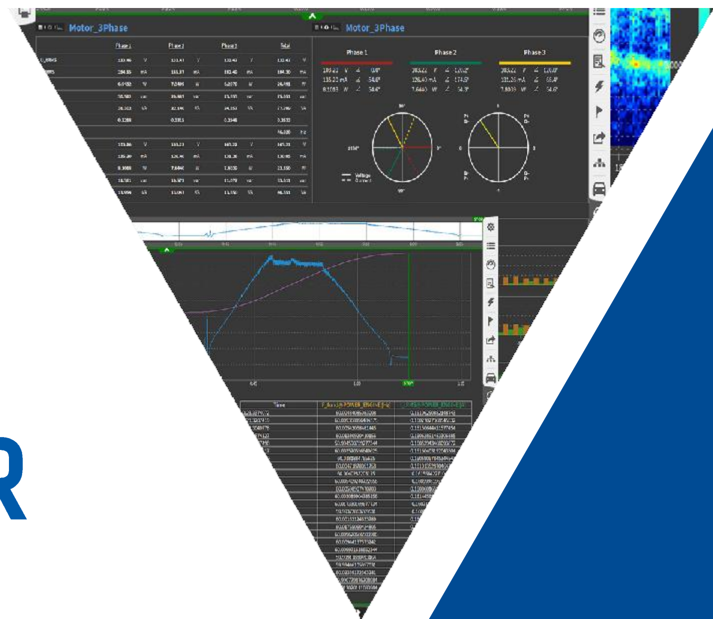
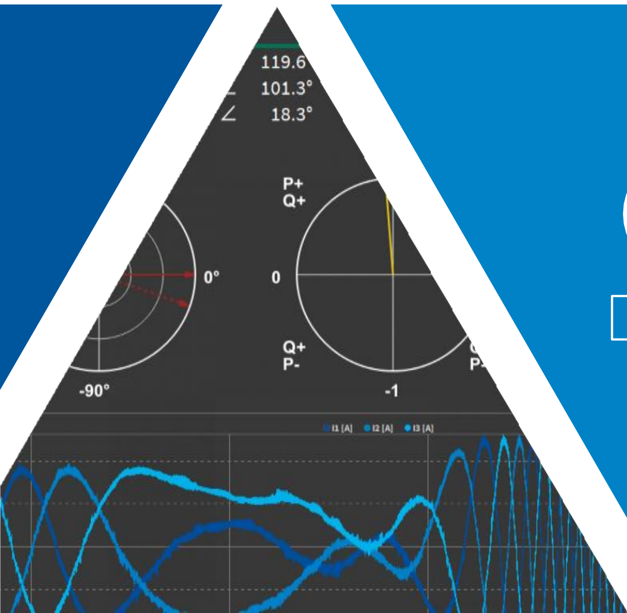
DEWETRON



OPT-POWER

SOFTWARE MANUAL



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CONTENTS

OXYGEN POWER Software Manual

CHAPTER

ONE

PREFACE

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Technical Support

Please contact your local authorized DEWETRON representative first for any support and service questions.

For Europe and Asia, please contact:

DEWETRON GmbH
Parkring 4, 8074 Grambach
AUSTRIA
Tel.:+43 316 3070-555
Fax: +43 316 3070-90
Email: support@dewetron.com
Web: http://www.dewetron.com
The telephone hotline is available Monday to Friday between 08:00 and 17:00 CET (GMT +1:00)

For America, please contact:

DEWETRON, Inc.
2850 South County Trail
East Greenwich, RI 02818
USA
Tel.: +1 401 398 7963
Fax: +1 401 284 3755
Email: us.support@dewetron.com
Web: http://www.dewetron.com

The telephone hotline is available Monday to Friday between 08:00 and 17:00 GST (GMT -5:00)

DEWETRON GmbH
Parkring 4
8074 Grambach
AUSTRIA

Please find further information at https://www.dewetron.com.

CHAPTER

TWO

DOCUMENT HISTORY

Date	Author	SW Version	Change	Doc. Rev.
15.12.2017	MO	OXYGEN 2.6	First release version – Power-BASIC, -HARM and -FLUC	x.x
29.05.2018	MO	OXYGEN 3.1	Update	x.x
08.04.2019	MO	OXYGEN 3.5	Rolling Computation added	x.x
21.06.2019	MO	OXYGEN 3.6	Update	x.x
26.09.2019	MO	OXYGEN 3.7	Delay Compensation added	x.x
20.12.2019	MO	OXYGEN 5.0	Mechanical Power Computation added	x.x
30.03.2020	MO	OXYGEN 5.1	Update	x.x
23.06.2020	MO	OXYGEN 5.2	Update	x.x
09.03.2021	MO	OXYGEN 5.5	d/q Analysis added	x.x
15.12.2021	MO	OXYGEN 6.0	Update	x.x
25.03.2022	MO	OXYGEN 6.1	Update	x.x
28.09.2022	MO	OXYGEN 6.3	Capacity calculation added	x.x
09.01.2023	MK	OXYGEN 6.4	Sensorless d/q Analysis added	x.x
26.04.2023	MK	OXYGEN 6.5	Fallback sync source added	x.x
11.07.2023	MK	OXYGEN 6.6	Flicker impedance angles added	x.x
28.09.2023	MK	OXYGEN 6.7	Update	x.x
02.02.2024	MK	OXYGEN 7.0	Power Screen Templates added	x.x
23.05.2024	MK	OXYGEN 7.1	Update	x.x
18.09.2024	MK	OXYGEN 7.2	Update	x.x
06.12.2024	MK	OXYGEN 7.3	Machine Excitation added	x.x
06.02.2025	MK	OXYGEN 7.4	Update	x.x
02.05.2025	MK	OXYGEN 7.5	Flicker Reporting added	x.x
31.07.2025	MK	OXYGEN 7.6	Harmonics Limit Table added	x.x
31.10.2025	MK	OXYGEN 7.7	Harmonics Faster Update option	x.x
30.01.2026	MK	OXYGEN 8.0	Update	x.x
12.05.2026	MK	OXYGEN 8.1	Realtime option	x.x
12.05.2026	MK	OXYGEN 8.2	Update	x.x

Authors: M. Kaiss (MK), M. Oberhofer (MO), T. Klug (TK), M. Fuchs (MF)

CHAPTER

THREE

GETTING STARTED

OXYGEN OPT-POWER (OXYGEN Power) is up to date Power Analyzer software option of the award winning OXYGEN Measurement Software from DEWETRON that you can use with most of the DEWETRON Hardware Devices.

In addition to the list of general features, this chapter describes how to perform the following tasks:

- Activate features
- Setting up transducers
- Perform simple measurement
- Save and load setups

Attention

DEWETRON offers taylor made product and application trainings to support you with your measurement and analysis. Please contact us for more information

3.1 General Features

The following table shows the general functions. Overview of major devices and features.

Table 3.1: Overview of major devices and features

Type	Hardware	Bandwidth	Samplerate	Phasecount
PA-TRIONet3	TRION3-1810-HV	5 MHz	1 MS/s	4
LITE[PA]	LITE[PA]-4	5 MHz	10 MS/s	8
DEWE3-A4/A4L/M4	TRION3-1810M-POWER-4	5 MHz	10 MS/s	8
DEWE3-PA8	TRION3-1810M-POWER-4	5 MHz	10 MS/s	16
DEWE3-RMX	TRION3-1810M-POWER-4	5 MHz	10 MS/s	16

The following configuration features are available to maximize flexibility and analysis comfort:

- Full flexible input configuration
- Simple setup within seconds
- Individual phase groups (up to 9 phases per PowerGroup)

- Free selectable sync channel
- Unlimited recording (only limited by harddisk space)

In addition to the great measurement functions of OXYGEN, the POWER-Option enables the detailed analysis of the phase values and total values in L-N configuration (each total and fundamental):

- Voltage (RMS, AVG, PHI, Peak-Peak)
- Current (RMS, AVG, PHI, Peak-Peak)
- Active Power (AVG, PHI)
- Reactive Power (AVG)
- Apparent Power (AVG)
- Power Factor (AVG)
- Fundamental Frequency (0.2 – 200 kHz)
- Harmonics (up to 1000th order)
- Interharmonic (up to 1000.5th order)
- Higher Frequencies (2-9 kHz Grouping)
- Supraharmonics (8-150 kHz with 2 kHz Grouping)
- Voltage Fluctuation Pst, Plt, dc, dmax, td (50 Hz, 60 Hz)
- Flicker Emission Pst_fic, Plt_fic (50 Hz, 60 Hz)
- Rolling Computation (Update every 1ms)
- Mechanical Power Computation and Efficiency
- D/Q Analysis

Note

The requirements for full functionality and maximum speed are:

- CPU: Intel Core i5 3rd Generation or better
- RAM: 8 GB or greater
- DAQ: TRION or Orion
- OS: Windows 7 64 Bit or newer (Linux Version on request)
- Preinstalled DAQ driver (TRION API or Orion driver)

3.2 Installation and Operation

1. Switch on your DEWETRON measurement device.
2. Use the provided DEWETRON OXYGEN Installer if not installed already.
3. Start the OXYGEN measurement software (if not automatically).

After startup, you see the following measurement screen:

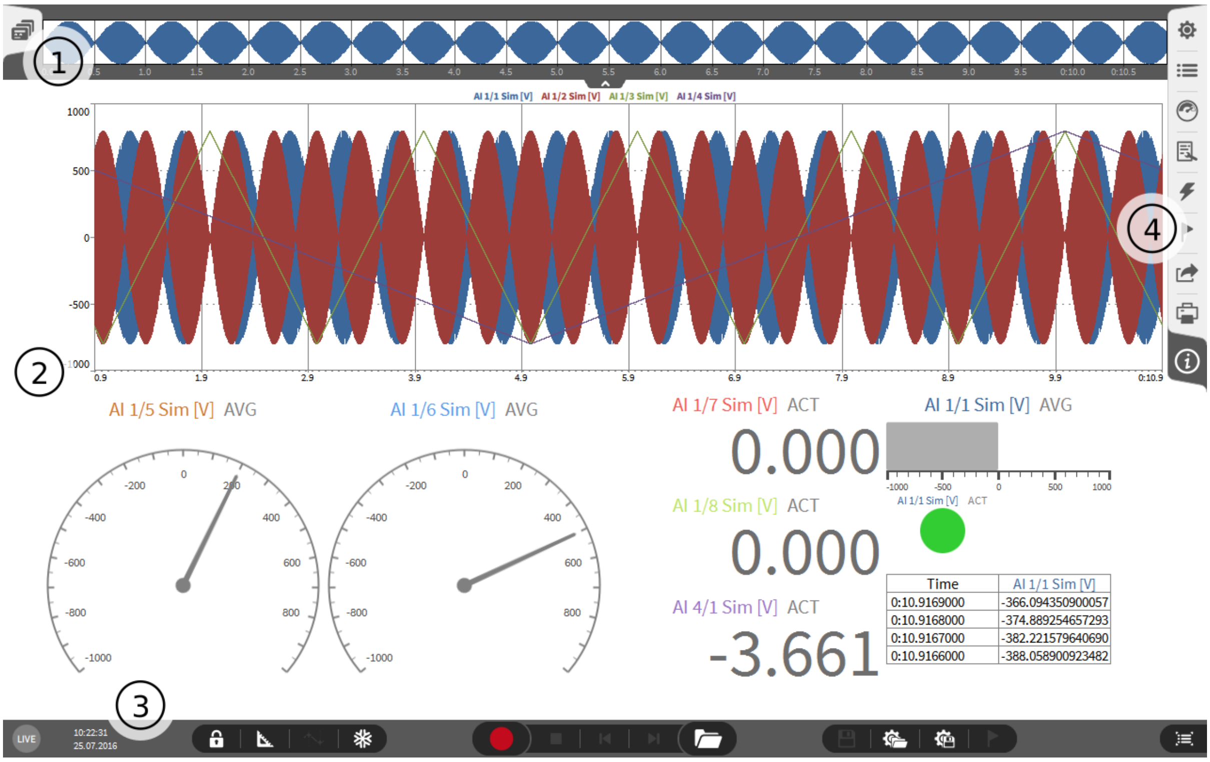


Fig. 3.1: Screen Area

1	Open screen overview	2	Instrument area
3	Action Bar	4	Menu

This is the "main" screen of the instrument to operate all measurements, readings, recordings and settings. There is not only one screen, you can define a couple of them, each with different instruments and views to stay focused during the measurement application. To open the *Screen Overview*, just click or slide **1**. The *Instrument Area* **2** is the place, where you can drag'n'drop all different instruments (recorder, scope, digital meter, gauge, power instrument...) and arrange them as you like. All actions can be performed in the *Action Bar* **3** to start/stop a recording, load and save data and configuration setups. The bar on the right side is the *Menu Bar* **4** contains the settings in logical groups.

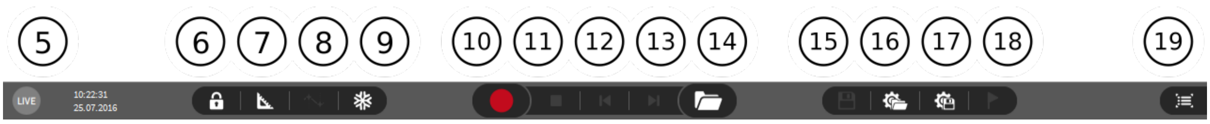


Fig. 3.2: Action Bar

5	Instrument state indicator	13	Jump forward
6	Screen lock	14	Open Data File for Analysis (.dmd)
7	Design mode	15	Save changes in Data File (Play Mode)
8	Activate/Deactivate cursor for active instrument	16	Open configuration setup (.dms)
9	Freeze screen content	17	Save configuration setup (.dms)
10	Start recording / Arm trigger	18	Insert marker during recording
11	Stop recording	19	Open/Close channel overview list
12	Jump backward		

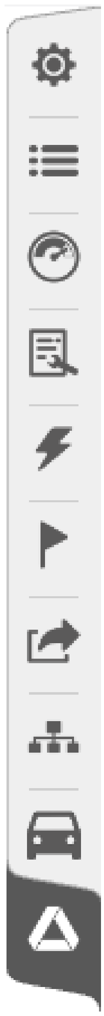


Fig. 3.3: Menu Bar

20	Open measurement settings and recording file name	25	Open event list
21	Open channel overview list	26	Open export menu
22	Open instrument selection	27	Open print/screen copy menu
23	Open current selected instrument properties	28	Open info screen and OXYGEN setup
24	Open trigger and storing options menu		

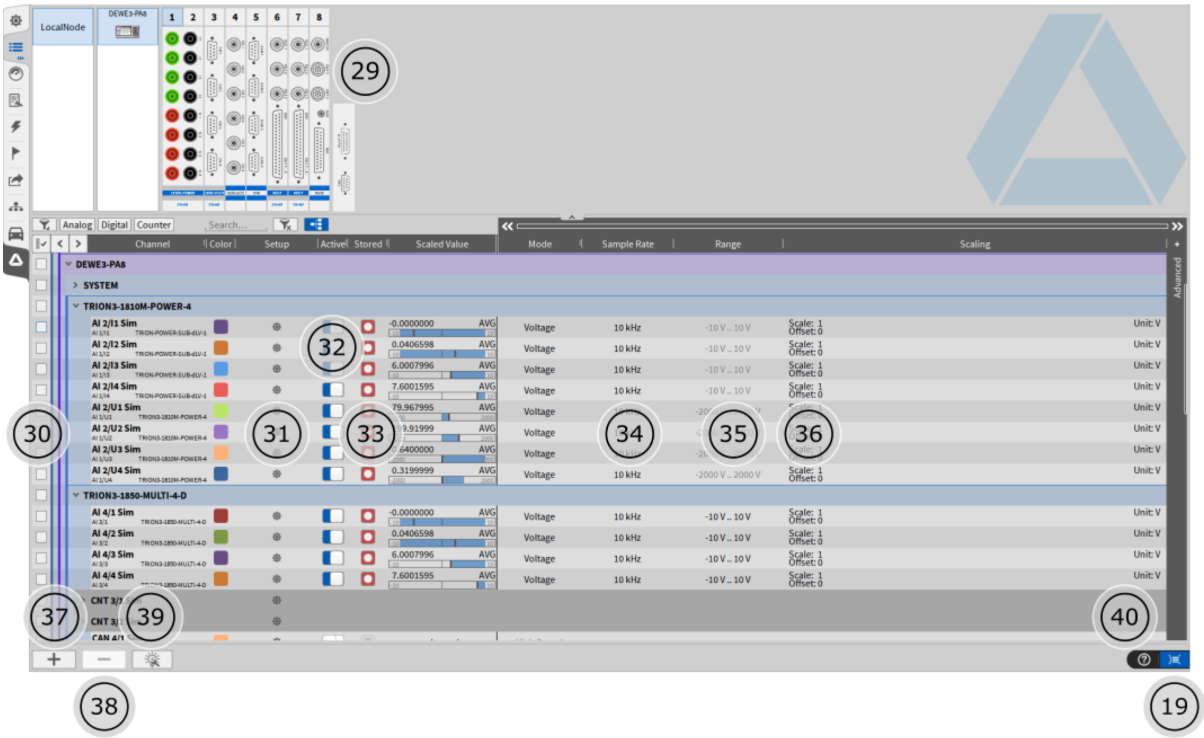


Fig. 3.4: Channel Overview List

29	Graphical and interactive input view	36	Scaling settings
30	Multi-Select indicator	37	Add calculated channel (statistics, filter, formulas, etc.)
31	Channel detail setup	38	Delete selected channels (if possible)
32	Channel active slider	39	Create PowerGroup with selected channels (channel count must be even number)
33	Storing indicator (red when stored, grey only for viewing)	40	OXYGEN help and welcome tour
34	Sample Rate selector	19	Open/Close channel overview list
35	Range selector		

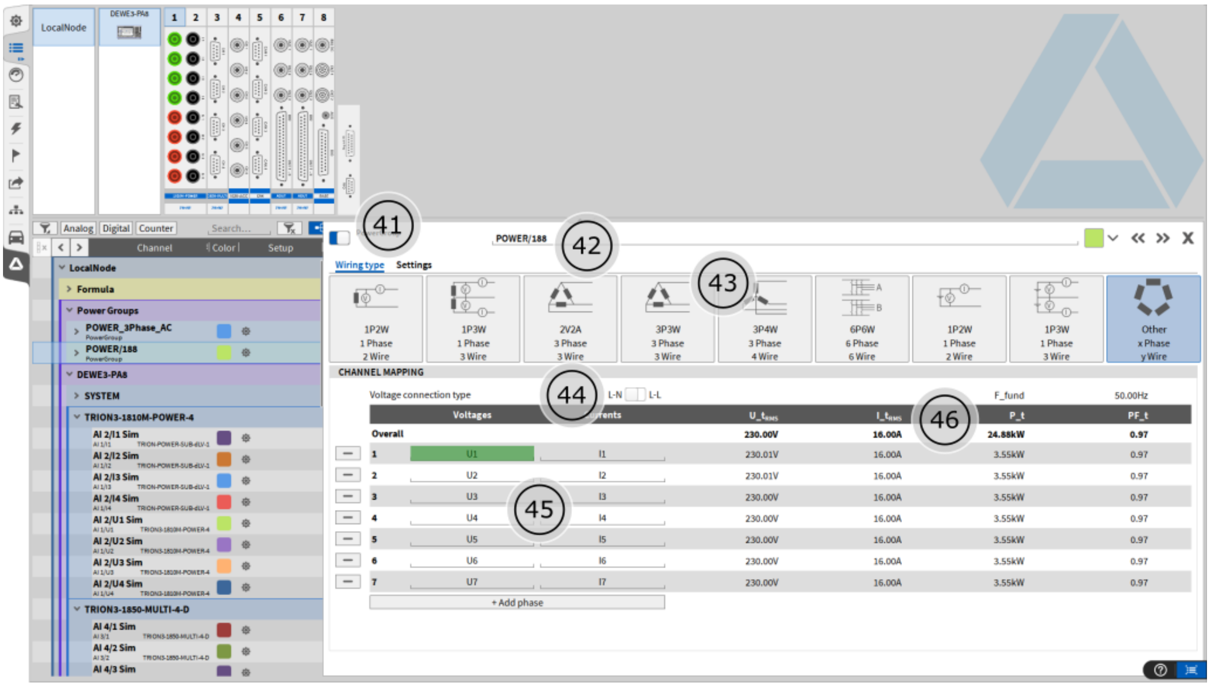


Fig. 3.5: PowerGroup Setup

41	Switch between Wiring Type and advanced Settings	44	Voltage input connection type switch (L-N: Input is Line-Neutral Voltage, L-L: Input is Line-Line Voltage)
42	Name of PowerGroup (click to change)	45	Phase input channels (drag'n'drop from left channel list)
43	Selected Wiring Type (choose one of the pre-defined or Other)	46	Overview Table

3.3 Functional Check

For a quick functional check and first measurement experience, use a test cable (mains plug with to safety banana plugs) and test voltage magnitude.

1. Switch on your DEWETRON device.
2. Connect the mains plug of the test cable to a wall socket and the banana plugs to an voltage input of the DEWETRON device.
3. Navigate to the channel list on the screen **19** or **21**.
4. Set Samplerate to at least 100 kHz.
5. Press "Create Power Group" button **39**.
6. Select the Wiring Type **1P2W** in the selection above.
7. Drag'n'Drop the Voltage Input channel into the U1 Field.
8. Drag'n'Drop Current Input channel into the I1 Field.
9. Check mains voltage in the preview.

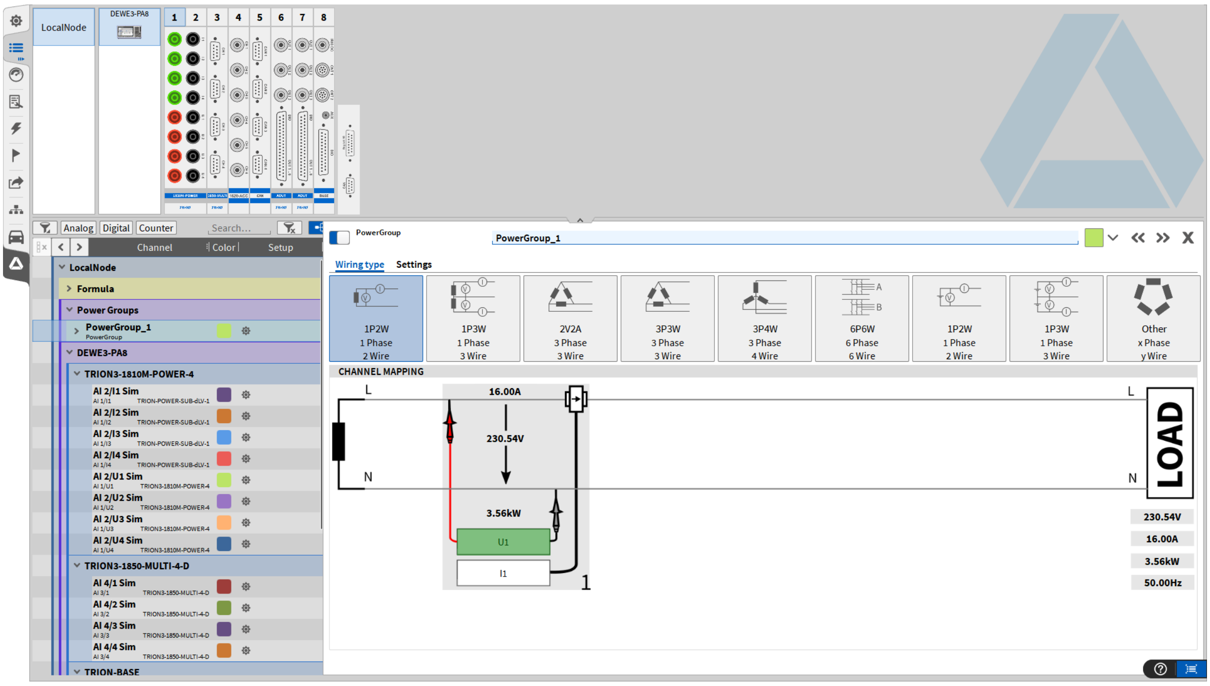


Fig. 3.6: First Setup

Attention

The green highlighted box is the actually selected synchronisation source.

Note

Make sure, that you use only an appropiate isolated input channel. Examples for this are TRION(3)-POWER and TRION(3)-HV boards.

3.4 Setting up sensors

To make properly measurements, the sensor scalings (e.g. current transducers) have to be set correctly. In the most cases, the sensor label gives information about the input/output scaling. This value is often known as "transducer factor", "ratio" or "sensitivity". Important is the unit of the scaling, e.g. 20 mV/A or 50 A/V or 1:50. The order to input the correct scaling is the following:

- Click/Touch the "Scaling" field of the concerning channel **35**.
- The Channel Scaling pops up to change the defaults.
- Change the unit to the primary measured unit (e.g. A for Amps).
- Enter the scaling value directly if given in the shown unit (e.g. A/V).
- If the sensitivity is given, select the sensitivity button and enter the value.

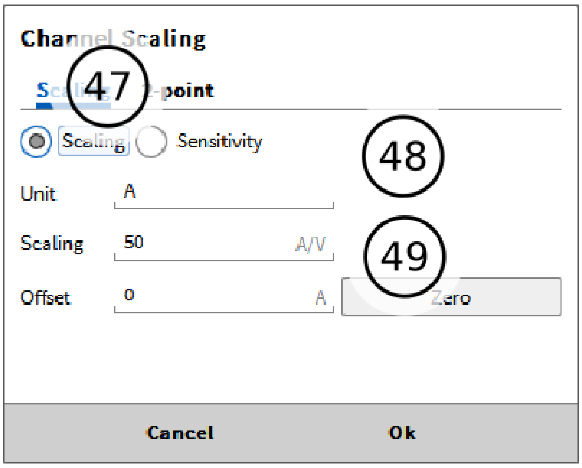


Fig. 3.7: Channel Scaling

47	Scaling/Sensitivity selector (switch between modes)	49	Unit field, input physical value here
48	Scaling/Sensitivity input (according to shown unit)		

3.5 Arrange Instruments

Now it is time to launch the measurement.

1. Leave the channel setup by pressing **19** (or sliding **21**)
2. Clear the screen by opening the instrument selector **22** and pressing the button “Clear” at the bottom.
3. Create an instrument (e.g. Power Instrument) by changing to the channel list (press **21**) and drag’n’drop the PowerGroup channel onto the instrument area (Default Name of PowerGroup is POWER/Number).
4. Arrange and resize the instrument for a good view.
5. Add another instrument by moving to the instrument list **22** and drag’n’drop an item to the screen.
6. Append Channels by selecting them from the channel list **21**.

3.6 Power Instrument

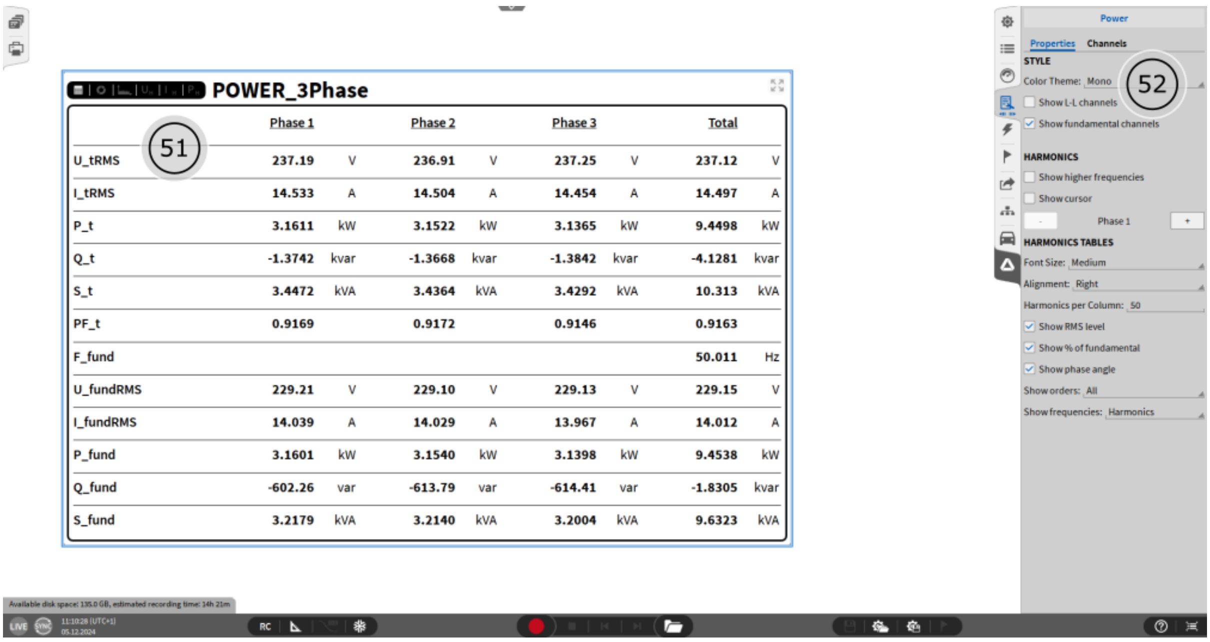


Fig. 3.8: Power Instrument

50	Name of shown PowerGroup	52	Instrument settings
51	Instrument view selector (Overview Table, Phasors, Harmonics)		

You can also add other instruments to the screen, simply by drag'n'drop. To add a channel to specific instruments, just select them in the channel list and drag'n'drop on the instrument. Or simple select the instrument first and assign channels afterwards by selecting them in the channel list.

3.7 Power Screen Templates

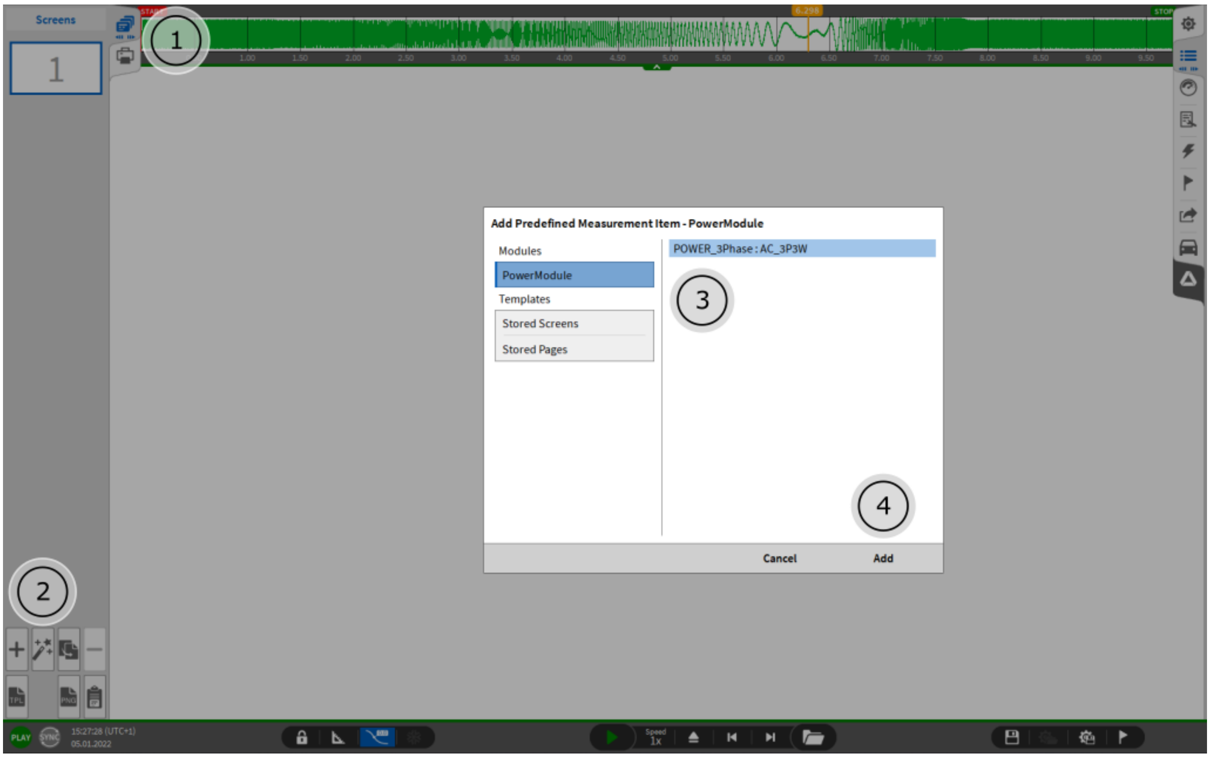


Fig. 3.9: Power Templates Setup

1	Open Screens	3	Select Power Module Template
2	Add predefined item	4	Add Power Screen Template

Adding the predefined PowerModule for a Power Group will add a new measurement screen with a pre-arranged group of instruments. This is available for each created Power Group in your setup. Templates are available for each wiring type.

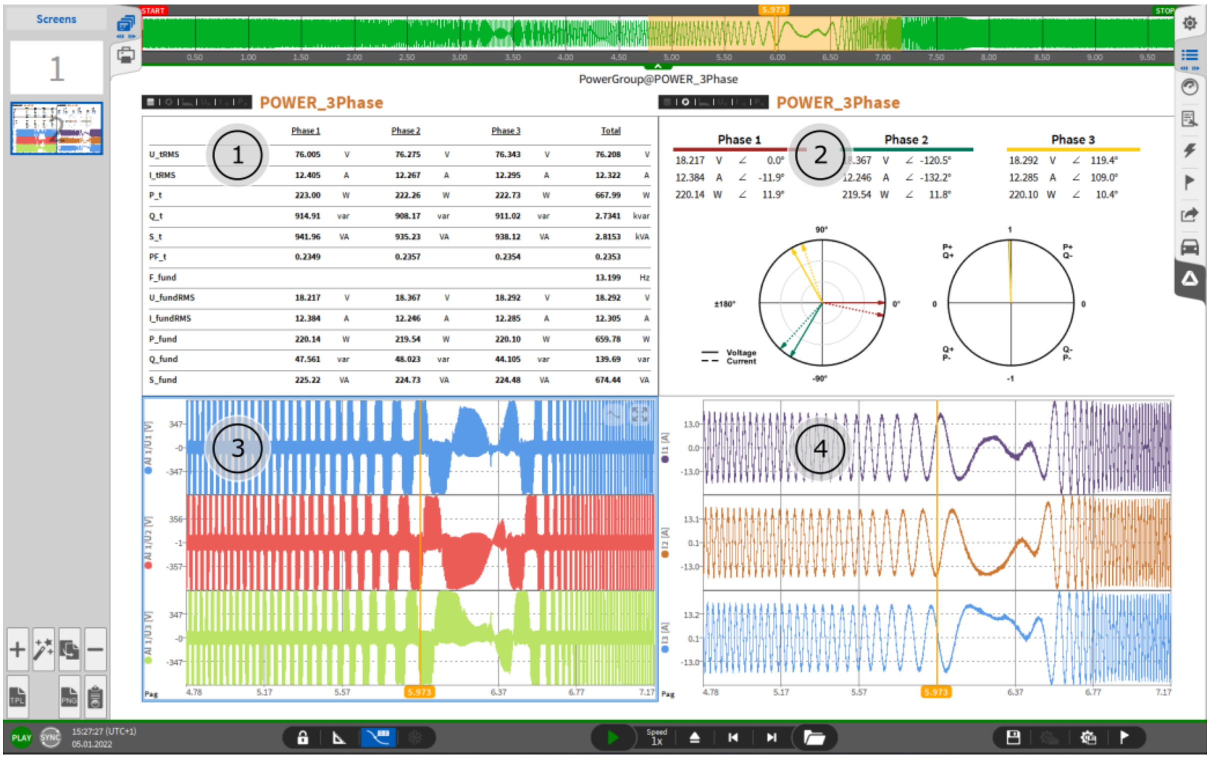


Fig. 3.10: Power Templates Screen

1	List display of the power instrument	3	Voltage Chart Recorder in Range of 10 seconds
2	Vector diagram of the power instrument	4	Current Chart Recorder in Range of 10 seconds

The Power Templates always consist of a group of 4 instruments. The top 2 instruments are displaying the calculated power values in list and vector form. The bottom two instruments are displaying the raw waveforms of voltage and current in chart recorders. The voltage signals and the current signals are displayed in one chart recorder respectively. The signals are displayed in a time range of 10s and automatically scaled to fit to the value-axis. The two chart recorders are linked, so scrolling in one recorder to change the time scale will also affect the other recorder in the same way. Double clicking on any instrument on the template measurement screen will open the Instrument Group Settings. You can change the Instrument Group display name, visible on the top center of the screen and you can dismantle the group into each separate instrument. After dismantling the Group it is possible to resize and rearrange the instruments as well as changing individual instrument settings.

CHAPTER

FOUR

UNDERSTANDING POWER ANALYZER FUNCTIONS

This chapter contains the basic functionality of OXYGEN Power, its provided measurement capabilities and output channels.

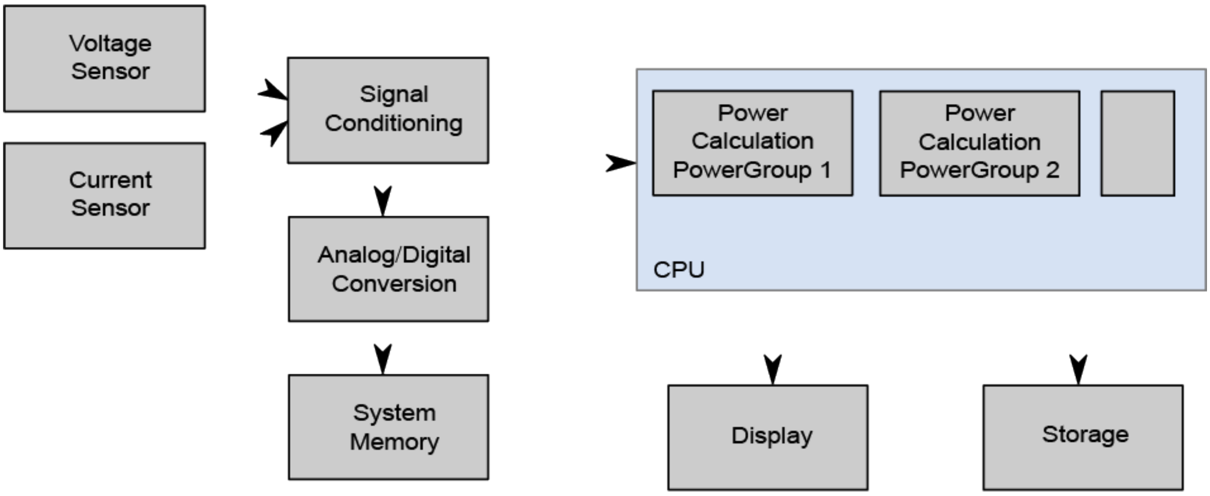


Fig. 4.1: Signal and Data Flow

4.1 Power Analysis in General

Power Analysis basically consists of the following Topics:

- Analysis of Voltage and Current Magnitude
- Analysis of Active Power
- Analysis of Reactive Power

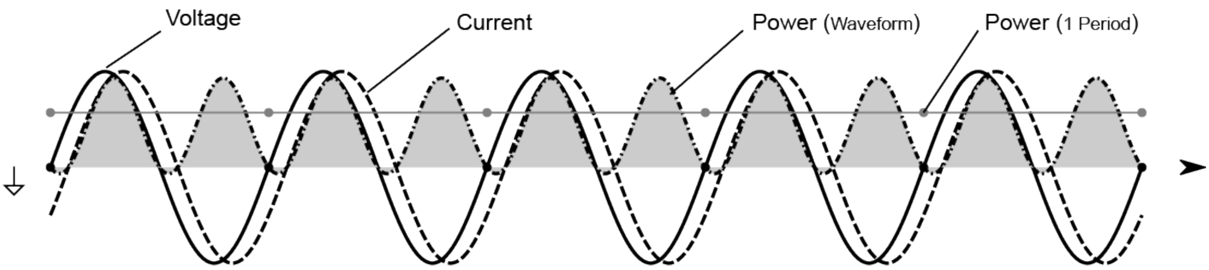


Fig. 4.2: Power Analysis Basics

4.2 Sub-Sampling Settings

To Reduce the calculation load on the measurement device, it is possible to select a subsampling factor. This can be AUTO or a Number between 1 to 5. It reduced the data rate of the input channel by the set factor via skipping algorithm. **Only modify if necessary!**

Table 4.1: AUTO Sub-sampling Factors

Samplerate	Sub-sampling Factor
<= 2 MS/s	1 (= no sub-sampling)
> 2 MS/s–4 MS/s	2
> 4 MS/s–6 MS/s	3
> 6 MS/s–8 MS/s	4
> 8 MS/s	5

4.3 Calculation Modes

The Calculation Cycles depends on the **SYNC Source** settings. This can be **Input Channel** (Waveform of the selected channel) or **Time Interval** (Fixed Interval, available only in DC or Other Wiring Types). The typically operation mode is Input Channel with the first voltage channel (U1).

4.3.1 Interval Mode

This mode is mainly for DC measurements and high fundamental frequencies.

4.3.2 Sync Channel Mode

The Sync Mode is typical for major periodic signals, like rotary field motors or grid connected appliances. In this mode, the calculation of all power output channels is synchronized to the selected channel's fundamental waveform Zero-Crossings. This guarantees a precise and highly dynamic measurement of all power channels. Most of the power values are updated every single period. The minimum update rate is 0.1 ms but at least 1 fundamental period.

Frequency Measurement

The frequency measurement is done by zero-cross detection. A smart frequency input filter guarantees maximum accuracy, speed and stability.

Table 4.2: Minimum Fundamental Frequency depending on Samplerate

Samplerate	Minimum Fundamental
< 10 kHz	None
10 kHz–20 kHz	0.2 Hz
20 kHz–1 MHz	0.2 Hz
1 MHz–2 MHz	0.5 Hz
2 MHz–4 MHz	1 Hz
> 5 MHz	2 Hz

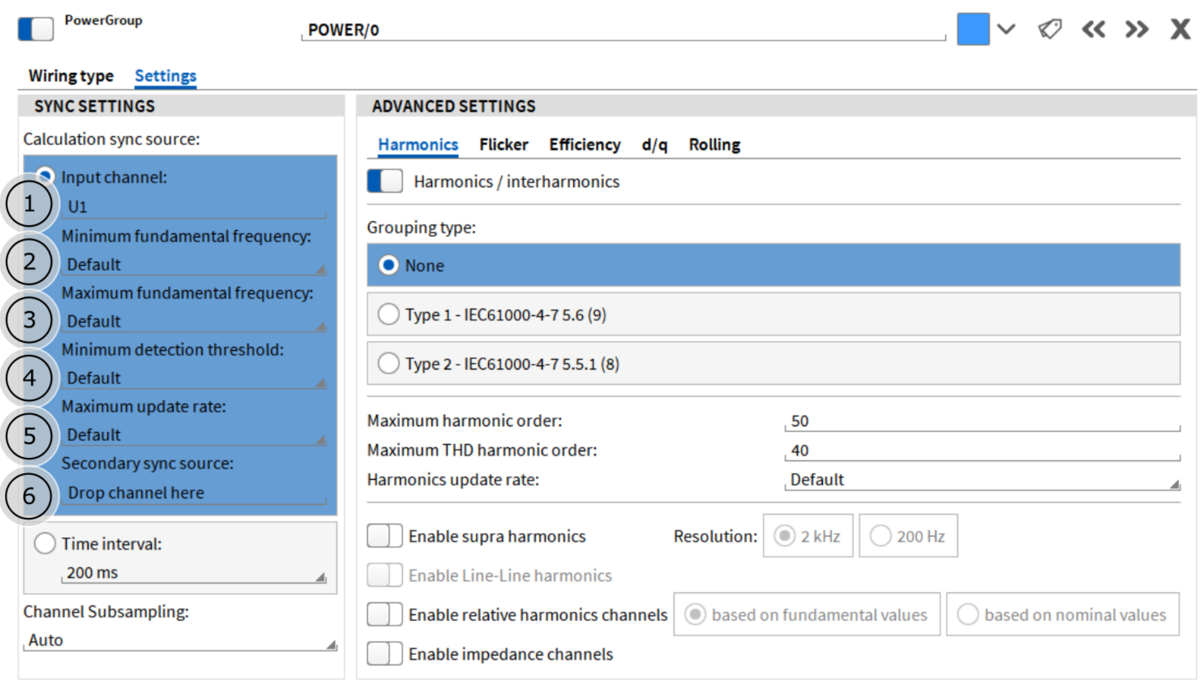


Fig. 4.3: Expert Settings of Power Group

1. Synchronisation channel, Drop channel from channel list, Default=First Voltage Channel of Power Group
2. Minimum fundamental frequency input field (0.2 – f_max)
3. Maximum fundamental frequency (f_min – 0.1*Samplerate Hz)
4. Minimum detection threshold (Default / 0.0 % to 50 % of Input Range)
5. Maximum update rate (Default / 1–5000 ms / 1–100 periods)
6. Secondary sync source, Drop channel from channel list, Default = Empty

Minimum Fundamental Frequency

This input field holds the setting for the minimum fundamental frequency in Hz which can be measured (lower limit). The following settings are available:

- **Default:** Standard setting, uses 0.2 Hz internally (up to 1 MS/s) and >0.5 Hz above. The actual value is the lower bound of the F_fund channel range.
- **0.2 .. f_max Hz:** User defined setting, the possible range is between Default and 100 Hz.

Maximum Fundamental Frequency

This input field holds the setting for the maximum fundamental frequency in Hz which can be measured (upper limit) The following settings are available:

- **Default:** Standard setting, uses 1500 Hz internally (>20 kS/s). The actual value is the upper bound of the F_fund channel range.
- **Auto:** Uses 1/10 of Samplerate
- **f_min .. Samplerate/10 Hz:** User defined setting, the possible range is between f_min and 1/10 of Samplerate.

Minimum Detection Threshold

This input field holds the setting for the Minimum detection threshold in % of the sync channels input range. The following settings are available:

- **Default:** Standard setting, dynamically adapted to actual fundamental frequency and SNR level
- **0–50 %:** Override setting for Zero Crossing detection threshold in % of range

Maximum Udate Rate

The Maximum update rate is the maximum frequency of the calculated output channels. Input a time interval in millisecond or a number of periods. After entering a number **ms** or **periods** can be selected from a dropdown menu.

- **Default:** Standard setting, uses 1 ms internally
- **1 .. 5000 ms:** User defined setting
- **1 .. 100 periods:** User defined setting
- **SYNC to HARMONIC:** Synchronize basic calculation parameters to Harmonic Calculation update rate.

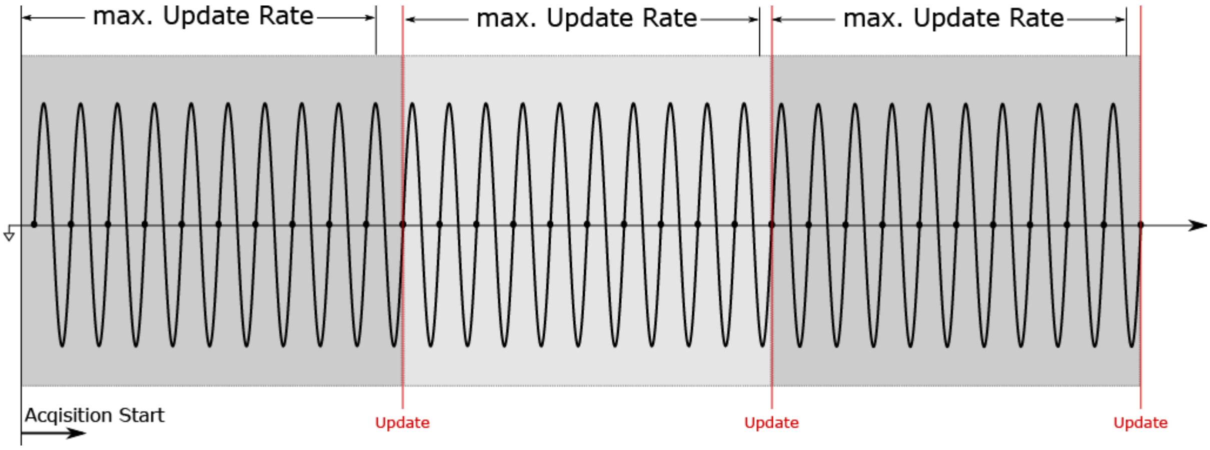


Fig. 4.4: Update Rate - Example

Secondary Sync Source

The secondary sync source is a fallback channel in case the fundamental frequency in the primary sync source in **1** cannot be detected.

Attention

If the fundamental Frequency value is out of range or the magnitude of the Sync Channel is lower than 0.2 % of the input range, the calculation interval is set to fixed time until the signal is back in range.

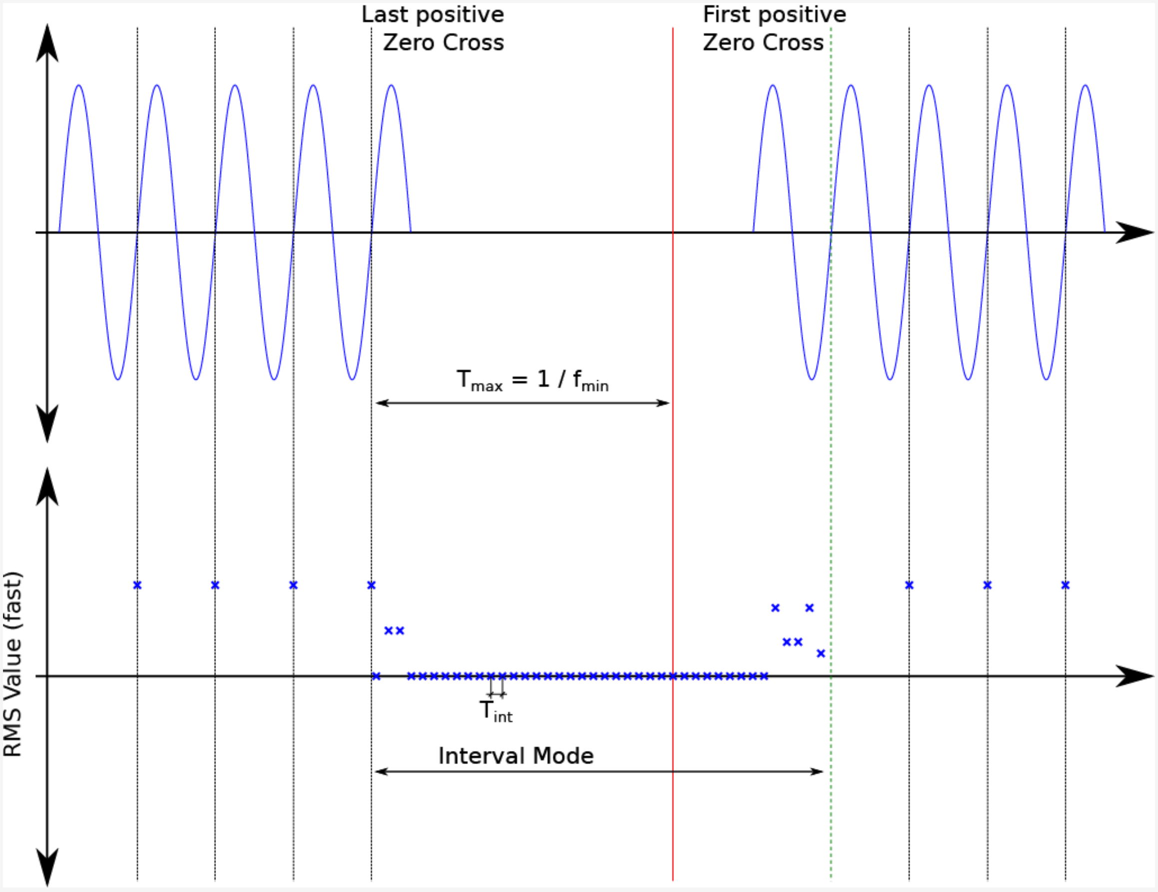


Fig. 4.5: Calculation Intervals with Gaps

If the distance between two positive Zero Crossings is greater than the maximum detectable fundamental period time, the calculation interval is switched to fixed time base until a full period is detected again.

CHAPTER

FIVE

OPERATING BASICS

The DEWETRON OXYGEN is arranged in different easy-to-use functional areas. This chapter provides a quick overview of the controls and visualisations.

5.1 The PowerGroup Idea

To understand the terminology of the PowerGroup and the PowerPhase, let's explain it with the following graphics: The PowerGroup consists of multiple PowerPhases which are Voltage-Current pairs. Each PowerPhase is evaluated individually and synchronously. The PowerGroup values are aggregated values from each PowerPhase and share their common fundamental frequency (Common Sync) which can be chosen separately.

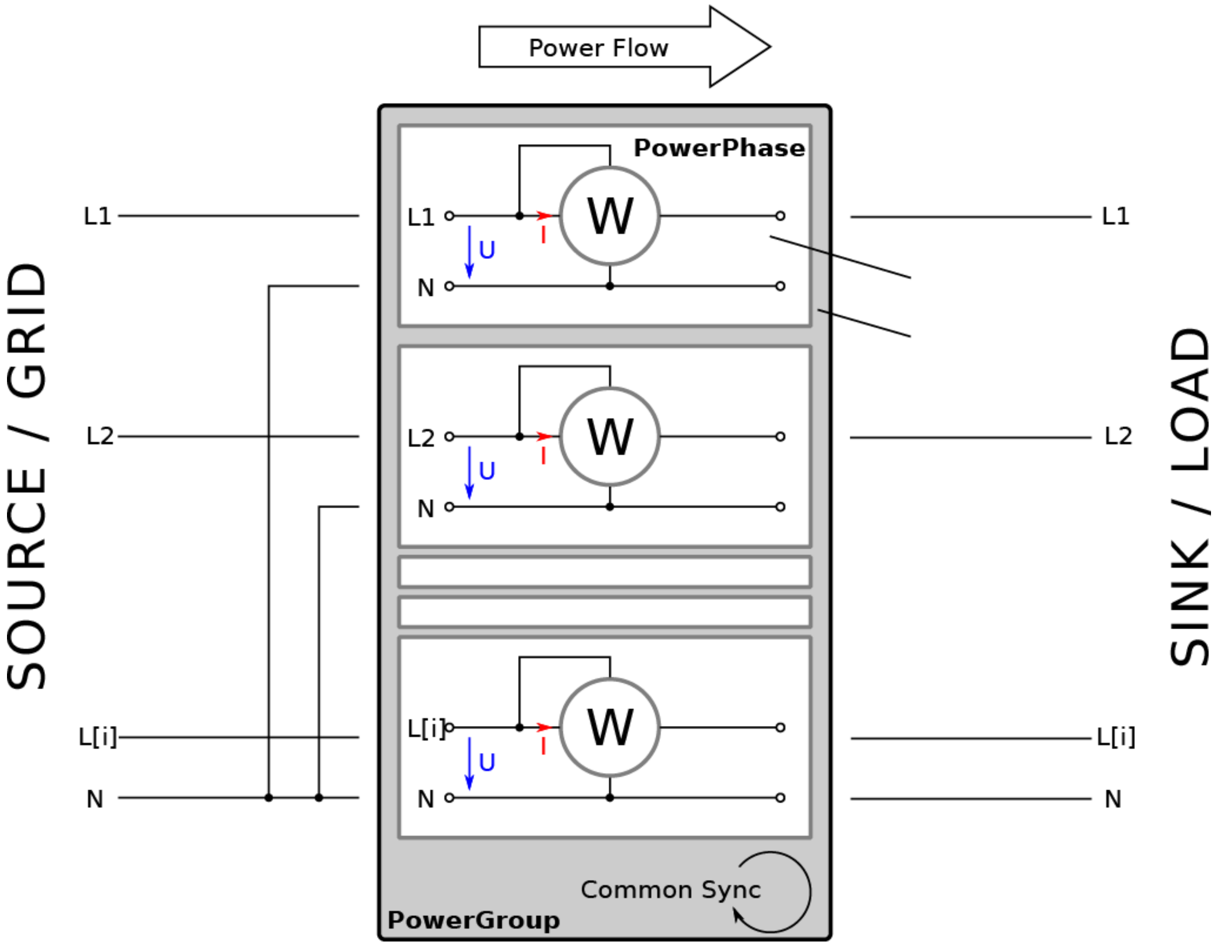
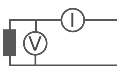
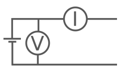
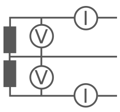
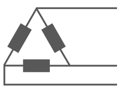
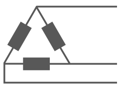
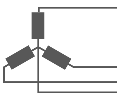
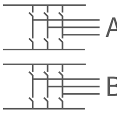
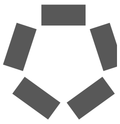


Fig. 5.1: PowerGroup Schematic

5.2 Connection Types

This design is open to be used with almost every connection type and phase count.

-  1 Phase (AC) Line-Neutral (1P2W)
-  1 Phase (DC) Line-Neutral (1P2W)
-  2 Phase (AC) Line-Neutral or Line-Line (1P3W)
-  3 Phase (AC) Line-Line 2-Wattmeter (2V2A)
-  3 Phase (AC) Line-Line (3P3W)
-  3 Phase (AC) Line-Neutral (3P4W)

-  6 Phase (AC) 2x Line-Line (2x 3P3W)
-  Individual Grid with up to 9 phases

Attention

Every PowerGroup can be used with any type of connection. This enables you, to do simultaneous measurements on different grid types and compare them online.

5.2.1 Single Phase (AC)

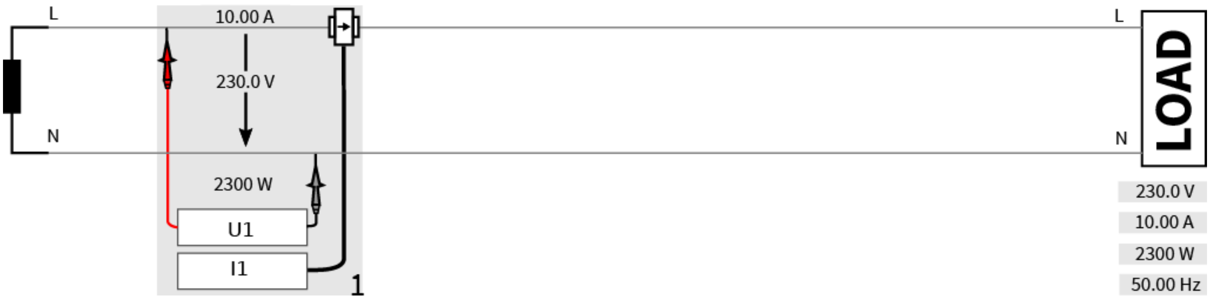


Fig. 5.2: Single Phase (AC)

• 1 Voltage Channel Line-Neutral	• 1 Current Channel	• Voltage Connection Type L-N	• Sync with Channel

5.2.2 Single Phase (DC)

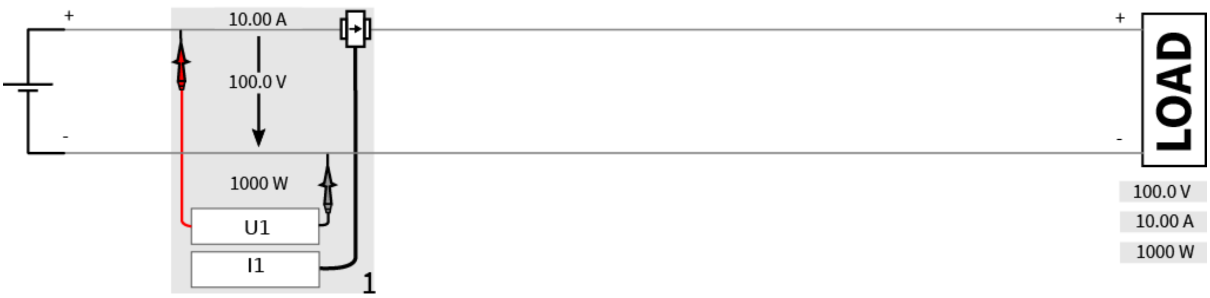


Fig. 5.3: Single Phase (DC)

• 1 Voltage Channel	• 1 Current Channel	• Voltage Connection Type L-N	• Sync with Time Interval

5.2.3 Two Phase with Neutral (AC)

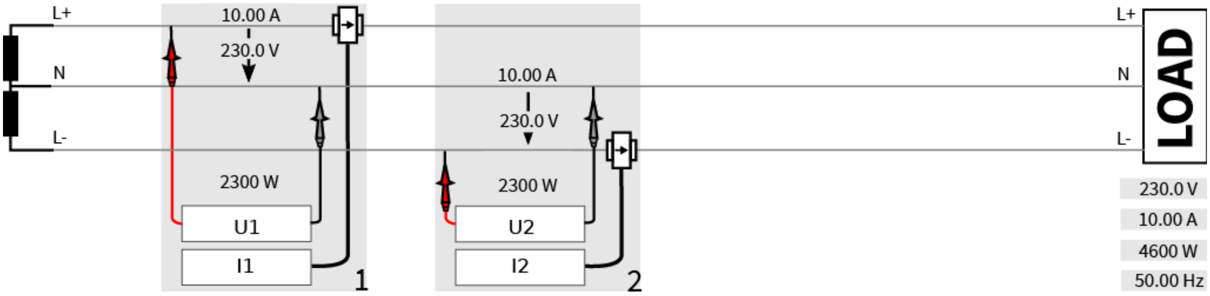


Fig. 5.4: Two Phase with Neutral (AC)

• 2 Voltage Channels Line-Neutral	• 2 Current Channels	• Voltage Connection Type L-N	• Sync with Channel

5.2.4 Two Phase (DC)

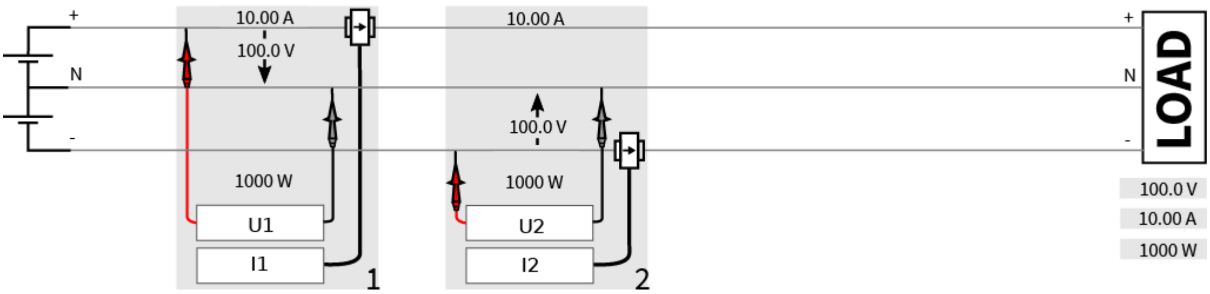


Fig. 5.5: Two Phase (DC)

• 2 Voltage Channels Line-Neutral	• 2 Current Channels	• Voltage Connection Type L-N	• Sync with Time Interval

5.2.5 Three Phase Wye (AC)

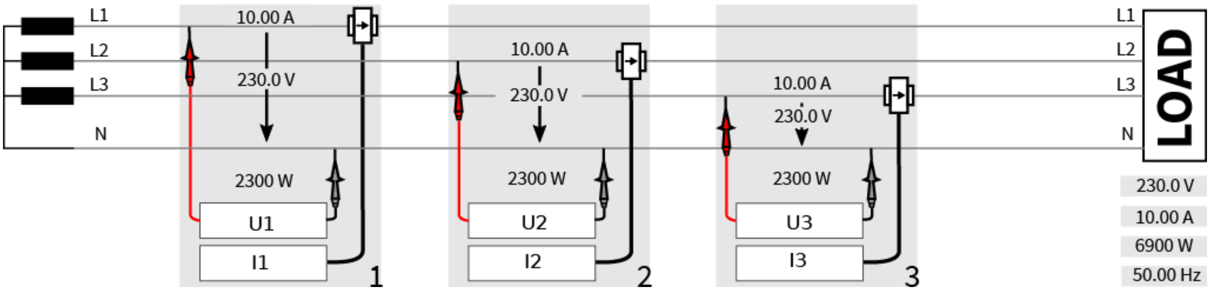


Fig. 5.6: Three Phase Wye (AC)

• 3 Voltage Channels Line-Neutral	• 3 Current Channels	• Voltage Connection Type L-N	• Sync with Channel

5.2.6 Three Phase Delta (AC)

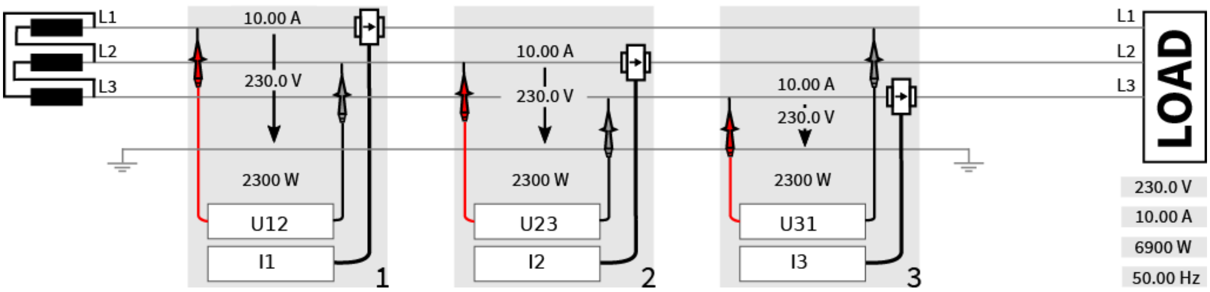


Fig. 5.7: Three Phase Delta (AC)

• 3 Voltage Channels Line-Line	• 3 Current Channels	• Voltage Connection Type L-L	• Sync with Channel

5.2.7 Three Phase 2-Wattmeter (AC)

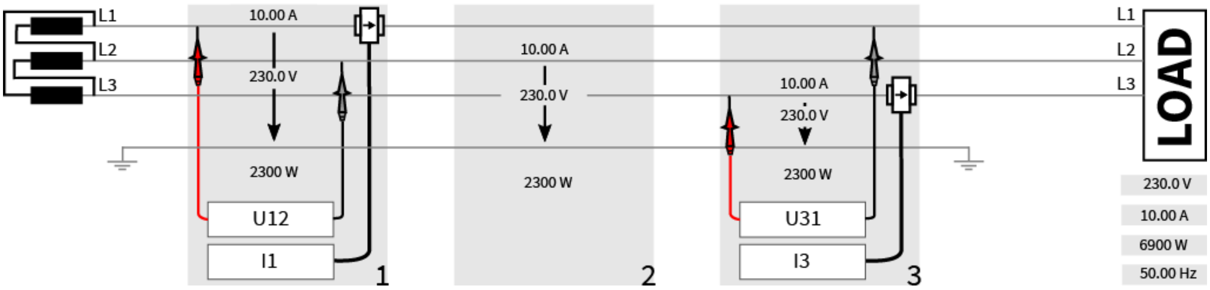


Fig. 5.8: Three Phase 2-Wattmeter (AC)

• 2 Voltage Channels Line-Line	• 2 Current Channels	• Voltage Connection Type L-L	• Sync with Channel

5.2.8 Six Phase (AC)

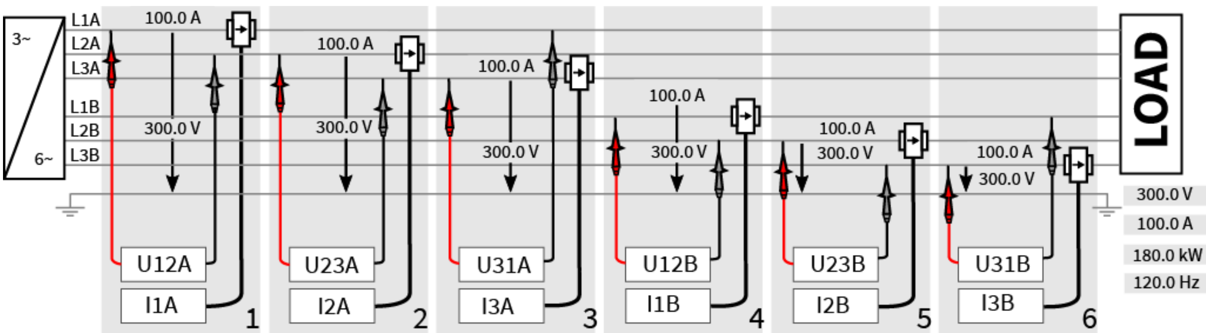


Fig. 5.9: Six Phase (AC)

• 6 Voltage Channel Line-Line (2x 3Phase)	• 6 Current Channel	• Voltage Connection Type L-L (2 pairs)	• Sync with Channel

Attention

The phase relation between the voltage and current lines is shown in the graphics below and is following this terminology: Phase of Voltage Channel 1 (U1_fundPHI) is defined with 0° and all other phase angles of Voltage (U[i]_fundPHI) and Current (I[i]_fundPHI) are relative aligned to this phasor. The Power phase is the phase difference between its Voltage and Current Phasor.

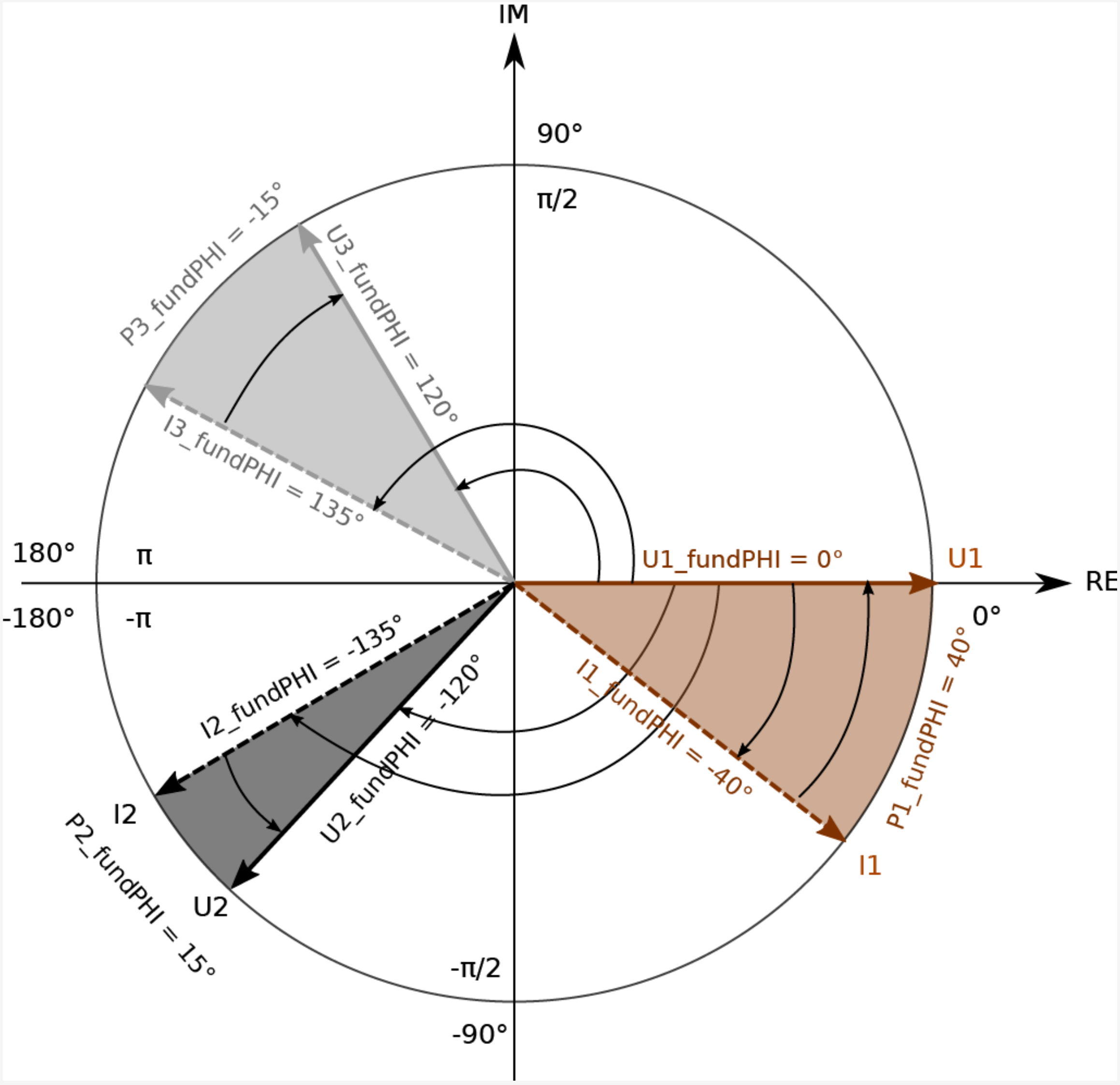


Fig. 5.10: Current Phasor

5.3 Line-Line Conversion

The Conversion from Line-Line Voltage to a Line-Neutral Voltage is automatically performed if necessary:

- Connection Type Switch is set to L-L
- Schematic is 3P3W or 6P6W

The principle relies on a virtual Star-Point, where the sum of all Line-Line Voltages AND the sum of all Line-Neutral Voltages is zero at all time.

5.3.1 3-Phase

$$
\begin{aligned}
u1(t) &= \frac{1}{3} \cdot (u12(t) - u31(t)) \\
u2(t) &= \frac{1}{3} \cdot (u23(t) - u12(t)) \\
u3(t) &= \frac{1}{3} \cdot (u31(t) - u23(t))
\end{aligned}
$$

5.3.2 6-Phase

Attention: This Calculation Method changed from 5.0 to 5.1! This 6-Phase calculation is now a 2x3P3W Calculation.

$$
\begin{aligned}
u1(t) &= \frac{1}{3} \cdot (u12(t) - u31(t)) \\
u2(t) &= \frac{1}{3} \cdot (u23(t) - u12(t)) \\
u3(t) &= \frac{1}{3} \cdot (u31(t) - u23(t)) \\
u4(t) &= \frac{1}{3} \cdot (u45(t) - u64(t)) \\
u5(t) &= \frac{1}{3} \cdot (u56(t) - u45(t)) \\
u6(t) &= \frac{1}{3} \cdot (u64(t) - u56(t))
\end{aligned}
$$

5.3.3 2-Wattmeter

$$
\begin{aligned}
u23(t) &= -u12(t) - u31(t) \\
i2(t) &= -i1(t) - i3(t)
\end{aligned}
$$

5.4 Power Instrument

The PowerGroup Instrument is a dedicated visualisation instrument for a specific PowerGroup. To place one in your instrument screen, just drag'n'drop the PowerGroup channel into the instrument area. Today, the instrument comes with 3 separate screens, an overview table, the phasor diagram and the harmonic chart. In the instrument properies **23**, you can select a different color schema.

5.4.1 Table Display

Power_3ph

	Phase 1		Phase 2		Phase 3		Total	
U_tRMS	238.22	V	238.62	V	237.87	V	238.24	V
I_tRMS	13.855	A	13.850	A	13.954	A	13.886	A
P_t	2.3305	kW	2.3361	kW	2.3365	kW	7.0032	kW
Q_t	2.3367	kvar	2.3372	kvar	2.3572	kvar	7.0312	kvar
S_t	3.3005	kVA	3.3048	kVA	3.3192	kVA	9.9245	kVA
PF_t	0.7061		0.7068		0.7039		0.7056	
F_fund							49.992	Hz
U_fundRMS	238.18	V	238.58	V	237.83	V	238.20	V
I_fundRMS	13.211	A	13.216	A	13.246	A	13.224	A
P_fund	2.3292	kW	2.3336	kW	2.3342	kW	6.9970	kW
Q_fund	-2.1153	kvar	-2.1200	kvar	-2.1152	kvar	-6.3505	kvar
S_fund	3.1467	kVA	3.1530	kVA	3.1503	kVA	9.4500	kVA

Fig. 5.11: PowerGroup Instrument Table

The Table consists of the PowerGroup name at the top, basic power values for each PowerPhase and their overall values. The display update rate is fixed to 500 ms.

5.4.2 Instrument Settings

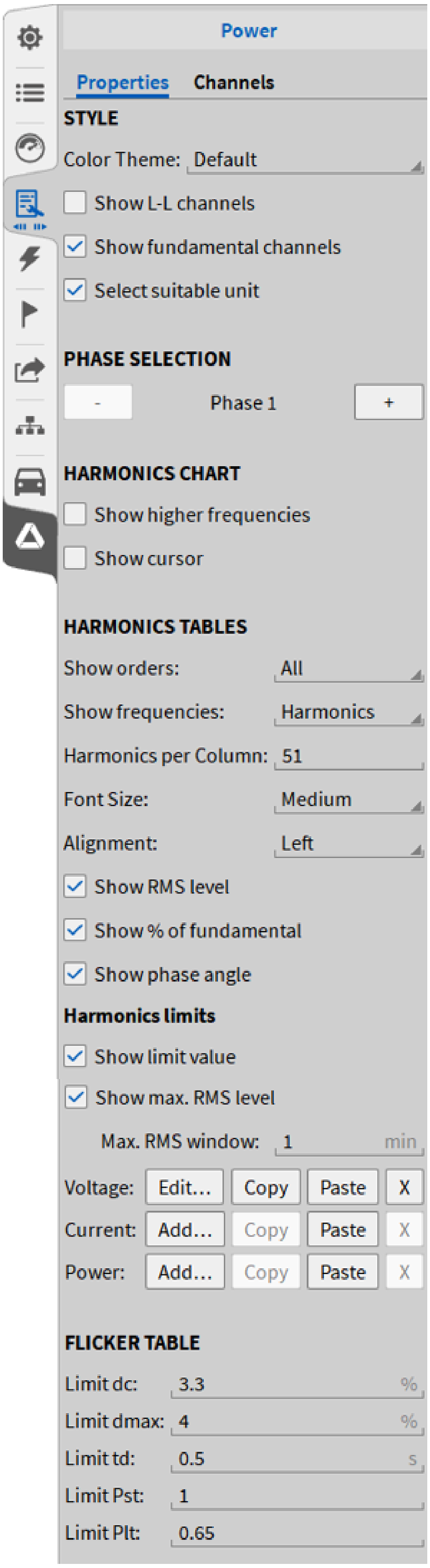


Fig. 5.12: Instrument Settings

- Style
  - Select Colour theme
  - Enable/Disable the display of Line-Line Voltage values
  - Enable/Disable the display of fundamentals
  - Enable/Disable suitable prefixes for units (mV, µV, kV)
- Phase Selection
  - Select Phase to be displayed in Harmonics Chart and Flicker Table
- Harmonic Chart
  - Show also Higher Frequency Grouped Spectrum (2.1–8.9 kHz)
  - Show Cursor in Harmonics Chart
- Harmonic Tables
  - Select displayed entries per column
  - Show odd, even ar all orders
  - Show Harmonics, Interharmonics or Both
  - Enter How many Harmonics per column should be displayed
  - Select Font Size
  - Select Text Alignment
  - Enable/Disable RMS, % of fundamental or phase angle columns
- Harmonics Limits
  - Enable/Disable Limit Value (defined below)
  - Enable/Disable max. RMS level with evaluation period (lookback time 1min by default)
  - Add, Edit, Copy, Paste or delete Limit Values for Voltage, Current, Power
- Flicker Table
  - Enter dc Limit
  - Enter dmax Limit
  - Enter Pst Limit
  - Enter Plt Limit

More Flicker settings are in the Power Group advanced settings, see chapter *Introduction*.

5.4.3 Phasor Display

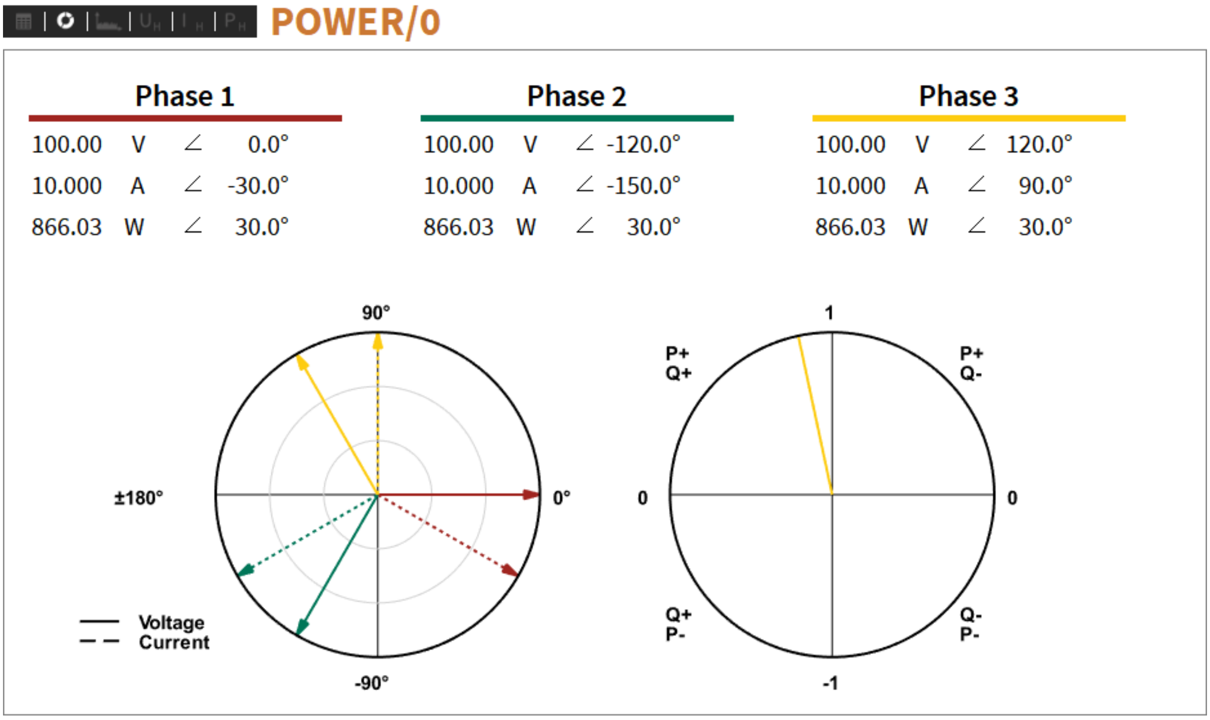


Fig. 5.13: PowerGroup Instrument Phasors

On the Phasor page, you can see the Voltage and Current fundamental Phasors in the left graph. The right graph shows the active and reactive power flow and its quadrant. For more information about the angle conventions, see Fig. 5.10.

5.4.4 Harmonics Chart Display

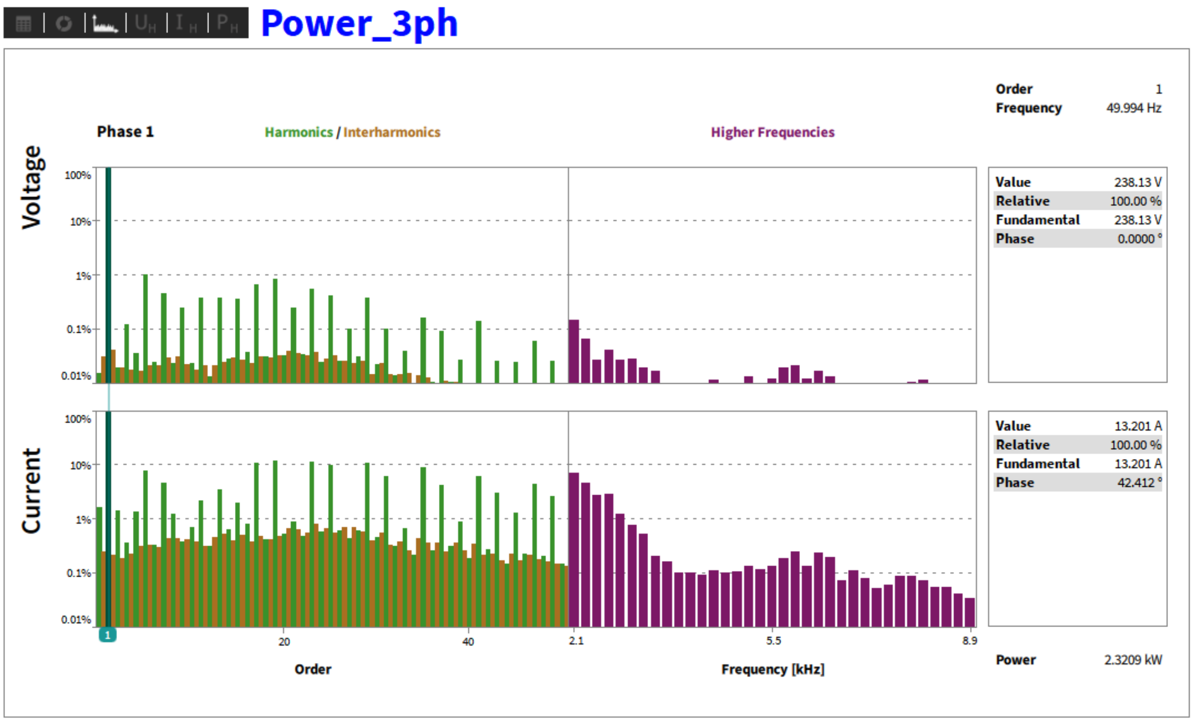


Fig. 5.14: PowerGroup Instrument Harmonics Chart

This view shows the voltage and current harmonics, interharmonics and higher frequency parts of the signal. The shown Phase and the cursor can be selected in the instrument details setup. The cursor can be moved over the whole spectrum to get absolute values. More technical information is available in chapter *Harmonic Analysis Reference (OPT-POWER-ADV)*.

5.4.5 Harmonics (Limits) Table Display

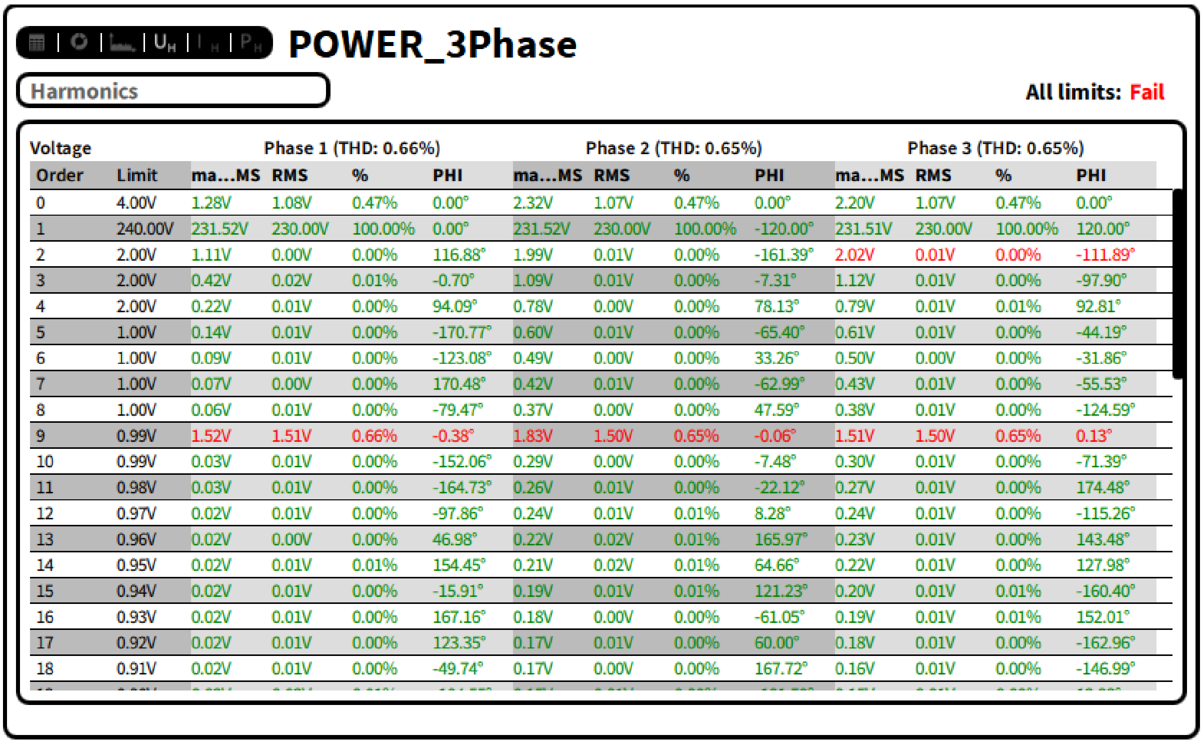
Power_3ph

Harmonics

Voltage	Phase 1 (THD: 2.05%)			Phase 2 (THD: 2.00%)			Phase 3 (THD: 2.01%)		
Order	RMS	%	PHI	RMS	%	PHI	RMS	%	PHI
0	46.99mV	0.02%	-180.00°	177.12mV	0.08%	0.00°	93.67mV	0.04%	-180.00°
1	229.99V	100.00%	0.00°	229.97V	100.00%	-120.03°	229.91V	100.00%	119.99°
2	181.11mV	0.08%	-18.41°	184.10mV	0.08%	-165.89°	150.30mV	0.07%	142.49°
3	4.70V	2.04%	0.83°	4.58V	1.99%	-120.41°	4.61V	2.00%	120.13°
4	14.26mV	0.01%	-134.54°	44.15mV	0.02%	92.33°	68.73mV	0.03%	105.76°
5	31.43mV	0.01%	57.93°	36.60mV	0.02%	117.96°	80.15mV	0.03%	50.24°
6	96.28mV	0.04%	-91.36°	75.97mV	0.03%	-113.38°	39.39mV	0.02%	88.57°
7	149.52mV	0.07%	11.15°	60.41mV	0.03%	158.52°	32.88mV	0.01%	40.03°
8	49.50mV	0.02%	-26.22°	102.25mV	0.04%	92.28°	57.50mV	0.03%	-87.55°
9	79.10mV	0.03%	8.94°	96.90mV	0.04%	-9.87°	114.80mV	0.05%	-159.75°
10	97.54mV	0.04%	-15.15°	23.17mV	0.01%	-3.64°	93.66mV	0.04%	158.61°
11	18.56mV	0.01%	118.81°	31.92mV	0.01%	-121.84°	40.46mV	0.02%	120.78°
12	137.29mV	0.06%	-29.11°	62.31mV	0.03%	52.09°	14.86mV	0.01%	-86.33°
13	43.50mV	0.02%	3.14°	92.17mV	0.04%	-112.40°	16.65mV	0.01%	-109.53°
14	94.86mV	0.04%	67.93°	73.72mV	0.03%	58.17°	33.99mV	0.01%	17.98°
15	42.28mV	0.02%	-57.34°	83.12mV	0.04%	-172.03°	41.47mV	0.02%	28.17°
16	20.02mV	0.01%	-8.35°	16.27mV	0.01%	-171.51°	47.53mV	0.02%	155.20°

Fig. 5.15: PowerGroup Instrument Harmonics Table (without Limits)

This three views shows the voltage, current and power harmonics in tabular view. The parameters shown in the table can be tuned in the instrument detail settings to reduce the shown data. RMS-Level, % of Fundamental or Nominal (selectable in Power Group settings) and Phase angle can be activated, as well as the number of shown orders ALL, EVEN, ODD. Harmonics, Interharmonics or both can be displayed. Number of entries per column can also be modified in the instrument settings. CTRL+C to Copy the data to e.g. Excel.



Voltage		Phase 1 (THD: 0.66%)				Phase 2 (THD: 0.65%)				Phase 3 (THD: 0.65%)			
Order	Limit	ma...MS	RMS	%	PHI	ma...MS	RMS	%	PHI	ma...MS	RMS	%	PHI
0	4.00V	1.28V	1.08V	0.47%	0.00°	2.32V	1.07V	0.47%	0.00°	2.20V	1.07V	0.47%	0.00°
1	240.00V	231.52V	230.00V	100.00%	0.00°	231.52V	230.00V	100.00%	-120.00°	231.51V	230.00V	100.00%	120.00°
2	2.00V	1.11V	0.00V	0.00%	116.88°	1.99V	0.01V	0.00%	-161.39°	2.02V	0.01V	0.00%	-111.89°
3	2.00V	0.42V	0.02V	0.01%	-0.70°	1.09V	0.01V	0.00%	-7.31°	1.12V	0.01V	0.00%	-97.90°
4	2.00V	0.22V	0.01V	0.00%	94.09°	0.78V	0.00V	0.00%	78.13°	0.79V	0.01V	0.01%	92.81°
5	1.00V	0.14V	0.01V	0.00%	-170.77°	0.60V	0.01V	0.00%	-65.40°	0.61V	0.01V	0.00%	-44.19°
6	1.00V	0.09V	0.01V	0.00%	-123.08°	0.49V	0.00V	0.00%	33.26°	0.50V	0.00V	0.00%	-31.86°
7	1.00V	0.07V	0.00V	0.00%	170.48°	0.42V	0.01V	0.00%	-62.99°	0.43V	0.01V	0.00%	-55.53°
8	1.00V	0.06V	0.01V	0.00%	-79.47°	0.37V	0.00V	0.00%	47.59°	0.38V	0.01V	0.00%	-124.59°
9	0.99V	1.52V	1.51V	0.66%	-0.38°	1.83V	1.50V	0.65%	-0.06°	1.51V	1.50V	0.65%	0.13°
10	0.99V	0.03V	0.01V	0.00%	-152.06°	0.29V	0.00V	0.00%	-7.48°	0.30V	0.01V	0.00%	-71.39°
11	0.98V	0.03V	0.01V	0.00%	-164.73°	0.26V	0.01V	0.00%	-22.12°	0.27V	0.01V	0.00%	174.48°
12	0.97V	0.02V	0.01V	0.00%	-97.86°	0.24V	0.01V	0.01%	8.28°	0.24V	0.01V	0.00%	-115.26°
13	0.96V	0.02V	0.00V	0.00%	46.98°	0.22V	0.02V	0.01%	165.97°	0.23V	0.01V	0.00%	143.48°
14	0.95V	0.02V	0.01V	0.01%	154.45°	0.21V	0.02V	0.01%	64.66°	0.22V	0.01V	0.00%	127.98°
15	0.94V	0.02V	0.01V	0.00%	-15.91°	0.19V	0.01V	0.01%	121.23°	0.20V	0.01V	0.01%	-160.40°
16	0.93V	0.02V	0.01V	0.00%	167.16°	0.18V	0.00V	0.00%	-61.05°	0.19V	0.01V	0.01%	152.01°
17	0.92V	0.02V	0.01V	0.00%	123.35°	0.17V	0.01V	0.00%	60.00°	0.18V	0.01V	0.00%	-162.96°
18	0.91V	0.02V	0.01V	0.00%	-49.74°	0.17V	0.00V	0.00%	167.72°	0.16V	0.01V	0.00%	-146.99°

Fig. 5.16: PowerGroup Instrument Harmonics Table (with Limits)

This view is the same display type as the harmonics in tabular view shown above but with harmonics limits enabled in the Power Group Instrument Settings, see *Instrument Settings*. The Limit columns shows the defined limit from the instrument settings tab. Voltage, Current and Power Limits can be defined. The 1min lookback period by default allows evaluating if the limit has been exceeded within the last 1min. If any element (order) has been over the limit it will be colored red and “All limits:” in the top right will show “Fail” for the Fail case. Otherwise it will show “Pass”.

5.4.6 Flicker Table Display

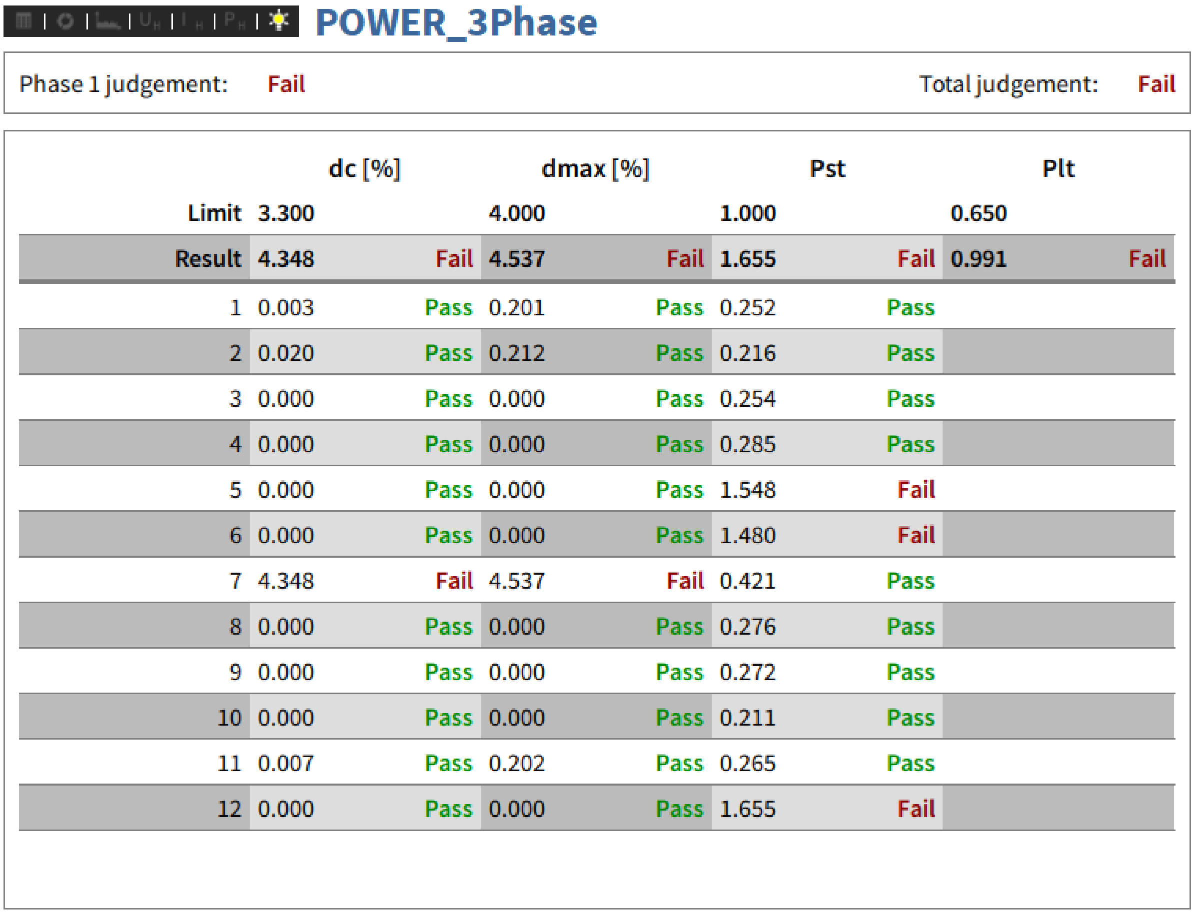
POWER_3Phase

Phase 1 judgement: Pass   Total judgement: Pass

	dc [%]		dmax [%]		Pst		Plt	
Limit	**3.300**		**4.000**		**1.000**		**0.650**	
Result	**0.863**	Pass	**1.051**	Pass	**0.394**	Pass	**0.254**	Pass
1	0.000	Pass	0.000	Pass	0.207	Pass		
2	0.000	Pass	0.000	Pass	0.258	Pass		
3	0.418	Pass	0.649	Pass	0.197	Pass		
4	0.000	Pass	0.000	Pass	0.256	Pass		
5	0.017	Pass	0.220	Pass	0.211	Pass		
6	0.000	Pass	0.000	Pass	0.394	Pass		
7	0.863	Pass	1.051	Pass	0.288	Pass		
8	0.000	Pass	0.000	Pass	0.179	Pass		
9	0.000	Pass	0.000	Pass	0.219	Pass		
10	0.000	Pass	0.000	Pass	0.236	Pass		
11	0.000	Pass	0.000	Pass	0.219	Pass		
12	0.000	Pass	0.000	Pass	0.231	Pass		

Fig. 5.17: PowerGroup Instrument Flicker Table (pass case)

This view shows the flicker results. The limits shown in the table can be tuned in the instrument detail settings. Total judgment, the Phase judgment and Plt will only be availible after one Plt time window (default 120 min, but definable in the power group settings). The Result row below the limits show the worst result from the list below. In case the worst result is not exceeding the defined limit each parameter dc, dmax, Pst and Plt will be in the pass case. If that is true for all Phases, the Total judgment, seen on the top right will show pass. In case one element in the list shows Fail for any phase, the Total judgement will show Fail. CTRL+C to Copy the data to e.g. Excel.



POWER_3Phase

Phase 1 judgement: Fail   Total judgement: Fail

	dc [%]		dmax [%]		Pst		Plt	
Limit	3.300		4.000		1.000		0.650	
Result	4.348	Fail	4.537	Fail	1.655	Fail	0.991	Fail
1	0.003	Pass	0.201	Pass	0.252	Pass		
2	0.020	Pass	0.212	Pass	0.216	Pass		
3	0.000	Pass	0.000	Pass	0.254	Pass		
4	0.000	Pass	0.000	Pass	0.285	Pass		
5	0.000	Pass	0.000	Pass	1.548	Fail		
6	0.000	Pass	0.000	Pass	1.480	Fail		
7	4.348	Fail	4.537	Fail	0.421	Pass		
8	0.000	Pass	0.000	Pass	0.276	Pass		
9	0.000	Pass	0.000	Pass	0.272	Pass		
10	0.000	Pass	0.000	Pass	0.211	Pass		
11	0.007	Pass	0.202	Pass	0.265	Pass		
12	0.000	Pass	0.000	Pass	1.655	Fail		

Fig. 5.18: PowerGroup Instrument Flicker Table (fail case)

As in the picture above, this shows the Power Group Flicker Table, but the fail case. Total judgement shows Fail, since at least one Result element exceeds the Limit. The Flicker Table will show the last Plt cycle, but it will not stop after the first window. The next Pst elements will be recorded and displayed in the list in brackets (as element (13), (14) and so on). These values will only be respected for the result row above if the next Plt period has passed. CTRL+C to Copy the data to e.g. Excel.

5.5 Load/Save Configuration Setup

To save your configuration (Input Settings, Channel Names, Instrument arrangement...) you just have to press the Save Setup Button **17** and select a name, that you can easy find it again the next time you do the same measurement.

Loading is similar to saving, just press Load Setup Button **16** and select the configuration you want to load.

5.6 Recording Data

Recording of the measurement data is very easy and flexible with the DEWETRON OXYGEN software. There are many options available to perfectly fit your requirements.

How to choose the right mode and settings, you have to think about some questions:

1. What do you need to analyze?
    - Channels: Exclude not needed channels from being stored **31**.
    - Samplerate: Select appropriate sampling rate according to your application.
2. What do you expect?
    - Trigger: Is it possible to set a trigger condition?
    - Static/Dynamic: Is the signal static or dynamic?
3. How long does it take?
    - Recording Time: Do you have to record only seconds or minutes or hours and days?
4. How is the analysis done?
    - Live: Do you want to analyze the data during recording?
    - Offline: or afterwards in the OXYGEN Software?
    - Export: or do you want to export the data to use it in a 3rd party app?

For more information, consult the OXYGEN Manual OXYGEN Manual.

5.7 Analyze Data

For more information, consult the OXYGEN Manual OXYGEN Manual.

5.8 Export Data

For more information, consult the OXYGEN Manual OXYGEN Manual.

CHAPTER

SIX

TROUBLESHOOTING

Table 6.1: Troubleshooting

Issue	Reason	Solution
Power Group Channel is red and all values are NaN	Samplerate of Input Channels is too low One or more Input/Sync Channels are not Ready No channel is assigned to any phase	Change the Samplerate of all dependent Input/Sync Channels to a minimum of 10 kHz (better 100 kHz) Check if all depended Input/Sync Channels are activated Drag'n'drop Channels to at least one phase
All Power Values are NaN but Power Group Channel is not red	Power Group is disabled An error in the calculation has occurred	Please enable the Power Group Please restart the calculation by deactivating and activating the Power Group
Fundamental Values are NaN	Fundamental Frequency is out of range Magnitude of Sync Channel is too low for Frequency detection Calculation Mode is set to Time Interval	No fundamental calculation available when Frequency is out of range Change Range of Sync Channel or select another Channel Change Calculation Mode to Sync

CHAPTER

SEVEN

ADDTIONAL INFORMATION

7.1 Hardware Specific Settings

This Section covers settings related to the Power Analysis function, which depends on specific hardware components.

7.1.1 Sensor Delay Compensation

Table 7.1: Compatible Haredware

Compatible Hardware	Additional Information
TRION-1820-POWER-4	Since Driver Ver. 3.7 and FW Ver. 55
TRION3-1810M-POWER-4	Since Driver Ver. 3.7 and FW Ver. 55

Current and voltage signals are often not perfectly synchronous due to group delays from the sensors. To compensate this delay (phase shift) between voltage and current input, a new function was added to the Hardware listed in Table 7.1. This function is also known as Deskew.

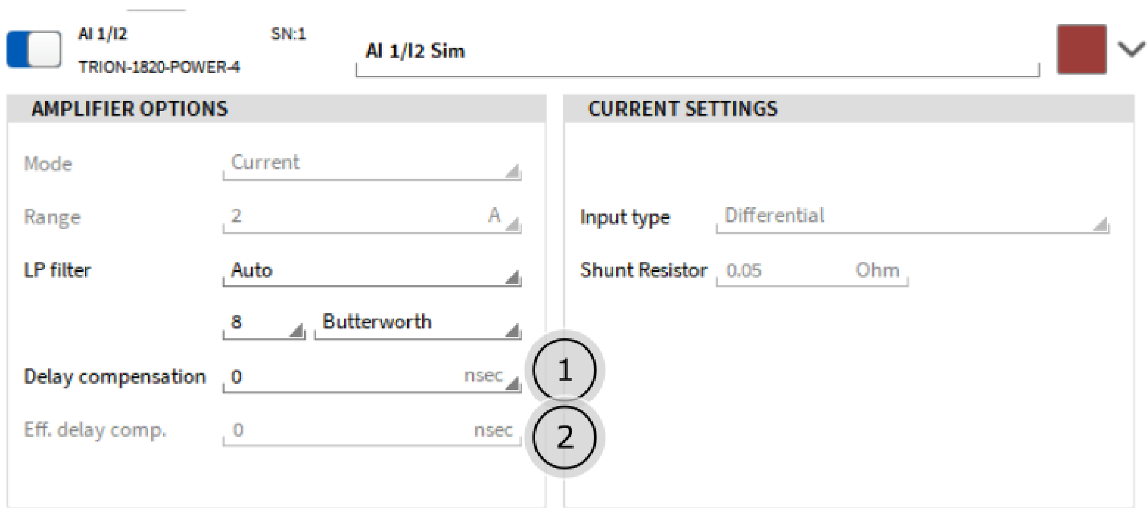


Fig. 7.1: Delay Compensation Settings: Detail setup (only available for current input)

1. Input field for target delay compensation in nanoseconds (ns). Allowed range is ± 10000ns. Negative values shifts the current backwards in time, positive forward.

2. Display of effective set delay compensation, the resolution is fixed to 100 ns.

Before adding a compensation value, in this example (Sine Signal with 1 kHz fundamental frequency), the current lags a few degree. This can be seen in the scope as well as in the phase shift of the fundamental:

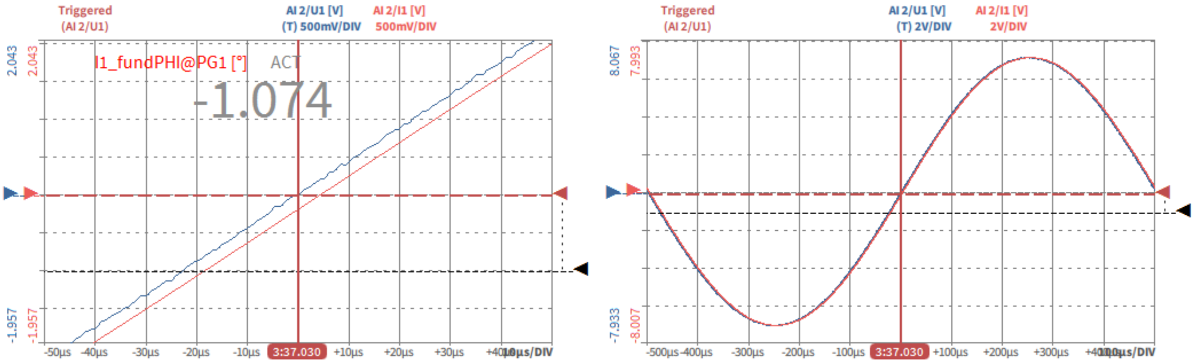


Fig. 7.2: Delay Compensation Example: Before

After adjusting the value to

$$t = \frac{1}{1000Hz} \cdot \frac{1}{360°} \cdot (-1.074°) \cdot 10^9 = -2983ns$$

the result is now nearly perfect:

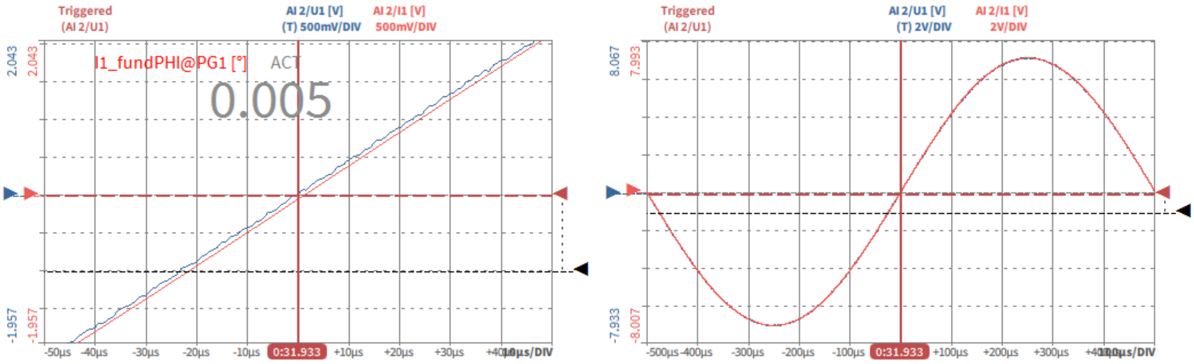


Fig. 7.3: Delay Compensation Example: After

CHAPTER

EIGHT

BASIC CALCULATION REFERENCE (OPT-POWER-BASIC)

Table 8.1: Legend

Symbol	Equation	Description
SR	–	Samplerate
NP	–	Number of Power Phases
N	$\frac{SR}{f_{fund}}$	Number of Samples
T_{int}	–	Integration Time, Time of Visualisation

8.1 Voltage (U)

8.1.1 U_tRMS

This is the Power Group average true RMS Voltage

$$U_{tRMS} = \frac{1}{NP}\sum_{i=1}^{NP} U[i]_{tRMS} \quad Unit: \mathbf{V}$$

8.1.2 U[i]_tRMS

This is the Power Phase number i True RMS Voltage

$$U[i]_{tRMS} = \sqrt{\frac{1}{N}\sum_{n=0}^{N} u_i[n]^2} \quad Unit: \mathbf{V}$$

8.1.3 U[ij]_tRMS

This is the Line-Line ij True RMS Voltage. This channel is only available in 3-Phase Power Configurations.

$$U[ij]_{tRMS} = \sqrt{\frac{1}{N}\sum_{n=0}^{N}(u_i[n]-u_j[n])^2} \quad Unit : \textbf{V}$$

8.1.4 U[i]_tAVG

This is the Power Phase number i Average Voltage

$$U[i]_{tAVG} = \frac{1}{N}\sum_{n=0}^{N}u_i[n] \quad Unit : \textbf{V}$$

8.1.5 U[i]_tPP

This is the Power Phase number i Peak-Peak Voltage

$$U[i]_{tPP} = \max_{0\to N} u_i[n] - \min_{0\to N} u_i[n] \quad Unit : \textbf{V}$$

8.1.6 U_fundRMS

This is the Power Group average fundamental effective Voltage

$$U_{fundRMS} = \frac{1}{NP}\sum_{i=1}^{NP}U[i]_{fundRMS} \quad Unit : \textbf{V}$$

8.1.7 U[i]_fundRMS

This is the Power Phase number i Fundamental Effective Voltage.

$$U[i]_{fundRMS} = \sqrt{Re\left\{\underline{U}[i]_{fund}\right\}^2 + Im\left\{\underline{U}[i]_{fund}\right\}^2} \quad Unit : \textbf{V}$$

8.1.8 U[ij]_fundRMS

This is the Line-Line ij Fundamental Effective Voltage.

$$U[ij]_{fundRMS} = \sqrt{Re\left\{\underline{U}[i]_{fund} - \underline{U}[j]_{fund}\right\}^2 + Im\left\{\underline{U}[i]_{fund} - \underline{U}[j]_{fund}\right\}^2} \quad Unit : \textbf{V}$$

8.1.9 U[i]_fundPHI

This is the Power Phase number i Fundamental Voltage Phase Angle.

$$U[i]_{fundPHI} = arctan2\left(Im\left\{\underline{U}[i]_{fund}\right\}, Re\left\{\underline{U}[i]_{fund}\right\}\right) \quad Unit: \textbf{deg}(^\circ)$$

8.1.10 U[ij]_fundPHI

This is the Line-Line ij Fundamental Voltage Phase Angle.

$$U[i]_{fundPHI} = arctan2\left(Im\left\{\underline{U}[i]_{fund} - \underline{U}[j]_{fund}\right\}, Re\left\{\underline{U}[i]_{fund} - \underline{U}[j]_{fund}\right\}\right) \quad Unit: \textbf{deg}(^\circ)$$

8.1.11 U_fundRMS_SYM+

This is the Power Group Fundamental Voltage Positive Sequence Magnitude. This channel is only available in 3-Phase Power Group.

$$a = e^{j\frac{2\pi}{NP}}$$

$$\underline{U}^+ = \frac{1}{NP}\sum_{i=1}^{NP} U[i]_{fundRMS} \cdot e^{j \cdot U[i]_{fundPHI}} \cdot a^{(i-1)}$$

$$U_{fundRMS\_SYM+} = \sqrt{Re\left\{\underline{U}^+\right\}^2 + Im\left\{\underline{U}^+\right\}^2} \quad Unit: \textbf{V}$$

8.1.12 U_fundRMS_SYM-

This is the Power Group Fundamental Voltage Negative Sequence Magnitude. This channel is only available with a minimum of two phases configured.

$$a = e^{j\frac{2\pi}{NP}}$$

$$\underline{U}^- = \frac{1}{NP}\sum_{i=1}^{NP} U[i]_{fundRMS} \cdot e^{j \cdot U[i]_{fundPHI}} \cdot a^{(NP+1-i)}$$

$$U_{fundRMS\_SYM-} = \sqrt{Re\left\{\underline{U}^-\right\}^2 + Im\left\{\underline{U}^-\right\}^2} \quad Unit: \textbf{V}$$

8.1.13 U_fundRMS_SYM0

This is the Power Group Fundamental Voltage Zero Sequence Magnitude. This channel is only available in 3-Phase Power Group.

$$a = e^{j\frac{2\pi}{NP}}$$

$$\underline{U}^0 = \frac{1}{NP}\sum_{i=1}^{NP} U[i]_{fundRMS} \cdot e^{j \cdot U[i]_{fundPHI}}$$

$$U_{fundRMS\_SYM0} = \sqrt{Re\left\{\underline{U}^0\right\}^2 + Im\left\{\underline{U}^0\right\}^2} \quad Unit: \textbf{V}$$

8.1.14 U_fundRMS_SYM

This is the Power Group Fundamental Voltage Symmetry.

$$U_{fundRMS\_SYM} = \frac{U_{fundRMS\_SYM+} - U_{fundRMS\_SYM-}}{U_{fundRMS\_SYM+} + U_{fundRMS\_SYM-}} \quad Unit : \textbf{None}$$

8.1.15 U_fund_UNBAL+

This is the Power Group Fundamental Voltage Positive Sequence Unbalance.

$$U_{fund\_UNBAL+} = \frac{U_{fundRMS} - U_{fundRMS\_SYM+}}{U_{fundRMS}} \cdot 100\% \quad Unit : \%$$

8.1.16 U_fund_UNBAL-

This is the Power Group Fundamental Voltage Negative Sequence Unbalance.

$$U_{fund\_UNBAL-} = \frac{U_{fundRMS\_SYM-}}{U_{fundRMS\_SYM+}} \cdot 100\% \quad Unit : \%$$

8.1.17 U_fund_UNBAL0

This is the Power Group Fundamental Voltage Zero Sequence Unbalance.

$$U_{fund\_UNBAL0} = \frac{U_{fundRMS\_SYM0}}{U_{fundRMS\_SYM+}} \cdot 100\% \quad Unit : \%$$

8.1.18 U_fundCOS_SYM+

The Real part of the fourier coefficients of the signal is. (F-1 in FGW-TG3 Annex F)

$$U[i]_{fund\_cos} = \frac{2}{N} \sum_{n=-N-1}^{0} u_i[n] \cdot cos(2 \cdot \pi \cdot F_{fund} \cdot \frac{n}{SR}) \quad Unit : \textbf{V}$$

The Imaginary part of the fourier coefficients of the signal is. (F-2 in FGW-TG3 Annex F)

$$U[i]_{fund\_sin} = \frac{2}{N} \sum_{n=-N-1}^{0} u_i[n] \cdot sin(2 \cdot \pi \cdot F_{fund} \cdot \frac{n}{SR}) \quad Unit : \textbf{V}$$

Using both fourier coefficients, this is the real vector component of the Positive Voltage Sequence.

$$\begin{aligned} U_{fundCOS\_SYM+} = & \frac{1}{6} \Big(2 \cdot U1_{fund\_cos} - U2_{fund\_cos} - U3_{fund\_cos} - \\ & \sqrt{3} \left(U3_{fund\_sin} - U2_{fund\_sin}\right)\Big) \qquad Unit : \textbf{V} \end{aligned}$$

8.1.19 U_fundSIN_SYM+

This is the imaginary vector component of the Positive Voltage Sequence.

$$U_{fundSIN\_SYM+} = \frac{1}{6}\left(2 \cdot U1_{fund\_sin} - U2_{fund\_sin} - U3_{fund\_sin} - \sqrt{3}\left(U2_{fund\_cos} - U3_{fund\_cos}\right)\right) \quad Unit: \mathbf{V}$$

8.1.20 U_fundPHI_SYM+

This is the phase angle of the Positive Voltage Sequence.

$$U_{fundPHI\_SYM+} = arctan2(U_{fundSIN\_SYM+}, U_{fundCOS\_SYM+}) \quad Unit: \mathbf{deg}(^\circ)$$

8.1.21 U_fundCOS_SYM-

This is the real vector component of the Negative Voltage Sequence.

$$U_{fundCOS\_SYM-} = \frac{1}{6}\left(2 \cdot U1_{fund\_cos} - U2_{fund\_cos} - U3_{fund\_cos} - \sqrt{3}\left(U2_{fund\_sin} - U3_{fund\_sin}\right)\right) \quad Unit: \mathbf{V}$$

8.1.22 U_fundSIN_SYM-

This is the imaginary vector component of the Negative Voltage Sequence.

$$U_{fundSIN\_SYM-} = \frac{1}{6}\left(2 \cdot U1_{fund\_sin} - U2_{fund\_sin} - U3_{fund\_sin} - \sqrt{3}\left(U3_{fund\_cos} - U2_{fund\_cos}\right)\right) \quad Unit: \mathbf{V}$$

8.1.23 U_fundPHI_SYM-

This is the phase angle of the Negative Voltage Sequence.

$$U_{fundPHI\_SYM-} = arctan2(U_{fundSIN\_SYM-}, U_{fundCOS\_SYM-}) \quad Unit: \mathbf{deg}(^\circ)$$

8.1.24 U_fundCOS_SYM0

Using the fourier coefficients, this is the real vector component of the Zero Voltage Sequence.

$$U_{fundCOS\_SYM0} = \frac{1}{3 \cdot \sqrt{2}}\left(U1_{fund\_cos} + U2_{fund\_cos} + U3_{fund\_cos}\right) \quad Unit: \mathbf{V}$$

8.1.25 U_fundSIN_SYM0

Using the fourier coefficients, this is the imaginary vector component of the Zero Voltage Sequence.

$$U_{fundSIN\_SYM0} = \frac{-1}{3 \cdot \sqrt{2}} (U1_{fund\_sin} + U2_{fund\_sin} + U3_{fund\_sin}) \quad Unit : \textbf{V}$$

8.2 Current (I)

8.2.1 I_tRMS

This is the Power Group average true RMS Current

$$I_{tRMS} = \frac{1}{NP} \sum_{i=1}^{NP} I[i]_{tRMS} \quad Unit : \textbf{A}$$

8.2.2 I[i]_tRMS

This is the Power Phase number i True RMS Current

$$I[i]_{tRMS} = \sqrt{\frac{1}{N} \sum_{n=0}^{N} i_i[n]^2} \quad Unit : \textbf{A}$$

8.2.3 I[i]_tAVG

This is the Power Phase number i Average Current

$$I[i]_{tAVG} = \frac{1}{N} \sum_{n=0}^{N} i_i[n] \quad Unit : \textbf{A}$$

8.2.4 I[i]_tPP

This is the Power Phase number i Peak-Peak Current

$$I[i]_{tPP} = \max_{0 \to N} i_i[n] - \min_{0 \to N} i_i[n] \quad Unit : \textbf{A}$$

8.2.5 I_fundRMS

This is the Power Group average fundamental effective Current

$$I_{fundRMS} = \frac{1}{NP} \sum_{i=1}^{NP} I[i]_{fundRMS} \quad Unit : \textbf{A}$$

8.2.6 I[i]_fundRMS

This is the Power Phase number i Fundamental Effective Current.

$$I[i]_{fundRMS} = \sqrt{Re\left\{I[i]_{fund}\right\}^2 + Im\left\{I[i]_{fund}\right\}^2} \quad Unit: \textbf{A}$$

8.2.7 I[i]_fundPHI

This is the Power Phase number i Fundamental Current Phase Angle.

$$I[i]_{fundPHI} = arctan2\left(Im\left\{I[i]_{fund}\right\}, Re\left\{I[i]_{fund}\right\}\right) \quad Unit: \textbf{deg}(^\circ)$$

8.2.8 I_fundRMS_SYM+

This is the Power Group Fundamental Current Positive Sequence Magnitude. This channel is only available in 3-Phase Power Group.

$$a = e^{j\frac{2\pi}{NP}}$$

$$\underline{I}^+ = \frac{1}{NP}\sum_{i=1}^{NP} I[i]_{fundRMS} \cdot e^{j \cdot I[i]_{fundPHI}} \cdot a^{(i-1)}$$

$$I_{fundRMS\_SYM+} = \sqrt{Re\left\{\underline{I}^+\right\}^2 + Im\left\{\underline{I}^+\right\}^2} \quad Unit: \textbf{A}$$

8.2.9 I_fundRMS_SYM-

This is the Power Group Fundamental Current Negative Sequence Magnitude. This channel is only available in 3-Phase Power Group.

$$a = e^{j\frac{2\pi}{NP}}$$

$$\underline{I}^- = \frac{1}{NP}\sum_{i=1}^{NP} I[i]_{fundRMS} \cdot e^{j \cdot I[i]_{fundPHI}} \cdot a^{(NP+1-i)}$$

$$I_{fundRMS\_SYM-} = \sqrt{Re\left\{\underline{I}^-\right\}^2 + Im\left\{\underline{I}^-\right\}^2} \quad Unit: \textbf{A}$$

8.2.10 I_fundRMS_SYM0

This is the Power Group Fundamental Current Zero Sequence Magnitude. This channel is only available in 3-Phase Power Group.

$$a = e^{j\frac{2\pi}{NP}}$$

$$\underline{I}^0 = \frac{1}{NP}\sum_{i=1}^{NP} I[i]_{fundRMS} \cdot e^{j \cdot I[i]_{fundPHI}}$$

$$I_{fundRMS\_SYM0} = \sqrt{Re\left\{\underline{I}^0\right\}^2 + Im\left\{\underline{I}^0\right\}^2} \quad Unit: \textbf{A}$$

8.2.11 I_fundRMS_SYM

This is the Power Group Fundamental Current Symmetry.

$$I_{fundRMS\_SYM} = \frac{I_{fundRMS\_SYM+} - I_{fundRMS\_SYM-}}{I_{fundRMS\_SYM+} + I_{fundRMS\_SYM-}} \quad Unit: \textbf{None}$$

8.2.12 I_fund_UNBAL+

This is the Power Group Fundamental Current Positive Sequence Unbalance.

$$I_{fund\_UNBAL+} = \frac{I_{fundRMS} - I_{fundRMS\_SYM+}}{I_{fundRMS}} \cdot 100\% \quad Unit: \%$$

8.2.13 I_fund_UNBAL-

This is the Power Group Fundamental Current Negative Sequence Unbalance.

$$I_{fund\_UNBAL-} = \frac{I_{fundRMS\_SYM-}}{I_{fundRMS\_SYM+}} \cdot 100\% \quad Unit: \%$$

8.2.14 I_fund_UNBAL0

This is the Power Group Fundamental Current Zero Sequence Unbalance.

$$I_{fund\_UNBAL0} = \frac{I_{fundRMS\_SYM0}}{I_{fundRMS\_SYM+}} \cdot 100\% \quad Unit: \%$$

8.2.15 I_fundCOS_SYM+

The Real part of the fourier coefficients of the signal is. (F-1 in FGW-TG3 Annex F)

$$I[i]_{fund\_cos} = \frac{2}{N} \sum_{n=-N-1}^{0} i_i[n] \cdot cos(2 \cdot \pi \cdot F_{fund} \cdot \frac{n}{SR}) \quad Unit: \textbf{A}$$

The Imaginary part of the fourier coefficients of the signal is. (F-2 in FGW-TG3 Annex F)

$$I[i]_{fund\_sin} = \frac{2}{N} \sum_{n=-N-1}^{0} i_i[n] \cdot sin(2 \cdot \pi \cdot F_{fund} \cdot \frac{n}{SR}) \quad Unit: \textbf{A}$$

Using both fourier coefficients, this is the real vector component of the Positive Voltage Sequence.

$$\begin{aligned} I_{fundCOS\_SYM+} = & \frac{1}{6} (2 \cdot I1_{fund\_cos} - I2_{fund\_cos} - I3_{fund\_cos} - \\ & \sqrt{3} \left(I3_{fund\_sin} - I2_{fund\_sin}\right)\Big) \qquad Unit: \textbf{A} \end{aligned}$$

8.2.16 I_fundSIN_SYM+

This is the imaginary vector component of the Positive Voltage Sequence.

$$I_{fundSIN\_SYM+} = \frac{1}{6}\left(2 \cdot I1_{fund\_sin} - I2_{fund\_sin} - I3_{fund\_sin} - \sqrt{3}\left(I2_{fund\_cos} - I3_{fund\_cos}\right)\right) \quad Unit: \textbf{A}$$

8.2.17 I_fundCOS_SYM-

This is the real vector component of the Negative Voltage Sequence.

$$I_{fundCOS\_SYM-} = \frac{1}{6}\left(2 \cdot I1_{fund\_cos} - I2_{fund\_cos} - I3_{fund\_cos} - \sqrt{3}\left(I2_{fund\_sin} - I3_{fund\_sin}\right)\right) \quad Unit: \textbf{A}$$

8.2.18 I_fundSIN_SYM-

This is the imaginary vector component of the Negative Voltage Sequence.

$$I_{fundSIN\_SYM-} = \frac{1}{6}\left(2 \cdot I1_{fund\_sin} - I2_{fund\_sin} - I3_{fund\_sin} - \sqrt{3}\left(I3_{fund\_cos} - I2_{fund\_cos}\right)\right) \quad Unit: \textbf{A}$$

8.2.19 I_fundCOS_SYM0

Using the fourier coefficients, this is the real vector component of the Zero Voltage Sequence.

$$I_{fundCOS\_SYM0} = \frac{1}{3 \cdot \sqrt{2}}\left(I1_{fund\_cos} + I2_{fund\_cos} + I3_{fund\_cos}\right) \quad Unit: \textbf{A}$$

8.2.20 I_fundSIN_SYM0

Using the fourier coefficients, this is the imaginary vector component of the Zero Voltage Sequence.

$$I_{fundSIN\_SYM0} = \frac{-1}{3 \cdot \sqrt{2}}\left(I1_{fund\_sin} + I2_{fund\_sin} + I3_{fund\_sin}\right) \quad Unit: \textbf{A}$$

8.3 Active Power (P)

8.3.1 P_t

This is the Power Group Overall active Power.

$$P_t = \sum_{i=1}^{NP} P[i]_t \quad Unit: \textbf{W}$$

8.3.2 P[i]_t

This is the Power Phase number i active Power.

$$P[i]_t = \frac{1}{N}\sum_{n=0}^{N} u_i[n] \cdot i_i[n] \quad Unit: \textbf{W}$$

8.3.3 P_fund

This is the Power Group Overall fundamental active Power.

$$P_{fund} = \sum_{i=1}^{NP} P[i]_{fund} \quad Unit: \textbf{W}$$

8.3.4 P[i]_fund

This is the Power Phase number i fundamental active Power.

$$P[i]_{fund} = U[i]_{fundRMS} \cdot I[i]_{fundRMS} \cdot cos\left(P[i]_{fundPHI}\right) \quad Unit: \textbf{W}$$

8.3.5 P[i]_fundPHI

This is the Power Phase number i fundamental Power Phase Angle.

$$P[i]_{fundPHI} = U[i]_{fundPHI} - I[i]_{fundPHI} \quad Unit: \textbf{deg}(^\circ)$$

8.4 Reactive Power (Q)

8.4.1 Q_t

This is the Power Group Overall reactive Power.

$$Q_t = s \cdot \sqrt{S_t^2 - P_t^2} \qquad s = \begin{cases} 1 & \text{if } Q_{fund} > 0 \\ -1 & \text{if } Q_{fund} <= 0 \end{cases} \quad Unit: \textbf{var}$$

8.4.2 Q[i]_t

This is the Power Phase number i reactive Power.

$$Q[i]_t = s \cdot \sqrt{S[i]_t^2 - P[i]_t^2} \qquad s = \begin{cases} 1 & \text{if } Q_{fund} > 0 \\ -1 & \text{if } Q_{fund} <= 0 \end{cases} \quad Unit: \textbf{var}$$

8.4.3 Q_fund

This is the Power Group Overall fundamental reactive Power.

$$Q_{fund} = \sum_{i=1}^{NP} Q[i]_{fund} \quad Unit: \textbf{var}$$

8.4.4 Q[i]_fund

This is the Power Phase number i fundamental reactive Power.

$$Q[i]_{fund} = U[i]_{fundRMS} \cdot I[i]_{fundRMS} \cdot sin\left(P[i]_{fundPHI}\right) \quad Unit: \textbf{var}$$

8.5 Apparent Power (S)

8.5.1 S_t

This is the Power Group Overall apparent Power.

$$S_t = \sum_{i=1}^{NP} S[i]_t \quad Unit: \textbf{VA}$$

8.5.2 S[i]_t

This is the Power Phase number i apparent Power.

$$S[i]_t = U[i]_{tRMS} \cdot I[i]_{tRMS} \quad Unit: \textbf{VA}$$

8.5.3 S_fund

This is the Power Group Overall fundamental apparent Power.

$$S_{fund} = \sum_{i=1}^{NP} S[i]_{fund} \quad Unit: \textbf{VA}$$

8.5.4 S[i]_fund

This is the Power Phase number i fundamental apparent Power.

$$S[i]_{fund} = U[i]_{fundRMS} \cdot I[i]_{fundRMS} \quad Unit: \textbf{VA}$$

8.6 Power Factor (PF)

8.6.1 PF_t

This is the Power Group Overall Power Factor

$$PF_t = \frac{P_t}{S_t} \quad Unit : \textbf{None}$$

8.6.2 PF[i]_t

This is the Power Phase number i Power Factor.

$$PF[i]_t = \frac{P[i]_t}{S[i]_t} \quad Unit : \textbf{None}$$

8.6.3 PF_fund

This is the Power Group Overall fundamental Power Factor.

$$PF_{fund} = \frac{P_{fund}}{S_{fund}} \quad Unit : \textbf{None}$$

8.6.4 PF[i]_fund

This is the Power Phase number i fundamental Power Factor.

$$PF[i]_{fund} = \frac{P[i]_{fund}}{S[i]_{fund}} \quad Unit : \textbf{None}$$

8.7 Energy (W)

8.7.1 W_t

This is the Power Group Overall active Energy.

$$W_t = \sum_{i=1}^{NP} W[i]_t \quad Unit : \textbf{Wh}$$

8.7.2 W[i]_t

This is the Power Phase number i active Energy.

$$W[i]_t = \sum_{k=0}^{T_{int}} P[i]_{t,k} \cdot \frac{N}{SR} \cdot \frac{1}{3600} \quad Unit : \textbf{Wh}$$

8.7.3 W_t+

This is the Power Group Overall positive aggregated active Energy.

$$W_{t+} = \sum_{i=1}^{NP} W[i]_{t+} \quad Unit: \textbf{Wh}$$

8.7.4 W[i]_t+

This is the Power Phase number i positive aggregated active Energy.

$$W[i]_{t+} = \sum_{k=0}^{T_{int}} \frac{N}{SR} \cdot \frac{1}{3600} \begin{cases} P[i]_{t,k} & \text{if } P[i]_{t,k} > 0 \\ 0 & \text{if } P[i]_{t,k} <= 0 \end{cases} \quad Unit: \textbf{Wh}$$

8.7.5 W_t-

This is the Power Group Overall negative aggregated active Energy.

$$W_{t-} = \sum_{i=1}^{NP} W[i]_{t-} \quad Unit: \textbf{Wh}$$

8.7.6 W[i]_t-

This is the Power Phase number i negative aggregated active Energy.

$$W[i]_{t-} = \sum_{k=0}^{T_{int}} \frac{N}{SR} \cdot \frac{1}{3600} \begin{cases} 0 & \text{if } P[i]_{t,k} > 0 \\ P[i]_{t,k} & \text{if } P[i]_{t,k} <= 0 \end{cases} \quad Unit: \textbf{Wh}$$

8.7.7 W_fund

This is the Power Group Overall fundamental active Energy.

$$W_{fund} = \sum_{i=1}^{NP} W[i]_{fund} \quad Unit: \textbf{Wh}$$

8.7.8 W[i]_fund

This is the Power Phase number i fundamental active Energy.

$$W[i]_{fund} = \sum_{k=0}^{T_{int}} P[i]_{fund,k} \cdot \frac{N}{SR} \cdot \frac{1}{3600} \quad Unit: \textbf{Wh}$$

8.7.9 W_fund+

This is the Power Group Overall positive aggregated active Energy.

$$W_{fund+} = \sum_{i=1}^{NP} W[i]_{fund+} \quad Unit: \textbf{Wh}$$

8.7.10 W[i]_fund+

This is the Power Phase number i fundamental positive aggregated active Energy.

$$W[i]_{fund+} = \sum_{k=0}^{T_{int}} \frac{N}{SR} \cdot \frac{1}{3600} \begin{cases} P[i]_{fund,k} & \text{if } P[i]_{fund,k} > 0 \\ 0 & \text{if } P[i]_{fund,k} <= 0 \end{cases} \quad Unit: \textbf{Wh}$$

8.7.11 W_fund-

This is the Power Group Overall fundamental negative aggregated active Energy.

$$W_{fund-} = \sum_{i=1}^{NP} W[i]_{fund-} \quad Unit: \textbf{Wh}$$

8.7.12 W[i]_fund-

This is the Power Phase number i fundamental negative aggregated active Energy.

$$W[i]_{fund-} = \sum_{k=0}^{T_{int}} \frac{N}{SR} \cdot \frac{1}{3600} \begin{cases} 0 & \text{if } P[i]_{fund,k} > 0 \\ P[i]_{fund,k} & \text{if } P[i]_{fund,k} <= 0 \end{cases} \quad Unit: \textbf{Wh}$$

8.7.13 C

This is the Power Group Overall accumulated electrical capacity.

$$Q = \sum_{i=1}^{NP} C[i] \quad Unit: \textbf{Ah}$$

8.7.14 C[i]

This is the Power Phase number i accumulated electrical capacity.

$$Q[i] = \sum_{k=0}^{T_{int}} I[i]_{tAVG,k} \cdot \frac{N_k}{SR} \cdot \frac{1}{3600} \quad Unit: \textbf{Ah}$$

8.7.15 C_+

This is the Power Group Overall positive accumulated electrical capacity.

$$C_{t+} = \sum_{i=1}^{NP} C[i]_{+} \quad Unit: \textbf{Ah}$$

8.7.16 C[i]_+

This is the Power Phase number i positive accumulated electrical capacity.

$$C[i]_{+} = \sum_{k=0}^{T_{int}} \cdot \frac{N}{SR} \cdot \frac{1}{3600} \cdot \begin{cases} I[i]_{tAVG,k} & \text{if } I[i]_{tAVG,k} > 0 \\ 0 & \text{if } I[i]_{tAVG,k} <= 0 \end{cases} \quad Unit: \textbf{Ah}$$

8.7.17 C-

This is the Power Group Overall negative accumulated electrical capacity.

$$C_{t-} = \sum_{i=1}^{NP} C[i]_{-} \quad Unit: \textbf{Ah}$$

8.7.18 C[i]_-

This is the Power Phase number i negative accumulated electrical capacity.

$$C[i]_{-} = \sum_{k=0}^{T_{int}} \cdot \frac{N}{SR} \cdot \frac{1}{3600} \cdot \begin{cases} 0 & \text{if } I[i]_{tAVG,k} > 0 \\ -I[i]_{tAVG,k} & \text{if } I[i]_{tAVG,k} <= 0 \end{cases} \quad Unit: \textbf{Ah}$$

8.7.19 C_RMS

This is the Power Group Overall accumulated current effective values.

$$C\_RMS = \sum_{i=1}^{NP} C[i]\_RMS \quad Unit: \textbf{Ah}$$

8.7.20 C[i]_RMS

This is the Power Phase number i accumulated accumulated current effective values.

$$C[i]\_RMS = \sum_{k=0}^{T_{int}} I[i]_{tRMS,k} \cdot \frac{N_k}{SR} \cdot \frac{1}{3600} \quad Unit: \textbf{Ah}$$

8.8 Additional Channels

8.8.1 F_fund

This is the fundamental frequency channel. See *Sync Channel Mode* for more information. T_{fund} is the period duration of the fundamental signal estimated by the Zero Crossing Detect

$$F_{fund} = \frac{1}{T_{fund}} \quad Unit : \textbf{Hz}$$

CHAPTER

NINE

HARMONIC ANALYSIS REFERENCE (OPT-POWER-ADV)

This Chapter describes the measurement of

- Harmonics (0 to 1000th Order)
- Interharmonics (0.5 to 49.5th Order)
- Higher Frequencies (2 to 9 kHz)
- Supraharmonics (8 to 150 kHz)

The further mentioned calculation methods are complying with IEC 61000-4-7 for 50 Hz and 60 Hz operation. Beside this fundamental frequencies, the calculation and grouping methods are similar.

Calculation Interval

The Harmonic Analysis is synchronized to N periods of the fundamental.

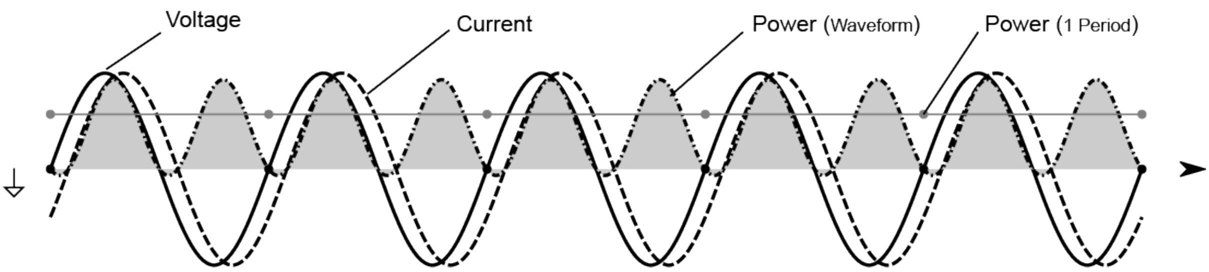


Fig. 9.1: Period Aggregation on an example with 50 Hz Fundamental (Number of Periods = 10)

In the following Table you will find the number of periods which are used at different fundamental Frequencies:

Table 9.1: Used number of periods for each calculation interval

Fundamental Frequency	Number of Periods N	Additional Information
1–4.99	1	
5–14.99	2	
15–24.99	4	
25–34.99	6	
35–44.99	8	
45–54.99	10	50 Hz Grid
55–64.99	12	60 Hz Grid
65–74.99	14	
…	…	…

The Harmonic Calculation interval will always be linked to N periods but equates to about 200ms of a time window.

This is true for the Harmonics update rate setting “Default”. In case the Harmonics update rate setting is set to “Fast” the time window will half from the “Default” setting to 100 ms. For example in a 50 Hz Grid the “Default” Harmonic output will be after every 10 Periods the “Fast” Harmonic output will be after every 5 Periods, meaning double the output rate of the “Default” Harmonic update rate setting. See more in Settings below.

9.1 Settings

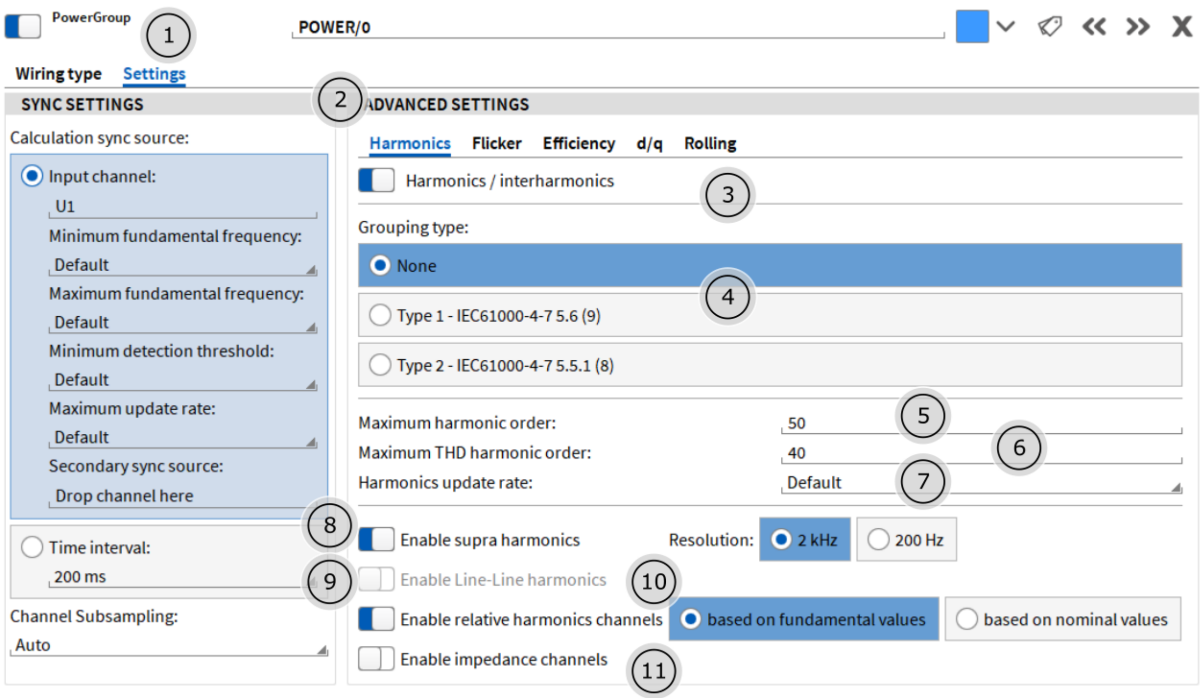


Fig. 9.2: Harmonic Settings

1. Power Group’s Tab for Settings

2. Details Tab for Settings of the Harmonic Analysis
3. Enable/Disable Harmonic Analysis
4. Selector for Grouping Type
5. Input Field for maximum order of Harmonics to be calculated and displayed
6. Input Field for number of Harmonics in THD calculation (must be lower or equal than (5))
7. Harmonic update rate, options: “Default” or “Fast”. “Fast” meaning double the output rate of “Default”
8. Enable/Disable supraharmonic analysis, options: Resolution of 2kHz or 200Hz
9. Enable/Disable Line-Line harmonics
10. Enable/Disable relative harmonics channels, options: set relative harmonics channels to be based on fundamental or nominal value
11. Enable/Disable impedance channels

9.2 Harmonic Grouping

Table 9.2: Legend

Symbol	Description
Y_c	RMS Magnitude of FFT-Bin
Y_h	RMS Magnitude of Harmonic Order h (Grouping “None”)
$Y_{sg,h}$	RMS Magnitude of Harmonic Order h (Grouping “Type 1”)
$Y_{g,h}$	RMS Magnitude of Harmonic Order h (Grouping “Type 2”)
NP_c	Number of fundamental Periods
h	Harmonic Order

9.2.1 Mode: "None"

When this mode is selected, only the harmonic bins are taken for generation of the harmonic data.

$$Y_h = Y_c[NP \cdot h]$$

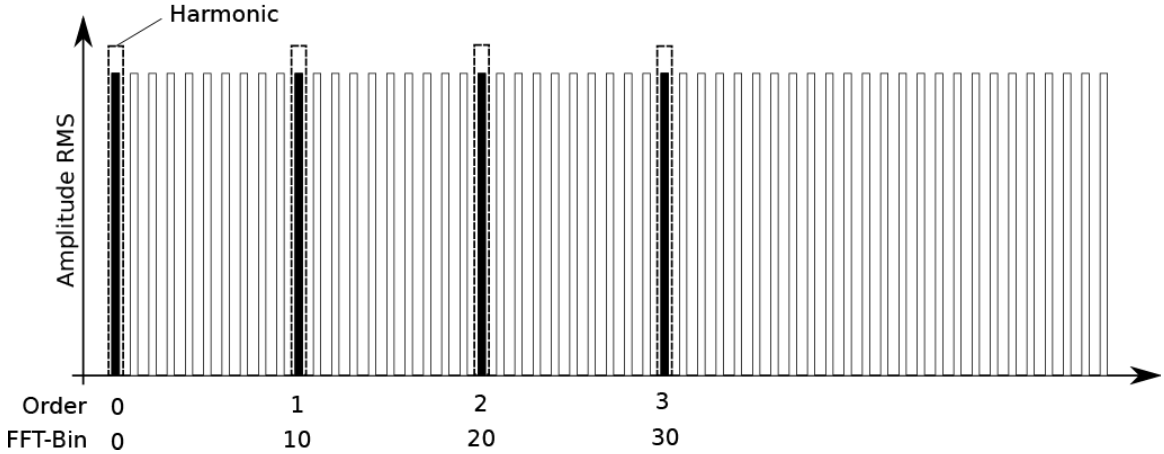


Fig. 9.3: Grouping Schema Mode "None"

This example shows the grouping for 50 Hz fundamental Frequency.

9.2.2 Mode: "Type 1"

When this mode is selected, the harmonics are grouped according to IEC61000-4-7 Section 5.6.

$$Y_{sg,h} = Y_c[NP \cdot h] \qquad NP < 2$$

$$Y_{sg,h} = \sqrt{\sum_{k=-1}^{1} Y_c\left[NP \cdot h + k\right]^2} \quad NP >= 2$$

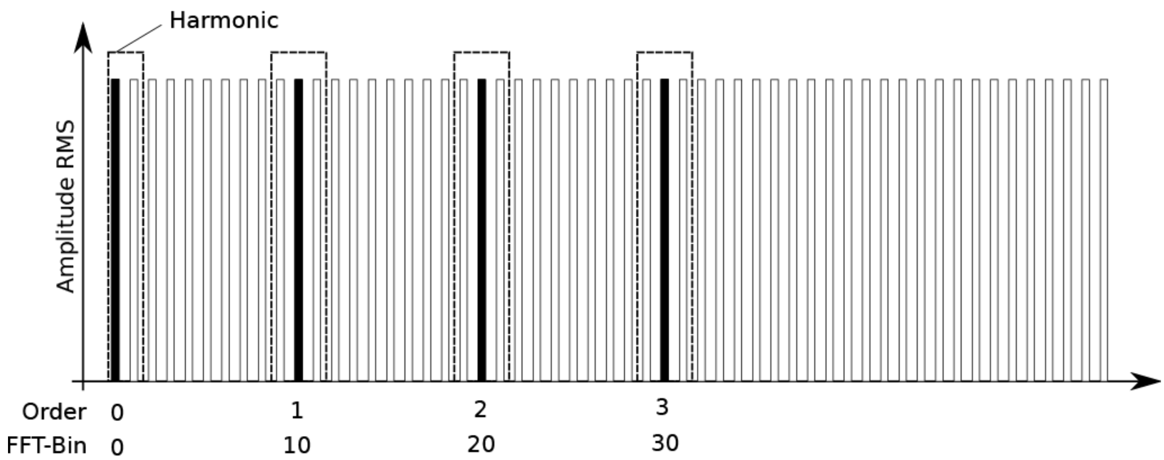


Fig. 9.4: Grouping Schema Mode "Type 1"

9.2.3 Mode: “Type 2”

When this mode is selected, the harmonics are grouped according to IEC61000-4-7 Section 5.5.1.

$$Y_{g,h} = Y_c[NP \cdot h] \qquad NP < 2$$

$$Y_{g,h} = \sqrt{\frac{1}{2}Y_c\left[NP \cdot h - \frac{N}{2}\right]^2 + \sum_{k=\frac{-N}{2}+1}^{\frac{N}{2}-1} Y_c\left[NP \cdot h + k\right]^2 + \frac{1}{2}Y_c\left[NP \cdot h + \frac{N}{2}\right]^2} \qquad NP >= 2$$

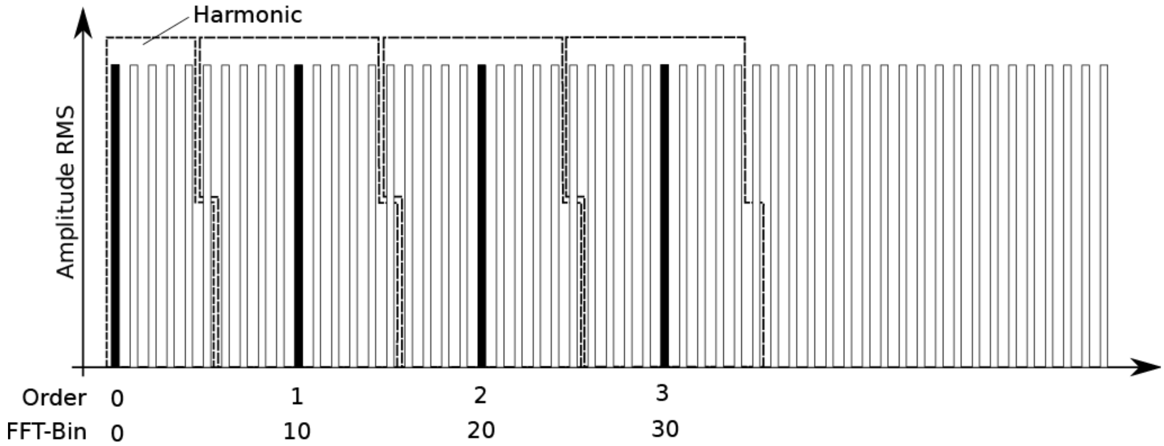


Fig. 9.5: Grouping Schema Mode “Type 2”

9.3 Interharmonic Grouping

Table 9.3: Legend

Symbol	Description
Y$_c$	RMS Magnitude of FFT-Bin
Y$_{ih}$	RMS Magnitude of Interharmonic Order h (Grouping “None”)
Y$_{isg,h}$	RMS Magnitude of Interharmonic Order h (Grouping “Type 1”)
Y$_{ig,h}$	RMS Magnitude of Interharmonic Order h (Grouping “Type 2”)
NP	Number of fundamental Periods
h	Interharmonic Order

9.3.1 Mode: “None”

When this mode is selected, all bins (except of harmonic bin) are taken for generation of the interharmonic data.

$$Y_{ih} = NaN \qquad NP = 1$$

$$Y_{ih} = \sqrt{\sum_{k=1}^{N-1} Y_c\left[NP \cdot h + k\right]^2} \qquad NP > 1$$

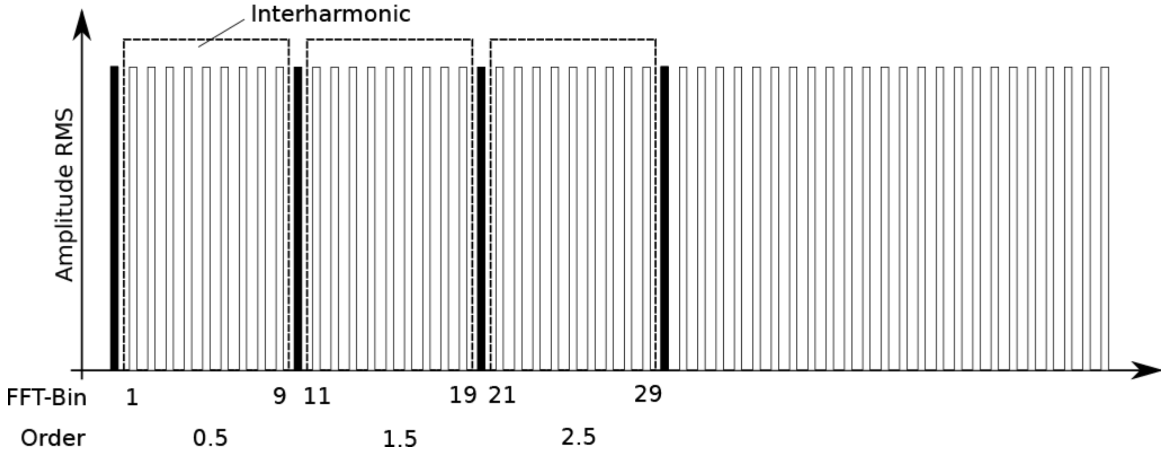


Fig. 9.6: Grouping Schema Mode ”None”

This example shows the grouping for 50 Hz fundamental Frequency.

9.3.2 Mode: “Type 1”

When this mode is selected, the Interharmonics are grouped according to IEC61000-4-7 Section 5.6.

$$Y_{isg,h} = NaN \qquad NP <= 2$$

$$Y_{isg,h} = \sqrt{\sum_{k=2}^{N-2} Y_c \left[NP \cdot h + k\right]^2} \qquad NP > 2$$

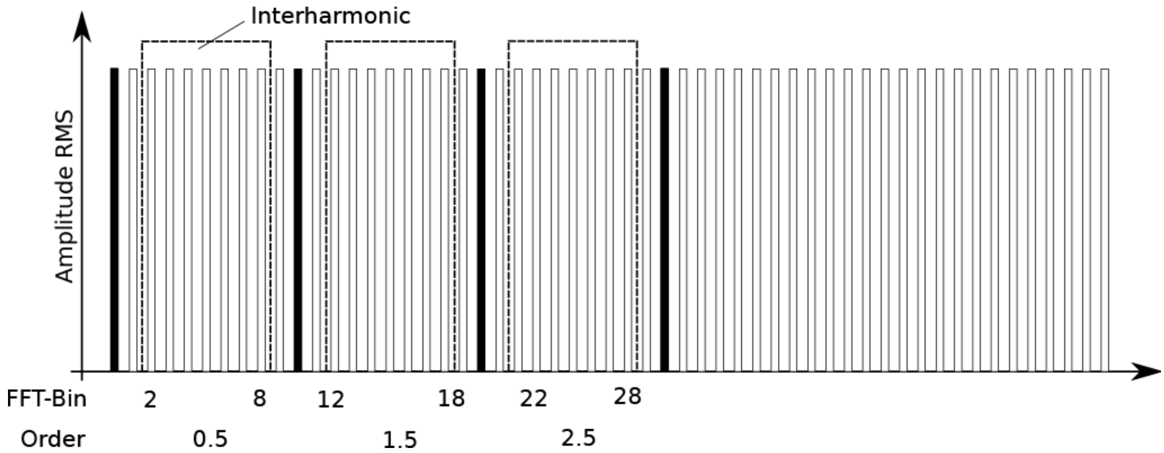


Fig. 9.7: Grouping Schema Mode “Type 1”

9.3.3 Mode: "Type 2"

When this mode is selected, the Interharmonics are grouped according to IEC61000-4-7 Section 5.5.1.

$$Y_{ig,h} = NaN \qquad NP = 1$$
$$Y_{ig,h} = \sqrt{\sum_{k=1}^{N-1} Y_c\left[NP \cdot h + k\right]^2} \qquad NP > 1$$

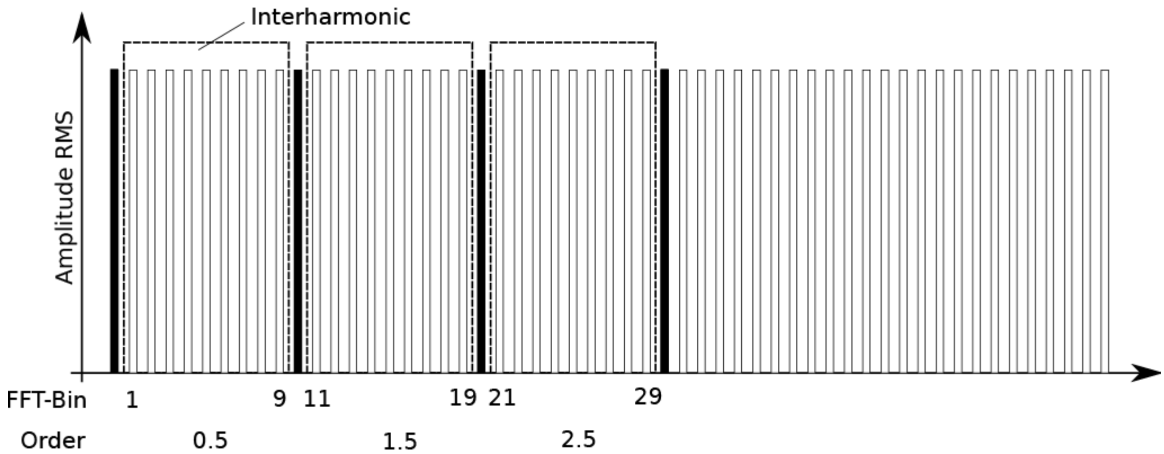


Fig. 9.8: Grouping Schema Mode "Type 2"

9.4 Higher Frequency Grouping

The Higher Frequency Grouping is orientated on fixed frequency bands (see IEC/EN61000-4-7 Appendix B). It is independent from the fundamental frequency and working between 10 and 1000 Hz.

Table 9.4: Legend

Symbol	Description
Y_{Cf}	RMS Magnitude of FFT-Bin
$Y_{B,b}$	RMS Magnitude of Higher Frequency Order b

$$Y_{B,b} = \sqrt{\sum_{f=b-95Hz}^{b+100Hz} Y_{C,f}^2}$$

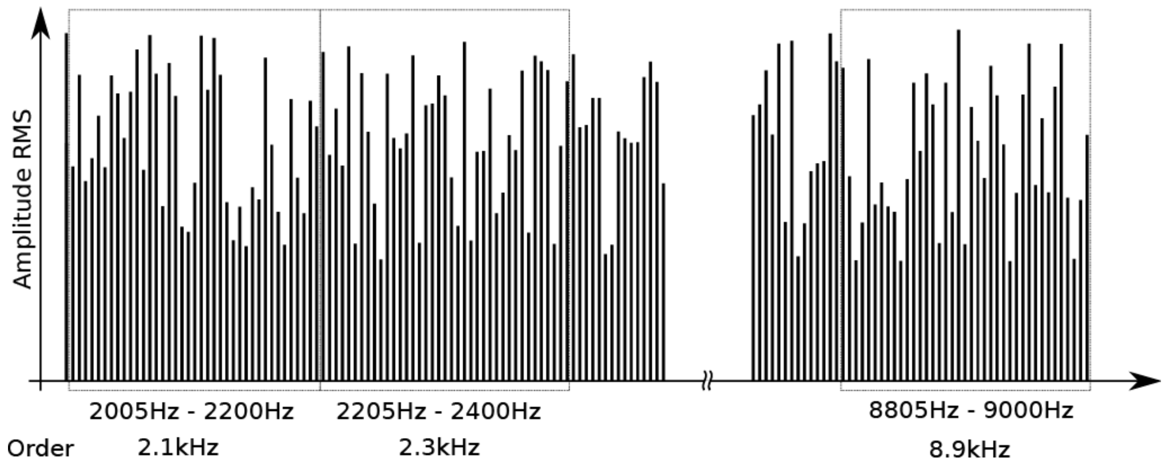


Fig. 9.9: Higher Frequency Grouping

This example shows the grouping for every fundamental frequency.

9.5 Supraharmonics Grouping

Unlike the other grouping methods, the Supraharmonics are aggregated in time. The Supraharmonics calculation will output channels with the Harmonic components in the frequency range between 8kHz and 150kHz.

Since the Line Resolution of 2kHz (or optional 200Hz) is much finer than the Harmonic Calculation Interval meaning the update rate of Supraharmonics is much faster than the Harmonic Interval the output channels will undergo a statistics evaluation (AVG, MIN, MAX). Each Supraharmonic Evaluation will result in 3 Channels with indices $\_shMIN, \_shMAX, \_shAVG$. As an example for the first Voltage: $U1\_shMIN, U1\_shMAX, U1\_shAVG$.

Table 9.5: Legend

Symbol	Description
$Y_{C,b}$	RMS Magnitude of FFT-Bin b
$Y_{SH,i,min}$	Minimum RMS Magnitude of Supraharmonics order i
$Y_{SH,i,avg}$	Average RMS Magnitude of Supraharmonics order i
$Y_{SH,i,max}$	Maximum RMS Magnitude of Supraharmonics order i
NP	Number of fundamental periods (10 @ 50 Hz, 12 @ 60 Hz)
Y_{FFT}	Number of Short Time FFTs in time interval of NP
SR	Samplerate

$$N_{FFT} = \frac{\frac{NP}{F_{fund}} \cdot SR}{500}$$

$$Y_{SH,b,min} = min(Y_{C,b})$$

$$Y_{SH,b,avg} = avg(Y_{C,b})$$

$$Y_{SH,b,max} = max(Y_{C,b})$$

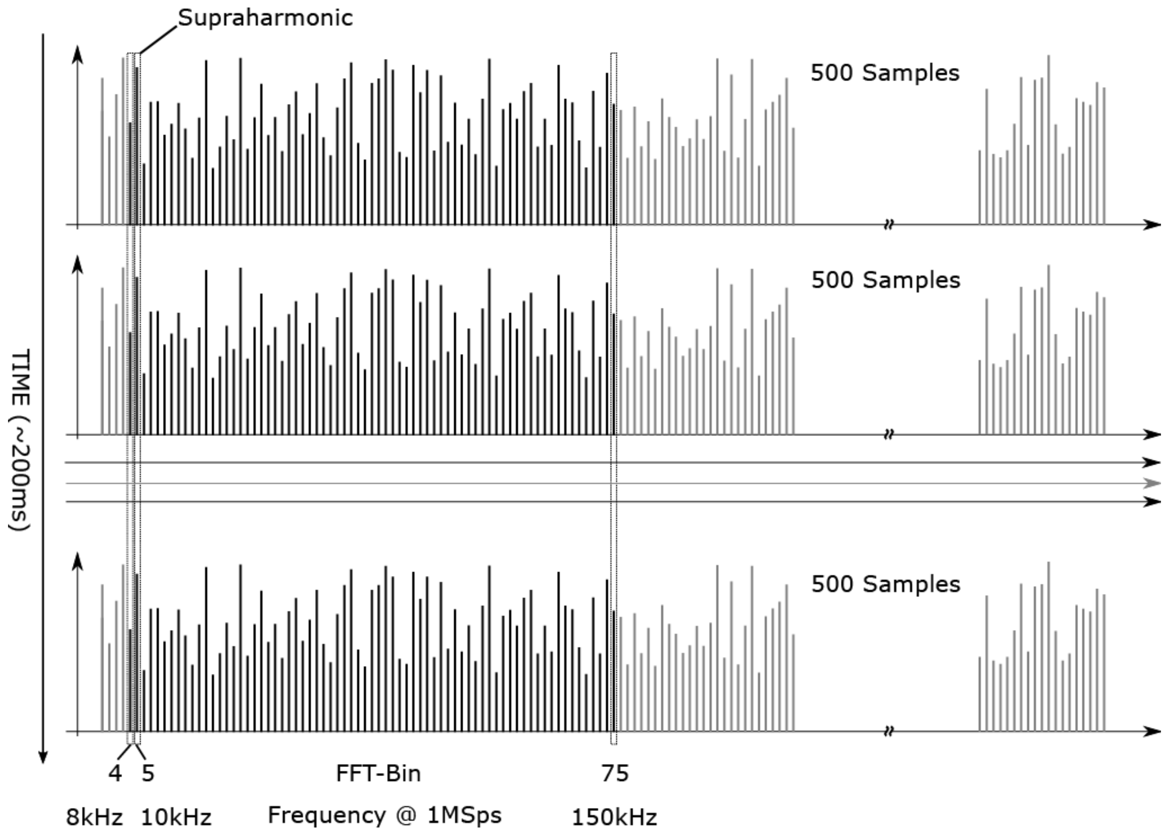


Fig. 9.10: Supraharmonic Grouping

This graphic shows the time domain aggregation of the short time FFT results. The number of FFTs is orientated on the number of fundamental periods.

In the graphics above the Supraharmonics Resolution is set to the default 2 kHz. In case the option in the Power Group settings is set to 200 Hz the FFT-Bin at 150 kHz will be 750, not 75, and the line resolution will be 200 Hz.

9.6 Harmonic Element Extraction

Specific elements from the Harmonic Vector can be extracted as separate channels.

Fig. 9.11: Harmonic Element Extraction

1. Open Channel Settings of Harmonic Vector
2. Select elements starting from zero
3. Each extracted element will create a new scalar channel under the Harmonic Vector

9.7 Voltage Channels (U)

9.7.1 U[i]_h[k]RMS

See *Harmonic Grouping*.

$$Y_c = abs(\underline{U}[i]_{fft}) \cdot \frac{1}{\sqrt{2}}$$

$$U[i]\_h[k]_{RMS} = \begin{cases} Y_h & \text{if } MODE = "None" \\ Y_{sg,h} & \text{if } MODE = "Type1" \\ Y_{g,h} & \text{if } MODE = "Type2" \end{cases} \quad Unit : \textbf{V}$$

9.7.2 U[i]_h[k]REL

Voltage relative harmonic value, referenced to fundamental. Must be enabled separately.

$$U[i]\_h[k]_{REL} = \frac{U[i]\_h[k]_{RMS}}{U[i]\_h[1]_{RMS}} \cdot 100\% \quad Unit : \textbf{\%}$$

9.7.3 U[ij]_h[k]RMS

Line-to-Line Harmonic Magnitude. Only available in 3-Phase Configurations (3P3W, 3P4W, 2V2A).

$$\begin{aligned}\underline{U}[i]_h = U[i]\_h[k]_{RMS} \cdot (cos(U[i]\_h[k]_{PHI} \cdot \frac{\pi}{180})+ \\ j \cdot sin(U[i]\_h[k]_{PHI} \cdot \frac{\pi}{180})) \\ \underline{U}[12]_h = \underline{U}[1]_h - \underline{U}[2]_h \\ \underline{U}[23]_h = \underline{U}[2]_h - \underline{U}[3]_h \\ \underline{U}[31]_h = \underline{U}[3]_h - \underline{U}[1]_h \\ U[ij]\_h[k]_{RMS} = abs(\underline{U}[ij]_h) \qquad Unit: \mathbf{V}\end{aligned}$$

9.7.4 U[i]_h[k]PHI

$$\begin{aligned}PHI_{ref} = arg(\underline{U1}_{fft}[1 \cdot NP]) + 90^\circ \\ U[i]\_h[k]_{PHI} = arg(\underline{U}[i]_{fft}[k \cdot NP]) + 90^\circ - k \cdot PHI_{ref} \quad Unit: \mathbf{deg}(^\circ)\end{aligned}$$

9.7.5 U[i]_ih[k]RMS

See *Interharmonic Grouping*.

$$Y_c = abs(\underline{U}[i]_{fft}) \cdot \frac{1}{\sqrt{2}}$$

$$U[i]\_ih[k]_{RMS} = \begin{cases} Y_{ih} & \text{if } MODE = "None" \\ Y_{isg,h} & \text{if } MODE = "Type1" \\ Y_{ig,h} & \text{if } MODE = "Type2" \end{cases} \quad Unit: \mathbf{V}$$

9.7.6 U[i]_ih[k]REL

Voltage relative interharmonic value, referenced to fundamental. Must be enabled separately.

$$U[i]\_ih[k]_{REL} = \frac{U[i]\_ih[k]_{RMS}}{U[i]\_h[1]_{RMS}} \cdot 100\% \quad Unit: \mathbf{\%}$$

9.7.7 U[i]_hf[k]RMS

See *Higher Frequency Grouping*.

$$\begin{aligned}Y_C = abs(\underline{U}[i]_{fft}) \cdot \frac{1}{\sqrt{2}} \\ U[i]\_hf[k]_{RMS} = Y_{B,b} \qquad Unit: \mathbf{V}\end{aligned}$$

9.7.8 U[i]_sh[k]MIN

Minimum Value of Voltage Supraharmonics Grouping. See *Supraharmonics Grouping*.

$$U[i]\_sh[k]_{MIN} = Y_{SH,b,min} \quad Unit: \mathbf{V}$$

9.7.9 U[i]_sh[k]AVG

Average Value of Voltage Supraharmonics Grouping. See *Supraharmonics Grouping*.

$$U[i]\_sh[k]_{AVG} = Y_{SH,b,avg} \quad Unit: \mathbf{V}$$

9.7.10 U[i]_sh[k]MAX

Maximum Value of Voltage Supraharmonics Grouping. See See *Supraharmonics Grouping*.

$$U[i]\_sh[k]_{MAX} = Y_{SH,b,max} \quad Unit: \mathbf{V}$$

9.7.11 U[i]_THD

Voltage Total Harmonic Distortion, highest used harmonic is k_{max} (selectable in menu in the Harmonics tab).

$$U[i]_{THD} = 100 \cdot \sqrt{\sum_{k=2}^{k_{max}} \left(\frac{U[i]_{h[k]RMS}}{U[i]_{h[1]RMS}} \right)^2} \quad Unit: \%$$

9.7.12 U[ij]_THD

Line-Line Voltage Total Harmonic Distortion, highest used harmonic is k_{max} (selectable in menu in the Harmonics tab).

$$U[ij]_{THD} = 100 \cdot \sqrt{\sum_{k=2}^{k_{max}} \left(\frac{U[ij]_{h[k]RMS}}{U[ij]_{h[1]RMS}} \right)^2} \quad Unit: \%$$

9.7.13 U[i]_THV

Total Harmonic Voltage, highest used harmonic is k_{max} (selectable in menu in the Harmonics tab).

$$U[i]_{THV} = \sqrt{\sum_{k=2}^{k_{max}} \left(U[i]_{h[k]RMS} \right)^2} \quad Unit: \mathbf{V}$$

9.8 Current Channels (I)

9.8.1 I[i]_h[k]RMS

See *Harmonic Grouping*

$$Y_c = abs(\underline{I}[i]_{fft}) \cdot \frac{1}{\sqrt{2}}$$

$$I[i]\_h[k]_{RMS} = \begin{cases} Y_h & \text{if } MODE = "None" \\ Y_{sg,h} & \text{if } MODE = "Type1" \\ Y_{g,h} & \text{if } MODE = "Type2" \end{cases} \quad Unit: \textbf{A}$$

9.8.2 I[i]_h[k]REL

Current relative harmonic value, referenced to fundamental. Must be enabled separately.

$$I[i]\_h[k]_{REL} = \frac{I[i]\_h[k]_{RMS}}{I[i]\_h[1]_{RMS}} \cdot 100\% \quad Unit: \textbf{\%}$$

9.8.3 I[i]_h[k]PHI

$$PHI_{ref} = arg(\underline{U1}_{fft}[1 \cdot NP]) + 90°$$
$$I[i]\_h[k]_{PHI} = arg(\underline{I}[i]_{fft}[k \cdot NP]) + 90° - k \cdot PHI_{ref} \quad Unit: \textbf{deg}(°)$$

9.8.4 I[i]_ih[k]RMS

See *Interharmonic Grouping*.

$$Y_c = abs(\underline{I}[i]_{fft}) \cdot \frac{1}{\sqrt{2}}$$

$$I[i]\_ih[k]_{RMS} = \begin{cases} Y_{ih} & \text{if } MODE = "None" \\ Y_{isg,h} & \text{if } MODE = "Type1" \\ Y_{ig,h} & \text{if } MODE = "Type2" \end{cases} \quad Unit: \textbf{A}$$

9.8.5 U[i]_ih[k]REL

Current relative interharmonic value, referenced to fundamental. Must be enabled separately.

$$I[i]\_ih[k]_{REL} = \frac{I[i]\_ih[k]_{RMS}}{I[i]\_h[1]_{RMS}} \cdot 100\% \quad Unit: \textbf{\%}$$

9.8.6 I[i]_hf[k]RMS

See *Higher Frequency Grouping*.

$$Y_C = abs(\underline{I}[i]_{fft}) \cdot \frac{1}{\sqrt{2}}$$
$$I[i]\_hf[k]_{RMS} = Y_{B,b} \qquad Unit: \textbf{A}$$

9.8.7 I[i]_sh[k]MIN

Minimum Value of Current Supraharmonics Grouping. See *Supraharmonics Grouping*.

$$I[i]\_sh[k]_{MIN} = Y_{SH,b,min} \quad Unit: \textbf{A}$$

9.8.8 I[i]_sh[k]AVG

Average Value of Current Supraharmonics Grouping. See *Supraharmonics Grouping*.

$$I[i]\_sh[k]_{AVG} = Y_{SH,b,avg} \quad Unit: \textbf{A}$$

9.8.9 I[i]_sh[k]MAX

Maximum Value of Current Supraharmonics Grouping. See *Supraharmonics Grouping*.

$$I[i]\_sh[k]_{MAX} = Y_{SH,b,max} \quad Unit: \textbf{A}$$

9.8.10 I[i]_THD

Current Total Harmonic Distortion, highest used harmonic is k_{max} (selectable in menu in the Harmonics tab).

$$I[i]_{THD} = 100 \cdot \sqrt{\sum_{k=2}^{k_{max}} \left(\frac{I[i]_{h[k]RMS}}{I[i]_{h[1]RMS}}\right)^2} \quad Unit: \%$$

9.8.11 I[i]_THC

Current Total Harmonic Current, highest used harmonic is k_{max} (selectable in menu in the Harmonics tab).

$$I[i]_{THC} = \sqrt{\sum_{k=2}^{k_{max}} \left(I[i]_{h[k]RMS}\right)^2} \quad Unit: \textbf{A}$$

9.9 Active Power Channels (P)

Grouping Mode always “None”

9.9.1 P[i]_h[k]

Active Power Harmonics.

$$P[i]\_h[k] = U[i]\_h[k]_{RMS} \cdot I[i]\_h[k]_{RMS} \cdot cos\left(U[i]\_h[k]_{PHI} - I[i]\_h[k]_{PHI}\right) \quad Unit: \textbf{W}$$

9.9.2 P[i]_h[k]REL

Relative active Power Harmonics, referenced to fundamental

$$P[i]\_h[k]_{REL} = \frac{P[i]\_h[k]_{RMS}}{P[i]\_h[1]_{RMS}} \cdot 100\% \quad Unit: \textbf{\%}$$

9.9.3 P[i]_THP

Total Harmonic Power, highest used harmonic is k_{max} (selectable in menu in the Harmonics tab).

$$P[i]_{THP} = \sum_{k=2}^{k_{max}} P[i]_{h[k]} \quad Unit: \textbf{W}$$

9.10 Impedance Channels (RXZ)

9.10.1 R[i]_h

Active Impedance harmonic value. Must be enabled separately.

$$R[i]\_h[k] = \frac{U[i]\_h[k]_{RMS}}{I[i]\_h[k]_{RMS}} \cdot cos\left(U[i]\_h[k]_{PHI} - I[i]\_h[k]_{PHI}\right) \quad Unit: \textbf{Ohm}$$

9.10.2 X[i]_h

Reactive Impedance harmonic value. Must be enabled separately.

$$X[i]\_h[k] = \frac{U[i]\_h[k]_{RMS}}{I[i]\_h[k]_{RMS}} \cdot sin\left(U[i]\_h[k]_{PHI} - I[i]\_h[k]_{PHI}\right) \quad Unit: \textbf{Ohm}$$

9.10.3 Z[i]_h

Impedance harmonic value. Must be enabled separately.

$$Z[i]\_h[k] = \frac{U[i]\_h[k]_{RMS}}{I[i]\_h[k]_{RMS}} \quad Unit : \textbf{Ohm}$$

CHAPTER

TEN

VOLTAGE FLUCTUATION AND FLICKER EMISSION ANALYSIS REFERENCE (OPT-POWER-ADV)

This chapter describes the measurement parameters according to IEC61000-4-15 and IEC61400-21 Section 7.3. For the Flicker Reporting Table in the Power Instrument see *Power Instrument*.

10.1 Introduction

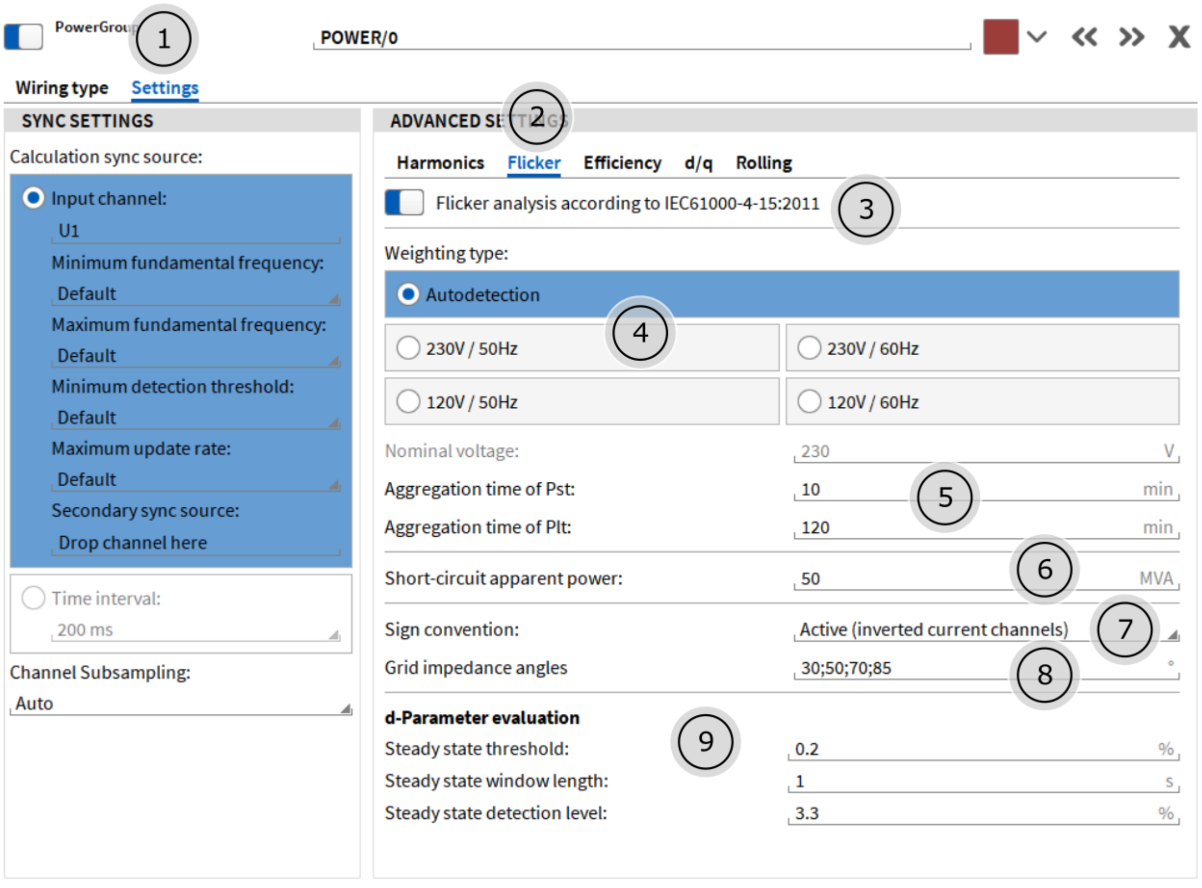


Fig. 10.1: Voltage Fluctuation Settings

1. Power Group's Settings Tab
2. Details Tab for Settings of the Voltage Fluctuation Analysis

3. Enable/Disable Voltage Fluctuation Analysis
4. Selector for Weighting Type
5. Input Field for Nominal Voltage, if weighting type is other than Autodetection;
   Input Field for Short Term (Pst) and Long Term (Plt) Voltage Fluctuation Aggregation time
6. Input Field for Short-Circuit Apparent Power $S_{K,fic}$ for Flicker Emission evaluation. This value has to be inserted as single phase value.
7. Sign convention (Passive / Active).
   In passive sign convention loads have positive power and sources have negative power. In active sign convention loads have negative power and sources have positive power.
   Use active when measuring positive real power on a generator.
   Use passive when measuring negative real power on a generator.
8. Grid impedance angles
9. d-Parameters

The grid impedance angles is an array with multiple values, separated by a semicolon. This angle gives the relation between ohmic and inductive behavior of the fictious grid. For more details about the fictous grid, see section *Flicker Emission*

The d-Paramaters can be manually defined to set the conditions of detected short term voltage fluctuations. For more details about the d-Parameters, see *Short Term Voltage Fluctuations / d-Parameter*.

Attention

Table 10.1: Working Conditions for Voltage Fluctuation

Fundamental Frequency	10 to 1000 Hz
Nominal Voltage	> 5% of Input Range
Weighting Functions	120V/50Hz, 120V/60Hz, 230V/50Hz, 230V/60Hz
Aggregation Time Pst	1 s to 60 min
Aggregation Time Plt	1 s to 1440 min
Short Circuit Apparent Power	0.001 to 10 000 MVA

10.2 Perform Analysis

To perform a Voltage Fluctuation Analysis, please proceed the following Steps:

1. Switch on the Feature **2**.
2. Select the Weighting Type **3** for your Application. Use Autodetection in low voltage grids (120V/230V). If you want to use the Voltage Fluctuation Algorithm outside these Conditions, please select the weighting type manually and insert the nominal voltage in **4**.
3. Change the Aggregation Time of Pst and Plt if needed **5** + **6**.
4. Change the sign convention to active if necessary **7**.
5. Go back to Measurement Screen, take an indicator instrument and assign the U[i]_fluc_ready Channel.

6. Take a Table Instrument and assign the U[i]_fluc_Pst Channels or any other Instrument to visualize the Voltage Fluctuation Values.
7. Wait for Channel Ready (1 or red).
8. Start the Recording.

10.3 Flicker Emission

Flicker Emission is the Analysis of the virtually generated voltage fluctuation caused by the emitted current. This analysis procedure is described in the IEC61400-21 Standard. It uses a fictitious grid for simulation of a fictitious voltage, which is then processed with the flicker algorithm to get the Pst,fic.

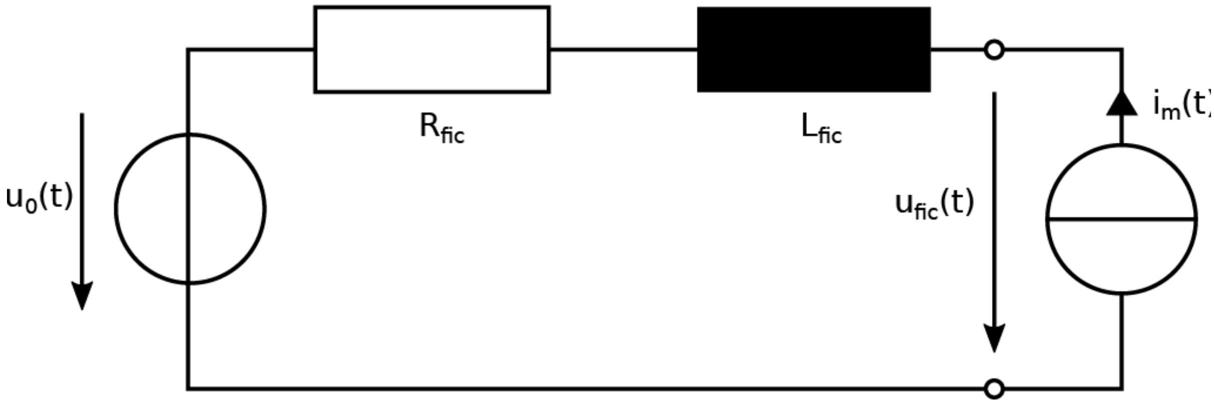


Fig. 10.2: Fictitious grid for simulation of fictitious voltage

$$u_{fic}(t) = u_0(t) + R_{fic} \cdot i_m(t) + L_{fic} \cdot \frac{di_m(t)}{dt}$$
$$i_m(t) = \begin{cases} -i_{inp}(t) & \text{if sign convention is passive} \\ i_{inp}(t) & \text{if sign convention is active} \end{cases}$$

$i_{inp}(t)$ is the measured current used as input for the flicker calculation.

10.3.1 Calculation Insights

Symbol	Description
$S_{K,fic}$	This is the short circuit power of the fictitious grid. To be given for one phase in MVA!
U_N	Nominal Voltage U_{L-N} of the analyzed grid
ψ_K	Phase Angle of the Grid Impedance (pre-defined with 30/50/70/85 deg)
R_{fic}	Fictitious Ohmic Impedance
X_{fic}	Fictitious Reactive Impedance
f_N	Nominal Frequency (50 or 60 Hz, depending on the selected Weighting)

$$S_{K,fic} = \frac{U_N^2}{\sqrt{R_{fic}^2 + X_{fic}^2}} \qquad Unit: \textbf{VA}$$

$$Z_{fic} = \sqrt{R_{fic}^2 + X_{fic}^2} = \frac{U_N^2}{S_{K,fic}} \qquad Unit:$$

$$R_{fic} = Z_{fic} \cdot cos(\psi_K) \qquad Unit:$$

$$X_{fic} = Z_{fic} \cdot sin(\psi_K) \qquad Unit:$$

$$L_{fic} = \frac{X_{fic}}{2 \cdot \pi \cdot f_N} \qquad Unit: \textbf{H}$$

10.4 Short Term Voltage Fluctuations / d-Parameter

This functionality evaluates the voltage change characteristics according to IEC61000-4-15. For this analysis, the half-period rms values from the voltage channels are calculated internally.

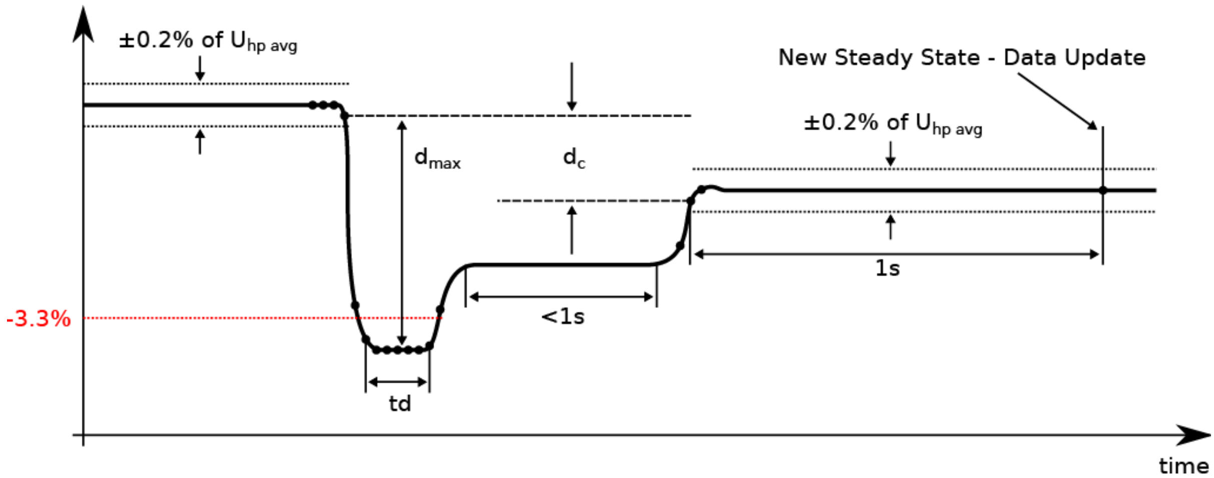


Fig. 10.3: Explanation of the evaluation of the d-Parameter

Attention

The half-period rms calculation goes strong with a possible channel offset and could never lead to a steady state. In this case it is recommended to zero the voltage inputs or use a 2nd order high-pass filter with 0.1 Hz to eliminate every DC component.

Attention

The **Auto-Detection Mode** is useful for the most applications. In the following graph you can see, which Mode is applied under different circumstances.

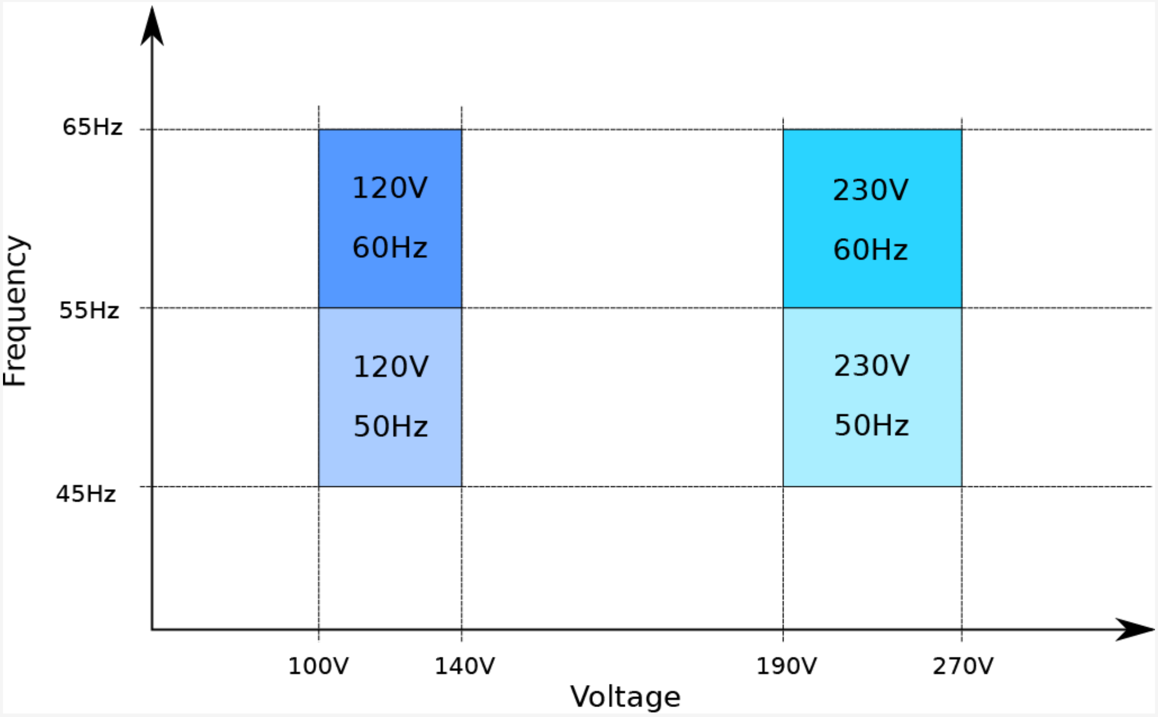


Fig. 10.4: Voltage Fluctuation Autodetection

Pst/Plt **Aggregation Time**: If the Recording is started before ready (1), the aggregation is started when ready. When recording is started while ready (2), the aggregation will be started with the recording start.

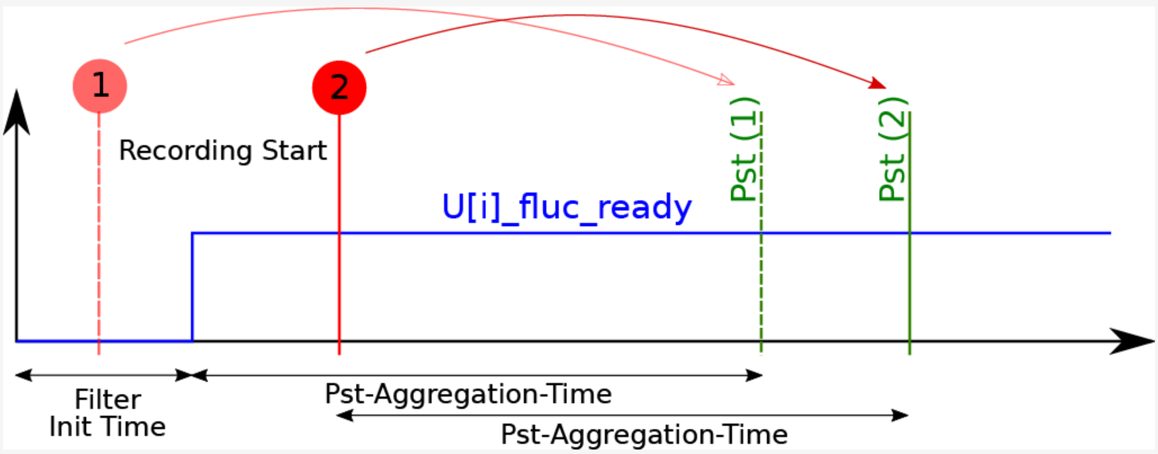


Fig. 10.5: Flicker Time Behaviour

10.5 Channel Reference

Symbol	Description
N	Number of Pst-Values in Plt-Aggregation-Time

10.5.1 U[i]_fluc_Pst

The short-term flicker severity

10.5.2 U[i]_fluc_Plt

The long-term flicker severity.

$$U[i]\_fluc\_Plt = \sqrt[3]{\frac{1}{N}\sum_{k=0}^{N-1} U[i]\_fluc\_Pst[k]^3} \quad Unit: \mathbf{A}$$

10.5.3 U[i]_fluc_Pinst

The instantaneous flicker sensation.

10.5.4 U[i]_fluc_ready

Indicator value for steady state of algorithm filters.

10.5.5 I[i]_fluc_Pst_[ψ]

The short-term flicker emission severity according to IEC61400-21. Equal to $P_{st,fic}$. $\psi \in [30°, 50°, 70°, 85°]$.

10.5.6 I[i]_fluc_Plt_[ψ]

The long-term flicker emission severity. $\psi \in [30°, 50°, 70°, 85°]$.

10.5.7 I[i]_fluc_Pinst_[ψ]

The instantaneous flicker emission sensation. $\psi \in [30°, 50°, 70°, 85°]$

10.5.8 U[i]_fluc_dc

Steady state voltage change

10.5.9 U[i]_fluc_dc_overall

Maximum of steady state voltage change. Maximum of U[i]_fluc_dc. Initialized with 0.

10.5.10 U[i]_fluc_dmax

Maximum voltage change during a voltage change characteristic

10.5.11 U[i]_fluc_d_max_overall

Maximum voltage change of all voltage change events. Maximum of U[i]_fluc_dmax. Initialized with 0.

10.5.12 U[i]_fluc_td

Duration of voltage change below detection level (default: 3.3 %).

10.5.13 U[i]_fluc_td_max_overall

Maximum duration of all voltage change events below detection level (default: 3.3 %). Initialized with 0.

10.5.14 U[i]_fluc_fic_[ψ]_hp_RMS

The Phase's i half period RMS value of the fictitious grid, used for Stage 1 in the IEC-Flickermeter. Can be used to calculate the Voltage change factor ku. $\psi \in [30°, 50°, 70°, 85°]$.

CHAPTER

ELEVEN

ROLLING COMPUTATION (OPT-POWER-EXP)

This chapter describes the Rolling Computation feature. It is designed for analysing fast changes in power grid connected applications e.g. renewable energy testing. In advance to the "normal" calculation, which is performed each single fundamental period, the computation in default setting is done every 1ms over the period of one fundamental cycle.

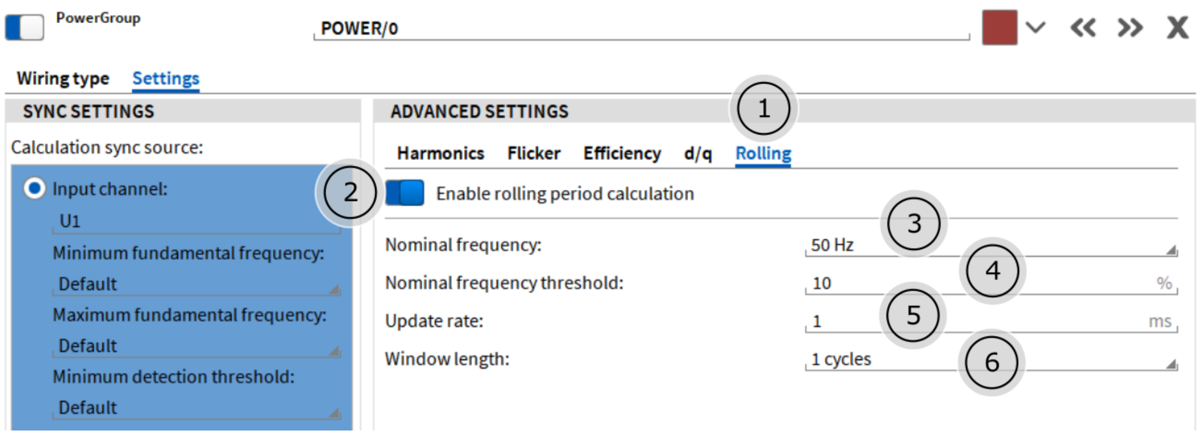


Fig. 11.1: Detail Settings in OXYGEN Power Group

1. Details Tab for Settings of the rolling computation
2. Enable/Disable Rolling Calculation
3. Selector for nominal frequency fallback (50 Hz / 60 Hz)
4. Input field for frequency threshold.

   If a frequency is detected within the nominal frequency $\pm$ threshold %, the rolling window size is the actual period duration. Otherwise, e.g. in the case of a voltage interruption, where no frequency can be measured, the window size is the inverse nominal frequency (0–95 %).
5. Update rate (0.1–20 ms)
6. Window length (0.5 cycles / 1 cycles)

Attention

The following graph shows the details of the operation principle. It is similar to a moving average calculation, but with a variable window size, which depends on the actual measured fundamental frequency. If the calculate window size exceeds the maximum allowed size, which is given by (1/Nominal Frequency)*(1 + Frequency Threshold/100), the window size is set to 1/Nominal Frequency.

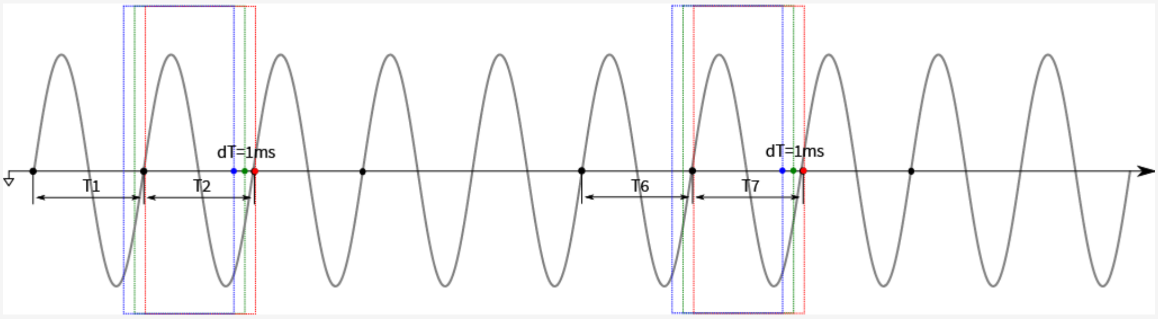


Fig. 11.2: Detail Settings in OXYGEN Power Group

11.1 Channel Reference (Basic)

Some of the shown intermediate results or variables are not available in the software today. They are marked with a *.

Table 11.1: Legend

Symbol	Equatiom	Description
SR	–	Samplerate
NP	–	Number of Power Phases
N	$\frac{SR}{f_{fund}}$	Number of Samples

11.1.1 U[i]_tRMS_rc

This is the Power Phase number i True RMS Voltage, updated every 1ms.

$$U[i]_{tRMS\_rc} = \sqrt{\frac{1}{N}\sum_{n=0}^{N} u_i[n]^2} \quad Unit: \mathbf{V}$$

11.1.2 U[ij]_tRMS_rc

This is the Line-Line ij True RMS Voltage, updated every 1ms. This channel is only available in 3-Phase Power Configurations.

$$U[ij]_{tRMS\_rc} = \sqrt{\frac{1}{N}\sum_{n=0}^{N}(u_i[n] - u_j[n])^2} \quad Unit: \mathbf{V}$$

11.1.3 I[i]_tRMS_rc

This is the Power Phase number i True RMS Current, updated every 1ms.

$$I[i]_{tRMS\_rc} = \sqrt{\frac{1}{N}\sum_{n=0}^{N} i_i[n]^2} \quad Unit: \mathbf{A}$$

11.1.4 P_t_rc

This is the Power Group Overall active Power, updated every 1ms.

$$P_{t\_rc} = \sum_{i=1}^{NP} P[i]_t \quad Unit: \mathbf{W}$$

11.1.5 P[i]_t_rc

This is the Power Phase number i active Power, updated every 1ms.

$$P[i]_{t\_rc} = \frac{1}{N}\sum_{n=0}^{N} u_i[n] \cdot i_i[n] \quad Unit: \mathbf{W}$$

11.1.6 P_fund_rc

This is the Power Group Overall fundamental active Power, updated every 1ms.

$$P_{fund\_rc} = \sum_{i=1}^{NP} P[i]_{fund\_rc} \quad Unit: \mathbf{W}$$

11.1.7 P[i]_fund_rc

This is the Power Phase number i fundamental active Power, updated every 1 ms.

$$P[i]_{fund\_rc} = U[i]_{fundRMS\_rc} \cdot I[i]_{fundRMS\_rc} \cdot cos\left(P[i]_{fundPHI\_rc}\right) \quad Unit: \mathbf{W}$$

$U[i]_{fundRMS\_rc}, P[i]_{fundPHI\_rc}$ are internal channels, not available for users.

11.1.8 Q_t_rc

This is the Power Group Overall reactive Power, updated every 1ms.

$$Q_{t\_rc} = s \cdot \sqrt{S_{t\_rc}^2 - P_{t\_rc}^2} \qquad s = \begin{cases} 1 & \text{if } Q_{fund\_rc} > 0 \\ -1 & \text{if } Q_{fund\_rc} <= 0 \end{cases} \quad Unit : \textbf{var}$$

11.1.9 Q[i]_t_rc

This is the Power Phase number i reactive Power, updated every 1 ms.

$$Q[i]_{t\_rc} = s \cdot \sqrt{S[i]_{t\_rc}^2 - P[i]_{t\_rc}^2} \qquad s = \begin{cases} 1 & \text{if } Q_{fund\_rc} > 0 \\ -1 & \text{if } Q_{fund\_rc} <= 0 \end{cases} \quad Unit : \textbf{var}$$

11.1.10 Q_fund_rc

This is the Power Group Overall fundamental reactive Power, updated every 1ms.

$$Q_{fund\_rc} = \sum_{i=1}^{NP} Q[i]_{fund\_rc} \quad Unit : \textbf{var}$$

11.1.11 Q[i]_fund_rc

This is the Power Phase number i fundamental reactive Power, updated every 1ms.

$$Q[i]_{fund\_rc} = U[i]_{fundRMS\_rc} \cdot I[i]_{fundRMS\_rc} \cdot sin\left(P[i]_{fundPHI\_rc}\right) \quad Unit : \textbf{var}$$

11.1.12 S_t_rc

This is the Power Group Overall apparent Power, updated every 1ms.

$$S_{t\_rc} = \sum_{i=1}^{NP} S[i]_{t\_rc} \quad Unit : \textbf{VA}$$

11.1.13 S[i]_t_rc

This is the Power Phase number i apparent Power, updated every 1ms.

$$S[i]_{t\_rc} = U[i]_{tRMS\_rc} \cdot I[i]_{tRMS\_rc} \quad Unit : \textbf{VA}$$

11.1.14 S_fund_rc

This is the Power Group Overall fundamental apparent Power, updated every 1ms.

$$S_{fund\_rc} = \sum_{i=1}^{NP} S[i]_{fund\_rc} \quad Unit: \textbf{VA}$$

11.1.15 S[i]_fund_rc

This is the Power Phase number i fundamental apparent Power, updated every 1ms.

$$S[i]_{fund\_rc} = U[i]_{fundRMS\_rc} \cdot I[i]_{fundRMS\_rc} \quad Unit: \textbf{VA}$$

11.1.16 U_DC_rc

This is the DC Voltage in case the DC Power Analysis is enabled in the Efficiency tab, updated every 1ms.

$$U_{DC\_rc} = \frac{1}{N} \sum_{n=0}^{N} u_{DC}[n] \quad Unit: \textbf{V}$$

11.1.17 I_DC_rc

This is the DC Current in case the DC Power Analysis is enabled in the Efficiency tab, updated every 1ms.

$$I_{DC\_rc} = \frac{1}{N} \sum_{n=0}^{N} i_{DC}[n] \quad Unit: \textbf{A}$$

11.1.18 P_DC_rc

This is the DC Power in case the DC Power Analysis is enabled in the Efficiency tab, updated every 1ms.

$$P_{DC\_rc} = \frac{1}{N} \sum_{n=0}^{N} u_{DC}[n] \cdot i_{DC}[n] \quad Unit: \textbf{W}$$

11.2 Channel Reference (Symmetrical Components)

This section describes the equations for symmetrical components according to FGW-TG3 Annex F and IEC 61400-21 Annex C.

11.2.1 U[i]_fund_cos_rc

This is the Real part of the fourier coefficients of the signal. (F-1 in FGW-TG3 Annex F)

$$U[i]_{fund\_cos\_rc} = \frac{2}{N} \sum_{n=-N-1}^{0} u_i[n] \cdot cos(2 \cdot \pi \cdot F_{fund} \cdot \frac{n}{SR}) \quad Unit: \mathbf{V}$$

11.2.2 U[i]_fund_sin_rc

This is the Imaginary part of the fourier coefficients of the signal (F-2 in FGW-TG3 Annex F).

$$U[i]_{fund\_sin\_rc} = \frac{2}{N} \sum_{n=-N-1}^{0} u_i[n] \cdot sin(2 \cdot \pi \cdot F_{fund} \cdot \frac{n}{SR}) \quad Unit: \mathbf{V}$$

11.2.3 U_fundCOS_SYM+_rc

This is the real vector component of the Positive Voltage Sequence.

$$U_{fundCOS\_SYM+\_rc} = \frac{1}{6}\left(2 \cdot U1_{fund\_cos\_rc} - U2_{fund\_cos\_rc} - U3_{fund\_cos\_rc} - \sqrt{3}\left(U3_{fund\_sin\_rc} - U2_{fund\_sin\_rc}\right)\right)$$

11.2.4 U_fundSIN_SYM+_rc

This is the imaginary vector component of the Positive Voltage Sequence.

$$U_{fundSIN\_SYM+\_rc} = \frac{1}{6}\left(2 \cdot U1_{fund\_sin\_rc} - U2_{fund\_sin\_rc} - U3_{fund\_sin\_rc} - \sqrt{3}\left(U2_{fund\_cos\_rc} - U3_{fund\_cos\_rc}\right)\right) \quad Unit: \mathbf{V}$$

11.2.5 U_fundPHI_SYM+_rc

This is the phase angle of the Positive Voltage Sequence.

$$U_{fundPHI\_SYM+\_rc} = arctan2(U_{fundSIN\_SYM+\_rc}, U_{fundCOS\_SYM+\_rc}) \quad Unit: \mathbf{deg}(^\circ)$$

11.2.6 U_fundCOS_SYM-_rc

This is the real vector component of the Negative Voltage Sequence.

$$U_{fund\_SYM-\_cos\_rc} = \frac{1}{6}\left(2 \cdot U1_{fund\_cos\_rc} - U2_{fund\_cos\_rc} - U3_{fund\_cos\_rc} - \sqrt{3}\left(U2_{fund\_sin\_rc} - U3_{fund\_sin\_rc}\right)\right) \quad Unit: \mathbf{V}$$

11.2.7 U_fundSIN_SYM-_rc

This is the imaginary vector component of the Negative Voltage Sequence.

$$U_{fund\_SYM-\_sin\_rc} = \frac{1}{6}\Big(2 \cdot U1_{fund\_sin\_rc} - U2_{fund\_sin\_rc} - U3_{fund\_sin\_rc} - \sqrt{3}\left(U3_{fund\_cos\_rc} - U2_{fund\_cos\_rc}\right)\Big) \quad Unit: \textbf{V}$$

11.2.8 U_fundPHI_SYM-_rc

This is the phase angle of the Negative Voltage Sequence.

$$U_{fundPHI\_SYM-\_rc} = arctan2(U_{fundSIN\_SYM-\_rc}, U_{fundCOS\_SYM-\_rc}) \quad Unit: \textbf{deg}(^\circ)$$

11.2.9 U_fundCOS_SYM0_rc

This is the real vector component of the Zero Voltage Sequence.

$$U_{fundCOS\_SYM0\_rc} = \frac{1}{3 \cdot \sqrt{3}}\left(U1_{fund\_cos\_rc} + U2_{fund\_cos\_rc} + U3_{fund\_cos\_rc}\right) \quad Unit: \textbf{V}$$

11.2.10 U_fundSIN_SYM0_rc

This is the real vector component of the Zero Voltage Sequence.

$$U_{fundSIN\_SYM0\_rc} = \frac{-1}{3 \cdot \sqrt{3}}\left(U1_{fund\_sin\_rc} + U2_{fund\_sin\_rc} + U3_{fund\_sin\_rc}\right) \quad Unit: \textbf{V}$$

11.2.11 U_fund_SYM+_rc

This is the RMS value of the Phase-Phase (Line-Line) voltages positive sequence system.

$$U_{fund\_SYM+\_rc} = \sqrt{\frac{3}{2}\left(U^2_{fundCOS\_SYM+\_rc} + U^2_{fundSIN\_SYM+\_rc}\right)} \quad Unit: \textbf{V}$$

11.2.12 U_fund_SYM-_rc

This is the RMS value of the Phase-Phase (Line-Line) voltages negative sequence system.

$$U_{fund\_SYM-\_rc} = \sqrt{\frac{3}{2}\left(U^2_{fundCOS\_SYM-\_rc} + U^2_{fundSIN\_SYM-\_rc}\right)} \quad Unit: \textbf{V}$$

11.2.13 U_fund_SYM0_rc

This is the RMS value of the Phase-Phase (Line-Line) voltages zero sequence system.

$$U_{fund\_SYM0\_rc} = \sqrt{3 \cdot \left(U^2_{fundCOS\_SYM0\_rc} + U^2_{fundSIN\_SYM0\_rc}\right)} \quad Unit: \textbf{V}$$

11.2.14 I[i]_fund_cos_rc

This is the Real part of the fourier coefficients of the signal (F-1 in FGW-TG3 Annex F).

$$I[i]_{fund\_cos\_rc} = \frac{2}{N} \sum_{n=-N-1}^{0} I_i[n] \cdot cos(2 \cdot \pi \cdot F_{fund} \cdot \frac{n}{SR}) \quad Unit: \textbf{A}$$

11.2.15 I[i]_fund_sin_rc

This is the Imaginary part of the fourier coefficients of the signal. (F-2 in FGW-TG3 Annex F)

$$I[i]_{fund\_sin\_rc} = \frac{2}{N} \sum_{n=-N-1}^{0} I_i[n] \cdot sin(2 \cdot \pi \cdot F_{fund} \cdot \frac{n}{SR}) \quad Unit: \textbf{A}$$

11.2.16 I_fundCOS_SYM+_rc

This is the real vector component of the Positive Current Sequence.

$$\begin{aligned} I_{fundCOS\_SYM+\_rc} = & \frac{1}{6} \left(2 \cdot I1_{fund\_cos\_rc} - I2_{fund\_cos\_rc} - I3_{fund\_cos\_rc} - \right. \\ & \left. \sqrt{3} \left(I3_{fund\_sin\_rc} - I2_{fund\_sin\_rc}\right)\right) \end{aligned}$$

11.2.17 I_fundSIN_SYM+_rc

This is the imaginary vector component of the Positive Current Sequence.

$$\begin{aligned} I_{fundSIN\_SYM+\_rc} = & \frac{1}{6} \left(2 \cdot I1_{fund\_sin\_rc} - I2_{fund\_sin\_rc} - I3_{fund\_sin\_rc} - \right. \\ & \left. \sqrt{3} \left(I2_{fund\_cos\_rc} - I3_{fund\_cos\_rc}\right)\right) \qquad Unit: \textbf{A} \end{aligned}$$

11.2.18 I_fundCOS_SYM-_rc

This is the real vector component of the Negative Current Sequence.

$$\begin{aligned} I_{fundCOS\_SYM-\_rc} = & \frac{1}{6} \left(2 \cdot I1_{fund\_cos\_rc} - I2_{fund\_cos\_rc} - I3_{fund\_cos\_rc} - \right. \\ & \left. \sqrt{3} \left(I2_{fund\_sin\_rc} - I3_{fund\_sin\_rc}\right)\right) \qquad Unit: \textbf{A} \end{aligned}$$

11.2.19 I_fundSIN_SYM-_rc

This is the imaginary vector component of the Negative Current Sequence.

$$\begin{aligned} I_{fundSIN\_SYM-\_rc} =& \frac{1}{6}\left(2 \cdot I1_{fund\_sin\_rc} - I2_{fund\_sin\_rc} - I3_{fund\_sin\_rc} - \right. \\ & \left. \sqrt{3}\left(I3_{fund\_cos\_rc} - I2_{fund\_cos\_rc}\right)\right) \qquad Unit: \textbf{A} \end{aligned}$$

11.2.20 I_fundCOS_SYM0_rc

This is the real vector component of the Zero Current Sequence.

$$I_{fundCOS\_SYM0\_rc} = \frac{1}{3 \cdot \sqrt{3}}\left(I1_{fund\_cos\_rc} + I2_{fund\_cos\_rc} + I3_{fund\_cos\_rc}\right) \quad Unit: \textbf{A}$$

11.2.21 I_fundSIN_SYM0_rc

This is the real vector component of the Zero Current Sequence.

$$I_{fundSIN\_SYM0\_rc} = \frac{-1}{3 \cdot \sqrt{3}}\left(I1_{fund\_sin\_rc} + I2_{fund\_sin\_rc} + I3_{fund\_sin\_rc}\right) \quad Unit: \textbf{A}$$

11.2.22 P_fund_SYM+_rc

$$\begin{aligned} P_{fund\_SYM+\_rc} = \frac{3}{2} \cdot & \left(U_{fundCOS\_SYM+\_rc} \cdot I_{fundCOS\_SYM+\_rc}\right. \\ & \left. + U_{fundSIN\_SYM+\_rc} \cdot I_{fundSIN\_SYM+\_rc}\right) \quad Unit: \textbf{W} \end{aligned}$$

11.2.23 P_fund_SYM-_rc

$$\begin{aligned} P_{fund\_SYM-\_rc} = \frac{3}{2} \cdot & \left(U_{fundCOS\_SYM-\_rc} \cdot I_{fundCOS\_SYM-\_rc}\right. \\ & \left. + U_{fundSIN\_SYM-\_rc} \cdot I_{fundSIN\_SYM-\_rc}\right) \quad Unit: \textbf{W} \end{aligned}$$

11.2.24 P_fund_SYM0_rc

$$\begin{aligned} P_{fund\_SYM0\_rc} = 3 \cdot & \left(U_{fundCOS\_SYM0\_rc} \cdot I_{fundCOS\_SYM0\_rc}\right. \\ & \left. + U_{fundSIN\_SYM0\_rc} \cdot I_{fundSIN\_SYM0\_rc}\right) \quad Unit: \textbf{W} \end{aligned}$$

11.2.25 Q_fund_SYM+_rc

$$\begin{aligned} Q_{fund\_SYM+\_rc} = \frac{3}{2} \cdot & \left(U_{fundCOS\_SYM+\_rc} \cdot I_{fundSIN\_SYM+\_rc}\right. \\ & \left. - U_{fundSIN\_SYM+\_rc} \cdot I_{fundCOS\_SYM+\_rc}\right) \quad Unit: \textbf{var} \end{aligned}$$

11.2.26 Q_fund_SYM-_rc

$$Q_{fund\_SYM-\_rc} = \frac{3}{2} \cdot (U_{fundCOS\_SYM-\_rc} \cdot I_{fundSIN\_SYM-\_rc} \\ - U_{fundSIN\_SYM-\_rc} \cdot I_{fundCOS\_SYM-\_rc}) \quad Unit: \textbf{var}$$

11.2.27 Q_fund_SYM0_rc

$$Q_{fund\_SYM0\_rc} = 3 \cdot (U_{fundSIN\_SYM0\_rc} \cdot I_{fundCOS\_SYM0\_rc} \\ - U_{fundCOS\_SYM0\_rc} \cdot I_{fundSIN\_SYM0\_rc}) \quad Unit: \textbf{var}$$

11.2.28 S_fund_SYM+_rc

$$S_{fund\_SYM+\_rc} = \sqrt{P^2_{fund\_SYM+\_rc} + Q^2_{fund\_SYM+\_rc}} \quad Unit: \textbf{VA}$$

11.2.29 S_fund_SYM-_rc

$$S_{fund\_SYM-\_rc} = \sqrt{P^2_{fund\_SYM-\_rc} + Q^2_{fund\_SYM-\_rc}} \quad Unit: \textbf{VA}$$

11.2.30 S_fund_SYM0_rc

$$S_{fund\_SYM0\_rc} = \sqrt{P^2_{fund\_SYM0\_rc} + Q^2_{fund\_SYM0\_rc}} \quad Unit: \textbf{VA}$$

11.2.31 I_fund_P_SYM+_rc

$$I_{fund\_P\_SYM+\_rc} = \frac{P_{fund\_SYM+\_rc}}{\sqrt{3} \cdot U_{fund\_SYM+\_rc}} \quad Unit: \textbf{A}$$

11.2.32 I_fund_P_SYM-_rc

$$I_{fund\_P\_SYM-\_rc} = \frac{P_{fund\_SYM-\_rc}}{\sqrt{3} \cdot U_{fund\_SYM-\_rc}} \quad Unit: \textbf{A}$$

11.2.33 I_fund_P_SYM0_rc

$$I_{fund\_P\_SYM0\_rc} = \frac{P_{fund\_SYM0\_rc}}{\sqrt{3} \cdot U_{fund\_SYM0\_rc}} \quad Unit: \textbf{A}$$

11.2.34 I_fund_Q_SYM+_rc

$$I_{fund\_Q\_SYM+\_rc} = \frac{Q_{fund\_SYM+\_rc}}{\sqrt{3} \cdot U_{fund\_SYM+\_rc}} \quad Unit: \textbf{A}$$

11.2.35 I_fund_Q_SYM-_rc

$$I_{fund\_Q\_SYM-\_rc} = \frac{Q_{fund\_SYM-\_rc}}{\sqrt{3} \cdot U_{fund\_SYM-\_rc}} \quad Unit: \textbf{A}$$

11.2.36 I_fund_Q_SYM0_rc

$$I_{fund\_Q\_SYM0\_rc} = \frac{Q_{fund\_SYM0\_rc}}{\sqrt{3} \cdot U_{fund\_SYM0\_rc}} \quad Unit: \textbf{A}$$

11.2.37 PF_fund_SYM+_rc

$$PF_{fund\_SYM+\_rc} = \frac{P_{fund\_SYM+\_rc}}{\sqrt{P^2_{fund\_SYM+\_rc} + Q^2_{fund\_SYM+\_rc}}} \quad Unit: -$$

11.2.38 PF_fund_SYM-_rc

$$PF_{fund\_SYM-\_rc} = \frac{P_{fund\_SYM-\_rc}}{\sqrt{P^2_{fund\_SYM-\_rc} + Q^2_{fund\_SYM-\_rc}}} \quad Unit: -$$

11.2.39 PF_fund_SYM0_rc

$$PF_{fund\_SYM0\_rc} = \frac{P_{fund\_SYM0\_rc}}{\sqrt{P^2_{fund\_SYM0\_rc} + Q^2_{fund\_SYM0\_rc}}} \quad Unit: -$$

CHAPTER

TWELVE

EFFICIENCY (OPT-POWER-ADV)

This chapter describes the Efficiency Computation feature. It is designed for analyzing DC power and mechanical power. The DC power analysis is done via voltage and current, while mechanical power is measured with speed and torque sensors, in the same calculation period. It calculates power, average speed, average torque and efficiency regarding the electrical power. In case of electrical excitation of the machine, excitation voltage and excitation current can be entered here and taken into account for the efficiency calculation.

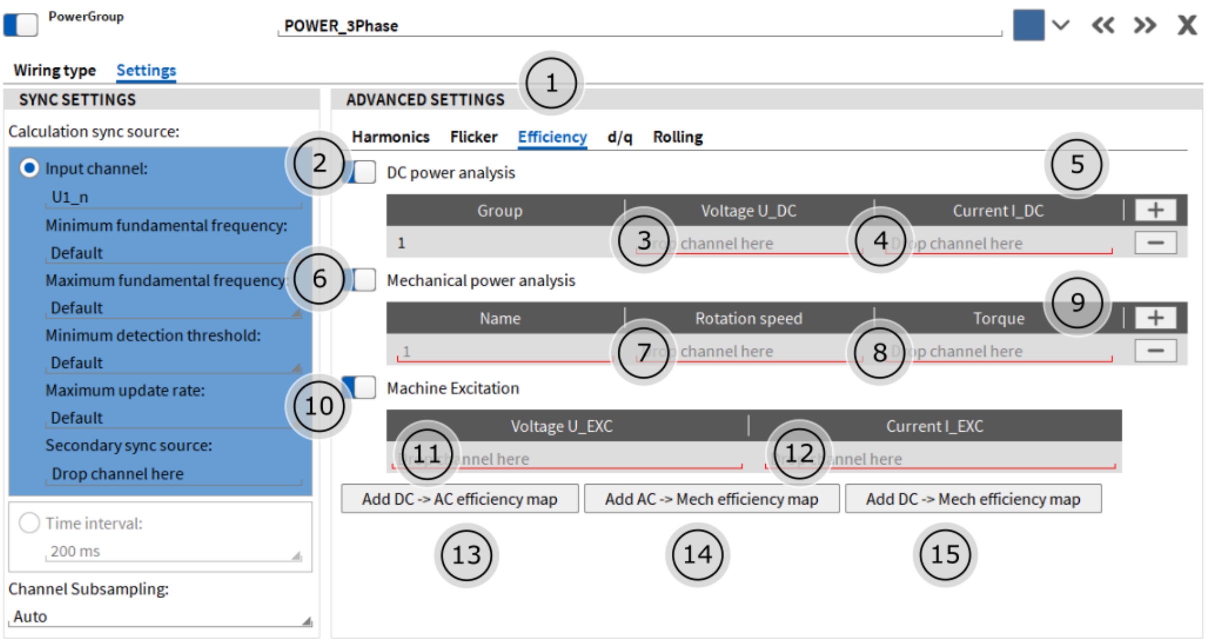


Fig. 12.1: Detail Settings in OXYGEN Power Group

1. Details Tab for Settings of Efficiency calculation.
2. Enable/Disable DC power analysis.
3. Input field for DC voltage channel (unit must be V).
4. Input field for DC current channel (unit must be A).
5. Button to add DC power analysis group. Voltage & Current Pair (up to 6)
6. Enable/Disable Mechanical power analysis.
7. Input field for rotation speed channel (unit must be rpm or U/min).
8. Input field for torque channel (unit must be Nm).

9. Button to add Mechanical power analysis group. (up to 6)
10. Enable/Disable Machine Excitation.
11. Input field for Machine Excitation voltage channel (unit must be V).
12. Input field for Machine Excitation current channel (unit must be A).
13. Button for creation of a DC power to AC power efficiency map module (Matrix Sampler).
14. Button for creation of an AC to Mechanical power efficiency map module (Matrix Sampler).
15. Button for creation of a DC to Mechanical power efficiency map module (Matrix Sampler).

12.1 Channel Reference

Table 12.1: Legend

Symbol	Equatiom	Description
SR	–	Samplerate (may differ from electrical input channels)
N	$\frac{SR}{f_{fund}}$	Number of Samples in calculation cycle

12.1.1 P_mech

This is the mechanical power, updated every calculation cycle given by calculation sync source (same as electrical power).

$$P_{mech} = \frac{1}{N}\sum_{n=0}^{N} speed[n] \cdot torque[n] \cdot \frac{2 \cdot \pi}{60} \quad Unit : \textbf{W}$$

12.1.2 n_mech

This is the rotational speed average, updated every calculation cycle given by calculation sync source (same as electrical power).

$$n_{mech} = \frac{1}{N}\sum_{n=0}^{N} speed[n] \quad Unit : \textbf{rpm}$$

12.1.3 M_mech

This is the mechanical torque average, updated every calculation cycle given by calculation sync source (same as electrical power).

$$M_{mech} = \frac{1}{N}\sum_{n=0}^{N} torque[n] \quad Unit : \textbf{Nm}$$

12.1.4 Eff_DC_AC

This is the efficiency of the inverter, related by the DC power input to the AC power output, updated every calculation cycle given by calculation sync source (same as electrical power).

$$Eff_{DC\_AC} = \begin{cases} \frac{P_{t\_AC}}{P_{DC}} \cdot 100 & \text{if } P_{t\_AC} > 0 \\ \frac{P_{DC}}{P_{t\_AC}} \cdot 100 & \text{if } P_{t\_AC} < 0 \; and \; P_{DC} < 0 \end{cases} \qquad Unit : \%$$

With P_{t_AC} being total AC active Power.

12.1.5 Eff_mech

This is the efficiency of the Motor, related to electrical power input, updated every calculation cycle given by calculation sync source (same as electrical power).

$$Eff_{mech} = \begin{cases} \frac{P_{mech}}{P_{t\_AC}+P_{exc}} \cdot 100 & \text{if } P_{t\_AC} > 0 \\ \\ \frac{|P_{t\_AC}|}{|P_{mech}|+P_{exc}} \cdot 100 & \text{if } P_{t\_AC} < 0 \; and \; P_{mech} < 0 \end{cases} \qquad Unit : \%$$

With P_{t_AC} being total AC active Power. In case the Machine Excitation is not used P_{exc} is zero.

12.1.6 Eff_sys

This is the efficiency of the system, related by electrical DC power intput to mechanical power output, updated every calculation cycle given by calculation sync source (same as electrical power).

$$Eff_{sys} = \begin{cases} \frac{P_{mech}}{P_{DC}+P_{exc}} \cdot 100 & \text{if } P_{DC} > 0 \\ \\ \frac{|P_{DC}|}{|P_{mech}|+P_{exc}} \cdot 100 & \text{if } P_{DC} < 0 \; and \; P_{mech} < 0 \end{cases} \qquad Unit : \%$$

In case the Machine Excitation is not used P_{exc} is zero.

> **Attention**
>
> In case of more groups for P_{mech} or P_{DC} (see **5** and **7**) P_{mech} or P_{DC} refers to the sum of power of these groups respectively.

CHAPTER

THIRTEEN

D/Q ANALYSIS (OPT-POWER-ADV)

This chapter describes the d/q analysis feature. The d/q analysis can be performed with a mechanical angle signal and sensorless without the need of an angle signal. The sensorless calculation requires specification of stator resistance and stator inductance The d/q analysis is designed for use with 3-phase synchronous machines.

The d/q transformation is also known as Park-Clarke transformation, often used in field orientated control to get steady state feedback of the machines current and flux. To perform the analysis with mechanical angle, any kind of angle signal (rotor position) must be provided.

13.1 Measured Angle

Following settings are for the d/q analysis with mechanical angle input.

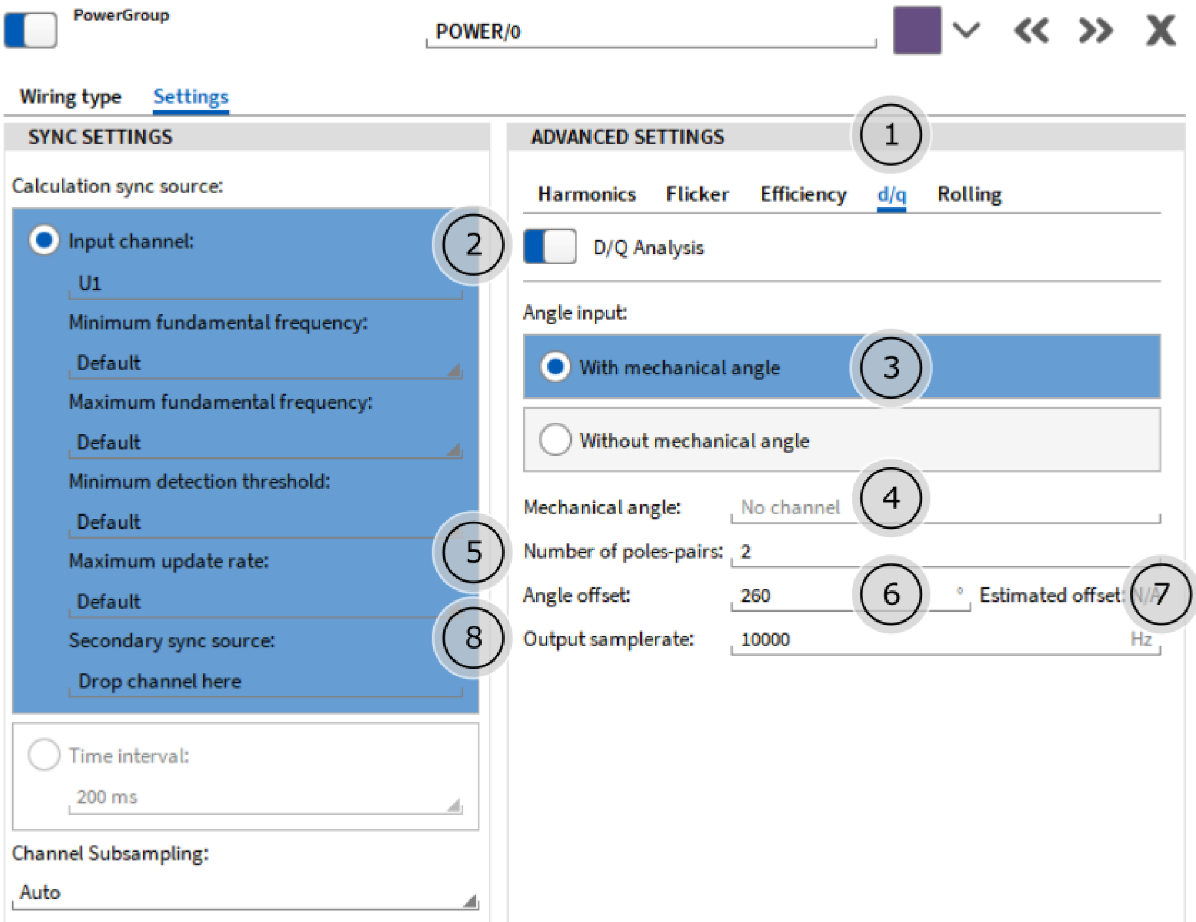


Fig. 13.1: Detail Settings in OXYGEN Power Group

1. Details Tab for Settings of the d/q analysis
2. Enable/Disable d/q calculation
3. Angle input selection, calculation with mechanical angle is selected
4. Input field for mechanical angle channel (drag-n-drop), must provide an angle signal between 0-360 deg.
5. Input field for number of pole-pairs
6. Input field for offset of the mechanical angle to the electrical (deg)
7. Button to detect the actual angle offset (use only without load)
8. Channel Output Sample rate (100 Hz is default).

13.2 Estimated Angle

Following settings are for the d/q analysis without mechanical angle input.

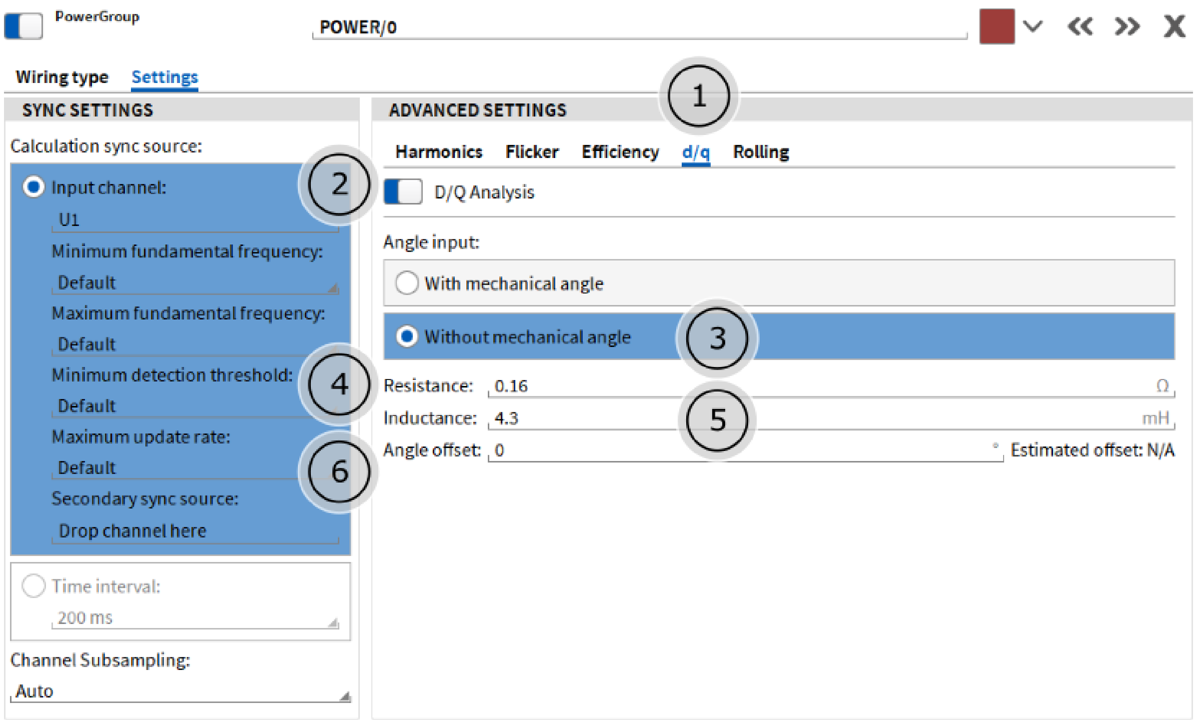


Fig. 13.2: Detail Settings in OXYGEN Power Group

1. Details Tab for Settings of the d/q analysis
2. Enable/Disable d/q calculation
3. Angle input selection, calculation without mechanical angle is selected
4. Input field for stator resistance (Ohm)
5. Input field for stator inductance (mH)
6. Input field for offset of the electrical angle to exact d-axis alignment (deg). This is just a debug channel and can be kept at zero.

The sensorless d/q computes the rotor posistion by calculating the electromotoric force (EMF) of the synchronous machine under use of stator resistance and inductance. This calculation assumes electric and magnetic symmetry and uniformity in all orientations. Since EMF is bound to the change of the magnetic field an thus the speed of the machine, the accuracy of the sensorless calculation suffers at low speeds. Acceptable results are achieved for speeds above 5% of nominal speed ($n > 5\% \, n_{\mathrm{n}}$).

The calculated angle of the sensorless computation can be found in the "dq_angle" channel of the d/q analysis. Unlike the calculation with mechanical angle input the sensorless version does not have a fixed output rate. It calculates 100 samples per electrical period and is therefore inherently asychronous, just like the power group. The following quick start guide is intended for the d/q analysis with mechanical angle input.

13.3 Quick Start

The key to get accurate readings from the resulting d/q channels is a good alignment of the Rotor Axis to the angle measurement sensor. To support the user with this task, we implemented a semi-automatic workflow.

1. Prepare the Typical power group settings for power analysis
2. Enable the d/q analysis feature (only possible within 3-phase measurements)
3. Assign the angle channel
4. Edit the number of pole-pairs according to your engine
5. Drive the DUT (device under test) with an auxiliary engine at constant speed (idle)
6. Press the "Detect" Button
7. Check the detected value

If there is no possibility to run the engine with an auxiliary drive, there are two other methods:

- Use the moment of inertia and use the induced voltage during coast down
- Drive your engine without any load at slow speed e.g. 100 rpm to reduce the effects of friction and ventilation

13.4 Angle Measurement

There are different methods available to measure the actual rotor position, these are necessary for the d/q analysis with mechanical angle:

13.4.1 Rotary Encoder

The rotary encoder is typically used in slow to medium speed drives. The signal of this encoders can be processed by the following Hardware inputs and transformed to an angle signal:

- TRION-CNT
- TRION-Base
- TRION-Timing / VGPS
- TRION-1802-dLV

13.4.2 One Pulse per Turn

In the case, where there no option to mount a rotary encoder, a single impulse (Z) can also be used as source for the angle measurement (with the same hardware listed above). The single pulse can be generated by a inductive or laser sensor.

13.4.3 SIN/COS Sensors

If your engine is equipped with an SIN/COS sensor (Magnetic field sensor, XMR-Sensor), use an analog input for these two signals. To calculate the correct angle, please create the following formula in OXYGEN: $mech\_angle = mod((atan2('sin','cos') + 2 * pi) * 180/pi, 360)$

13.5 Channel Reference

The channel reference reveals how the d/q analysis output channels are calculated. Note that the variant with mechanical angle input uses raw waveforms channels for voltage and current and the sensorless method uses the fundamental counterparts.

Table 13.1: Legend

Symbol	Equation	Description
θ	$mech\_angle \cdot \frac{pi}{180}$	Actual rotor angle
SR	–	Samplerate of U/I Channels
red_SR	–	Reduced Samplerate for Output
U_{iN}	–	Line-to-Neutral Voltage of Phase i

13.5.1 U_d

d-Axis Voltage, reduced with block-wise average to given output samplerate.

$$U_d^* = \frac{2}{3} \cdot \left(U_{1N} \cdot cos(\theta) + U_{2N} \cdot cos(\theta - \frac{2\pi}{3}) + U_{3N} \cdot cos(\theta + \frac{2\pi}{3}) \right)$$

$$U_d = \frac{red\_SR}{SR} \cdot \sum_{i=0}^{\frac{SR}{red\_SR}} U_d^* \qquad Unit: \mathbf{V}$$

13.5.2 U_q

q-Axis Voltage, reduced with block-wise average to given output samplerate.

$$U_q^* = \frac{2}{3} \cdot \left(-U_{1N} \cdot sin(\theta) - U_{2N} \cdot sin(\theta - \frac{2\pi}{3}) - U_{3N} \cdot sin(\theta + \frac{2\pi}{3}) \right)$$

$$U_q = \frac{red\_SR}{SR} \cdot \sum_{i=0}^{\frac{SR}{red\_SR}} U_q^* \qquad Unit: \mathbf{V}$$

13.5.3 I_d

d-Axis Current, reduced with block-wise average to given output samplerate.

$$I_d^* = \frac{2}{3} \cdot \left(I_1 \cdot cos(\theta) + I_2 \cdot cos(\theta - \frac{2\pi}{3}) + I_3 \cdot cos(\theta + \frac{2\pi}{3}) \right)$$

$$I_d = \frac{red\_SR}{SR} \cdot \sum_{i=0}^{\frac{SR}{red\_SR}} I_d^* \qquad Unit: \textbf{A}$$

13.5.4 I_q

q-Axis Current, reduced with block-wise average to given output samplerate.

$$I_q^* = \frac{2}{3} \cdot \left(-I_1 \cdot sin(\theta) - I_2 \cdot sin(\theta - \frac{2\pi}{3}) - I_3 \cdot sin(\theta + \frac{2\pi}{3}) \right)$$

$$I_q = \frac{red\_SR}{SR} \cdot \sum_{i=0}^{\frac{SR}{red\_SR}} I_q^* \qquad Unit: \textbf{A}$$

CHAPTER

FOURTEEN

REALTIME

OXYGEN offers a low latency (typ. 2 ms) realtime calculation option for the POWER Group.

For more information, refer to the to the OXYGEN Power Realtime Technical Reference Manual which is available on the CCC Portal.

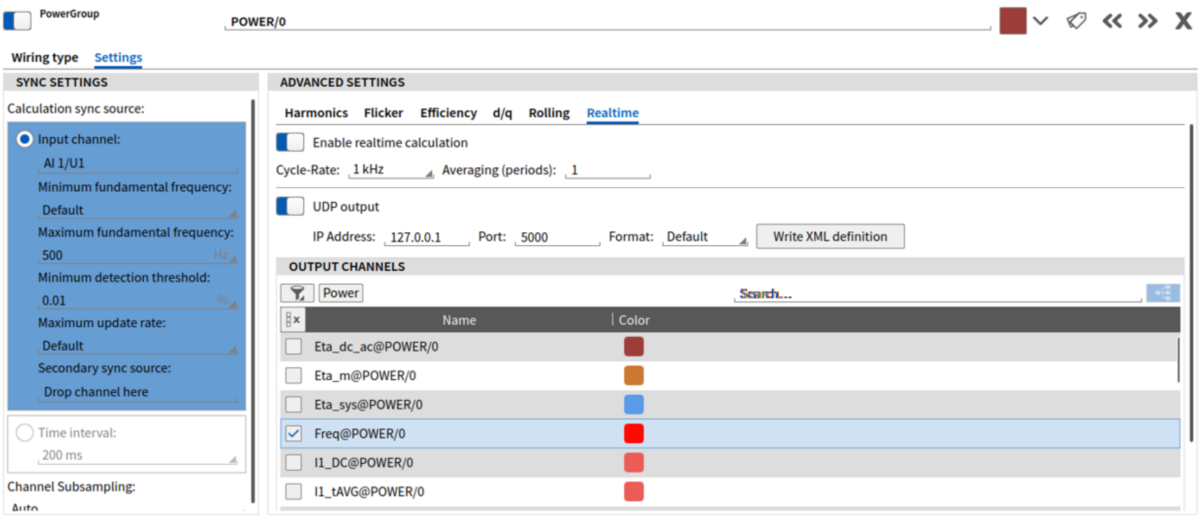


Fig. 14.1: OXYGEN Power Realtime