Application Note

IEC 61850 Measurement with CMC and EnerLyzer Live

Author
Lukas Dieterich | *lukas.dieterich@omicronenergy.com*

Date
May 26, 2021

Related OMICRON Product
CMC, EnerLyzer Live, OTMC

Application Area
IEC 61850 measurement with CMC and EnerLyzer Live

Keywords
CMC, EnerLyzer Live, IEC 61850, Sampled Values, GOOSE

Version
v1.0

Document ID
ANS_21006_ENU

Abstract

The *EnerLyzer Live* software turns a CMC 430 into a multi-functional measurement device featuring functions of an oscilloscope, recorder and analyzer in one software. This application note exemplarily describes two measurement applications for *EnerLyzer Live* in an IEC 61850 environment. At first, a hybrid (analog and digital) test of a merging unit is presented and second an overcurrent trip test of a fully digital protection relay.

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 undertaken 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 content

1 Safety instructions 4

2 About this Application Note 5

2.1 General requirements 5

2.2 What this application note describes 5

2.3 Template 5

3 Introduction to IEC 61850 functions of EnerLyzer Live 6

3.1 Sampled Values (SV) 6

3.2 GOOSE 6

4 Example 1: Testing a Merging Unit 7

4.1 System under test 7

4.2 Test setup 7

4.2.1 Hardware 8

4.2.2 Software 10

4.3 Test procedure 11

4.4 Test assessment 12

4.4.1 General verification of the correct function of the DUT 12

4.4.2 Verification of the measurement accuracy 14

5 Example 2: Overcurrent Protection Test of a Fully Digital Relay 15

5.1 System under test 15

5.2 Test setup 15

5.2.1 Hardware 15

5.2.2 EnerLyzer Live software 17

5.2.3 Test Universe software 20

5.3 Test procedure 22

5.4 Test assessment 22

5.4.1 Example: Assessment of trip 22

6 Network communication analysis with DANEO 400 24

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 responsible for any application that makes use of OMICRON products.

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

NOTICE

Equipment damage or loss of data possible

- Carefully read and understand the content of this Application Note as well as the manuals of the systems involved before taking them into operation.
- Please contact OMICRON support if you have any questions or doubts regarding the safety or operating instructions.
- Follow each instruction listed in the manuals, especially the safety instructions, since this is the only way to avoid the danger that can occur when working on high voltage or high current systems.
- Only use the equipment involved 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.
- Before starting a test always check that the test signals are suitable for your system under test.

DANGER

Death or severe injury caused by high voltage or current.

- Always obey the five safety rules and follow the detailed safety instructions in the respective user manuals.
- Before wiring up or rewiring the equipment always turn off each system involved to the test process.

Only experienced and competent professionals that are trained for working in high voltage or high current environments may implement this Application Note. Additionally, 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/proficient in working with the CMC test sets.

2 About this Application Note

2.1 General requirements

Before you get started with this application note, read the “Getting started” manual of *EnerLyzer Live.* Please make sure that you also have a good knowledge about the CMC test system.

2.2 What this application note describes

The application note describes typical IEC 61850 test and measurement applications for the CMC and *EnerLyzer Live* software. Therefore, exemplarily two applications are described in more detail: doing a basic merging unit test and testing the overcurrent function of a fully digital protection relay.

It covers the following content:

1. Introduction to **IEC 61850 functions of EnerLyzer Live**
2. Basic test of a **merging unit**
3. **Fully digital overcurrent trip test** of a protection relay.

The application note gives examples of IEC 61850 test and measurement applications for the CMC and EnerLyzer Live software. It is no exclusive and detailed description of all possible fields of application.

2.3 Template

For this application note the following templates are provided in the .zip-folder of the application note:

- *EnerLyzer Live:* **CMC-AppNote-EnerLyzer-Live-IEC-61850-Measurement-ENU_Measurement_MU**
- *EnerLyzer Live:* **CMC-AppNote-EnerLyzer-Live-IEC-61850-Measurement-ENU_Measurement_Relay**
- *GOOSE Configuration:* **CMC-AppNote-EnerLyzer-Live-IEC-61850-Measurement-ENU_GOOSE_Config_Meas_CMC**
- *Omicron Control Center:* **CMC-AppNote-EnerLyzer-Live-IEC-61850-Measurement-ENU_Digital_Relay_Test**

The templates can be used to perform tests as described in this application note. The application note refers to them in the corresponding chapters.

3 Introduction to IEC 61850 functions of EnerLyzer Live

The *EnerLyzer Live* software supports the measurement and display of IEC 61850-9-2 Sampled Measured Values and IEC 61850 GOOSE messages. This chapter gives an idea of the general concept of how IEC 61850 functions are handled in *EnerLyzer Live*. A detailed description on how to configure and use these functions will follow in the corresponding chapter later on.

3.1 Sampled Values (SV)

The configuration of Sampled Measured Values is done in the *test set configuration* via the tab *IEC 61850*. By clicking on *Add Sampled Values system* in the ribbon, there is one voltage and one current system (both: three phases with neutral) added.

The configuration of a Sampled Values System via the tab *Sampled Values* requires the setting of the *Sampled Value ID (svID), Multicast MAC address, Sampling rate* and the connected *Ethernet port* of the CMC, as shown in Figure 1 (left).

3.2 GOOSE

GOOSE inputs are added by clicking on *Add GOOSE virtual binary input* in the ribbon.

The configuration of GOOSE inputs is done in two steps:

1. Use the Test Universe *GOOSE Configuration* module to subscribe to specific GOOSEs
    a. GOOSEs can be added manually or automatically by using the *Import SCL* button.
    b. Either map a defined GOOSE to a physical or virtual input.
    c. Virtual inputs are enabled in the *Hardware Configuration* via the *General* tab.
    d. The advantage of using virtual inputs is, that no physical analog / binary input of the CMC will be blocked.
2. Do the *EnerLyzer Live* settings for GOOSEs via the tab *IEC 61850 > GOOSE* according to the configured Test Universe *GOOSE Configuration* module. As shown in Figure 1 (right), this requires:
    a. Setting of the correct *Group* from list.
    b. Setting of the correct *Input* from list.

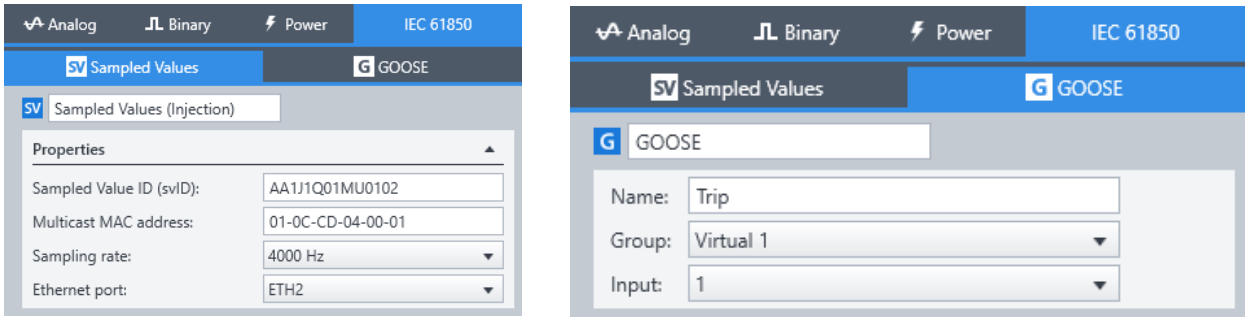


Figure 1: Sampled Values (left) and GOOSE (right) configuration settings in *EnerLyzer Live*.

4 Example 1: Testing a Merging Unit

Doing a basic merging unit test with *EnerLyzer Live* is a perfect example to demonstrate its suitability for hybrid measurement applications. Hybrid in this context means a measurement environment consisting of conventional analog signals combined with modern digital IEC 61850 Sampled Values.

4.1 System under test

The system under test is a common merging unit. It may either literally be a dedicated stand-alone merging unit, measuring analog input values and publishing digital Sampled Values or any other device with this kind of capability, e.g. a specific protection relay.

A typical merging unit can be seen in Figure 2 below.

Figure 2: Typical merging unit from Siemens, source: siemens.com.

4.2 Test setup

The test environment as described in UCA International Users Group, Testing Subcommittee: Test procedures for Sampled Values Publishers according to the "Implementation Guideline for Digital Interface to Instrument Transformers using IEC 61850-9-2". Version 1.0., 2010 is shown in Figure 3.

It consists of:

- The device under test (DUT), which publishes the SV (in this case “9-2LE”) stream.
- A voltage and/or current signal source.
- A SV (“9-2LE”) analyzer.
- A time synchronization setup.

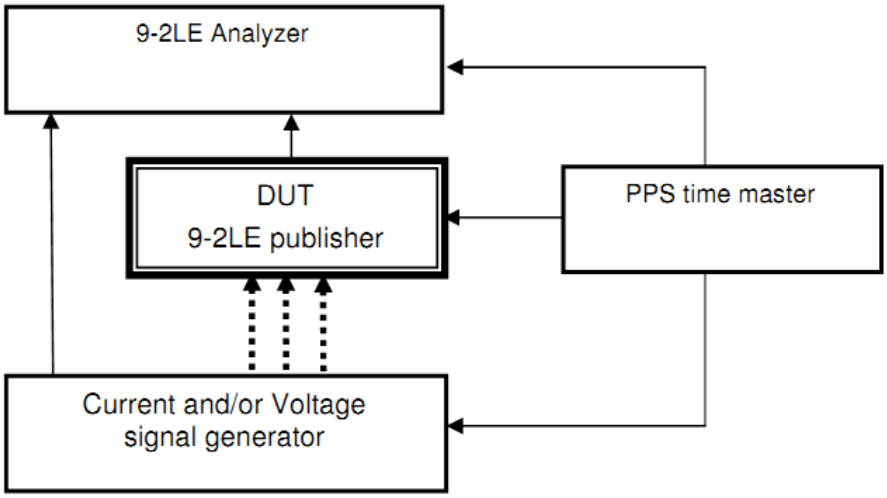


Figure 3: Generic test environment according to UCA International Users Group, Testing Subcommittee: Test procedures for Sampled Values Publishers according to the "Implementation Guideline for Digital Interface to Instrument Transformers using IEC 61850-9-2". Version 1.0., 2010

4.2.1 Hardware

The hardware test setup consists of the device under test, the CMC 430 and a device for time synchronization. In accordance with Figure 3 the CMC 430 will serve as generator of the analog signals and as analyzer for the Sampled Values stream of the DUT at once.

Depending on the device under test, the time synchronization can be done via precision time protocol (PTP). Therefore, an OMICRON CMGPS 588 or OTMC 100 can be used as PTP grandmaster clock according to IEEE 1588.

All devices (and the operating PC) are connected to a PTP transparent switch to facilitate the time synchronization and communication of the entire test setup. Furthermore, the setup requires the wiring of the following analog voltage and current signals:

- Voltage and current signals from analog output of the CMC to analog (measurement) input of the CMC
  - For current measurement use an OMICRON C-Shunt
- Voltage and current signals from analog output of the CMC to analog input of the device under test

The complete test setup can be seen in Figure 4.

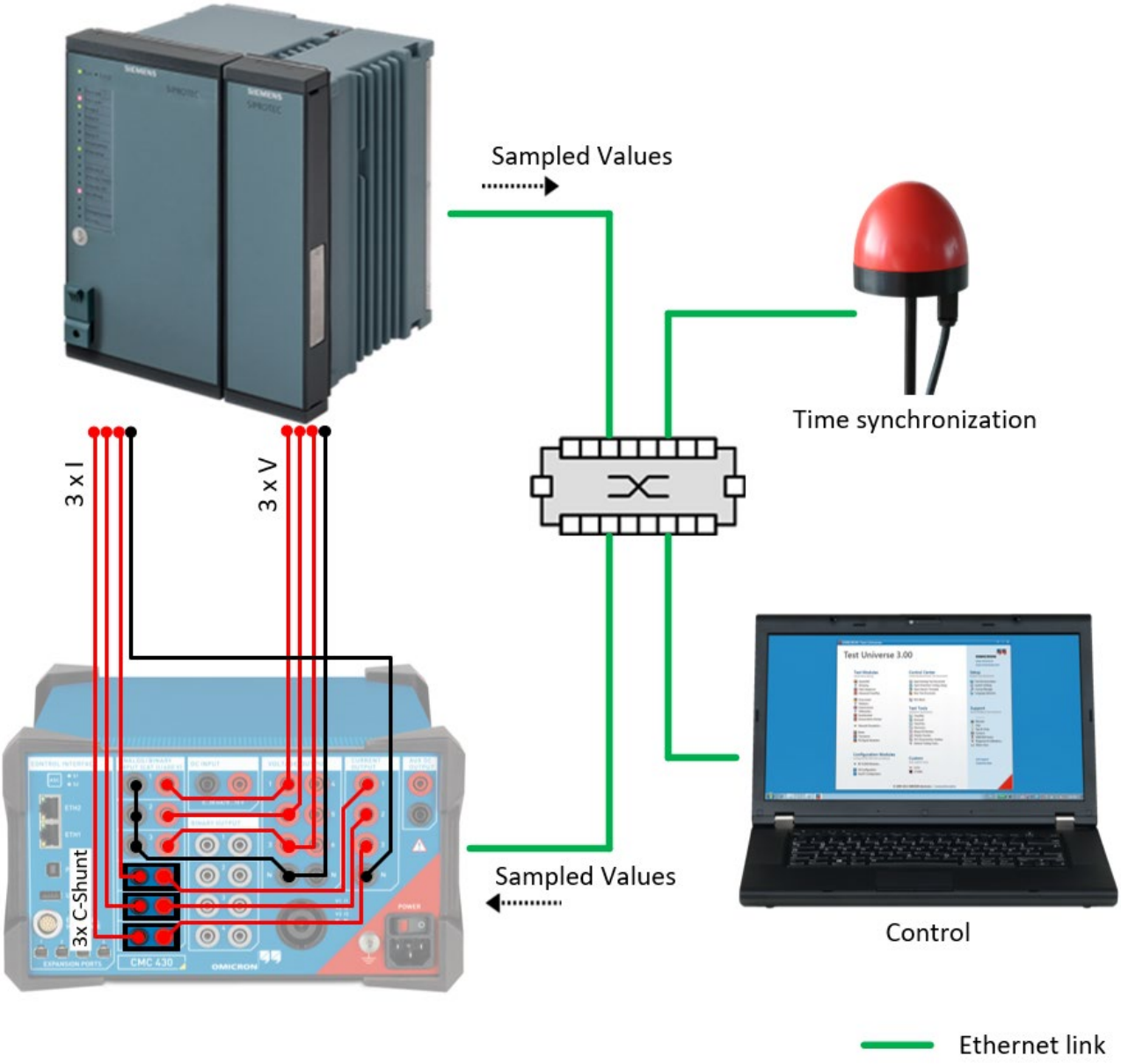


Figure 4: Hardware setup for Example 1: Testing a merging unit.

4.2.2 Software

The *EnerLyzer Live* software turns a CMC 430 into a multi-functional measurement device featuring functions of an oscilloscope, recorder and analyzer in one software.

It is possible to either use the provided *EnerLyzer Live* measurement template **CMC-AppNote-EnerLyzer-Live-IEC-61850-Measurement-ENU_Measurement_MU** or to easily set the measurement document up by yourself as briefly described in the following.

To set up the *EnerLyzer Live* measurement document, do the following steps:

1. After opening the *EnerLyzer Live* software, you have to choose the already associated test set.
2. Doing the *test set configuration*, the most important settings are:
    a. Choose the *Nominal frequency*, *Sampling rate* and *Live buffer* setting.
    b. Do the configuration of the *Time synchronization* via the button *Configure.*
    c. Configuration of analog measurement channels, as exemplarily shown in Figure 5:
        i. Voltage measurement
        ii. Current measurement

    (For the correct display of the primary values, the ratios of VTs and CTs must be entered into the respective field.)
    d. Configuration of IEC 61850 Sampled Values measurement streams, as exemplarily shown in Figure 6:
        i. Voltage measurement
        ii. Current measurement

    (Make sure to enter the same VT and CT ratios for the Sampled Values measurements as for the analog channels.)

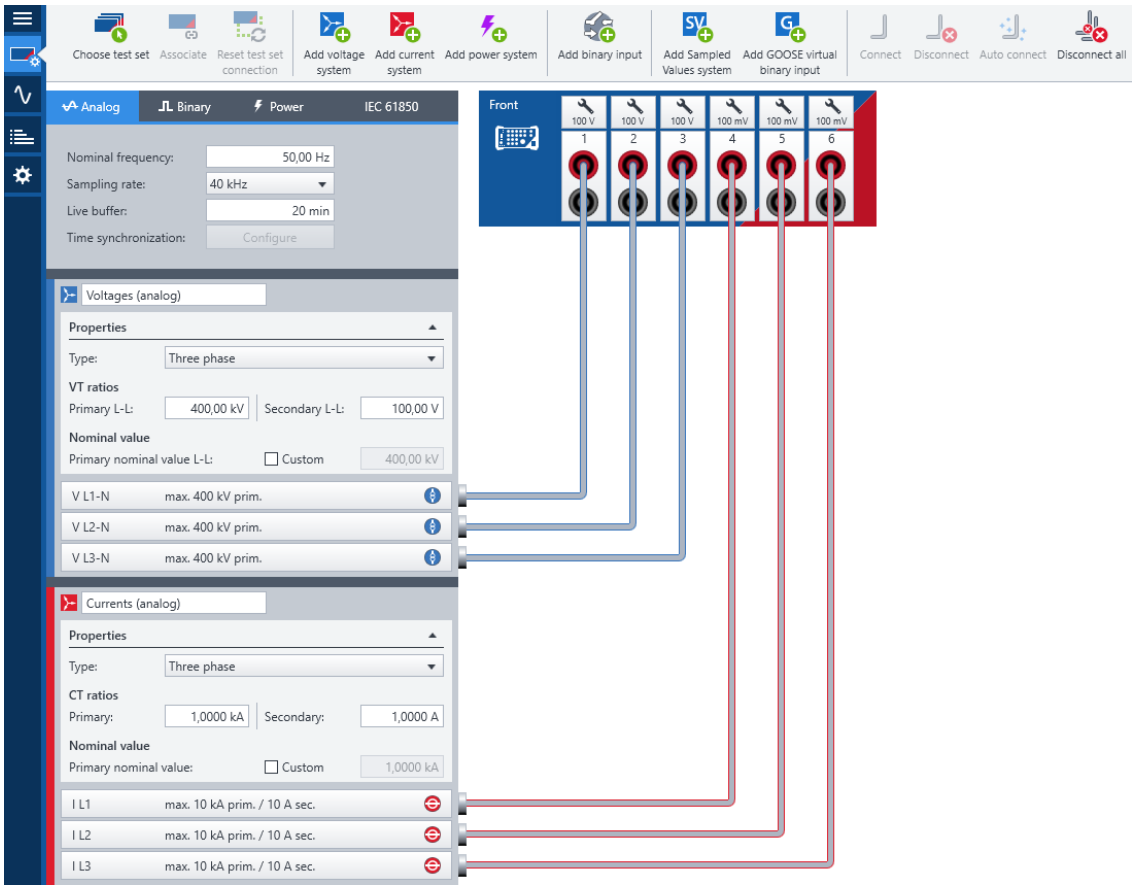


Figure 5: Test set configuration for analog measurement channels.

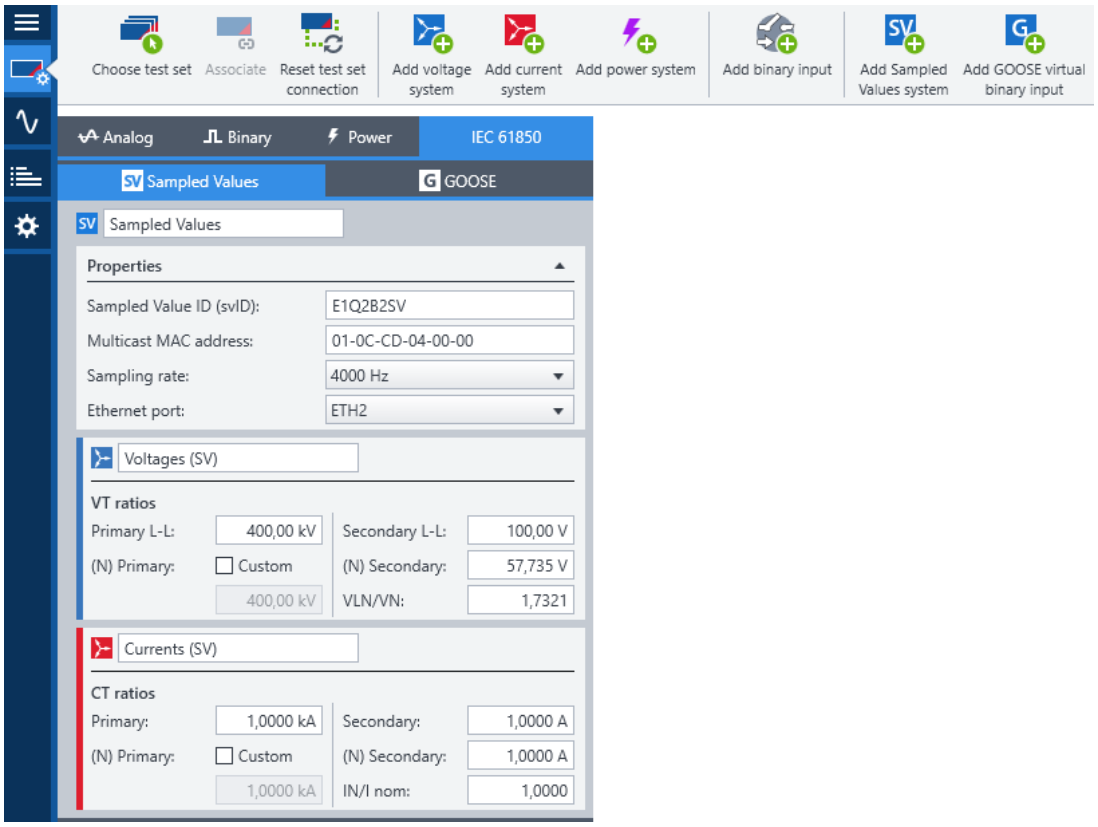
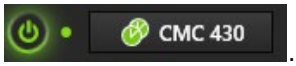


Figure 6: Test set configuration for Sampled Values measurement streams.

3. After switching to the tab *Signal pool*, the configured measurement channels are visualized by dragging & dropping the signals into the measurement sheet. (Depending on the personal preferences the view of instantaneous values and / or phasors is most appropriate for this test.)

4. If necessary, press the button *Click to start measurement* so it becomes green: 

. The green clock symbol besides the CMC type description indicates, that the test set is time synchronized.

4.3 Test procedure

The test procedure consists of the following steps:

1. Make sure the *EnerLyzer Live* measurement is running.
2. Make sure the time synchronization is working for the entire test setup.
3. Output any analog voltage and current values with Test Universe, e.g. *QuickCMC* module.
4. Check the measurement of analog values and Sampled Values in *EnerLyzer Live*.
5. *Hold live data* and *Create recording* for later analysis of the measurement, if needed.

4.4 Test assessment

The described test procedure can be used for the:

- General verification of the correct function of the device under test, including time synchronization and communication of the whole test setup and the
- erification of the conversion accuracy of the device under test between analog input and Sampled Values output signal.

4.4.1 General verification of the correct function of the DUT

EnerLyzer Live allows to verify the correct general function of the device under test at first glance, as exemplarily can be seen in Figure 7:

- Wiring done correctly,
- Analog input and Sampled Values output working,
- Communication of whole test setup working,
- …

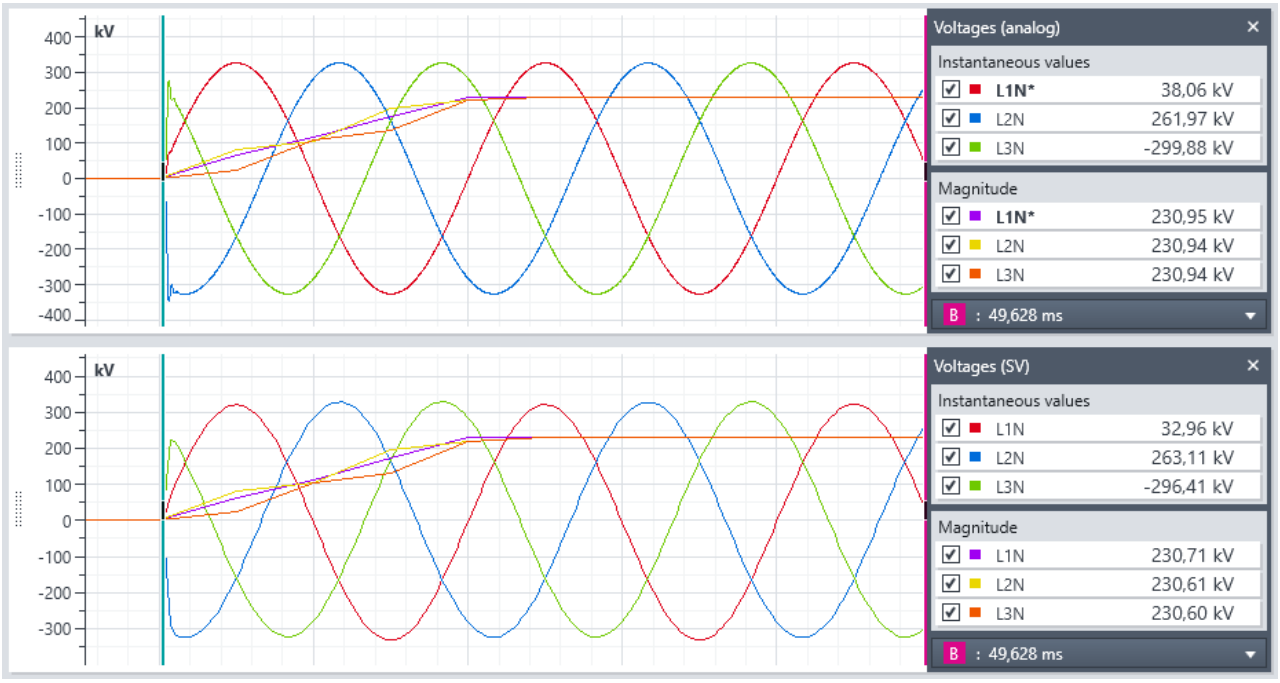


Figure 7: Measurement of analog input signal and Sampled Values output stream.

Using the function *Hold live data* and/or *Create recording* allows to compare the timing of the analog signal and the Sampled Values stream in detail with two cursors. Exemplarily this is shown in Figure 8, where the zero crossing of L1N of the analog signal is used as time reference and compared to the timing of the zero crossing of L1N of the SV stream. The difference here is - 40,4 µs. From this almost negligible small value, the conclusion can be drawn, that the time synchronization of the test setup is working. (The remaining inaccuracy is caused by the phase error of the merging unit, as discussed in chapter 4.4.2 .)

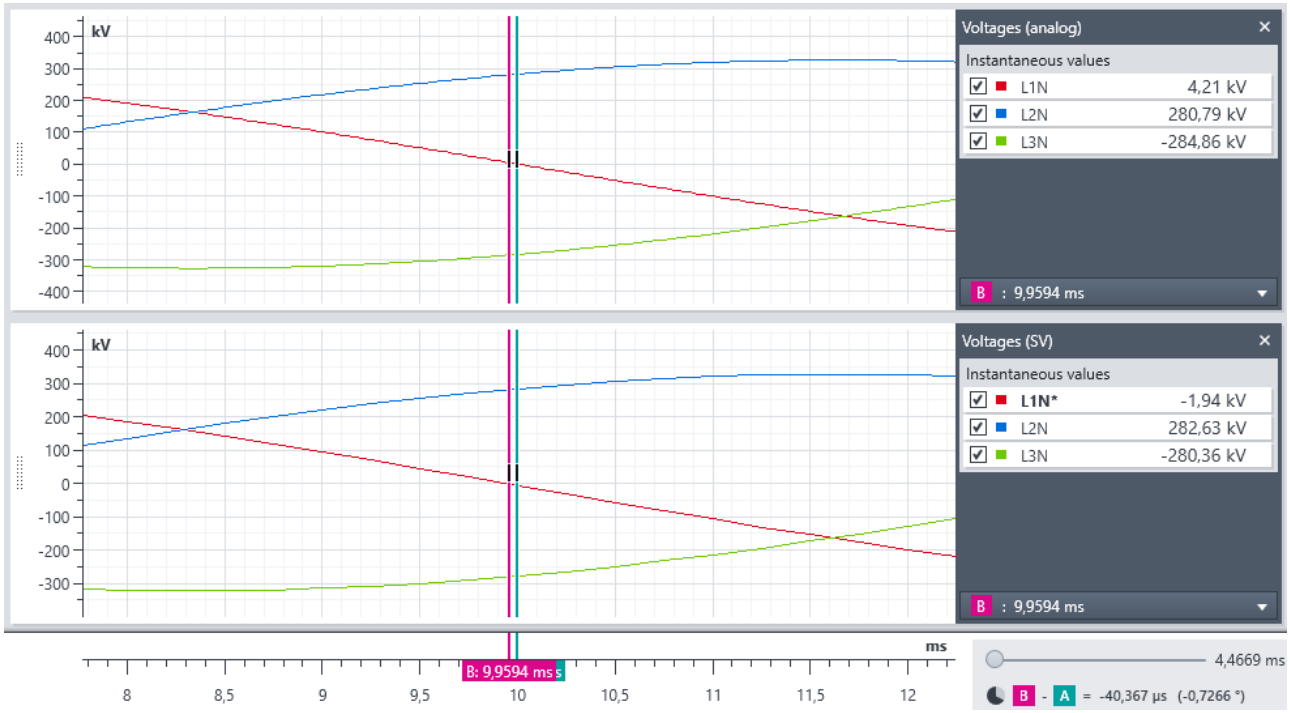


Figure 8: Timing difference between analog input signal and Sampled Values output stream.

4.4.2 Verification of the measurement accuracy

The *EnerLyzer Live* software, as hybrid measurement software, allows to directly compare the measurement of analog signals with Sampled Values. Therefore, it's possible to check, if analog signal and Sampled Values stream match, as exemplarily shown in Figure 9. The phasor view is most useful to compare the relevant quantities (magnitude and phase angle) within one single view.

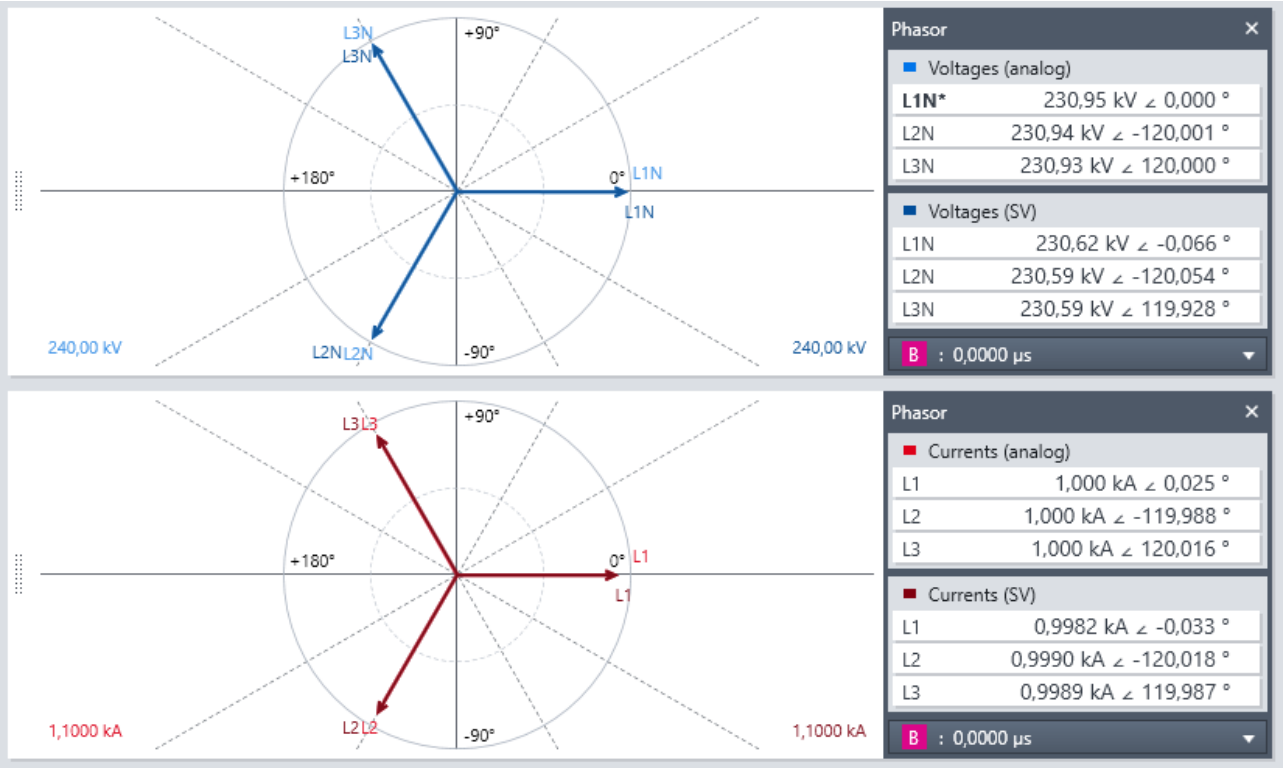


Figure 9: Measurement accuracy of analog signal and Sampled Values stream; voltage (top), current (bottom).

The use of *Calculated signals* allows to automatically calculate and display the amplitude and phase error between analog input signal and Sampled Values output stream of the device under test, as can be seen in Figure 10.

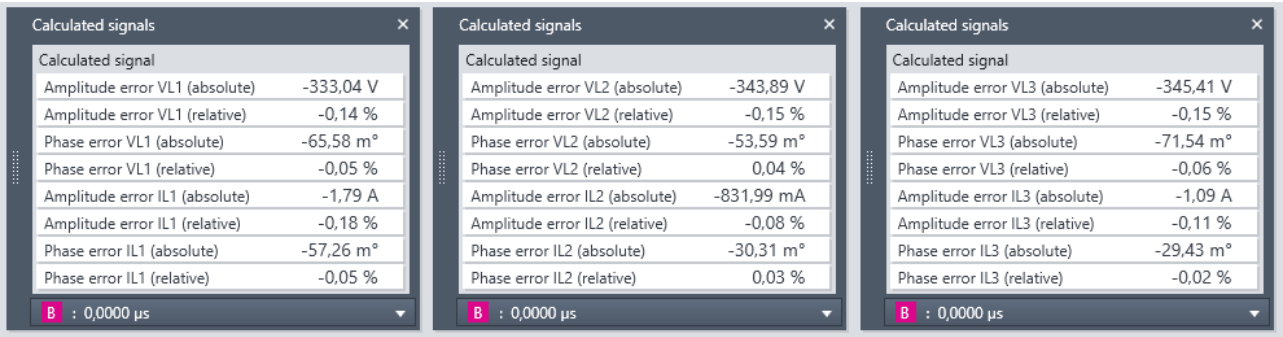


Figure 10: Calculation and display of amplitude and phase error.

5 Example 2: Overcurrent Protection Test of a Fully Digital Relay

In addition to hybrid measurement tasks, *EnerLyzer Live* is perfectly suitable for fully digital measurement environments, too. A good example for this is the monitoring of an overcurrent protection relay test based on IEC 61850 Sampled Values and GOOSE messages.

5.1 System under test

The system under test is a common digital protection relay, as can be seen in Figure 2 below.

Figure 11: Typical digital protection relay from ABB, source: abb.com.

5.2 Test setup

5.2.1 Hardware

The hardware test setup consists of the device under test, a CMC 430 (from now on referred to as: “measurement” CMC) and another CMC (from now on referred to as: “test” CMC).

The CMC 430 will serve as monitoring system for the Sampled Values and GOOSE traffic of the total test setup. The second CMC is used as source for the Sampled Values stream injection into the relay. If no circuit breaker is connected to the relay, but nevertheless the reporting of the auxiliary contacts 52a and 52b is required, the second CMC can additionally be utilized for a circuit breaker simulation.

If time synchronization is required, it may be done via precision time protocol (PTP). Therefore, an OMICRON CMGPS 588 or OTMC 100 can be used as PTP grandmaster clock according to IEEE 1588.

All devices (and the operating PC) are connected to a switch to facilitate the communication of the entire test setup.

The complete test setup can be seen in Figure 12.

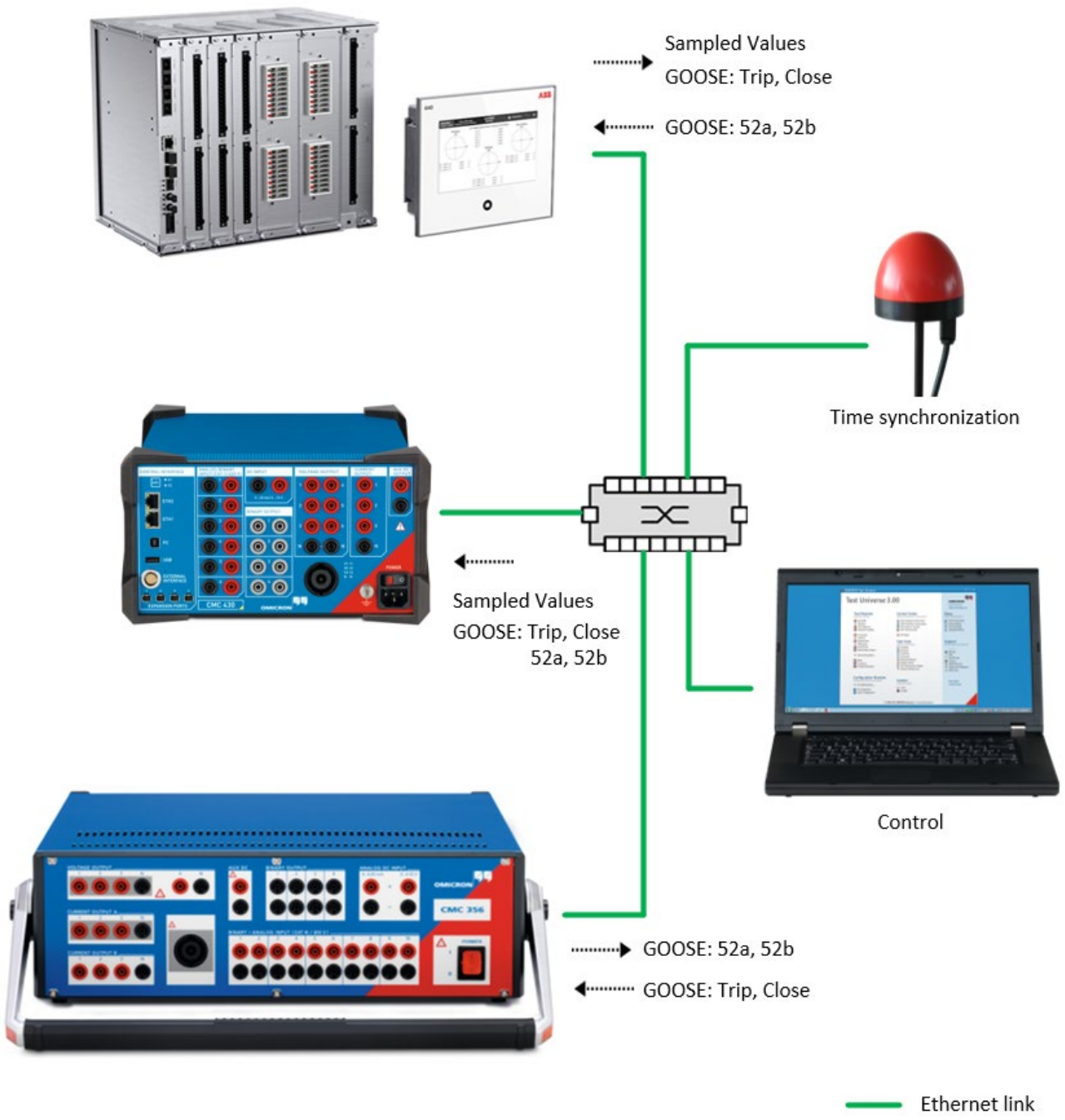


Figure 12: Test setup for Example 2: Test of fully digital relay.

5.2.2 EnerLyzer Live software

The *EnerLyzer Live* software turns a CMC 430 into a multi-functional measurement device featuring functions of an oscilloscope, recorder and analyzer in one software.

Before setting up the *EnerLyzer Live* measurement document, it is recommended to do the GOOSE configuration, as mentioned in chapter 3.2 . Either use the provided configuration template **CMC-AppNote-EnerLyzer-Live-IEC-61850-Measurement-ENU_GOOSE_Config_Meas_CMC** or set it up by yourself. The configuration is shown in Figure 13 and requires the subscription of the following GOOSEs:

- Trip
- Close command (optional, only for monitoring of close event)
- Auxiliary contact 52a
- Auxiliary contact 52b.

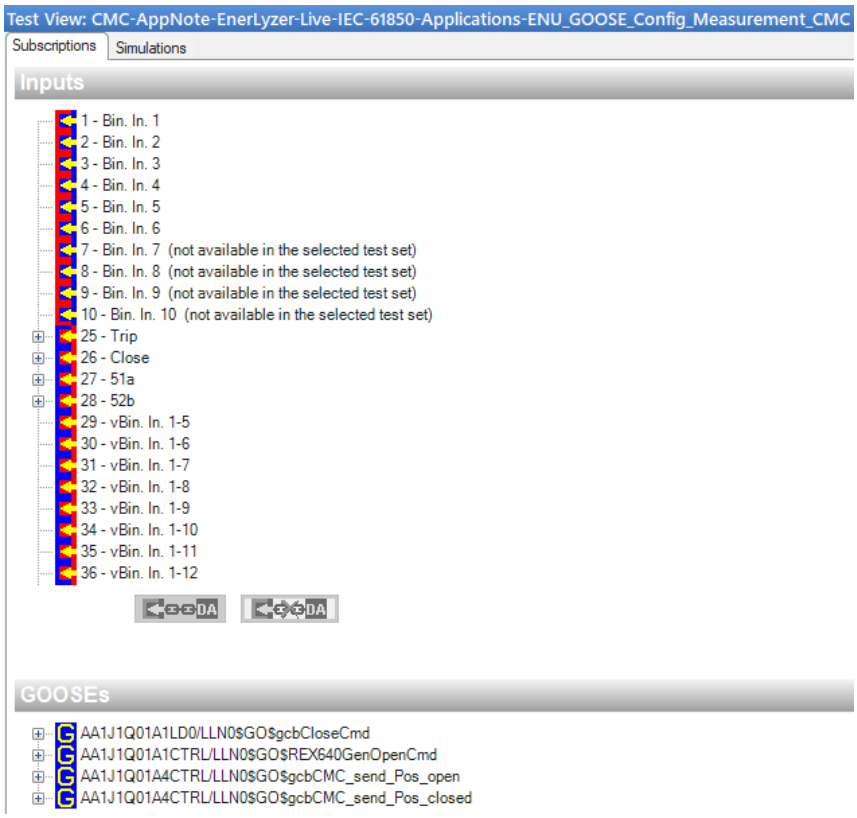


Figure 13: GOOSE configuration for “measurement” CMC 430.

Afterwards, it is possible to either use the provided *EnerLyzer Live* measurement template **CMC-AppNote-EnerLyzer-Live-IEC-61850-Measurement-ENU_Measurement_Relay** or to easily set the measurement document up by yourself as briefly described in the following.

To set up the *EnerLyzer Live* measurement document, do the following steps:

1. After opening the *EnerLyzer Live* software, you have to choose the already associated test set.
2. Doing the *test set configuration*, the most important settings are:
    a. Choose the *Nominal frequency* and do the *Live buffer* setting.
    b. Do the configuration of the *Time synchronization* via the button *Configure* (if required).
    c. Configuration of IEC 61850 Sampled Values measurement streams, as exemplarily shown in Figure 14:
        i. Voltage measurement
        ii. Current measurement

    (Make sure to enter the correct VT and CT ratios for the Sampled Values measurement.)
    d. Configuration of IEC 61850 GOOSE messages, as exemplarily shown in Figure 15:
        i. Trip
        ii. Optional: Close command (if close event shall be monitored)
        iii. Auxiliary contact 52a
        iv. Auxiliary contact 52b

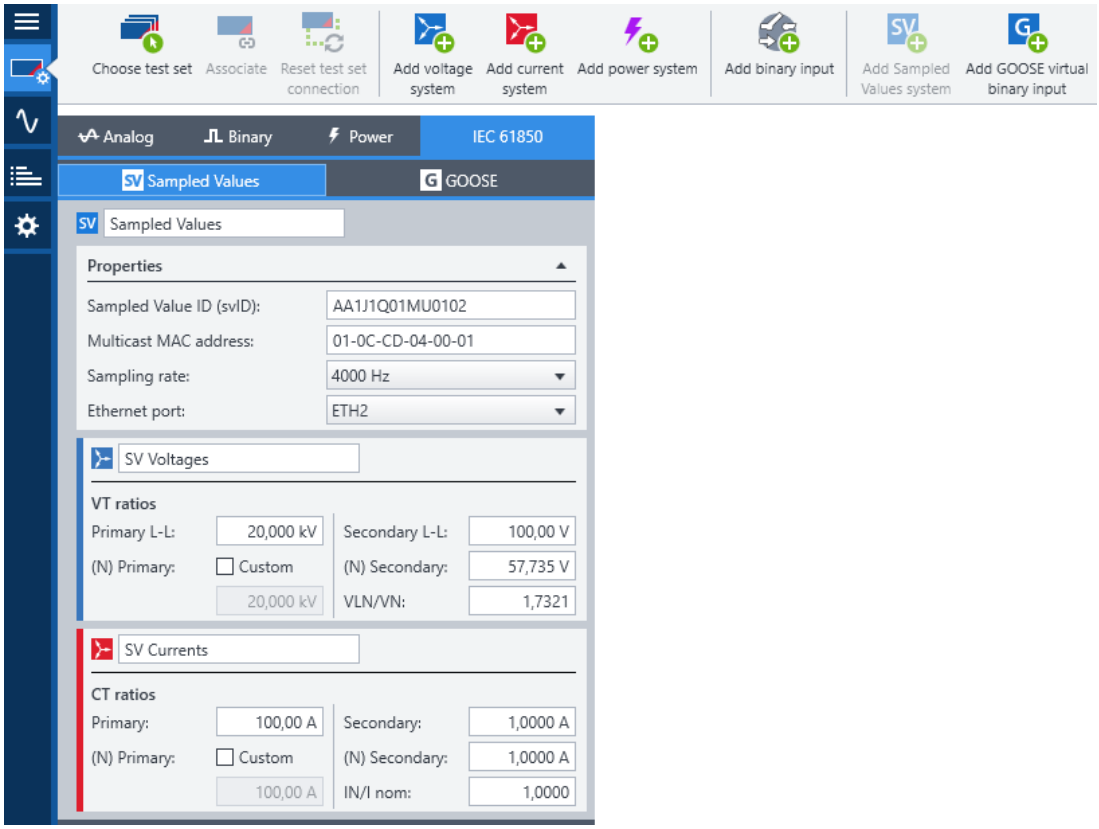


Figure 14: Test set configuration for Sampled Values measurement streams.

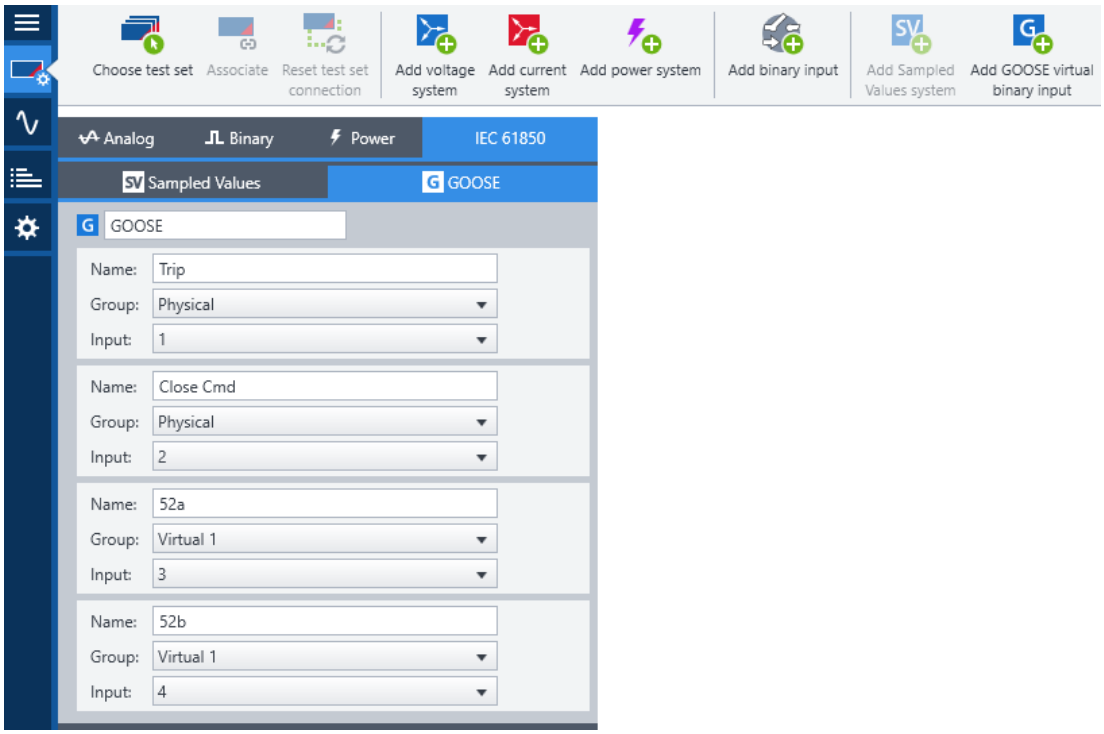
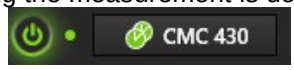


Figure 15: Test set configuration for GOOSE messages.

3. After switching to the tab *Signal pool*, the configured Sampled Values streams and GOOSE virtual binary inputs are visualized by dragging & dropping the signals into the measurement sheet.
4. Starting the measurement is done by pressing the button *Click to start measurement,* so it becomes green: 

.

5.2.3 Test Universe software

Several Test Universe modules are required to configure the “test” CMC for GOOSE communication and Sampled Values injection and to finally perform the protection test.

It is possible to either use the provided *Omicron Control Center* (*OCC*) test template **CMC-AppNote-EnerLyzer-Live-IEC-61850-Measurement-ENU_Digital_Relay_Test** or to easily set the measurement document up by yourself, as briefly described in the following.

To set up the *Omicron Control Center* test document do the following steps:

1. After opening a new *Omicron Control Center* document, do the *Test Object* settings and *Hardware Configuration*. The *Hardware Configuration* requires:
    a. Virtual input group 1 (in the *Virtual Inputs/Outputs* section)
    b. The *Binary / Analog Inputs*: Trip and Close command
    c. The *Binary* Outputs: 52a and 52b
2. If a circuit breaker simulation is required (e.g. because no real circuit breaker is connected to the relay), insert the Test Universe module *CB configuration* to the test document and set it up, as exemplarily shown in Figure 16:

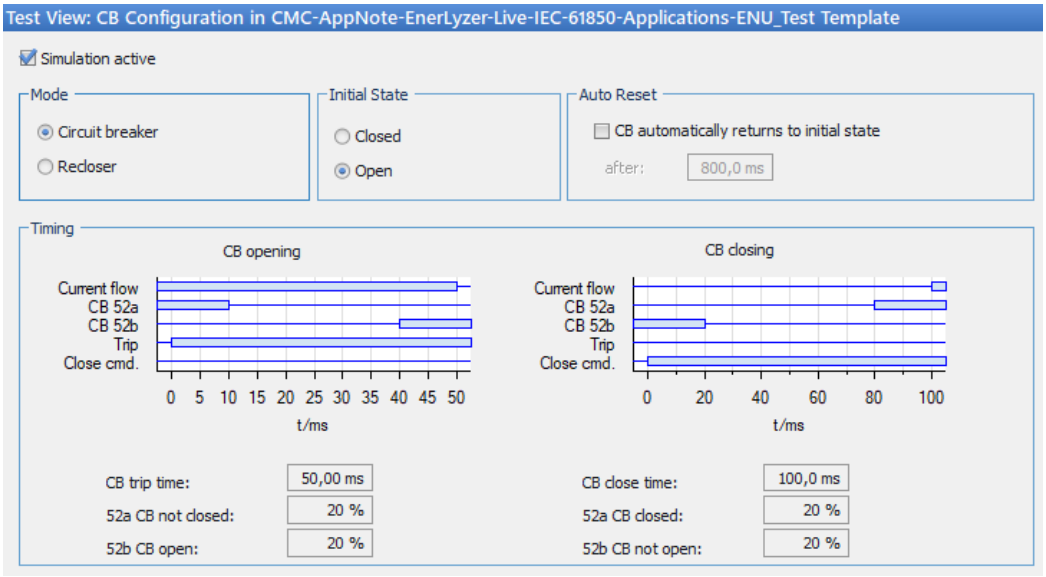


Figure 16: Configuration of the circuit breaker simulation.

3. Insert the Test Universe module *GOOSE Configuration* to the test document and set it up, as exemplarily shown in Figure 17:
    a. Subscription of: Trip and Close
    b. Simulation of: 52a and 52b

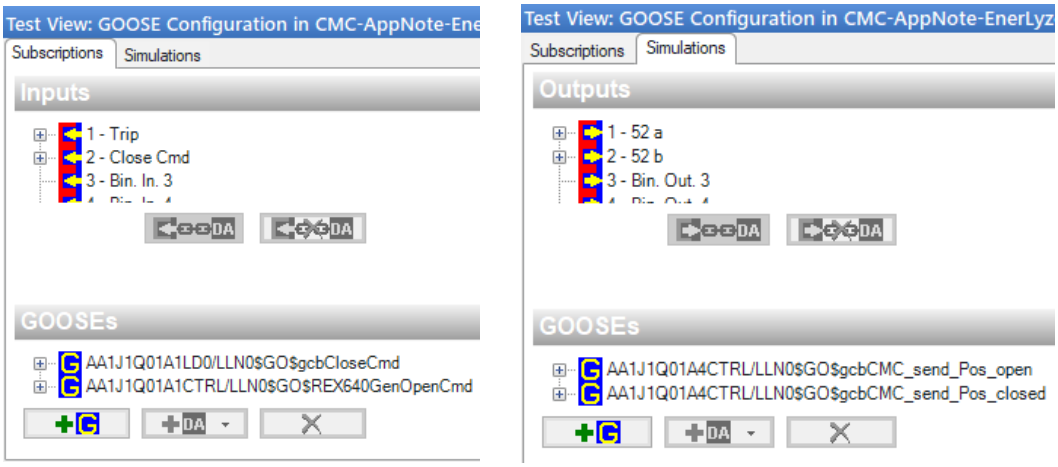


Figure 17: GOOSE configuration of "test" CMC; left: *Subscriptions*, right: *Simulations*.

4. Insert the Test Universe module *Sampled Values Configuration* to the test document and set it up, as exemplarily shown in Figure 18:

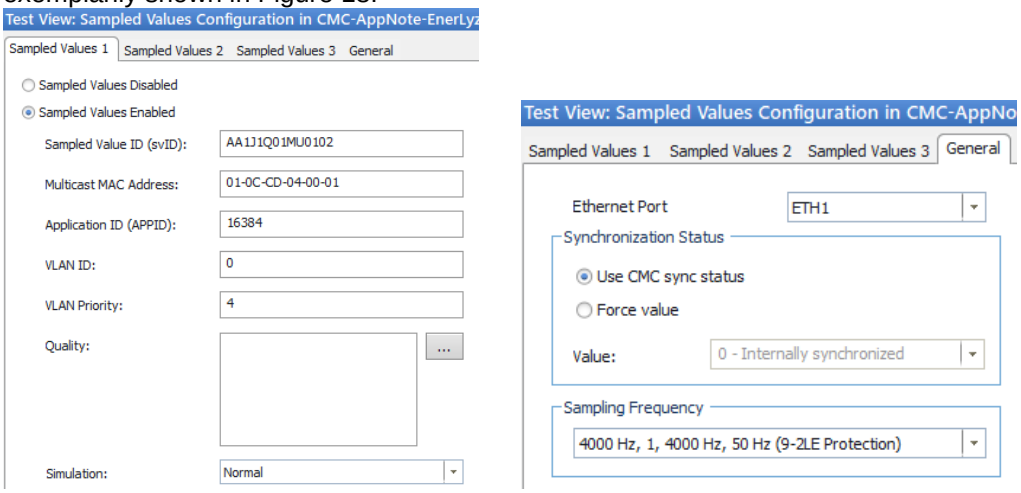


Figure 18: Sampled Values configuration of "test" CMC; left: configuration of stream, right: general configuration.

5. Insert the Test Module *QuickCMC* to the test document.

5.3 Test procedure

The test procedure consists of several steps and should strictly be done in the following order:

1. Make sure the test setup is done correctly and switch on both CMCs.
2. Open the *GOOSE Configuration* module for the “measurement” CMC and apply it to the CMC 430. Afterwards close the module.
3. Open the *EnerLyzer Live* measurement document and make sure the measurement is running. If required and available, activate the time synchronization.
4. Open the *Omicron Control Center* test document: Make sure, that the “test” CMC is chosen in the *Hardware Configuration* and start the test procedure by clicking *Start/Continue All*.
5. Automatically the *OCC* test file will run through the *CB Configuration*, *GOOSE Configuration* and *Sampled Values Configuration* modules. Afterwards the *QuickCMC* module is opened.
6. Using *QuickCMC*, inject *Sampled Values* to trip the protection relay according to its parameter settings.
7. Monitor the protection test with *EnerLyzer Live*. *Hold live data* and *Create recording* for later analysis of the measurement, if needed.

5.4 Test assessment

To begin with, the described test setup and test procedure can be used to draw general conclusions regarding the:

- verification of correct function of device under test,
- verification of correct function of the system consisting of relay and circuit breaker,
- verification of correct function of IEC 61850 communication of whole test setup,
- verification of correct function of time synchronization.

Moreover, the *EnerLyzer Live* software with its multiple visualization possibilities is perfectly suited as tool during the engineering process or for any troubleshooting in case one of the above-mentioned points is not working.

5.4.1 Example: Assessment of trip

As an example, the recording of a trip test in Figure 19 shows:

- Correct behavior of all above-mentioned points
- A trip time of 208 ms (the parameter setting of the relay was 200 ms)
- The trip signal is present for 250 ms
- …

Figure 19: Recording of trip measurement.

6 Network communication analysis with DANEO 400

As presented in this application note, the *EnerLyzer Live* software offers several possibilities for IEC 61850 measurement applications.

For a detailed network communication and packet timing analysis, the OMICRON DANEO 400 network analyzer offers dedicated functionality.

The DANEO 400 visualizes additionally to measurement values also details of network communication packets and timing statistics (e.g. packet interval, packet delay) which are relevant to verify the correct operation of SV and GOOSE publishers.

The autonomous network traffic supervision detects any kind of abnormalities and triggers network packet recordings for further troubleshooting and assessing the network performance.

A distributed measurement system with multiple DANEO 400 units offers a time aligned view on signals covering the entire scope of a distributed substation automation system.

Further details see www.omicronenergy.com/en/products/daneo-400/.

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/en/support

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

https://my.omicronenergy.com/

The Customer Portal 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.omicron.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 offices worldwide please visit our website.