. All changes made to settings in this section apply to all config-selected channel groups, as indicated by the presence of the symbol.

The *DC* voltage to plot selection box controls which channel group is used to supply the DC voltage reading for the channel group's *PD/DC* pulses and voltages diagram. All enabled AC and V input channels will be available as options in the selection, as well as the *None* option, which means the no DC voltage reading will be plotted in the diagram.

The Auto-scaling of DC voltage axis enabled checkbox enables or disables auto-scaling for the voltage axis used by the channel in the PD/DC pulses and voltages diagram. When enabled, the MPD Suite will automatically keep the DC voltage scale and DC voltage offset settings of all config-selected channel groups updated such that all config-selected PD/DC pulses and voltages diagrams show all DC voltage readings. When DC voltage axis auto-scaling is disabled, the DC voltage scale value edit is editable and controls the vertical scaling of all config-selected channel groups' DC voltage axes, while the DC voltage offset value edit controls the vertical offset of the DC voltage axes.

The Auto-scaling of PD axis enabled checkbox enables or disables auto-scaling for the PD axis used by the channel in the PD/DC pulses and voltages diagram. When enabled, the MPD Suite will automatically keep the charge scale and charge offset settings³¹ of all config-selected channel groups updated such that all config-selected PD/DC pulses and voltages diagrams are vertically scaled in such a way that all PD pulses are fully visible. When PD axis auto-scaling is disabled, the Charge scale and PD voltage scale value edits are editable and control the vertical scaling of all config-selected channel groups' PD axes, while the Charge offset and PD voltage offset value edits control the vertical offset of the PD axes.

15.8.4 CSV export options

This section controls exporting of PD events and DC voltages to CSV files.



³¹or the PD voltage scale and PD voltage offset settings when using mV PD mode

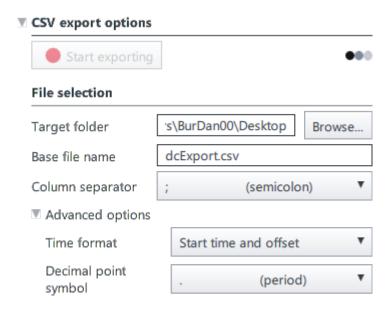


Figure 15.32: CSV export option section

The Start exporting button begins exporting of CSV files. The button is enabled when PD/DC capturing is enabled. When the button is checked, the MPD Suite will begin exporting PD and DC data to CSV files for all config-selected channel groups.

The *File selection* section contains settings that control where CSV files are placed and how they are named. The *target folder* setting selects the folder in which CSV files are stored. Use the *Browse...* button to browse for a folder. The *Base file name* edit field controls the base file name from which the file name for each CSV file is constructed. The base file name contains the *name* and *extension* components. For the default setting of dcExport.csv, the *name* component is dcExport and the *extension* component is csv³². To construct the actual name for the CSV files, the *name* component of the *base file name* setting is extended by the name of the channel, with the special symbols:, <, >, ?, *, /, \, & and the space symbol replaced with _, and the _ symbol inserted between the *name* component and the channel name. Files containing PD pulse data will then have the text _pd appended to them, while the names of files with DC voltage data are concatenated with the string _dc. For all files, the date and time of the moment when the file was created is further appended. Together with the extension configured in the *base file name* field, this produces file names such as dcExport_mpd_800_1_1_1_pd-2021-03-02_12h17m09s.csv.

The Column separator selection box controls the symbol that will be used to separate columns in CSV files. You can choose between semicolon (;), comma (,), the pipe symbol (|), the tilde symbol (~), a caret (^) or a tabulator character (, represented by the ASCII code 9).

The Advanced options expander contains additional settings that control the exact format of the CSV files to be created. The *Time format* selection box allows you to define the format used to represent time points in CSV files. This selection box provides the following options:

- Start time and offset reports the absolute time of the first time point in the column header, and then reports subsequent time points as an offset to the first time point, given in seconds.
- Compatible with Microsoft Excel reports each time point in a format that Microsoft Excel can consume when loading CSV files. The time point "March 4th, 2021, 01:17:20 pm and 1237.456 ms"



³²While csv is the recommended extension, other common extensions for CSV files include tsv, txt, and dat

would be reported as $2021-03-04_{\square}13:17:20.1237456$.

- *ISO 8601* uses the ISO 8601 format to report time points. "March 4th, 2021, 01:17:20 pm and 1237.456 ms" would be reported as 2021-03-04T13:17:20.1237456.
- *Default* uses the following format for the time point "March 4th, 2021, 01:17:20 pm and 1237.456 ms": 04-03-2021 13:17:20.1237456.

The *Decimal point symbol* selection box allows you to configure the symbol to be used as the decimal point in numbers. In English, usually a *period* symbol (.) is used. This is the default option. Alternatively, you can choose the *comma* symbol (,) instead.

