OMICRON

Application Note

Measuring PV systems with DANEO 400 sub-title: Distributed, time synchronized, long-term measurement

Author
Ines Halbritter | ines.halbritter@omicronenergy.com

Date
Dec 07, 2013

Related OMICRON Product
DANEO 400 – DANEO Control

Application Area
Fault recording, Measurement and analysis, IEC 61850

Keywords
Measurement, PV, Long-term measurement, Time synchronization, DANEO 400, Analog

Version
v1.0

Document ID
ANS 17002 ENU

General information

OMICRON electronics GmbH, including all international branch offices, is henceforth referred to as OMICRON.

The product information, specifications and technical data embodied in this application note represent the technical status at the time of writing and are subject to change without prior notice.

We have done our best to ensure that the information given in this application note is useful, accurate and entirely reliable. However, OMICRON does not assume responsibility for any inaccuracies which may be present.

OMICRON translates this application note from the source language English into a number of other languages. Any translation of this document is done for local requirements, and in the event of a dispute between the English and a non-English version, the English version of this note shall govern.

Table of contents

1 Safety instructions

This application note may only be used in conjunction with the relevant product manuals which contain all safety instructions. The user is fully responsibility for any application that makes use of OMICRON products.

Instructions are always characterized by a ▶ symbol even if they are included to a safety instruction.

DANGER

Death or severe injury caused by high-voltage or current if the respective protective measures are not complied with.

- ▸ Carefully read and understand the contents of this application note (as well as the manuals of the systems involved) before you start to work with it.
- ▸ Please contact OMICRON Support if you have any questions or doubts regarding the safety or operating instructions.
- ▸ Follow each instruction listed in the manuals particularly the safety instructions, since this is the only way to avoid danger that can occur when working at high-voltage or high current systems.
- ▸ Only use the equipment according to its intended purpose to guarantee safe operation.
- ▸ Existing national safety standards for accident prevention and environmental protection may supplement the equipment’s manual.

Only experienced and competent professionals who are trained for working in high-voltage or high current environments may perform the applications in this document. In addition the following qualifications are required:

- Authorized to work in environments of energy generation, transmission or distribution and familiar with the approved operating practices in such environments.
- Familiar with the five safety rules.
- Good knowledge of the *DANEO 400* and the corresponding Safe Use manual.

WARNING

Death or severe injury caused by high voltage or current possible.

DANEO 400 does not output any dangerous voltages or currents. The analog/binary inputs and binary outputs are functionally isolated from each other and from potential hazardous voltages (4 mm). However, the measured signals in the test setup might be dangerous.

- ▸ Always make sure that DANEO 400 is unplugged from power supply and all parts in the working area are powerless before working on test objects, connections or terminals connected to DANEO 400.

2 Introduction

This application note discusses the implementation of a long-term measurement using three distributed *DANEO 400* devices which are time-synchronized via two PTP Grandmaster Clocks *OTMC 100*.

The configuration includes conventional currents and voltages which are recorded and analysed. The network is used for controlling the devices and time-synchronization only.

2.1 Application

The continuous development of decentralized photovoltaic systems feeding into the electric distribution system leads to new questions and aspects in the subject matter of power quality. How can the power grid stability and quality be ensured if the feed-in power is subject to time- and weather-dependent variation?

Before this question can be answered, it is necessary to investigate the actual impact of photovoltaic systems on the power quality parameters of the grid and analyse potential repercussions on the medium voltage level. The investigation and conclusions are based on the following test environment.

3 Equipment and environment

The measurement is performed based on the test setup as shown in Figure 1 using the following test equipment:

> 3 *DANEO 400*
> 2 *OTMC 100*
> 3 current clamps *OMICRON C-Probe 1*
> Ethernet network cables
> 4 mm/0.16 ‘’ banana plug wires

Although the *DANEO 400* are distributed at three different locations in the grid with distances from a few dozens to over hundred meters in between, the devices are controlled from one single PC via communication network. Since the PTP Grandmaster clocks are directly connected to the DANEO devices, the switches in the communication network do not need to be PTP transparent.

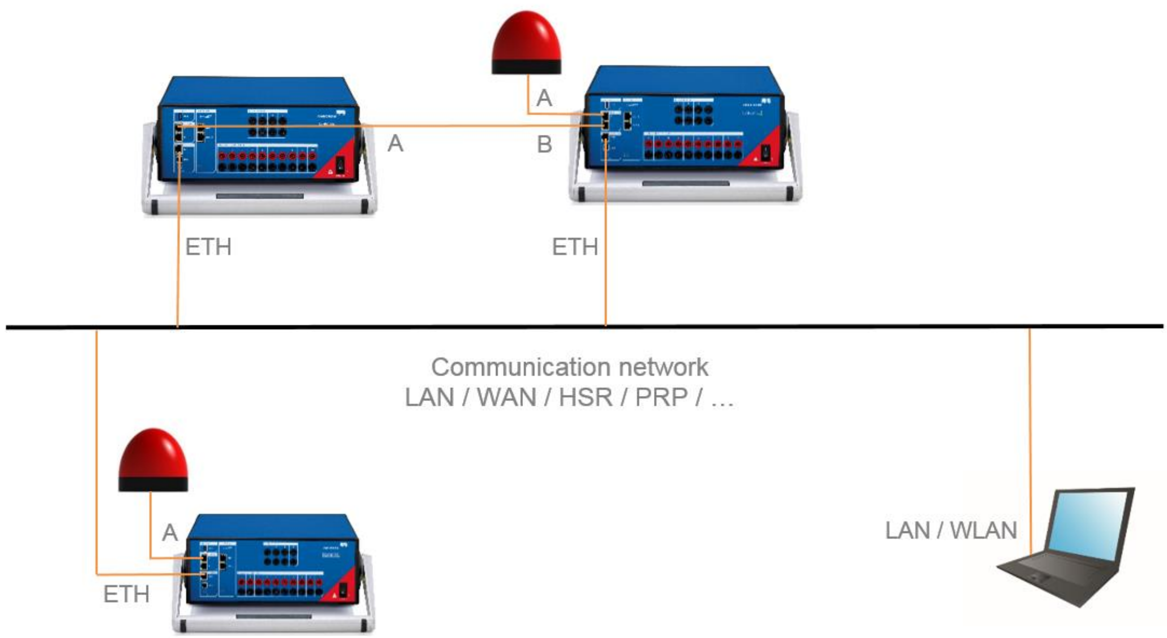

Figure 1: Communication setup

3.1 Application environment

The application environment consists of

> a photovoltaic system whose impact on the distribution grid shall be investigated
> a distributed transformer with a rated power of 1 MVA connecting the low-voltage to the medium-voltage grid to observe potential repercussions (e.g. back-feeding of harmonics)

and is tested using the equipment as described in Figure 2.

One DANEO 400 (named “PV”) is positioned right next to the feeding point of the photovoltaic system which is on low-voltage side. At this position, not only voltage but also current and power measurements are recorded.

The second DANEO 400 (named “SFH”) is positioned in the low-voltage grid with some distance to the feeding point of the photovoltaic system in order to get information about the impact on the distribution grid (simulates a Single Family House somewhere in the local distribution system).

The third DANEO 400 (named “Trafo”) is located right next the transformer on medium-voltage level to be able to make statements about potential repercussions.

To get a significant amount of data including different weather conditions which have a direct impact on the actual yield of the photovoltaic system, a long-term examination over a period of 20 days is performed.

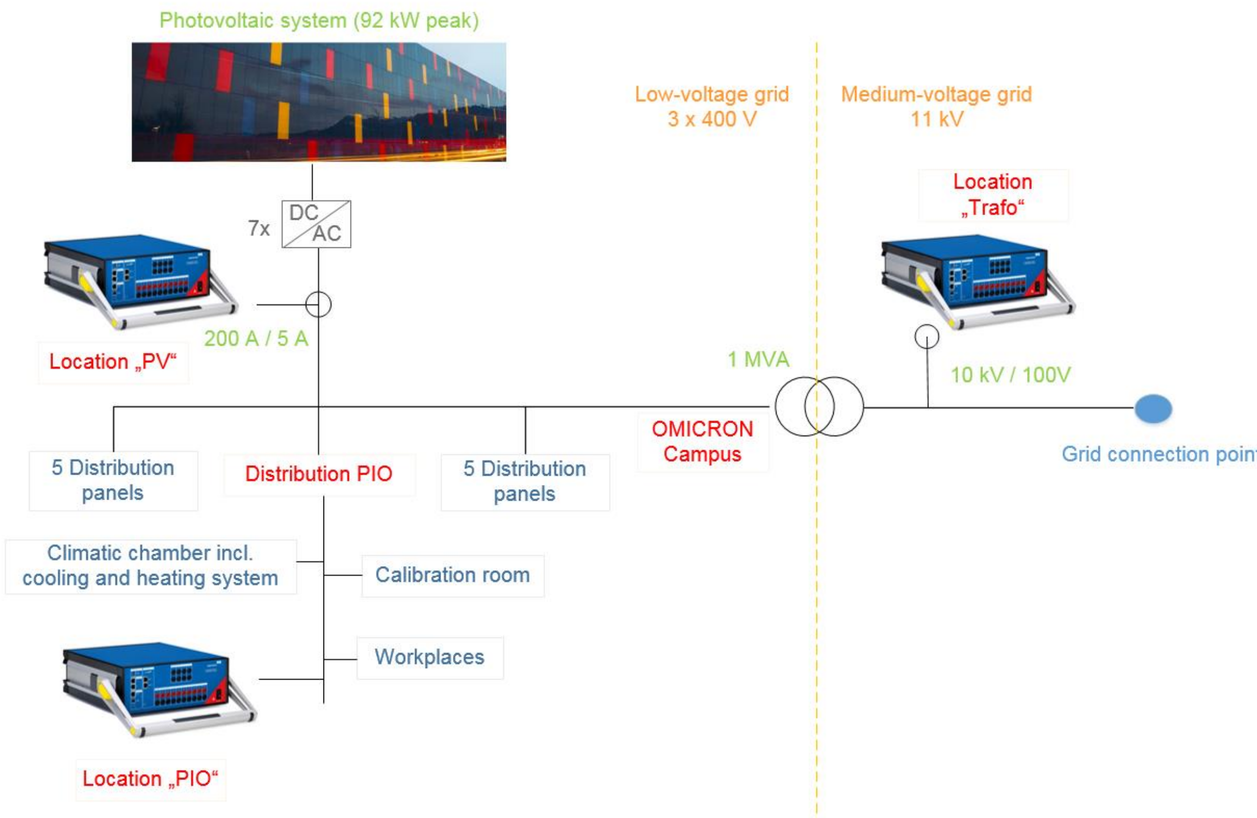

Figure 2: Application environment

4 Wiring and configuration

WARNING

Death or severe injury caused by high voltage or current possible.

DANEO 400 does not output any dangerous voltages or currents. The analog/binary inputs and binary outputs are functionally isolated from each other and from potential hazardous voltages (4 mm). However, the measured signals in the test setup might be dangerous.

- Always make sure that DANEO 400 is unplugged from power supply and all parts in the working area are powerless before working on test objects, connections or terminals connected to DANEO 400.

The following figure shows the wiring setup of the test equipment including the defined device and channel names.

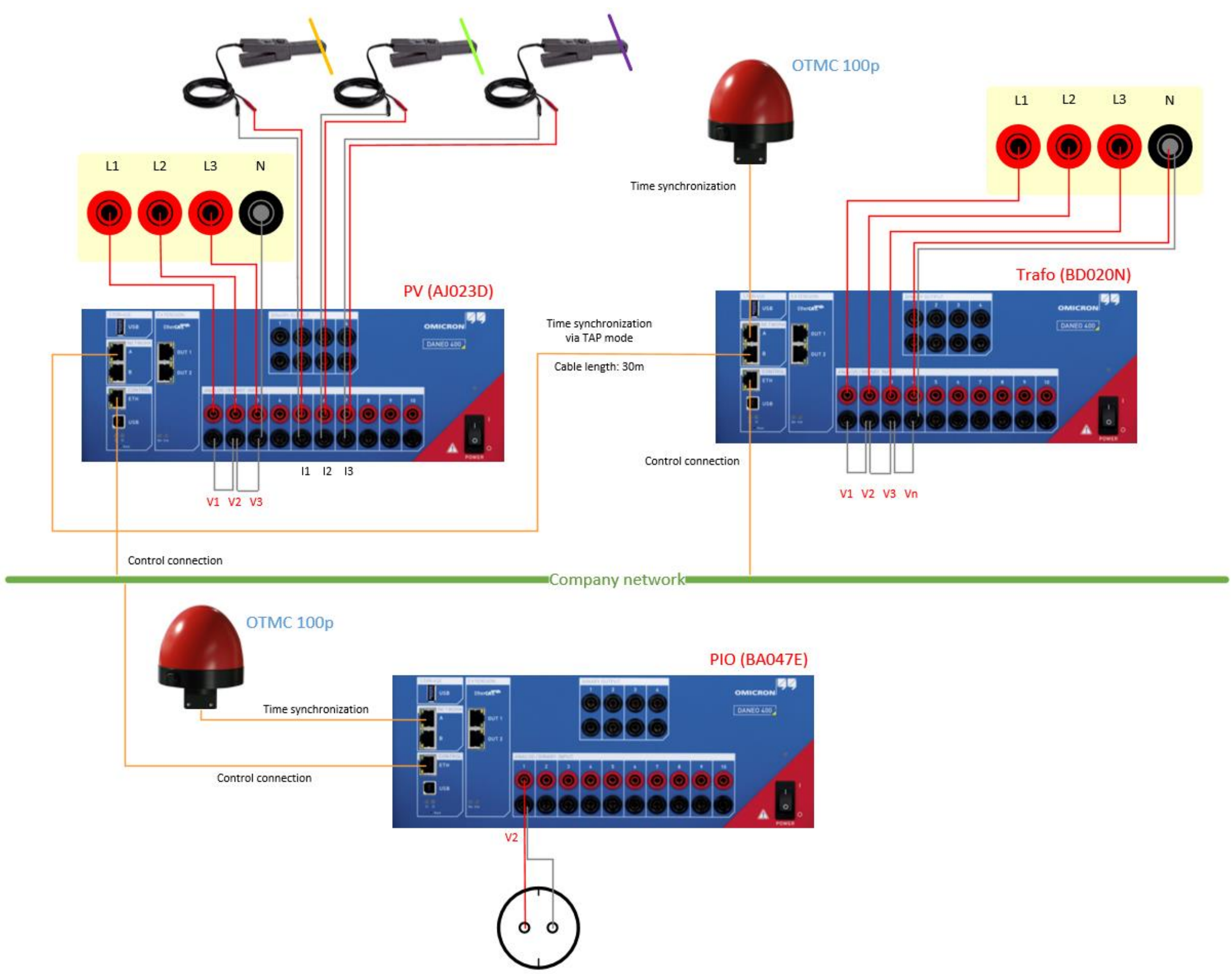

Figure 3: Wiring of test equipment

Each *DANEO 400* has a separate control connection (port ETH) to the communication network and is time-synchronized based on the IEEE 1588-2008 standard (port A).

DANEO "PV" and DANEO "Trafo" share one PTP Grandmaster clock by using the TAP mode. As a result, only two PTP Grandmaster clocks are needed instead of three and duplicated lines are avoided. The required configuration steps are described in chapter 4.1.

The *OTMC 100* are Powered-Over-Ethernet (PoE) by the *DANEO 400* and are configured to use the power profile (IEEE PC37.238). For further information on how to configure the power profile in the *OTMC 100*, see the user manual.

Each *DANEO 400* input can be configured either as voltage, current or binary input. As a result, the inputs need to be configured and the input ranges as well as the conversion factors need to be defined (see 4.3.1).

For safety reasons, use safe test leads and pay attention that all inputs are grounded properly!

4.1 Configuring the TAP mode

The NETWORK ports A and B of DANEO "Trafo" are set to **TAP** mode. As a result, incoming traffic at port A is passed to port B and vice versa and the PTP traffic can be passed from one DANEO to another device.

Since there is only data link-layer traffic on port A and B, no IP addresses are required on those ports.

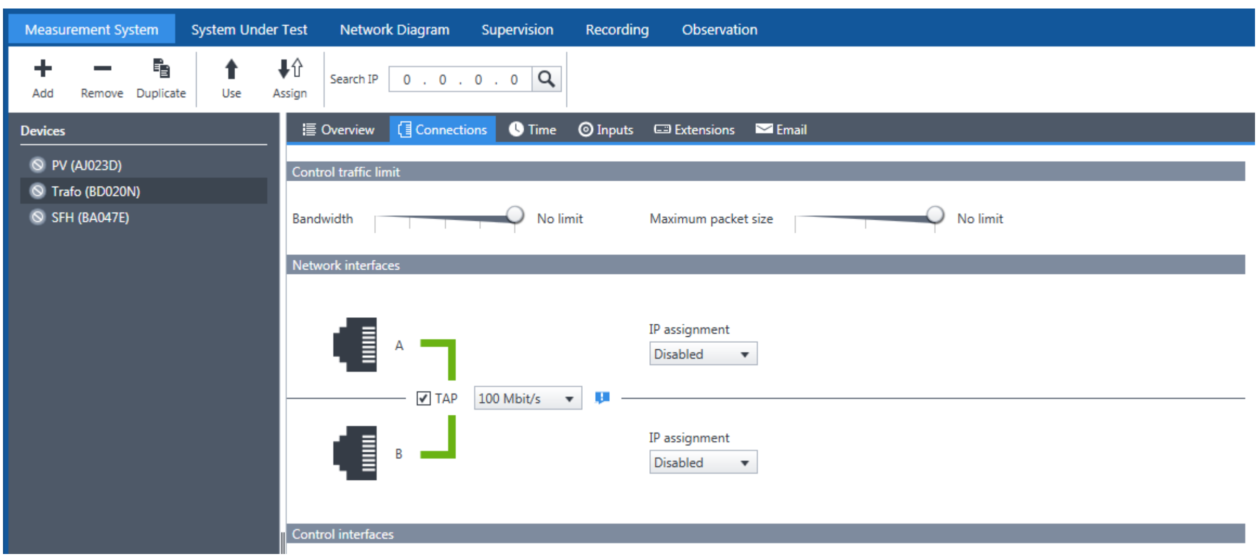

Figure 4: TAP mode configuration

4.2 Time synchronization

Time synchronization gets important when using multiple devices and analysing their recordings together.

For a simple configuration of the time settings, *DANEO Control* offers a **PTP Sniffer** which searches for available PTP sources on the network which are listed with their status.

The green status icon indicates that the PTP source is configured in the power profile mode and comes with high accuracy (time error < 250 ns). By selecting a usable PTP source and clicking OK, all settings are automatically filled in and the configuration changes can be applied on the device.

Note that for using the PTP Sniffer, the device must be online.

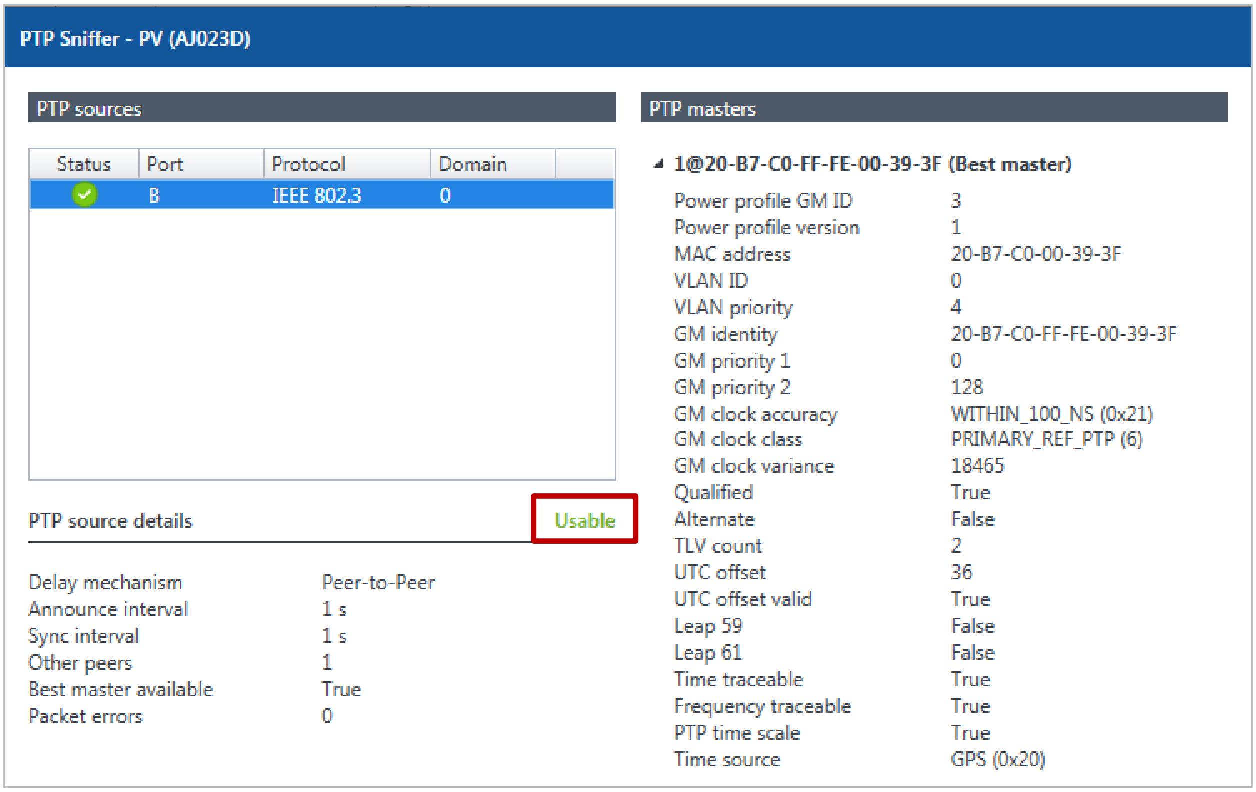

Figure 5: PTP sniffer

4.2.1 Time synchronization using TAP mode

Since the cable length between device “Trafo” which passes the PTP traffic via **TAP** mode and the receiving device “PV” cannot be determined automatically, it must be defined manually in the **Time** view.

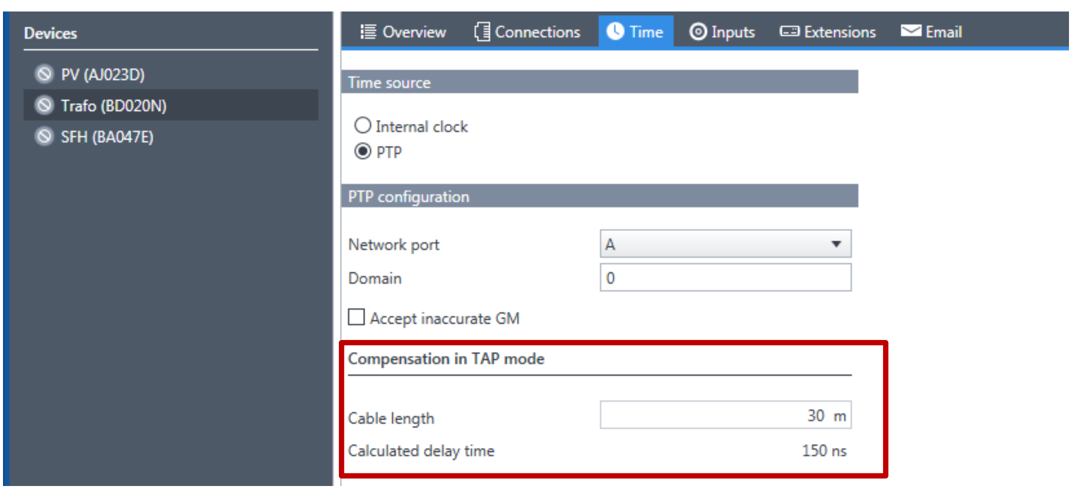

Figure 6: Time synchronization using TAP mode

4.3 Input configuration

The **Inputs** configuration specifies the sampling frequency, the nominal frequency, the different inputs types and their ranges and factors as well as the phase systems.

To be able to differ between the measurements of different devices, short and unique names for the inputs and the phase systems are defined. They are based on the device prefix, the input type and the input phase number (e.g. PV_V1, PV_I1).

At the measurement location next to the photovoltaic system ("PV") current clamps of the type *OMICRON C-Probe 1* are used to measure the current and power values in addition to the voltages. The current clamps come with a transmission ratio of 10 mV/A. If the deducted currents are additionally transformed, this transmission ratio needs be considered in addition to calculate the total conversion factor.

4.3.1 Application environment

In the measurement environment, the deducted currents are transformed from 200 A to 5 A. Together with the current probe ratio, this leads to a total conversion factor of 4 kA/V. An input range of 100 mV is chosen in the inputs configuration.

The measurements on the medium-voltage level ("Trafo") are executed based on a three-phase voltage transformer with a transmission ratio of 10 kV to 100 V. The transmission ratio of 100 V/V is again specified in the factor of the corresponding voltage inputs.

The third device "SHF" connects only one single voltage phase to the local power grid. The phase corresponds to the second phase of the three phase system and is therefore named accordingly.

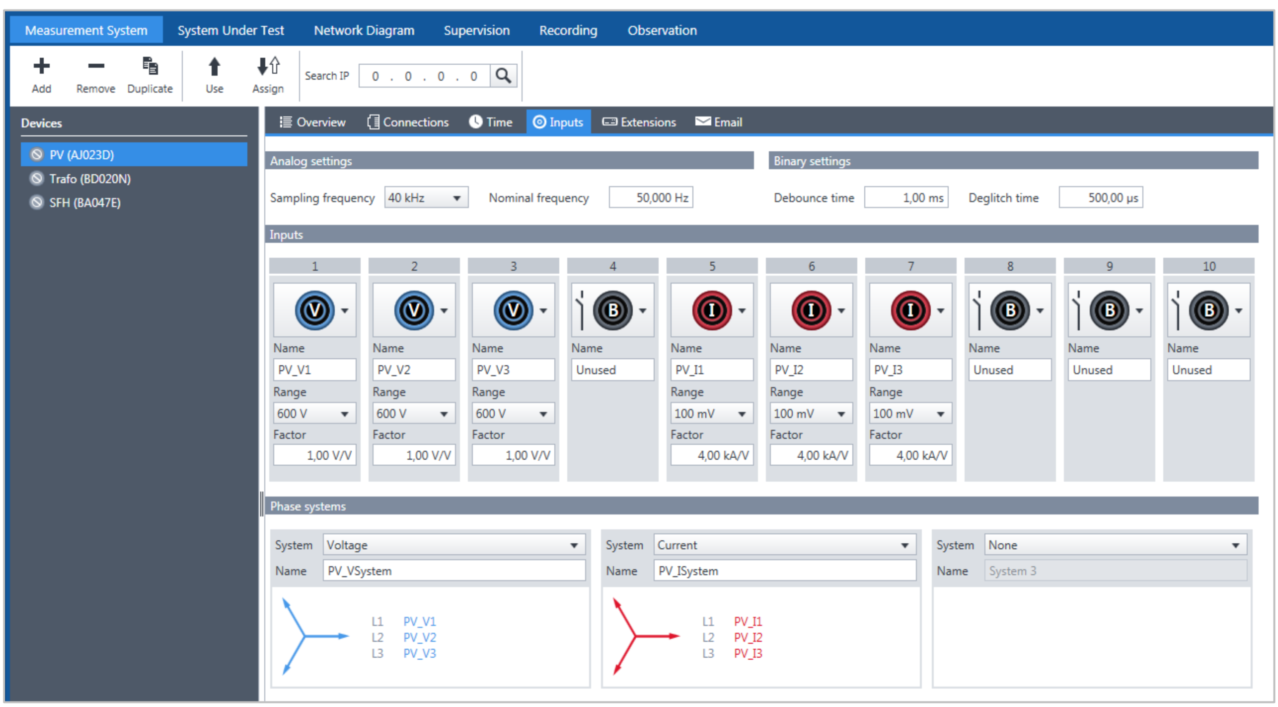

Figure 7: Input configuration of DANEO 400 "PV"

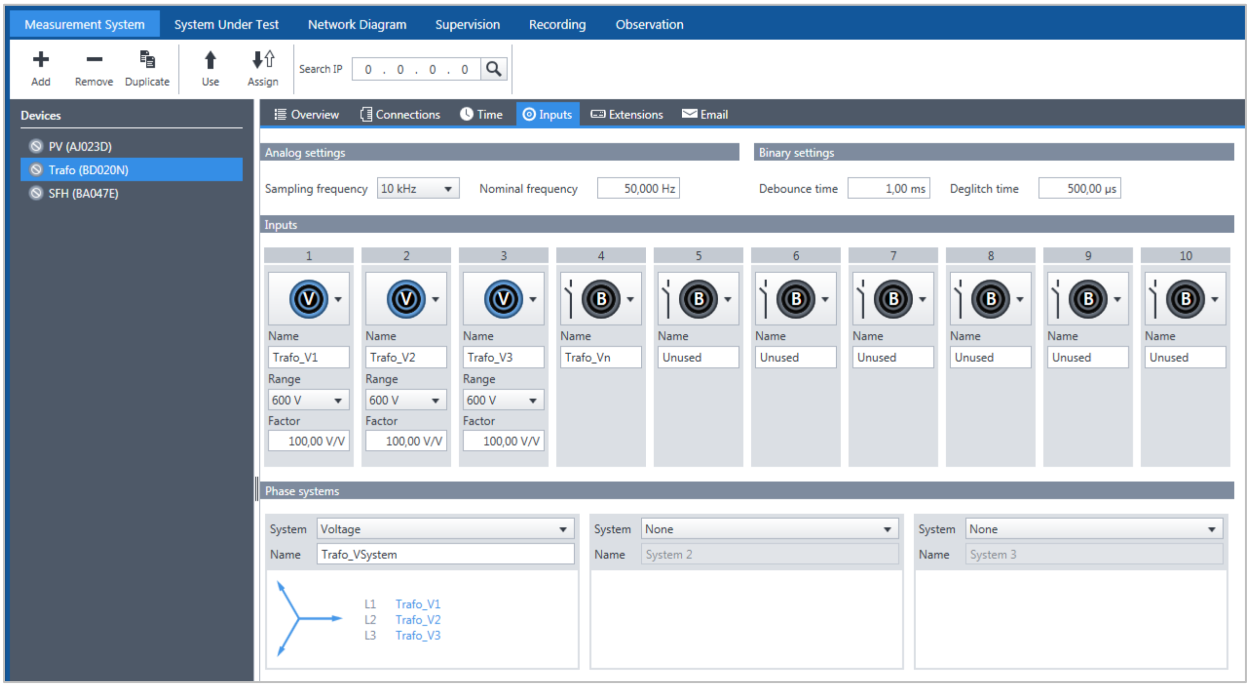

Figure 8: Input configuration of DANEO 400 "Trafo"

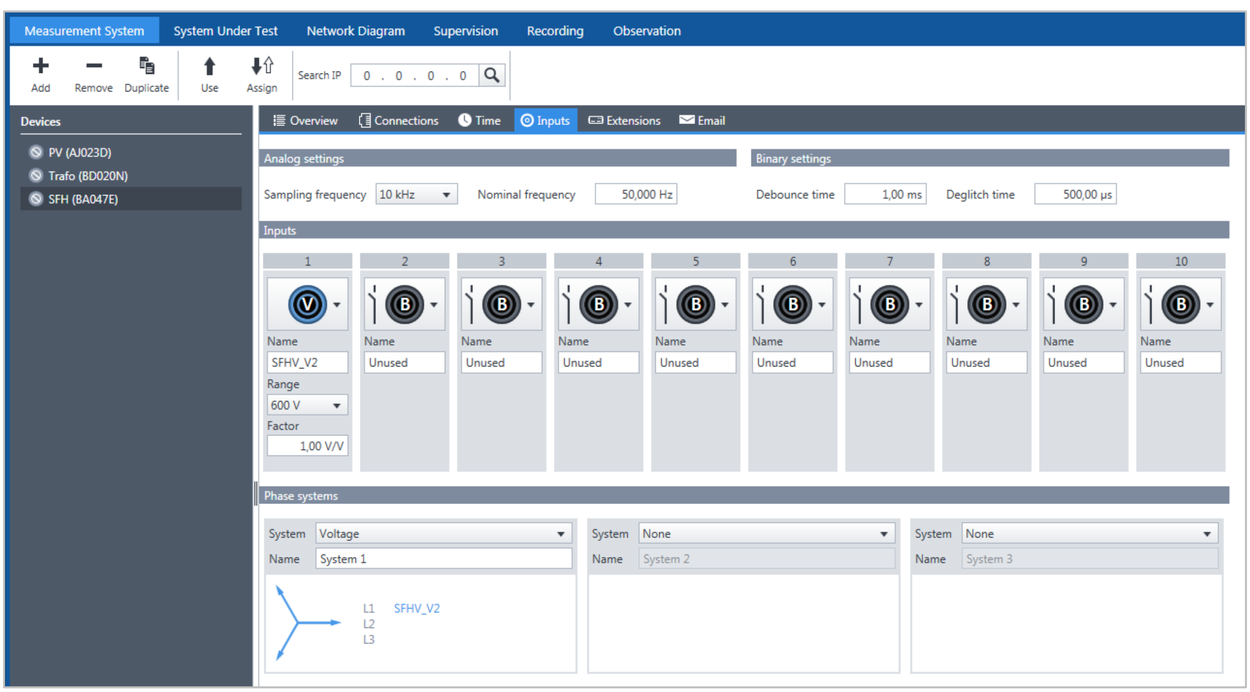

Figure 9: Input configuration of DANEO 400 "SFH"

4.4 Define harmonics and power system signals

In addition to the analogue and current signals which are created by configuring the inputs, harmonic and power system values shall be recorded. To create the corresponding signals, the harmonics and the power systems are created by opening the **Signal Configuration**.

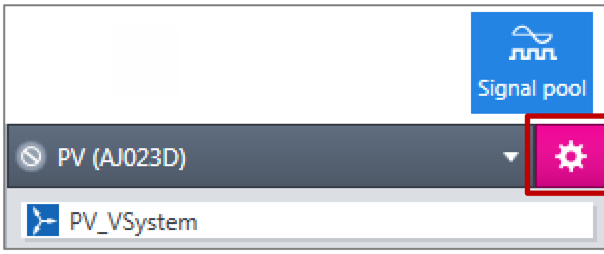

Figure 10: Open Signal configuration

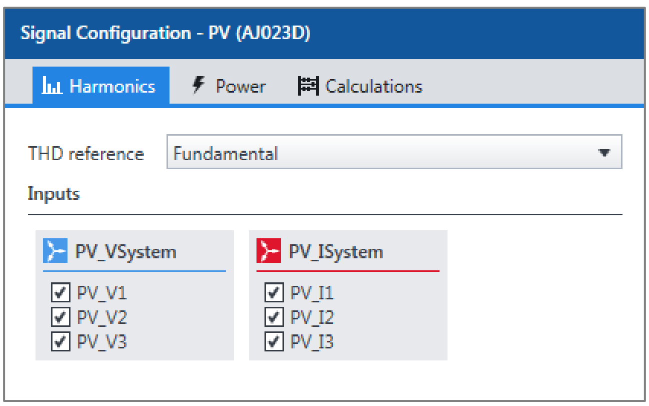

Figure 11: Select harmonic inputs

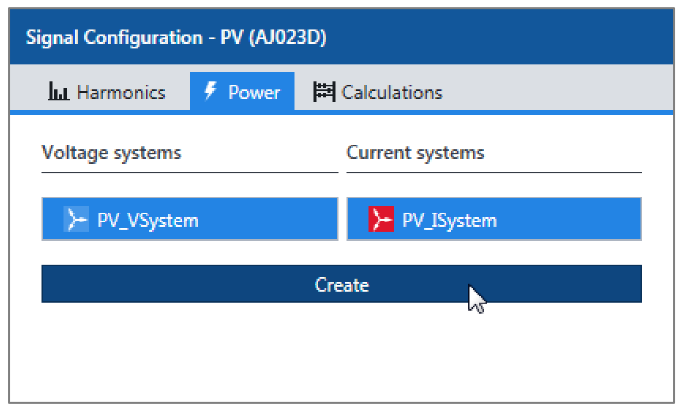

Figure 12: Create power systems

5 Measurement

The measurement is performed using the following DANEO 400 features:

> Observation
> Recording

5.1 Live observation

The live observation features of *DANEO Control* are used to verify the correct test setup by comparing the actual values to the expected values. This pre-check avoids that wiring or conversion errors distort the recorded signal values of the long-time measurements.

For example, the phase voltage (L-N) of the Magnitude or RMS signals needs to be in the range of 230 V for the phase to ground voltage in the low-voltage grid and 6.0 kV – 6.4 kV on the medium-voltage level.

To observe signals, add one or multiple signals in a group via drag-drop or the “Add”-button in the toolbar to the Observation pane. The observation is started automatically for online devices. Use multiple sheets to create different views and organize your observed signals.

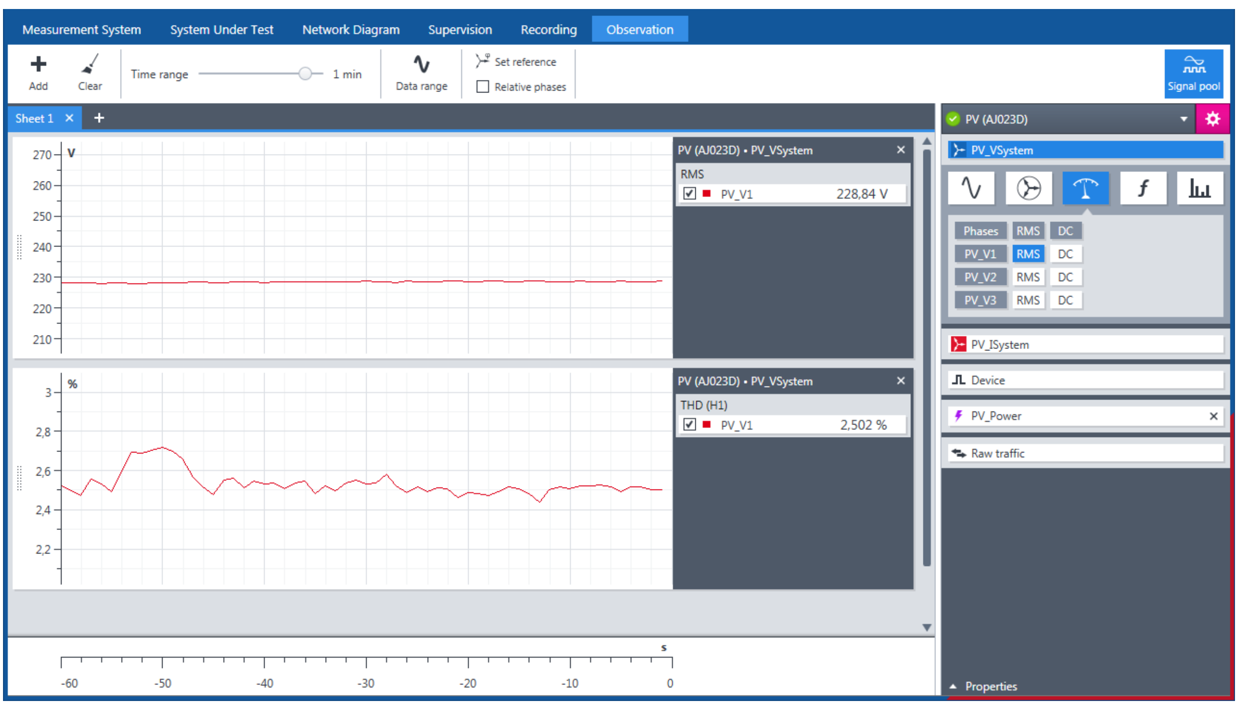

Figure 13: Live observation

5.2 Recording

To get a significant information about the stability of a system long-term recordings are needed. However, long-term measurements do not implicitly require continuous recordings which generate a huge amount of data. This might even exceed the storage size and the long recordings are very hard to analyse. A better way is to define triggers which start a new recording as soon as their condition is true.

5.2.1 Define the recording content

All signals of the **Signal pool** which to be recorded are added to the Recording **Signals**. This can be easily done by selecting the whole group (e.g. PV_VSystem) and adding the group of signals via double-click.

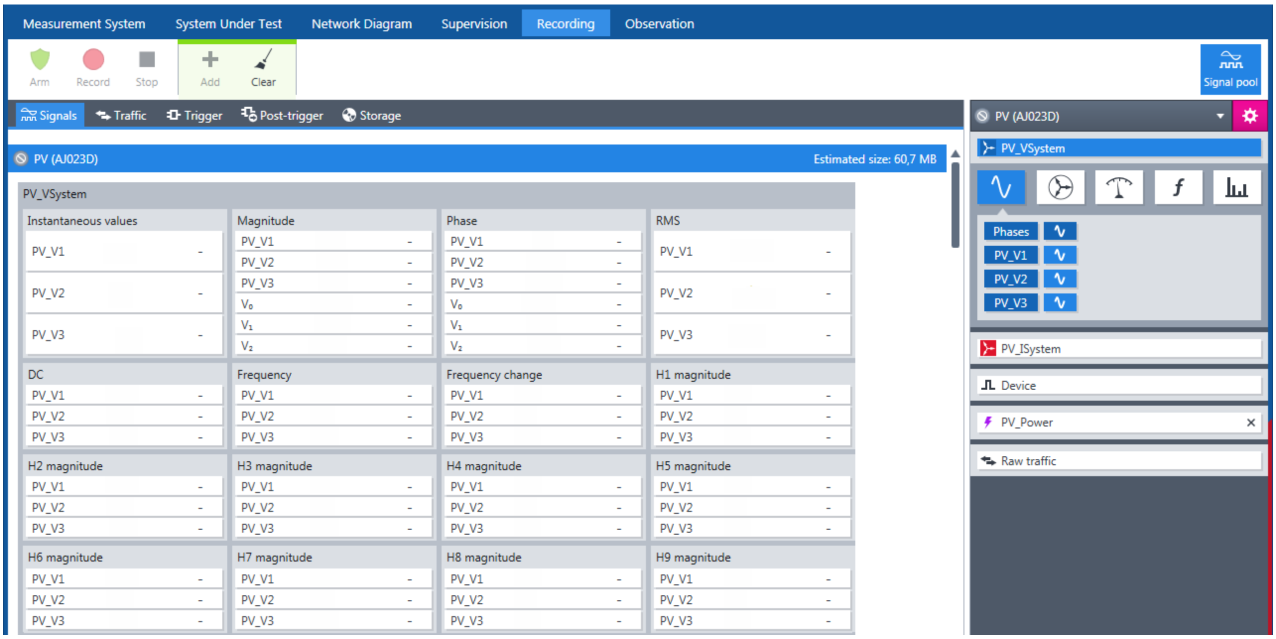

Figure 14: Add the signals to record

5.2.2 Triggered long-term measurements

For long-term measurements and fault-recording scenarios, it is recommended to use trigger conditions. The trigger condition ensures that only important and interesting scenarios are recorded and therefore decreases the analysis time.

For this real application, a time-based trigger condition is used to record 1 minute each hour. Each device triggers exactly at 15 minutes after full hour starting on 2016-03-21 at 10:15:00.

Therefore, define a Post-trigger time of 60 seconds and a Lockout of 3540 seconds
(1 hour = 3600 s = 60 s + 3540 s).

Since the long-term measurement is terminated manually in this case, no limit for the re-arming count needs to be defined. If the measurements are expected to be stopped automatically, calculate and enter the maximum number of possible recordings (e.g. 20 days à 24 recordings per day = 480 recordings).

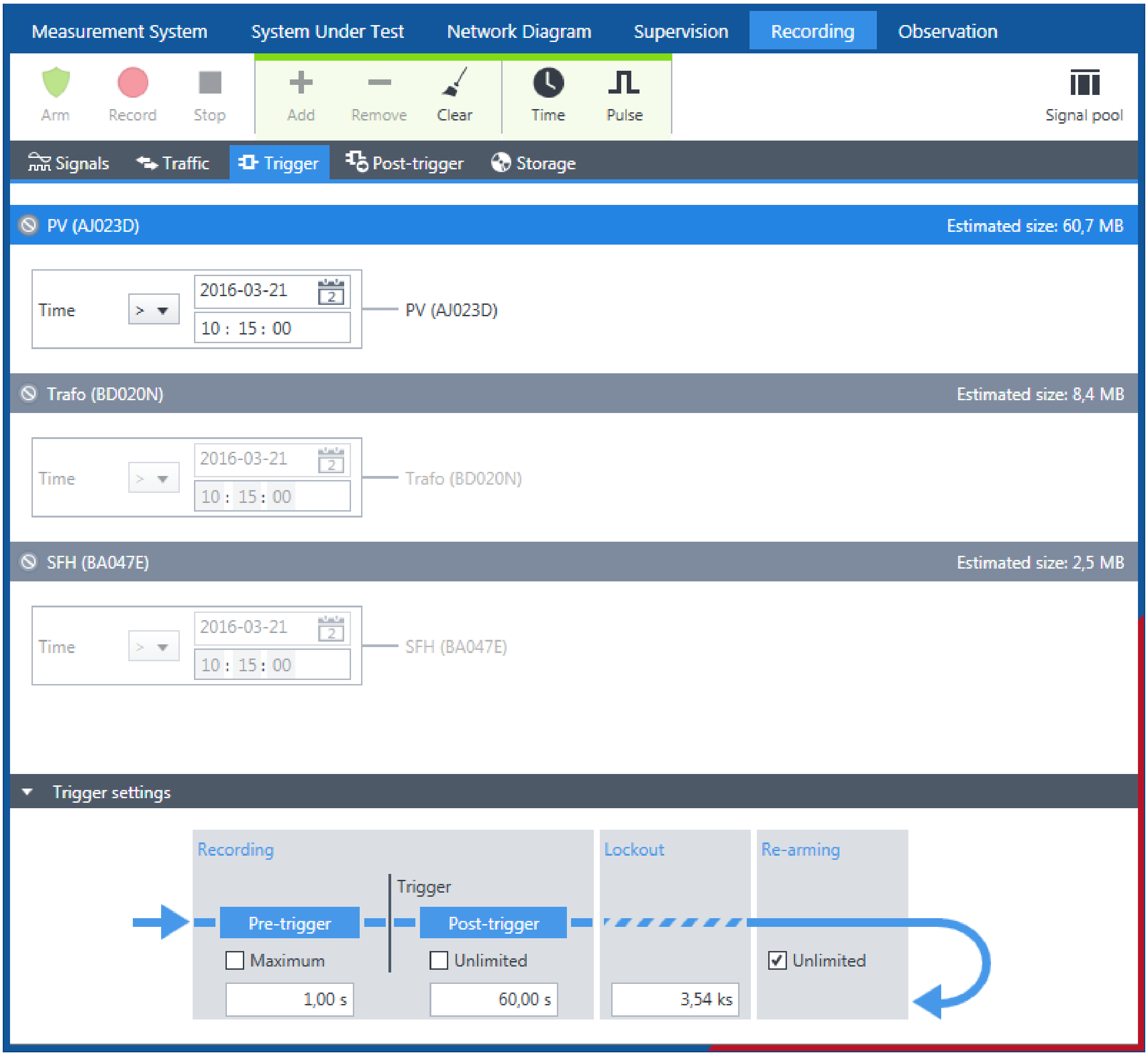

Figure 15: Trigger definition

5.2.3 Unattended recording

As soon as the devices are armed, *DANEO Control* can be closed and the devices can remain unattended.

To avoid that the long-term measurements are interrupted by e.g. a network outage, enable the **Permanent mode** in the **Overview** of the test devices. This feature enables that after a restart, the previous operation automatically continues.

6 Analysis

Download the performed recordings to local folders to analyse them in the *DANEO Control* **Analysis** without the presence of any device. Alternatively, analyse the recordings having the recording devices attached and online.

Select the time-related recordings in the Analysis **Data** and collect them.

Following, create one or multiple Time Signal analyses and investigate the recorded data using different chart types.

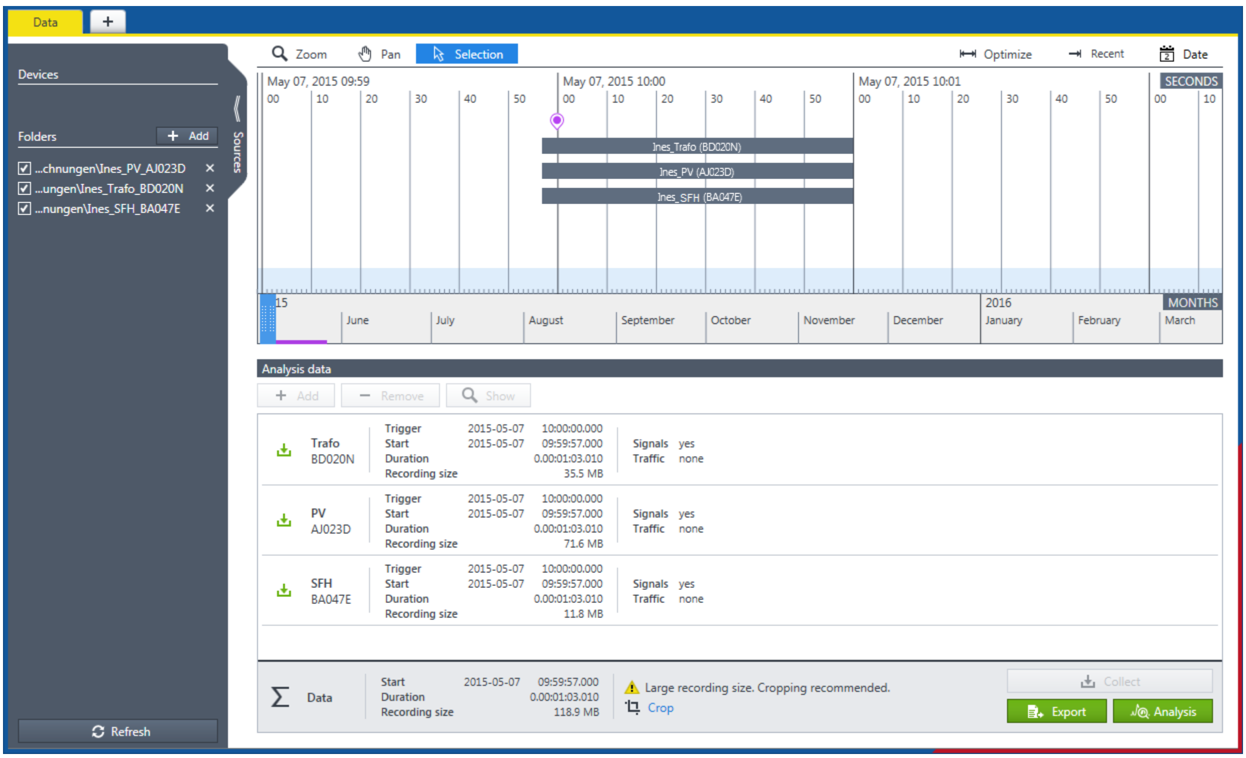

Figure 16: Analysis

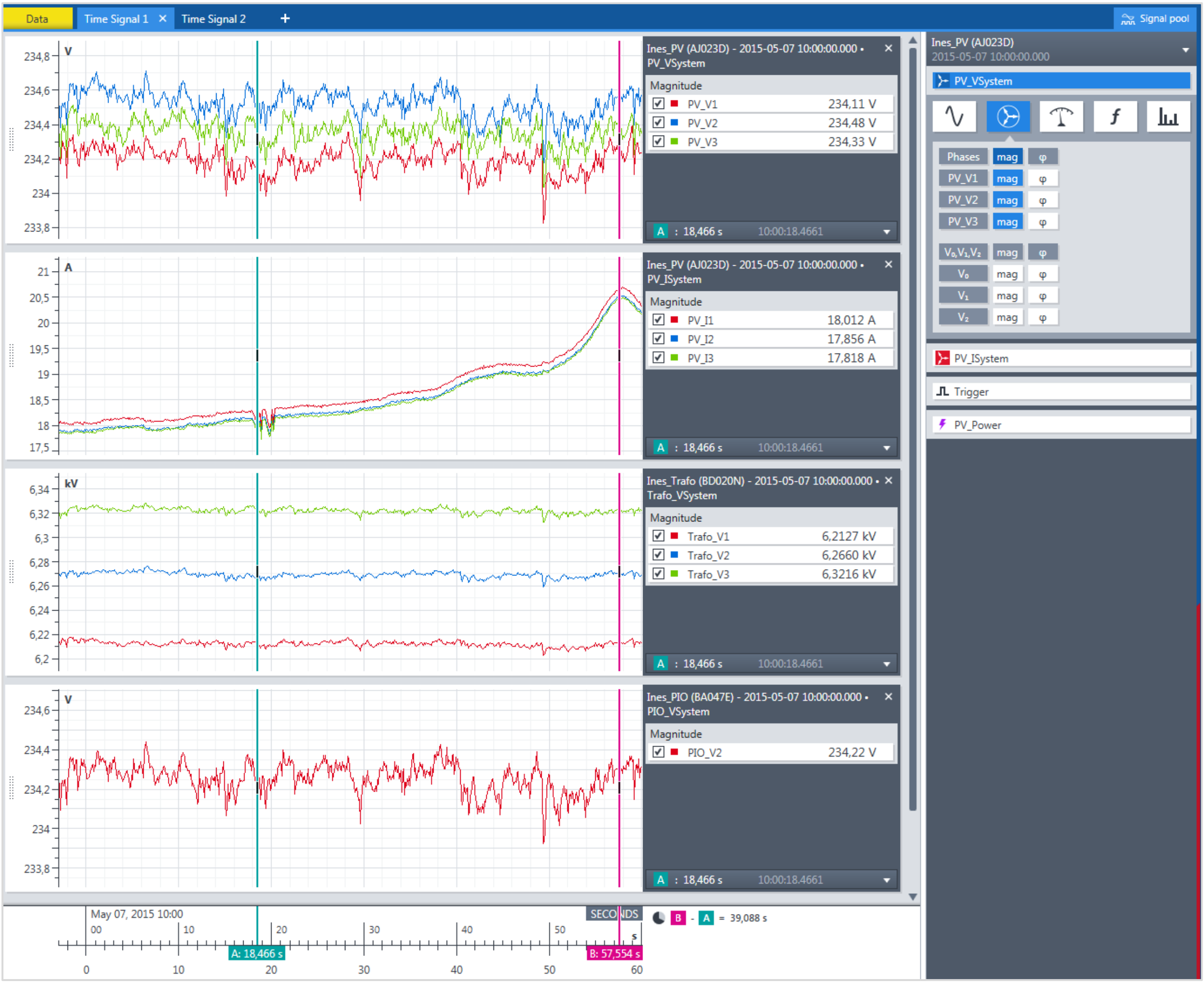

Figure 17: Time signal analysis

Figure 18: Analysis of harmonics

7 Hints

Current clamps

- Do not forget to perform the zero adjustment!
  Otherwise, your current values might be distorted with a DC offset.
- If active current clamps are used, check the battery condition.
- Use passive clamps for long-time measurements to become independent of battery lifetime.

Ripple control

- Do a sample check of your recordings after 1 day for irregularities (e.g. ripple control signals always sent in the first minute after full hour) which may have an impact on the measured values.

8 Results

The PV system delivers high quality for voltages but not always for current signals. Especially if the PV inverters were not operating in their optimal range (e.g. morning, evening, bad weather conditions), the current quality (but also the generated power) was significantly reduced.

Though, no noticeable influences of the PV installation, neither on the internal, nor any repercussions on the medium-voltage-level grid could be observed because of two main reasons. First, the PV system at OMICRON is installed close to the transformer connecting the internal and the medium-voltage grid. Second, the total infeed power of the PV system is lower than the infeed power from the medium-voltage-level grid. As a result, the stability of the medium-voltage-level grid is predominant and balancing distorted PV currents.

However, it cannot be assumed that the PV system is always installed close to a transformer, especially when having a local distribution grid. If the PV generated electricity is directly used, the distorted currents can have a bad influence on all electric devices and reduce their lifespan or cause issues like data loss, PC crashes, etc.

8.1 Outlook

In the future, intelligent PV inverters providing an active and reactive power control and filtering harmonics will contribute positively in the grid quality. Furthermore, software controlled dynamic filters are conceivable.

Field tests using test grids were already successfully performed and were promising.

OMICRON

9 List of literature

Bundesverband Photovoltaic Austria, 2015. *PV Austria.* [Online]
Available at: http://www.pvaustria.at

Die Vorarlberger Verteilnetzbetreiber Vorarlberg Netz, Stadtwerke Feldkrich, E-Werke Frastanz und Montafonerbahn AG, 2014. *Vorarlberger Energienetze.* [Online]
Available at: http://www.vorarlbergnetz.at/downloads/at/PV-Rundschreiben_1-2014_AT_unterschrieben.pdf
[Zugriff am 22 Februar 2015].

Esslinger, P. et al., 2011. *Verbesserung der Spannungsqualität und Aufnahmefähigkeit von Niederspannungsnetzen bei dezentraler Einspeisung durch intelligente Wechselrichter.* Würzburg, s.n.

Kamenka, A., 2014. *Sechs Themen rund um Oberschwingungen und die Netzqualität in Stromversorgungsnetzen,* Luterbach: Schaffner Gruppe.

OMICRON electronics GmbH, 2017. *DANEO Control 4.0.* Klaus: s.n.

Schegner, P., Meyer, J. & Darda, T., 2014. *Seminar "Power Quality in Verteilungsnetzen - Eine praxisorientierte Einführung".* Dresden: M.J. Raak GmbH.

Wesselak, V. & Voswinckel, S., 2012. *Photovoltaik - Wie Sonne zu Strom wird.* Heidelberg: Springer-Verlag Berlin.

Support

When you are working with our products we want to provide you with the greatest possible benefits. If you need any support, we are here to assist you.

24/7 Technical Support – Get Support

www.omicronenergy.com/support

At our technical support hotline, you can reach well-educated technicians for all of your questions. Around the clock – competent and free of charge.

Make use of our 24/7 international technical support hotline:

Europe / Middle East / Africa	+43 59495 4444	
Americas	+1 713 830-4660	+1 800-OMICRON
Asia-Pacific	+852 3767 5500	

Additionally, on our website you can find our Service Center or Sales Partner closest to you.

Customer Area – Stay Informed

www.omicronenergy.com/customer

The Customer Area on our website is an international knowledge exchange platform. Download the latest software updates for all our products and share your own experiences in our user forum.

Browse through the knowledge library and find application notes, conference papers, articles about daily working experiences, user manuals and much more.

OMICRON Academy – Learn More

www.omicronenergy.com/academy

Learn more about your product in one of the training courses offered by the OMICRON Academy.

For more Information, additional literature, and detailed contact information of our worldwide office please visit our website.

www.omicronenergy.com