OMICRON

Application Note

Transient Recording and Analysis with EnerLyzer Live – Transformer Inrush, Point-on-Wave Switching, Synchronization, Motor Startup

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Abstract

The recording, understanding, and analysis of typical transient events in the grid helps to avoid damage to equipment, checks the proper function of auxiliary systems and allows exact parameterization of protection relays. This application note describes how *EnerLyzer Live* is used for transient recording and analysis and therefore discusses four examples: transformer inrush, point-on-wave switching, synchronization, and motor startup event.

General information

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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:

- Authorization for working in environments with energy generation, transmission or distribution, and being familiar with the approved operating practices in such environments.
- Familiar with the five safety rules.
- Good knowledge in working with the CMC test sets.

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2 About this application note

2.1 General requirements

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

2.2 What this application note describes

The application note describes how recording and analysis of transient events in the grid can be performed with a CMC 430 and the *EnerLyzer Live* software. Therefore, besides a general description, there are different examples discussed.

It covers the following content:

1. Introduction to **recording and analysis of transient events**
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** and **assessment**
6. Discussion of examples:
    a. Example 1: **Transformer inrush**
    b. Example 2: **Point-on-wave controller switching**
    c. Example 3: **Synchronizing event**
    d. Example 4: **Motor startup**

The application note also mentions testing secondary equipment by playback of transient recordings with Advanced TransPlay **but does not describe** it in detail.

2.3 Template

For all the above-mentioned examples measurement templates with recordings are provided. For the Examples 1, 2, and 4 these can be found in the *EnerLyzer Live* installation folder: **C:\Program Files\OMICRON\EnerLyzer Live\SampleDocuments**.

For Example 3 the measurement template **CMC-AppNote-Transient-Recording-and-Analysis-with-EnerLyzer-Live-2021-ENU_Measurement_Synchronizing_Event** is provided in the .zip-folder of this application note.

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

Typical transient events are happening in the grid under normal operation, for example during:

- Switching of circuit breakers,
- Transformer inrush,
- Motor startup.

Recording, understanding, and deep analysis of these kinds of events help to avoid damage to equipment (e.g., voltage surges in consequence of switching operation), allows exact parameterization of protection relays (e.g., modeling of motor startup characteristic), checks the proper function of auxiliary systems (e.g., point on wave controller for circuit breaker) and guarantees the correct function of protection systems (e.g., harmonic blocking function for transformer inrush).

Different features of *EnerLyzer Live* make the software perfectly suited for transient recording and analysis:

- Numerous different views and visualization options
- High sampling frequency of 40 kHz
- Trigger function for automatic recording
- Live buffer, manual hold, and manual creation of recordings
- Cursors for measurement and analysis
- Display of harmonics and THD
- Export of recordings as COMTRADE or CSV files.

4 System under test

A typical system under test may be a specific asset (transformer, motor, or circuit breaker) or a section of the electrical grid of special interest, as in Figure 1. The primary voltage and /or current of the system under test are measured and converted to secondary values, e.g., through voltage and current transformers.

The secondary measurement quantities must be available for the measurement and recording with *EnerLyzer Live*.

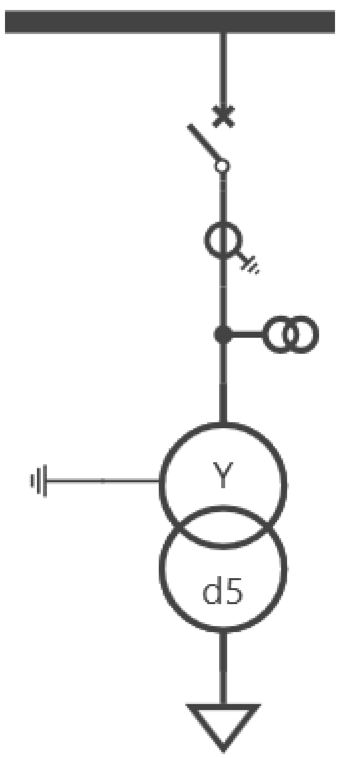

Figure 1: Typical system under test for recording transformer inrush currents.

5 Test setup

5.1 Hardware

The hardware test setup consists of the system under test and a CMC 430. If currents shall be recorded, three current probes are required in addition. Moreover, a device for time synchronization may be included, if the recording shall be synchronized to an external time source.

As the CMC 430 test set is limited to six analog / binary inputs, the OMICRON accessory ISIO 200 may be used to enable additional virtual binary inputs, if needed. The optional ISIO 200 setup is described in chapter 5.2 . (If applicable, in an IEC 61850 environment, another option would be to do a digital or hybrid measurement with GOOSE and Sampled Values.)

The general wiring of the test setup consists of the following signals:

- Voltage measurement
- Current measurement via current probes
- Binary signals (e.g., trip, close signal of circuit breaker).

Exemplarily the wiring for recording a transformer inrush event is shown in Figure 2.

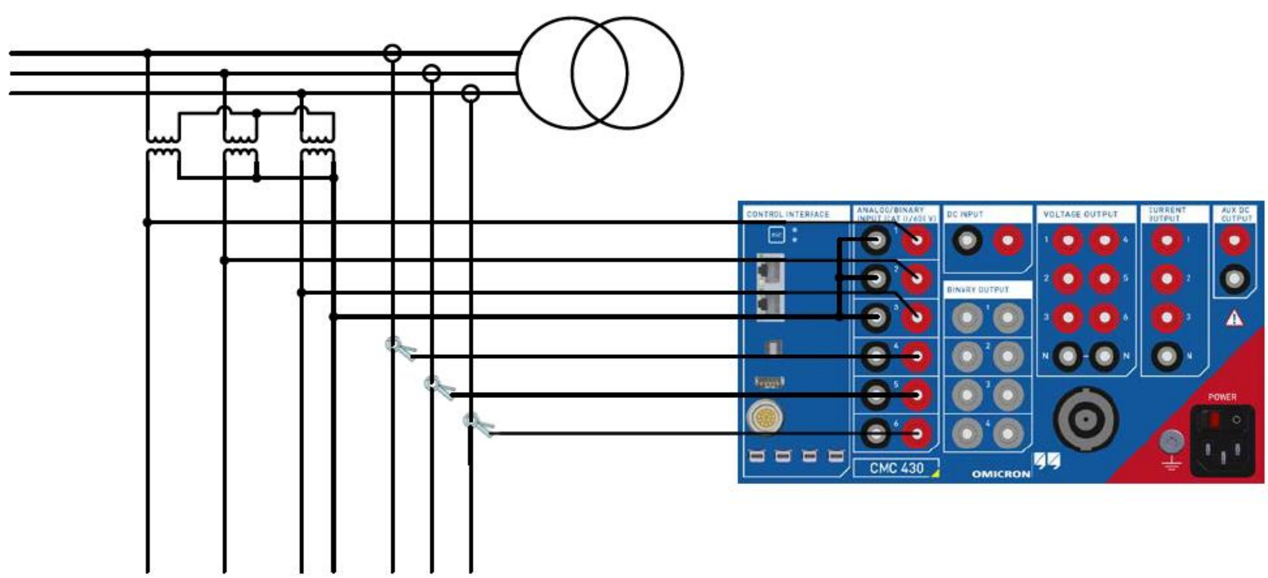

Figure 2: Wiring for recording a transformer inrush event.

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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, one must 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 4:

      i. Voltage measurement

      ii. Current measurement

   c. Configuration of the analog measurement inputs by setting the according *Range* and, for current inputs only, the correct kind of *Physical input*, as shown in Figure 3:

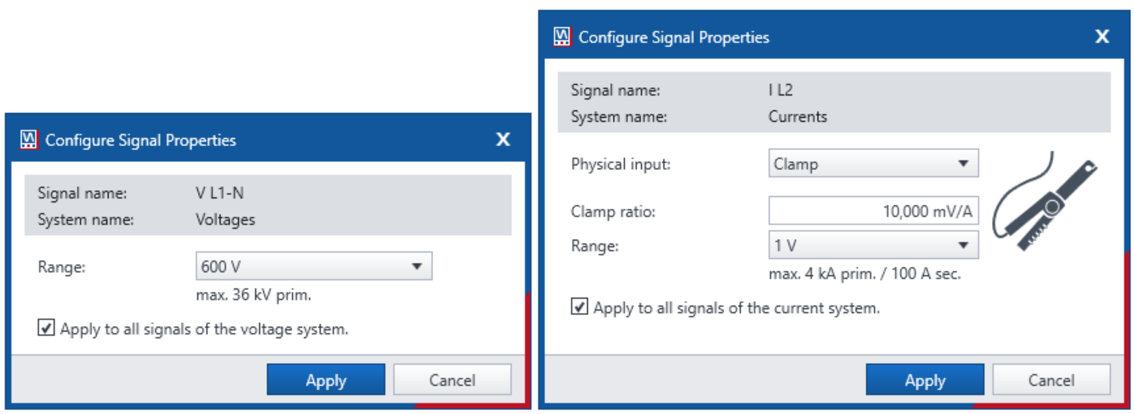

Figure 3: Configuration of analog measurement inputs for voltage (left) and current (right).

   d. For the correct conversion of primary and secondary values, the ratios of VTs / CTs must be entered into the respective field, see Figure 4.

   e. Optional: Connection of binary inputs.

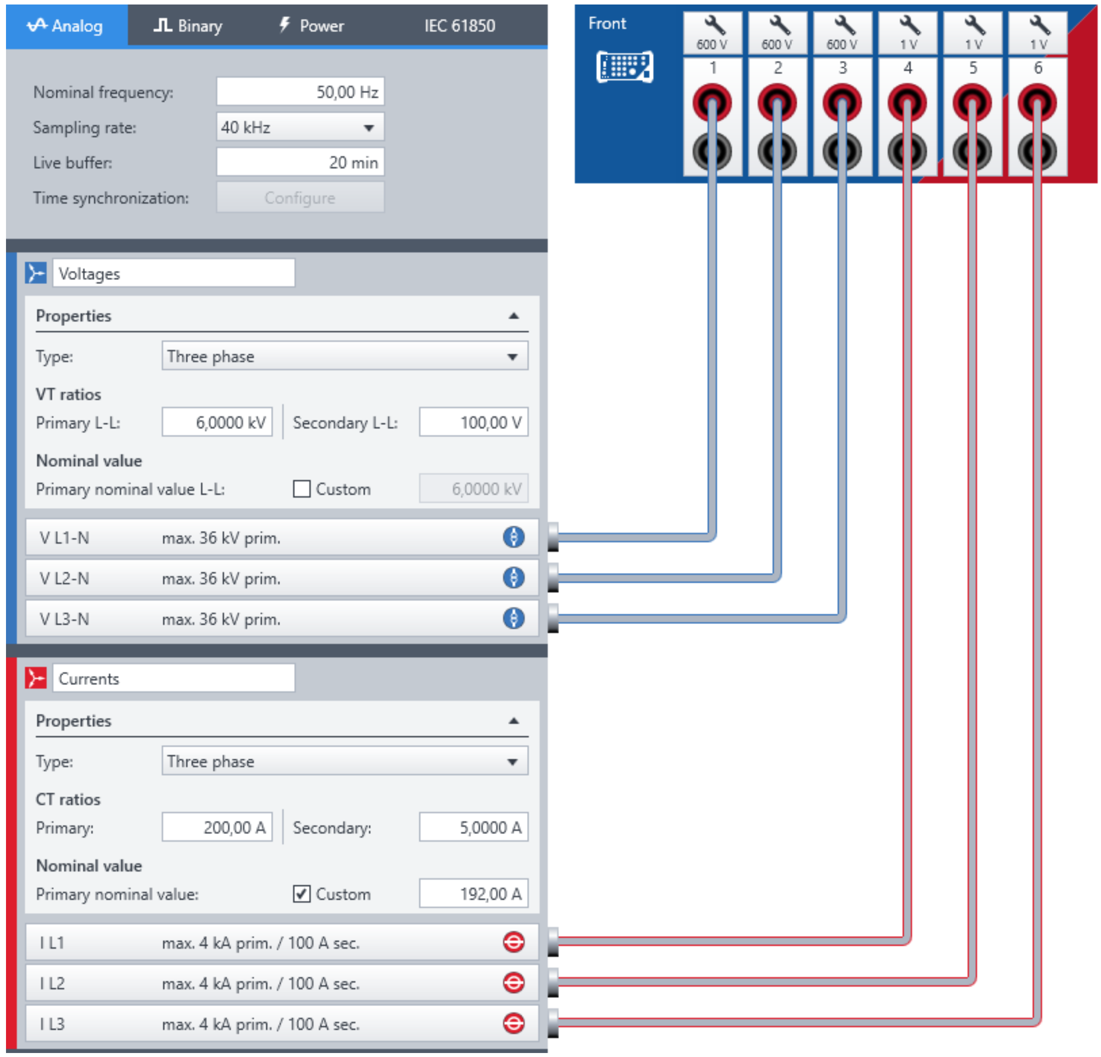

Figure 4: Test set configuration and analog measurement settings.

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 5, enables the automated recording.

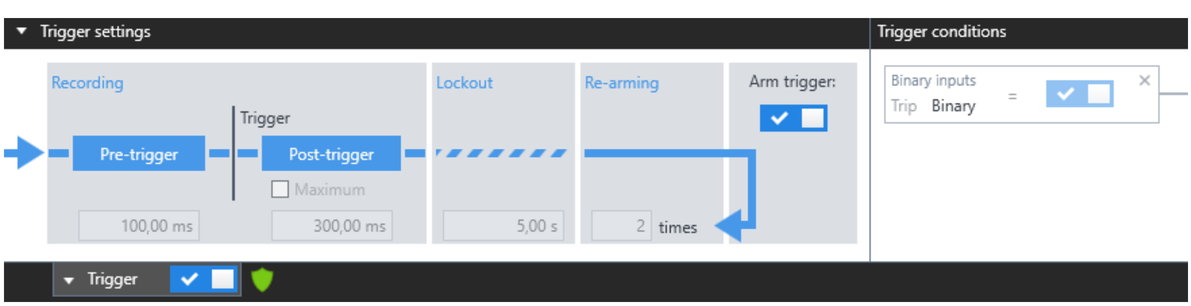

Figure 5: Trigger setting and arming for trip signal.

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

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Optional: OMICRON ISIO 200 setup

An OMICRON ISIO 200 accessory extends a CMC test setup by additional binary inputs/outputs. Therefore, it does a conversion between binary input/output signals and IEC 61850 GOOSE messages.

To use an ISIO 200 as additional virtual binary inputs in *EnerLyzer Live* do the following steps:

A. In the web interface of ISIO 200: Select the *Generic IO terminal model*

B. In the *ISIO Connect* software (accessible via the *Test Universe* start page), as shown in Figure 6:

   1. Enter the serial number of the ISIO 200
   2. Select the ethernet port (ETH1 / ETH2) of the CMC 430, where the ISIO 200 is connected to
   3. Apply configuration

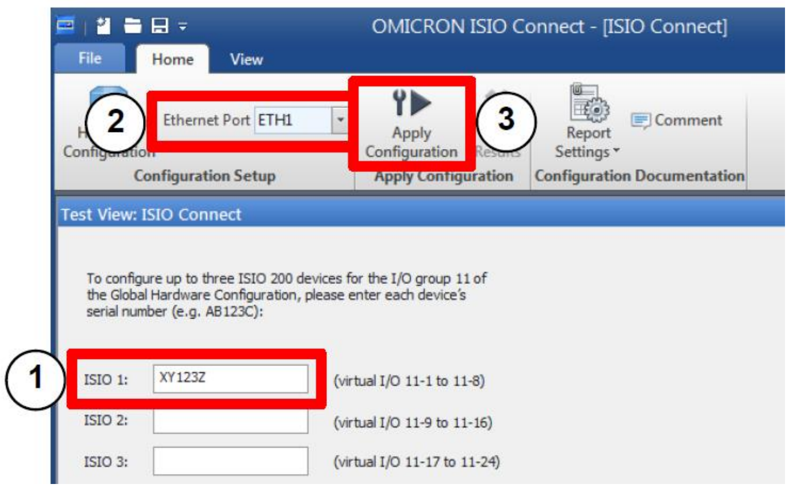

Figure 6: *ISIO Connect* configuration.

C. In the *EnerLyzer Live Test set configuration* (as in Figure 7):

   1. Go to the *GOOSE* tab via the *IEC 61850* tab
   2. *Add GOOSE virtual binary input*
   3. Set *Group* to *Virtual 11* and enter an appropriate name for the binary input.

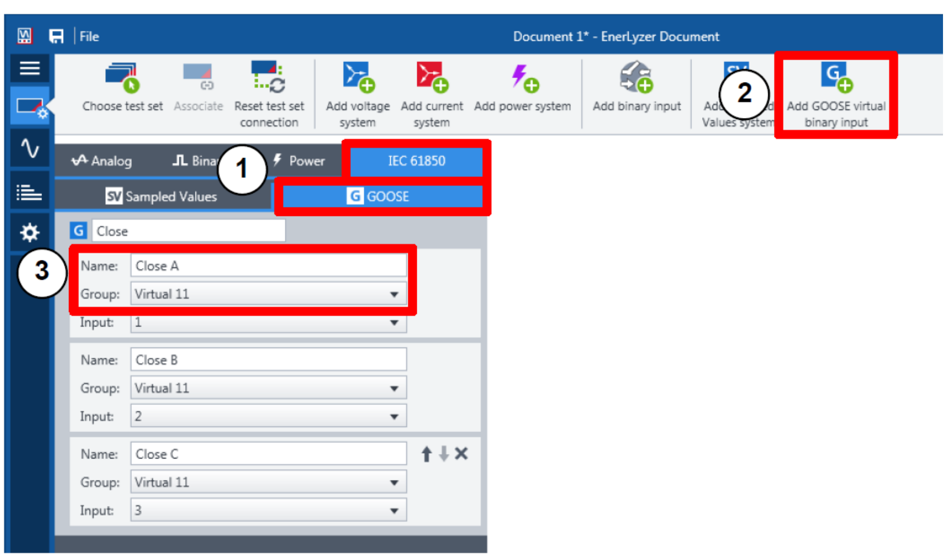

Figure 7: *Test set configuration* for virtual binary inputs.

6 Measurement procedure

The test procedure consists of the following steps:

1. Make sure the *EnerLyzer Live* measurement is running.
2. If necessary:
    a. Make sure the time synchronization is working
    b. Make sure the trigger settings are correct and active.
3. Wait until the event to be recorded has happened.
4. Check the automated (triggered) recording or manually *Hold live data* and *Create recording*.
5. Use the provided tools of EnerLyzer Live for analysis (measurement cursors, harmonic spectrum, …).

7 Practical examples

For the practical Examples 1, 2, and 4 measurement templates with recordings are provided in the *EnerLyzer Live* installation folder: **C:\Program Files\OMICRON\EnerLyzer Live\SampleDocuments**.

7.1 Example 1: Transformer inrush event

7.1.1 Test setup

Do the test setup (hardware and software) according to chapter 5 .

For a transformer inrush event the three-phase voltages and currents shall be recorded, any binary signals are optional. The wiring diagram is shown in Figure 8.

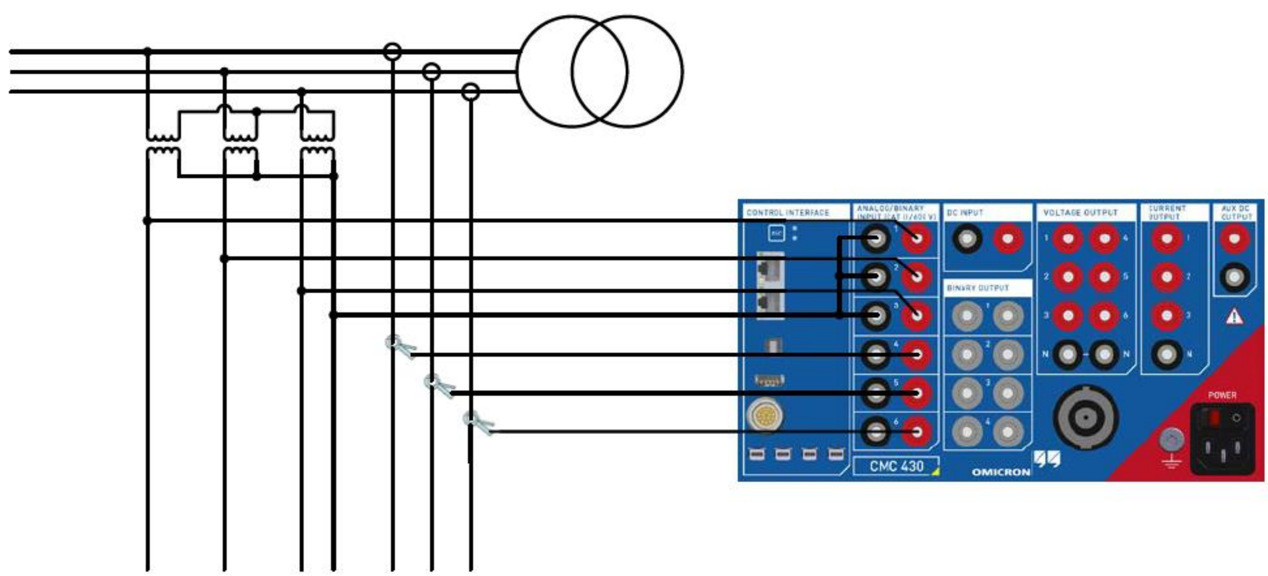

Figure 8: Wiring for recording a transformer inrush event.

Set an appropriate trigger condition for automatic recording. A suitable trigger for this measurement would be, that the recording starts, as soon as at least one of the phase currents exceeds a certain limit, as in Figure 9.

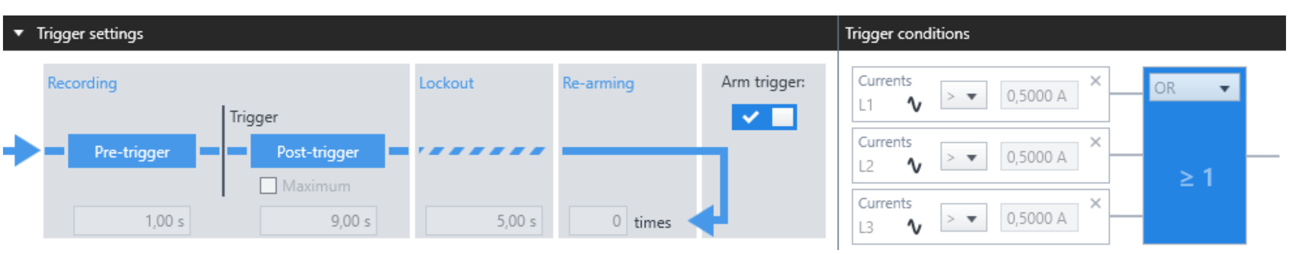

Figure 9: Example for trigger setting for transformer inrush recording.

7.1.2 Measurement procedure

Follow the described test procedure in chapter 6 .

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7.1.3 Measurement assessment

As an example, the recording of a transformer inrush event in Figure 10 shows:

- Characteristic time signal for inrush event
- Almost no impact on busbar voltage
- Asymmetric event: on phases L1 and L2 almost equal current and on phase 3 less current
- On phases L1 and L2 highest absolute magnitude of second harmonic [A]
- On phase L3 highest relative magnitude of second harmonic [%]
- …

Figure 10: Recording of transformer inrush event.

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7.2 Example 2: Point-on-wave controller switching event

7.2.1 Test setup

Do the test setup (hardware and software) according to chapter 5 .

For a point-on-wave controlled switching event, the three-phase voltages and currents shall be recorded. Additionally, for each phase the binary signal for closing (or opening) the circuit breaker is required.

As the CMC 430 test set is limited to six analog / binary inputs, the OMICRON accessory ISIO 200 is used to enable additional virtual binary inputs. (If applicable, in an IEC 61850 environment, another option would be to do a digital or hybrid measurement with GOOSE and Sampled Values.)

Set an appropriate trigger condition for automatic recording. A suitable trigger for this measurement would be, that the recording starts, as soon as at least one of the binary close signals becomes active, as in Figure 11.

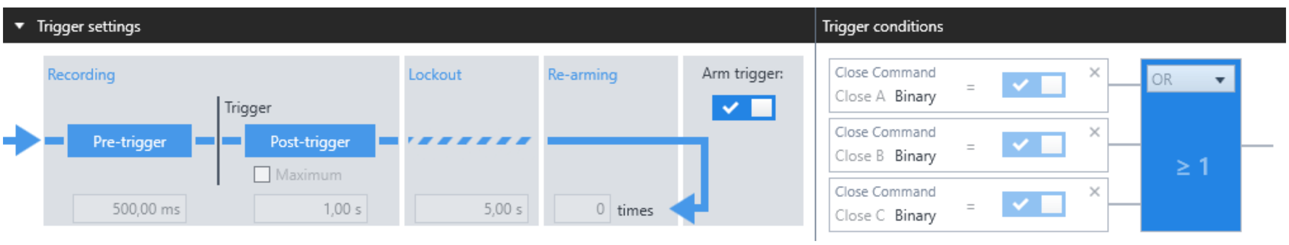

Figure 11: Example for trigger setting for point-on-wave controlled switching event recording.

7.2.2 Measurement procedure

Follow the described test procedure in chapter 6 .

7.2.3 Measurement assessment

As an example, the recording of a point-on-wave controlled switching event in Figure 12 shows:

- Characteristic signals for point-on-wave controlled switching event
  - Voltage notches as minor impact on busbar voltage
  - Successive current rise in every phase after effective close of particular circuit breaker pole
  - Successive close commands for all three phases
- Time between zero crossing of voltage and current rise as inaccuracy of the switching operation:
  - For phase A: 862,6 µs
  - For phase B: 871,4 µs
  - …
- Correct function of the point-on-wave controller

Figure 12: Recording of point-on-wave controlled switching event.

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7.3 Example 3: Synchronizing event

For this example, the measurement template **CMC-AppNote-Transient-Recording-and-Analysis-with-EnerLyzer-Live-2021-ENU_Measurement_Synchronizing_Event** is provided in the .zip-folder of the application note.

7.3.1 Test setup

Do the test setup (hardware and software) according to chapter 5 .

For a synchronizing event (or synchro-check) at least on phase of each voltage system shall be recorded. Additionally, the following binary signals coming from the paralleling device are required:

- V < (decrease voltage),
- V > (increase voltage),
- f < (decrease frequency),
- f > (increase frequency) and
- Close (close the circuit breaker).

Moreover, the binary commands for the synchronizer must be wired:

- Start (start synchronization) and
- Stop (stop synchronization).

As the CMC 430 test set is limited to six analog / binary inputs, the OMICRON accessory ISIO 200 is used to enable additional virtual binary inputs. (If applicable, in an IEC 61850 environment, another option would be to do a digital or hybrid measurement with GOOSE and Sampled Values.)

Set an appropriate trigger condition for automatic recording. A suitable trigger for this measurement would be, that the recording starts, as soon as the binary *Start* signal becomes active, as in Figure 13.

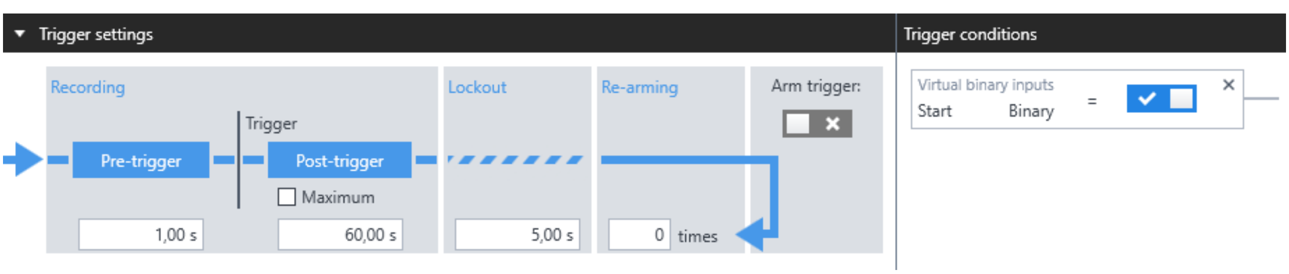

Figure 13: Example for trigger setting for synchronizing event recording.

7.3.2 Measurement procedure

Follow the described test procedure in chapter 6 .

7.3.3 Measurement assessment

As an example, the recording of synchronizing event in Figure 14 shows:

- Characteristic signals for synchronizing event
  - Voltage magnitude of second system is successively adjusted to voltage of first system
  - Frequency of second system is successively adjusted to frequency of first system
  - Phase angle of second system rotates from 0 to 360° relative to first system
- Characteristic binary traces for synchronizing event
- Successful synchronization
- Correct function of the synchronizer / paralleling device

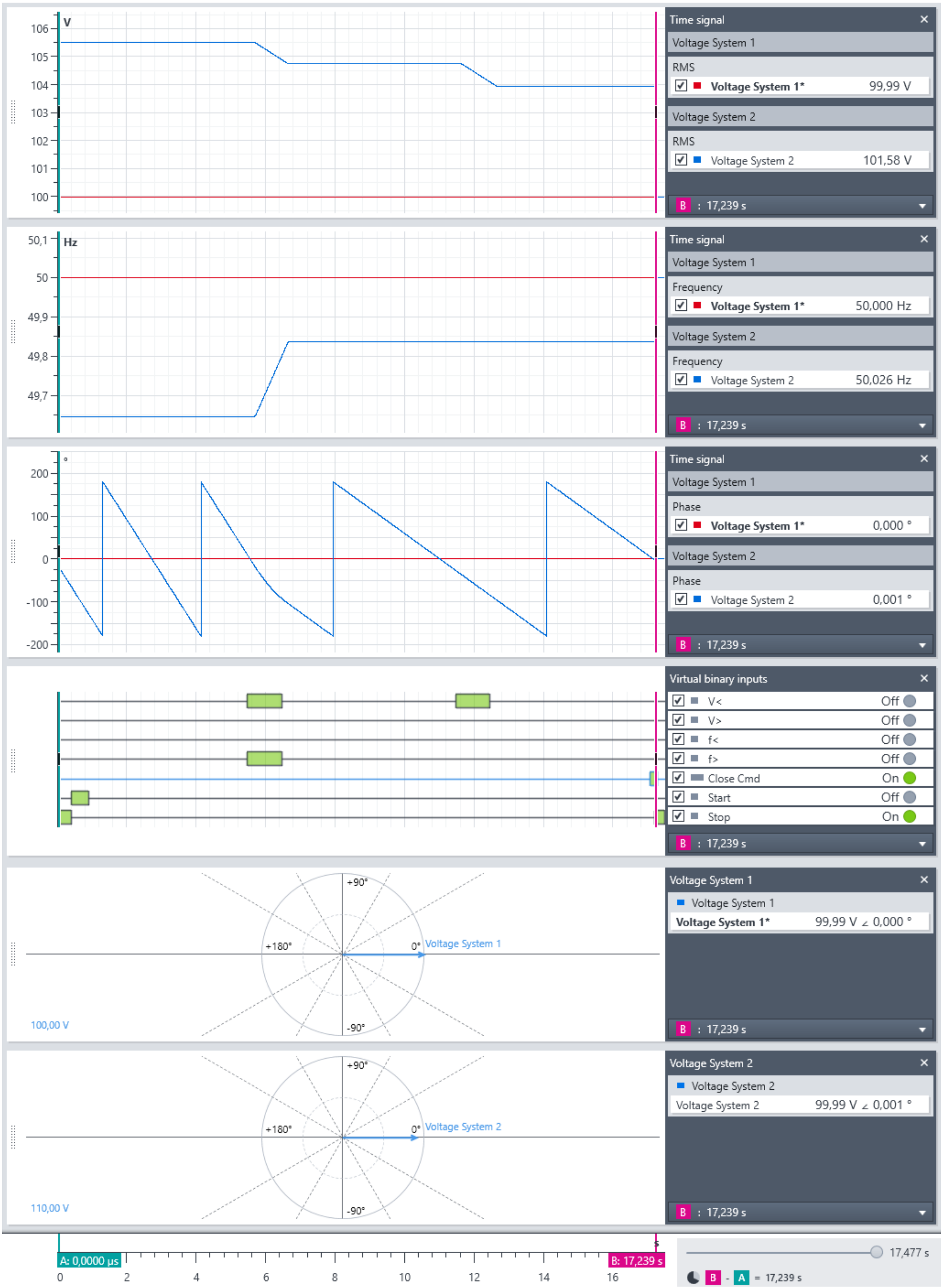

Figure 14: Recording of synchronizing event.

7.4 Example 4: Motor startup event

7.4.1 Test setup

Do the test setup (hardware and software) according to chapter 5 .

For a motor startup event the three-phase voltages and currents shall be recorded, any binary signals are optional. The wiring diagram is shown in Figure 15.

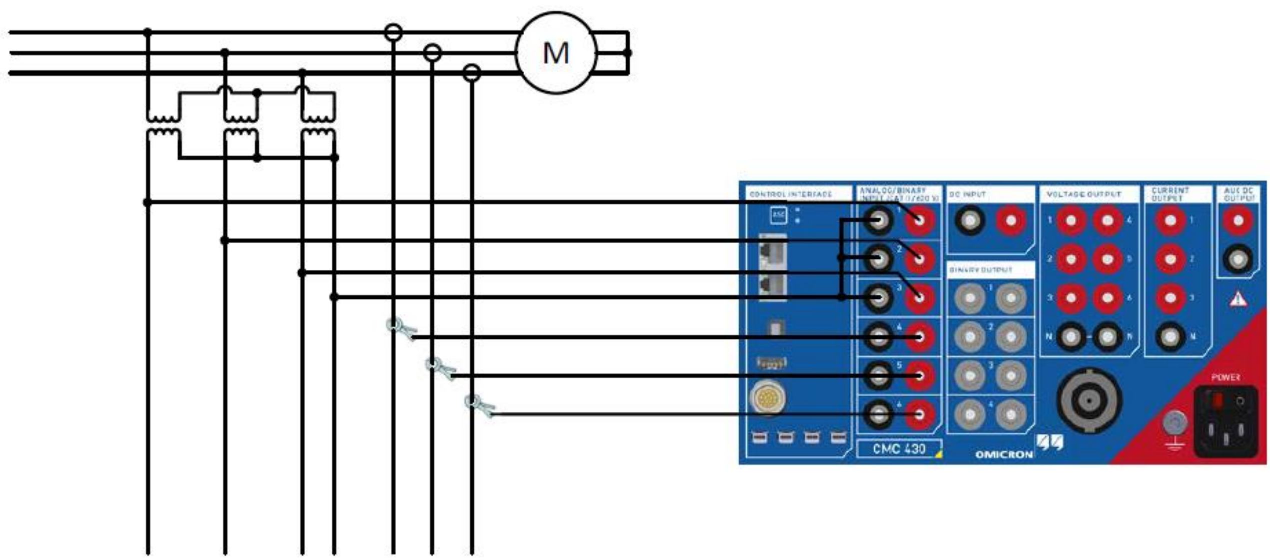

Figure 15: Wiring for recording a motor startup event.

Set an appropriate trigger condition for automatic recording. A suitable trigger for this measurement would be, that the recording starts, as soon as at least one of the phase currents exceeds a certain limit, as in Figure 16.

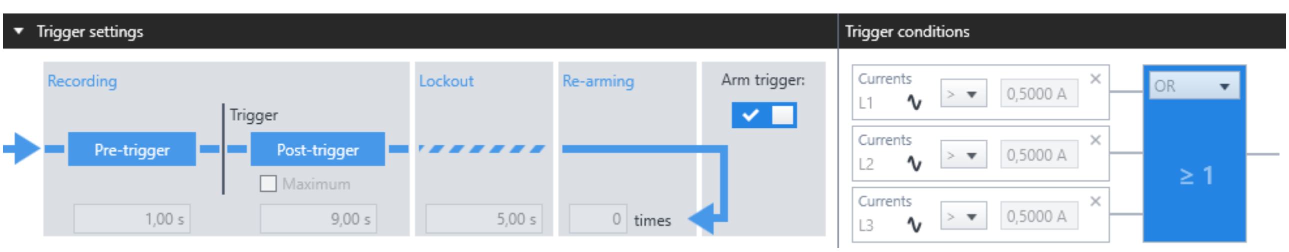

Figure 16: Example for trigger setting for motor startup recording.

7.4.2 Measurement procedure

Follow the described test procedure in chapter 6 .

7.4.3 Measurement assessment

As an example, the measurement of a motor startup event in Figure 17 shows:

- Characteristic time signal for motor startup event
- Significant drop of busbar voltage of about 0,4 kV and recovery after motor startup
- Duration of motor startup about 6 s
- Startup current is a multiple of the nominal current
- …

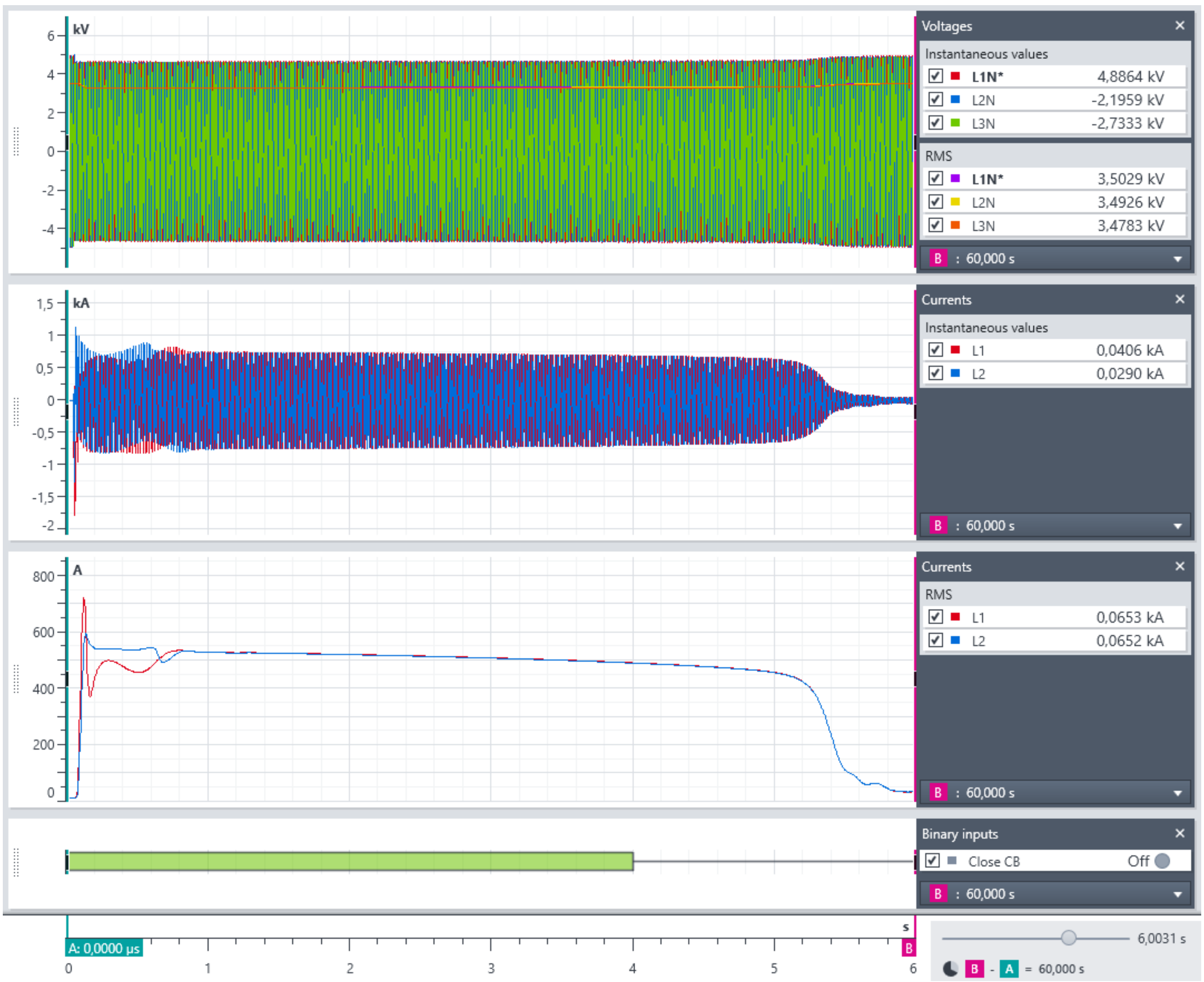

Figure 17: Recording of motor startup event.

8 Further Analysis

In further steps, the recordings of transient events in the grid may be used for various purposes.

8.1 Detect anomalies

Already the initial recording of an event helps to detect anomalies, e.g., between the three phases and therefore can be an indicator for malfunction. Moreover, this first measurement may be used as a fingerprint for future recordings and analysis. By doing this, any deviation or deterioration over time can easily be discovered and monitored.

8.2 Verify parametrization of protection relay

Recordings and their exported COMTRADE files may be used for testing protection systems. Therefore, these recordings are played back, e.g., with TransPlay or Advanced TransPlay, and injected into protection relays. By doing this, the expected and correct behavior of a protection relay can be tested.

8.3 Determine parameters for protection relay

Based on the recordings of transient events important parameters for protection systems can be determined. For example, from the measurement of a motor startup event, the crucial parameters for a motor overcurrent protection relay can be identified, as shown in Figure 18.

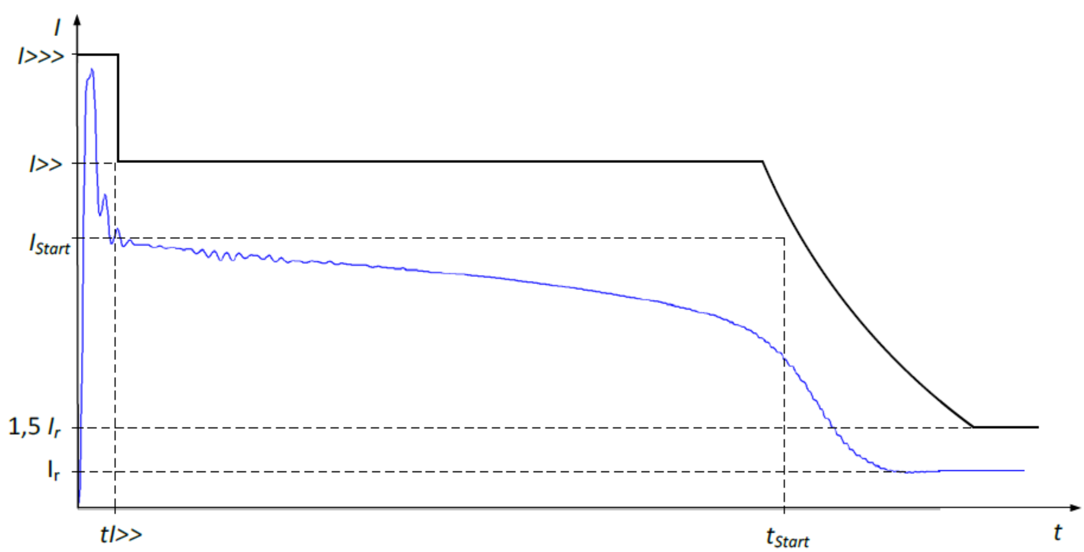

Figure 18: Determine parameters for overcurrent protection relay from motor startup event recording.

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