Application Note

Online Medium Voltage Circuit Breaker Check with CMC Test Set and EnerLyzer Live

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Abstract

Especially for medium voltage switchgears it is common practice to amend a routine protection relay test by a simple circuit breaker check. This application note describes the indirect timing measurement of the main contacts of a circuit breaker with a CMC test set and EnerLyzer Live. The method is perfectly suitable for systems, where the main contacts are not accessible, e.g. switchgear in operation or GIS, or if there are no auxiliary contacts available.

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

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.

- Do not enter the high-voltage area while doing this test.
- 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 how a basic medium voltage circuit breaker check can be performed with the CMC and the *EnerLyzer Live* software. This check consists of operating the circuit breaker and measuring the timing of the main (and auxiliary) contacts.

It covers the following content:

1. Introduction to **circuit breaker (CB)** testing
2. Description of the **system under test**
3. Description of the **test setup**
4. Setting up the ***EnerLyzer Live* measurement document**
5. Description of the **test procedure**
6. **Assessment** of the CB check

The application note **does not describe** a complete circuit breaker test. To test a CB thoroughly further tests are also recommended. This applications note does also not describe an offline CB timing check with the CMC and *Test Universe State Sequencer* module, which is covered by a separate document.

2.3 Template

For this application note the corresponding *EnerLyzer Live* templates **CB-Check-with-CMC-and-EnerLyzer-Live-Online-ENU_Measurement_Trip_Template** and **CB-Check-with-CMC-and-EnerLyzer-Live-Online-ENU_Measurement_Close_Template** are provided in the .zip-folder of the application note.

The templates can be used to perform a circuit breaker check as described in this application note. Whereas the former template is used for a trip/open operation of a circuit breaker, the second template is for a close operation.

3 Introduction to Circuit Breaker Testing

3.1 Typical tests for circuit breakers

A circuit breaker can be separated into several functional parts. As can be seen in Figure 1, these parts are the control, operating mechanism, mechanical linkage and the interrupter units(s). There are typical tests for circuit breakers, which are listed according to the individual functional parts in the following:

- Tests on control: performance of control circuits
  - Coil current profile analysis
  - Undervoltage test
  - Minimum pick-up test
  - Timing of auxiliary contacts
- Tests on operating mechanism: performance of spring charging motor
  - Motor current analysis
- Tests on mechanical linkage: performance of kinematic chain
  - Contact travel (motion) of main contacts
- Tests on interrupter unit:
  - Static contact resistance
  - Dynamic contact resistance
  - Timing of main contacts

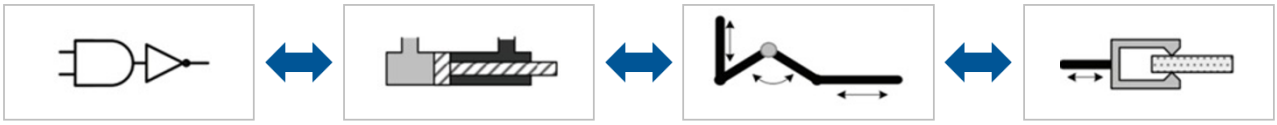


Figure 1: Functional parts of a circuit breaker.

3.2 Online circuit breaker check

Especially for medium voltage switchgears it is common practice to amend a routine protection relay test by a simple circuit breaker check. This check often only consists of a trip test, which means tripping the protection relay with connected circuit breaker (, which therefore opens). The idea behind this procedure is, that the entire protections system is tested; consisting of the protection relay, signal transmission and the circuit breaker with all of the functional parts.

On the other side, the trip test has just limited significance and doesn't allow any further conclusions, e.g. to the condition of the circuit breaker.

In order to gain further evidence about the condition of a circuit breaker this application note focuses on how the tripping (or closing) test of a circuit breaker is complemented by the measurement of the timing of the main (and auxiliary) contacts. This timing measurement additionally allows to check the trip (or close) time of a circuit breaker as well as to investigate the synchronism of the individual breaker poles. Advantages are that no additional test equipment is needed (compared to a protection relay test), it is simple and fast and at least for MV switchgears the relay and circuit breaker are in close proximity to each other.

The complete procedure can be done online (in service) or offline (off service). This document concentrates on performing an online test. Therefore, the main contacts of a circuit breaker typically cannot be accessed and that's why a technique is described, which utilizes an indirect timing measurement of the main contacts. Another important field of application for this method, where the main contacts of a CB are not accessible, is testing gas-insulated switchgears (GIS), which are state of the art on the medium voltage level. A third option for an indirect measurement of the main contacts may be switchgears where the auxiliary contacts 52a and 52b are not available.

4 System Under Test

A typical system under test may be a modern medium voltage gas-insulated switchgear, e.g. a ring main unit, as in Figure 2. This consists of several bays and at least one circuit breaker connected to a protection relay.

There are two possibilities to facilitate the indirect timing measurement of the circuit breaker's main contacts:

1. Voltage based method
2. Current based method

Figure 2: Typical medium voltage gas-insulated switchgear.

4.1 Voltage based method

The voltage-based indirect timing measurement of the main contacts is possible for single feeders with a voltage transformer or VDS (voltage detection system) interface in direction of the line. An exemplary single line diagram is shown in Figure 3.

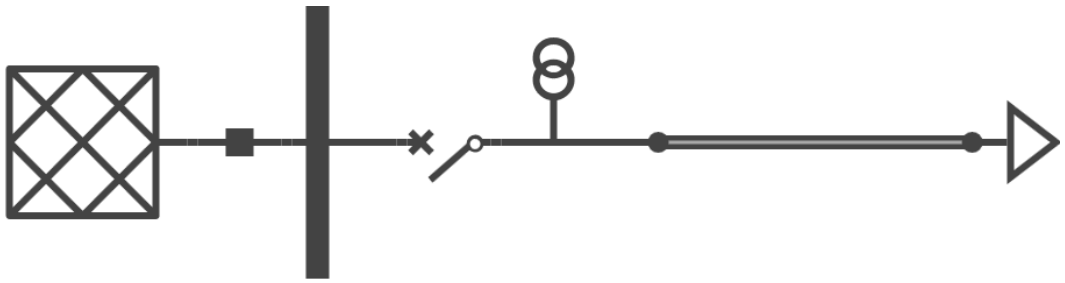


Figure 3: Single line diagram of single feeder with VT directed towards line.

A VDS typically describes a capacitive sensor to display, e.g. with a lightning symbol, if the feeder is potential free or not, as can be seen in Figure 4. Additionally, to the display, the VDS has sockets which allow to connect to a measurement device via standard test lead adapters.

Figure 4: VDS, source: www.horstmanngmbh.com.

The principle behind the voltage-based method is to measure the voltage at the VT or VDS and therefore draw a conclusion for the position of the circuit breaker's main contacts:

- No voltage present = circuit breaker is open
- Voltage present = circuit breaker is closed.

4.2 Current based method

The current based indirect timing measurement of the main contacts is possible for any feeders with a current transformer (and at least a minimum measurable current flowing). An exemplary single line diagram is shown in Figure 3.

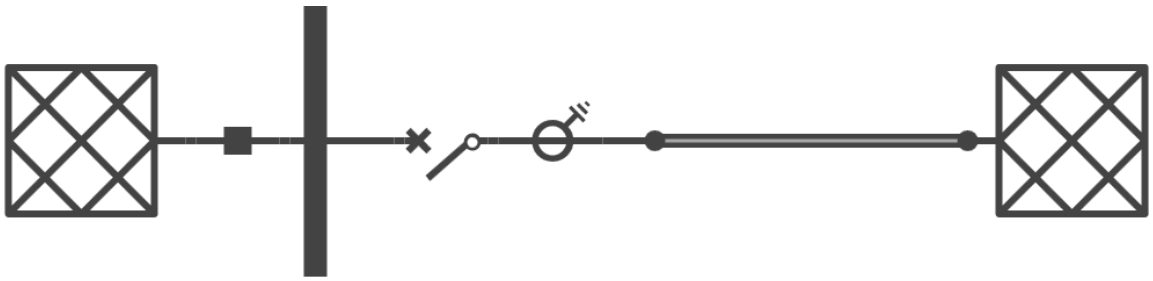


Figure 5: Single line diagram of feeder with CT.

The principle behind the current based method is to measure the current at the CT and therefore draw a conclusion for the position of the circuit breaker's main contacts:

- No current flowing = circuit breaker is open
- Current flowing = circuit breaker is closed.

5 Test Setup

NOTICE

If the voltage-based method with VDS is performed:

- The *EnerLyzer Live* document and configuration of the CMC shall be done before the wiring of CMC and system under test.

The reason behind is, that:

- If the switchgear is online and the circuit breaker is closed, the VDS visualizes (see Figure 4), that a potentially hazardous voltage is present
- Connecting the CMC to the sockets of the VDS before configuring the CMC by setting up the *EnerLyzer Live* measurement document as described in chapter 5.2 Software, may force the VDS voltage below the threshold for voltage detection.
- In consequence the VDS will not visualize and warn from a potentially hazardous voltage anymore.

5.1 Hardware

DANGER

Death or severe injury caused by high voltage or current.

- Do not enter the high-voltage area while doing this test.
- 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.

For an online test, the hardware test setup basically just consists of the system under test and the CMC 430, which is used as measurement device. (For an offline test an additional voltage or current source is required to generate the assessment relevant line voltage or current, see chapter 4 System Under Test.)

The following signals from the switchgear must be connected to the CMC:

- Measurement of line voltage via VT or
- Measurement of line voltage via VDS or
- Measurement of feeder current via CT

And:

- Trip command for circuit breaker (for trip time measurement),
- Close command for circuit breaker (for close time measurement),
- Circuit breaker auxiliary contacts 52a and 52b (optional, only if information is relevant for user).

The wiring diagram of the test setup for the voltage-based method using a VDS interface can be seen in Figure 6.

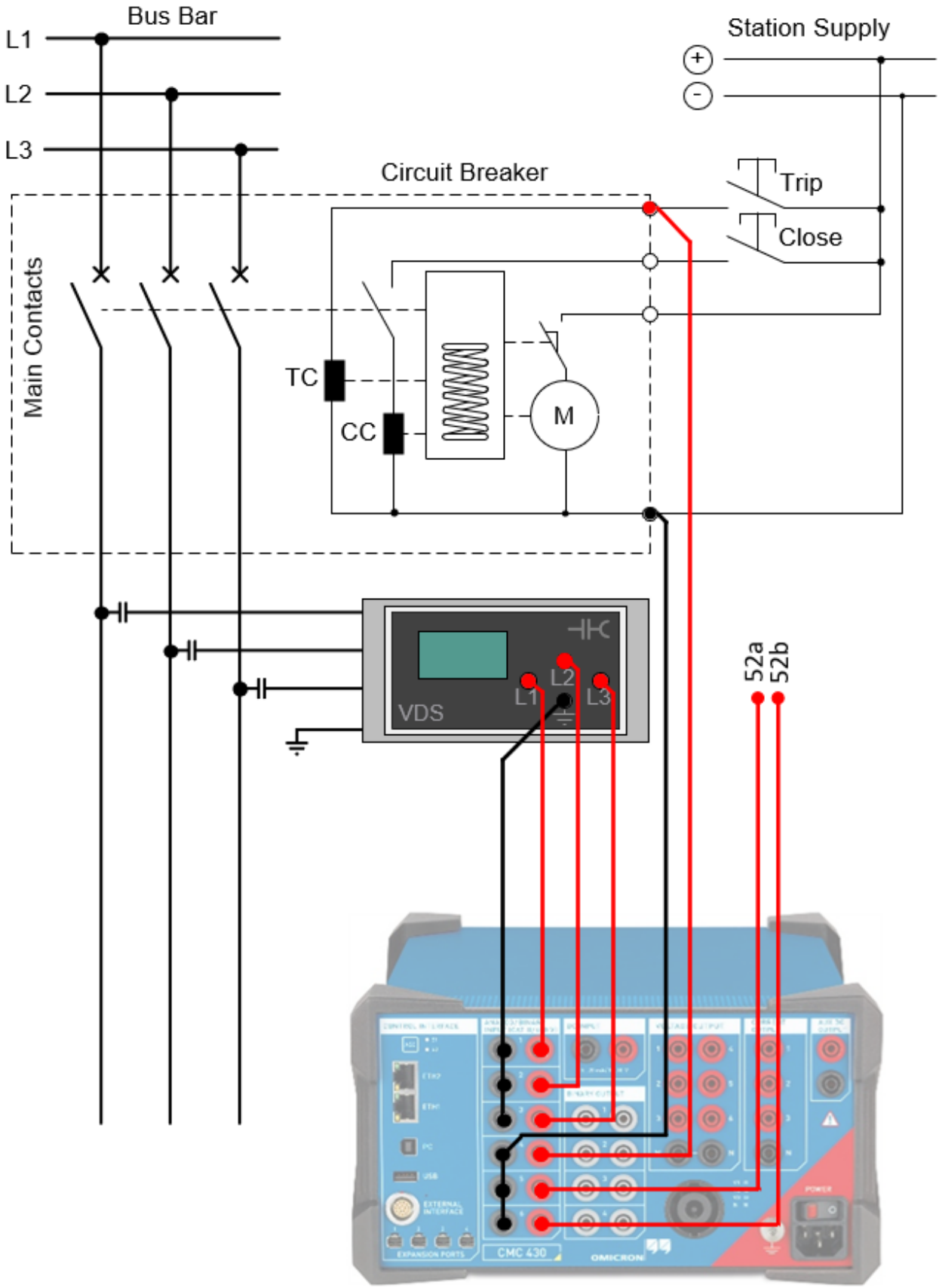


Figure 6: Wiring diagram for trip time measurement with voltage-based method using a VDS.

5.2 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 templates or to easily set a 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. *Nominal frequency* setting
    b. Connection of analog measurement channels, as exemplarily shown in Figure 7
        i. Voltage measurement for voltage-based method
        ii. Current measurement for current based method

    (For the correct display of the primary and secondary values, the ratios of VTs / VDS / CTs must be entered into the respective field. For the qualitative assessment of the test only, the ratios are optional. For an accurate measurement the range of the analog inputs of the CMC should be set accordingly.)
    c. Connection of binary inputs, as exemplarily shown in Figure 8
        i. Trip command and/or close command
        ii. Auxiliary contact 52a (optional)
        iii. Auxiliary contact 52b (optional)

    (Depending on the system under test, the binary inputs of the CMC must be configured, e.g. set to dry or wet.)

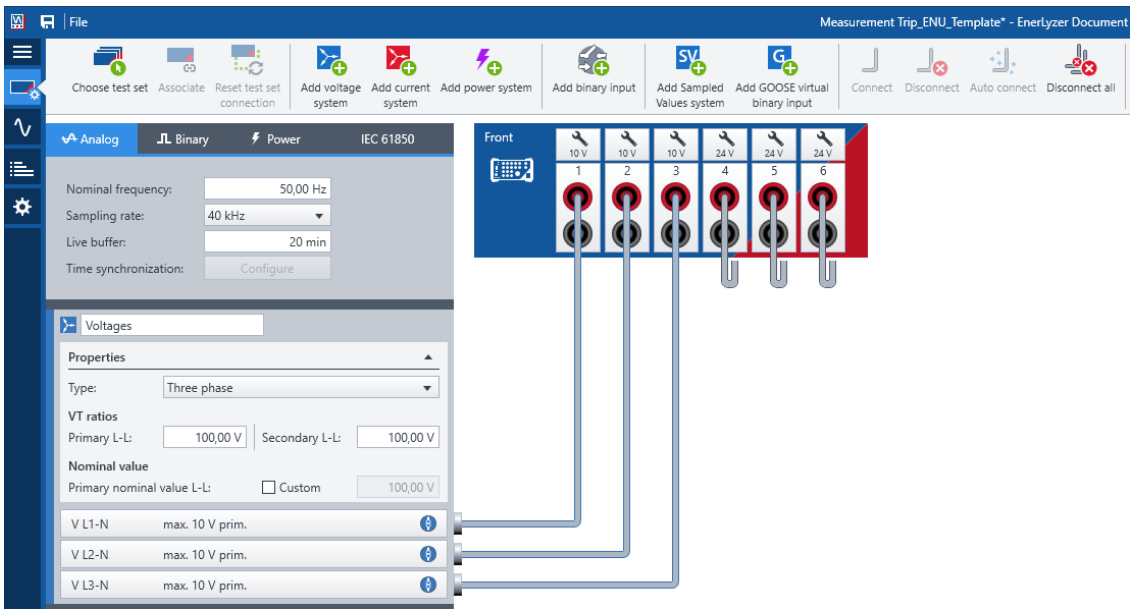


Figure 7: Test set configuration and analog measurement for voltage-based method.

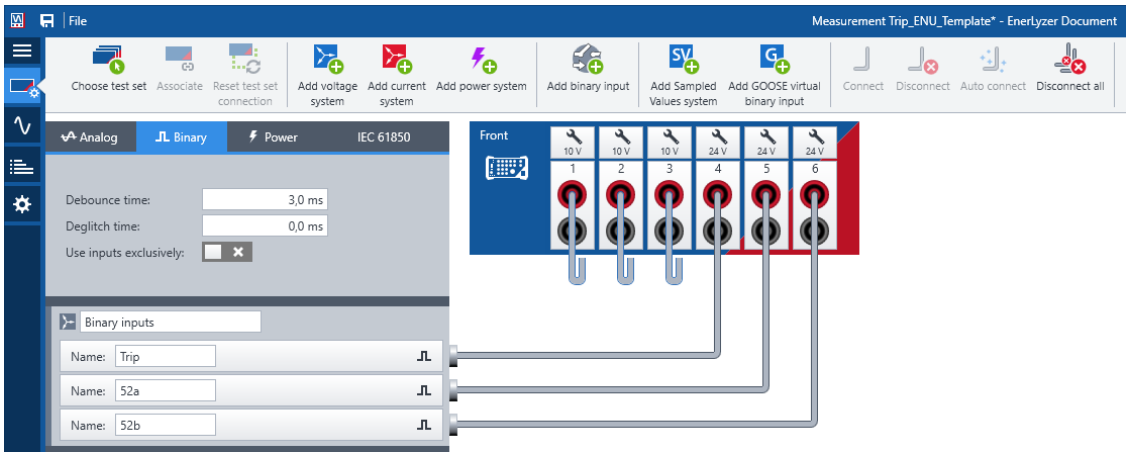


Figure 8: Binary input configuration for trip measurement.

3. After switching to the tab *Signal pool*, the configured measurement channels are visualized (drag & drop the signals into the measurement sheet).
4. Setting up and arming a trigger, as exemplarily shown in Figure 9, enables the automated recording of the opening (or closing) action of the circuit breaker.

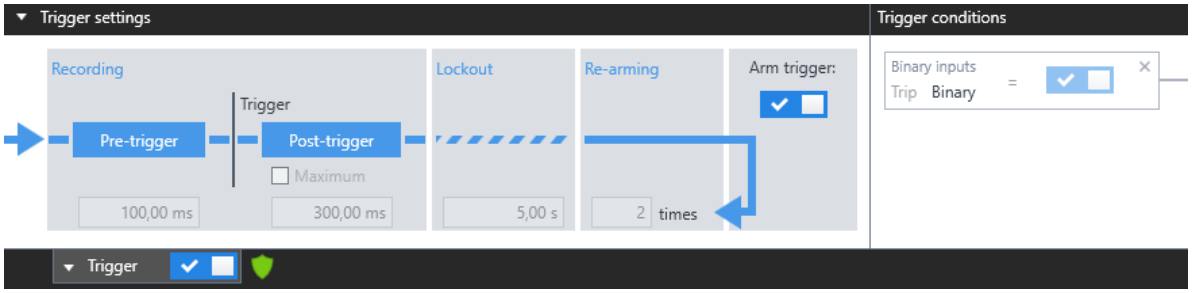
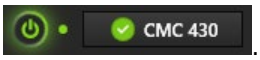


Figure 9: Trigger setting and arming for trip measurement.

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

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6 Test procedure

Exemplarily the test procedure is described for the voltage-based method using a VDS.

6.1 Trip measurement

The test procedure consists of the following steps:

1. Make sure the *EnerLyzer Live* measurement is running and the trigger armed.
2. Make sure the circuit breaker is closed.
3. The VDS must indicate that a line voltage is present.
4. Trip the circuit breaker by manual action (push button or relay interface) or by tripping the relay.
5. The VDS now must indicate that no line voltage is present.
6. Check the recorded measurement in the *EnerLyzer Live* tab *Recordings*.

6.2 Close measurement

The test procedure consists of the following steps:

1. Make sure the *EnerLyzer Live* measurement is running and the trigger armed.
2. Make sure the circuit breaker is open.
3. The VDS must indicate that no line voltage is present.
4. Close the circuit breaker by manual action (push button or relay interface).
5. The VDS now must indicate that a line voltage is present.
6. Check the recorded measurement in the *EnerLyzer Live* tab *Recordings*.

7 Test assessment

In general, the (indirect) timing measurement of the main and auxiliary circuit breaker contacts provides evidence for:

- The operation time of the circuit breaker as defined in IEC 62271-100. The measured values are compared with the manufacturer specifications or previous test protocols.
- The synchronism between the phases should not exceed 1/6th of a cycle of rated frequency for open operation and should not exceed 1/4th of a cycle of rated frequency for a close operation.
- Principle phenomena, as deterioration or abnormalities and also allows a comparison to similar circuit breakers.

7.1 Example: assessment of trip

As an example, the measurement of a trip test in Figure 10 shows:

- Correct behavior of VDS voltage and binary contacts
- A break time of 38 ms
- The trip signal is present for ca. 70 ms
- The auxiliary contacts are delayed compared to the voltage fall of the VDS
    - The time difference from 52a to the main contacts is 3,7 ms
      (Note: Typically, the expected time difference between 52a and the main contacts is expected to be negative for the opening action of a CB.)
    - The time difference from 52b to the main contacts is 6,1 ms
- …

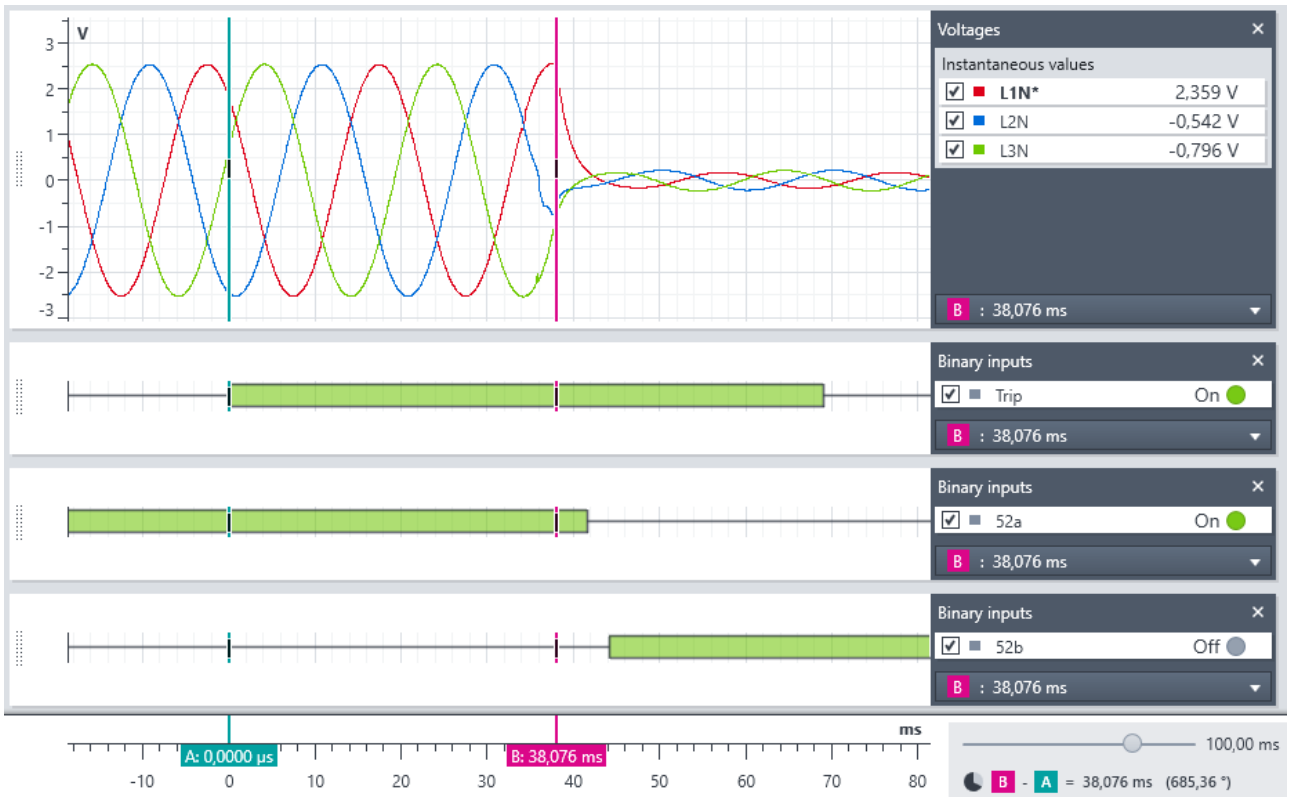

Figure 10: Measurement of trip.

7.2 Example: assessment of close

As an example, the measurement of a close test in Figure 11 shows:

- Correct behavior of VDS voltage and binary contacts
- A make time of 18,3 ms
- The close signal is present for ca. 270 ms (not displayed)
- A bouncing of the auxiliary contact 52a and of the phase voltage L2
- The auxiliary contacts are delayed compared to the voltage fall of the VDS
    - The time difference from 52a to the main contacts is 1,7 ms
    - The time difference from 52b to the main contacts is -0,3 ms
- …

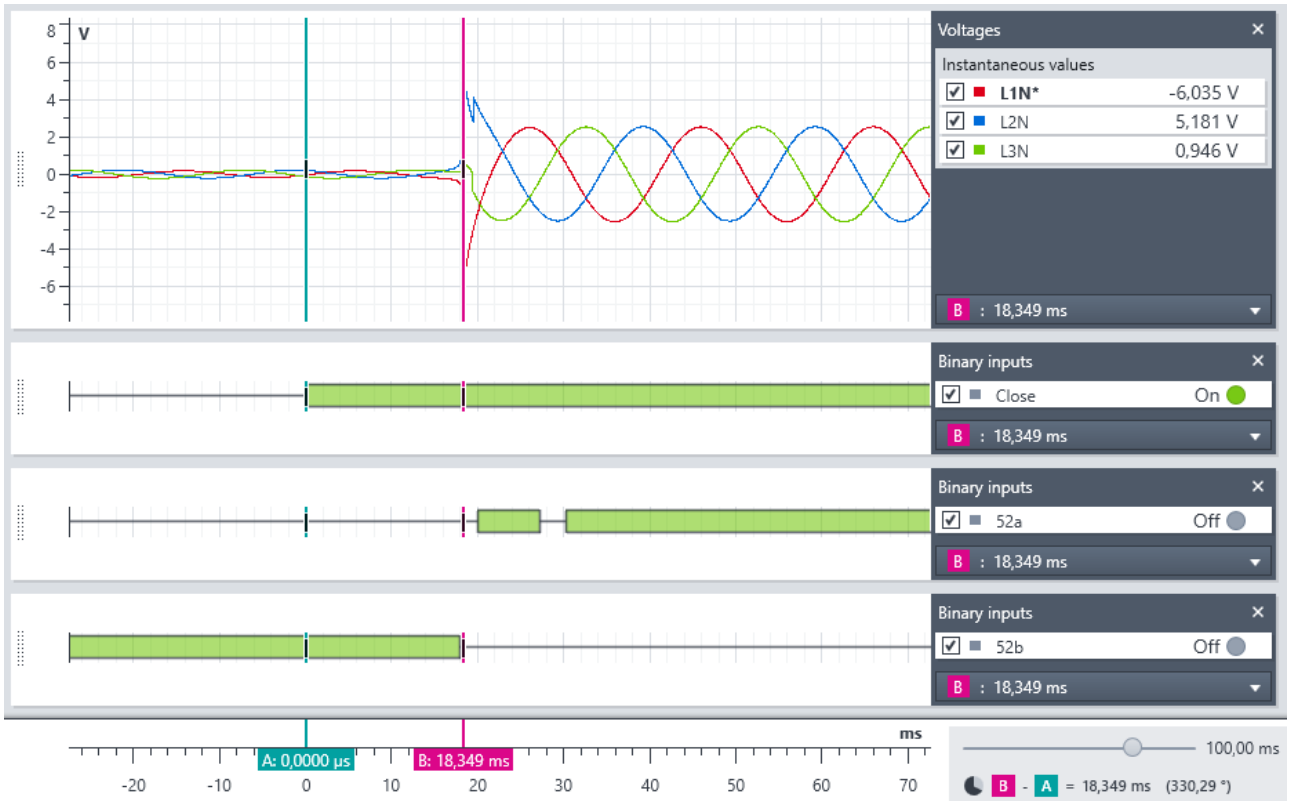

Figure 11: Measurement of close.

8 Further analysis

Utilizing the *EnerLyzer Live* software offers additional options for a further analysis of a circuit breaker. Moreover, the dedicated circuit breaker analysis and testing tool CIBANO 500 is available.

8.1 First trip measurement

First of all, the described methods can easily be performed for a first trip measurement, which describes the tripping of a CB after a long time without switching operation.

Typically, a longer trip time will be measured in a first trip test, e.g. because of dried out lubricant. Nevertheless, the trip time must still be within the tolerance of the setting time of the protection relay.

8.2 Measurement of coil and motor current

Additional to the described method, the measurement of the trip and / or close coil current as well as the motor current with *EnerLyzer Live* allows deeper analysis of a CB's condition.

For this method current clamps are placed around the supply lead of the coils and motor.

The measurement provides information about the supplied current as well as the needed power. From that a conclusion can be drawn, e.g. by comparison to other measurements, if there are any abnormalities.

8.3 CIBANO 500

OMICRON offers with the CIBANO 500 a dedicated switchgear test set which consists of:

- a multi-channel timing and travel analyzer,
- a high accuracy digital micro-ohm meter,
- a powerful coil and motor AC/DC supply.

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