



ABSTRACT

Current transformers are the link between the primary and the secondary system and are therefore essential components of the electrical energy system. Their commissioning is an important phase of evaluating their proper functionality. Nowadays, the time available for testing is continuously decreasing. Moreover, it should be considered how the transformers and the protection system can be adequately tested within a reasonable timeframe. This paper discusses how a test plan for commissioning or refurbishing a substation might look.

KEYWORDS:

commissioning, CT analyzer, current transformers, measurement methods, tests

Commissioning of current transformers

Commissioning and site acceptance tests

Some checks of the transformer are part of the acceptance and commissioning test procedures and are useful to detect transport and installation errors.

Winding resistance

The winding-resistance measurement is a well-established method for detecting shorted turns or open circuits in the windings of a current transformer. It works by injecting a DC current while the resulting voltage

drop is measured across the winding. As the core shows inductive behavior, it is important to have both current and voltage stabilized before taking the measurement. The resistance during the measurement over time will look as indicated in Fig. 1. A stable winding resistance can then be read once the resistance deviation over time has settled below a defined threshold [2].

The DC-winding resistance is then calculated by Formula 1.

$$R_{DC} = \frac{V_{DC}}{I_{DC}} \quad (1)$$

In terms of assessing the test results, one can compare the on-site resistance reading with either reference results from the factory or with current transformers from the other two phases (same class ratings). It is important to correct the measured resistance (R_{meas}) measured at ambient temperature (T_{meas}) in temperature [2].

Typically, a reference temperature of 75 °C (T_{ref}) is used when comparing results [5].

$$R_{ref} = R_{meas} * \frac{235 + T_{ref}}{235 + T_{meas}} \quad (2)$$

Turns-ratio measurement

The turns-ratio measurement is a suitable method for detecting shorted turns. On current transformers, two methods exist: Either a test current is injected on the primary side of the current transformer, and the current is measured back on the secondary side. Or, a test voltage is applied on the secondary winding, and the resulting induced voltage is measured on the primary side [2].

Modern equipment can provide a very accurate voltage and current measurement to identify outliers or even provide a model-based assessment of the CT or VT performance precisely at the operating burden.

Knee point

A measurement of the knee point of each current transformer is useful to check whether each core is installed in the correct place. By comparing the knee-point voltages to the factory values and in between the installed cores, it is possible to find potential situations where metering and protection cores have been mixed up [1].

Who decides what has to be tested and how?

To ensure consistency in testing quality and comparability, the scope of the test and how it is to be carried out should be laid down by the plant operator in a policy document and monitored accordingly. If the plant operator does not already have such a policy, then industrial standards, such as the IEC 61869-2, and guidelines provided by industry associ-

The winding-resistance measurement is a well-established method for detecting shorted turns or open circuits in the windings, and it is one of the first measurements conducted in the commissioning process

ations, such as the Forum Netztechnik Netzbetrieb (FNN) in Germany can be a useful starting point.

As an example, the FNN guideline covers the use of protection systems in electrical networks and contains recommendations concerning how transformers can be tested during commissioning [1]:

- Comparison of the data on the rating plate with the required values
- Insulation test to demonstrate that the insulation values of the individual cores to the ground and each other are being maintained
- Checking the wiring and ratio of the individual current transformer cores, ideally by a primary injection test of the transformer
- Checking the winding direction in cases where examination of the factory test report provided by the transformer manufacturer is not possible
- Measurement of the operating burden
- Measurement of the internal burden, if unknown.

This testing proposal for current transformers and their circuits complies with the recommendations of the FNN. These are recognized as state-of-the-art, so in the event of a fault, provide the tester with a certain degree of legal security [1].

Proposed test sequence for a current transformer

The information on the rating plate is important as it is used in all test reports to identify the test object. Incorrectly installed transformers can be readily identified by comparing the data on the rating plate with the circuit diagrams or plant drawings. This is also a good moment to compare the installation orientation of the current transformer (direction P1 and P2) with the single-phase wiring diagram. If a current transformer with multiple primary ratios needs to be tested, the configuration should also be checked before carrying out any measurements [1].

It is also recommended to use an injection of asymmetric current values (cf. Fig. 2),

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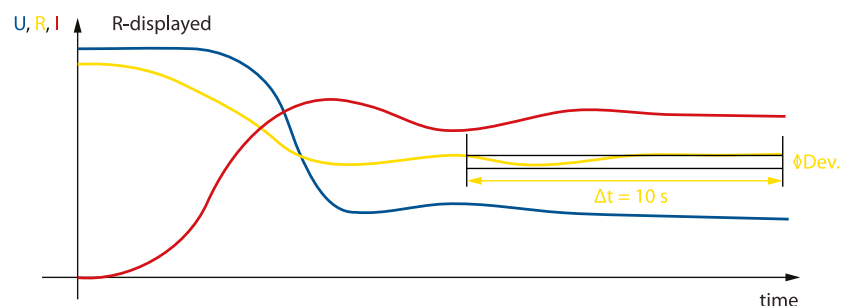


Figure 1. Winding resistance profile over time

Industrial standards, such as the IEC 61869-2, and guidelines provided by industry associations, such as the Forum Netztechnik Netzbetrieb (FNN) in Germany, can be a useful starting point for commissioning

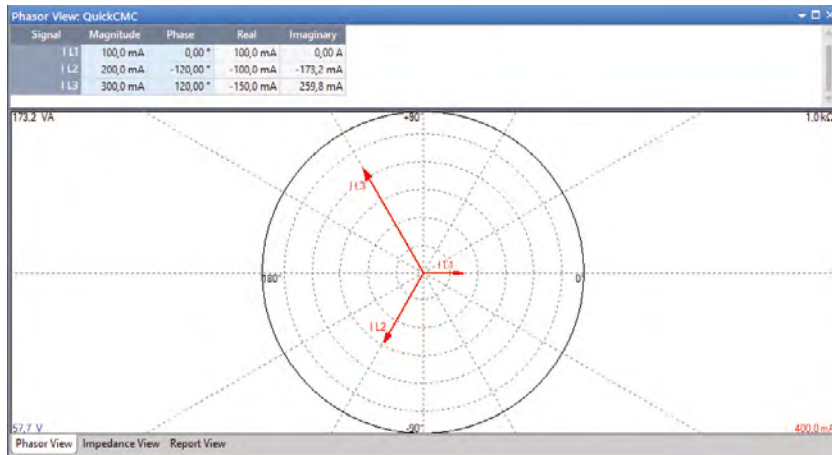


Fig. 2: Asymmetric injection with the QuickCMC of OMICRON's Test Universe

for example, 100 mA, 200 mA, and 300 mA, using a three-phase test device (e.g., a protection test set) to ensure that the wiring from the transformer terminal box to the protection device is correct. The values can be checked on the display or by using a current probe on the protection device [1].

The insulation measurement is carried out as described in the FNN recommendations. The insulation resistance is measured using an insulation tester at 1000 VDC for a maximum of 10 seconds per core or line. The insulation of the cores is measured against the ground (the secondary grounding on the transformer cores has to be removed in order to do this), and all the cores are measured against each other. In addition, the secondary wiring should also be measured to check that its insulation resistance is adequate. An insulation resistance value of above 100 MΩ can be considered good. The cores and the cables can become

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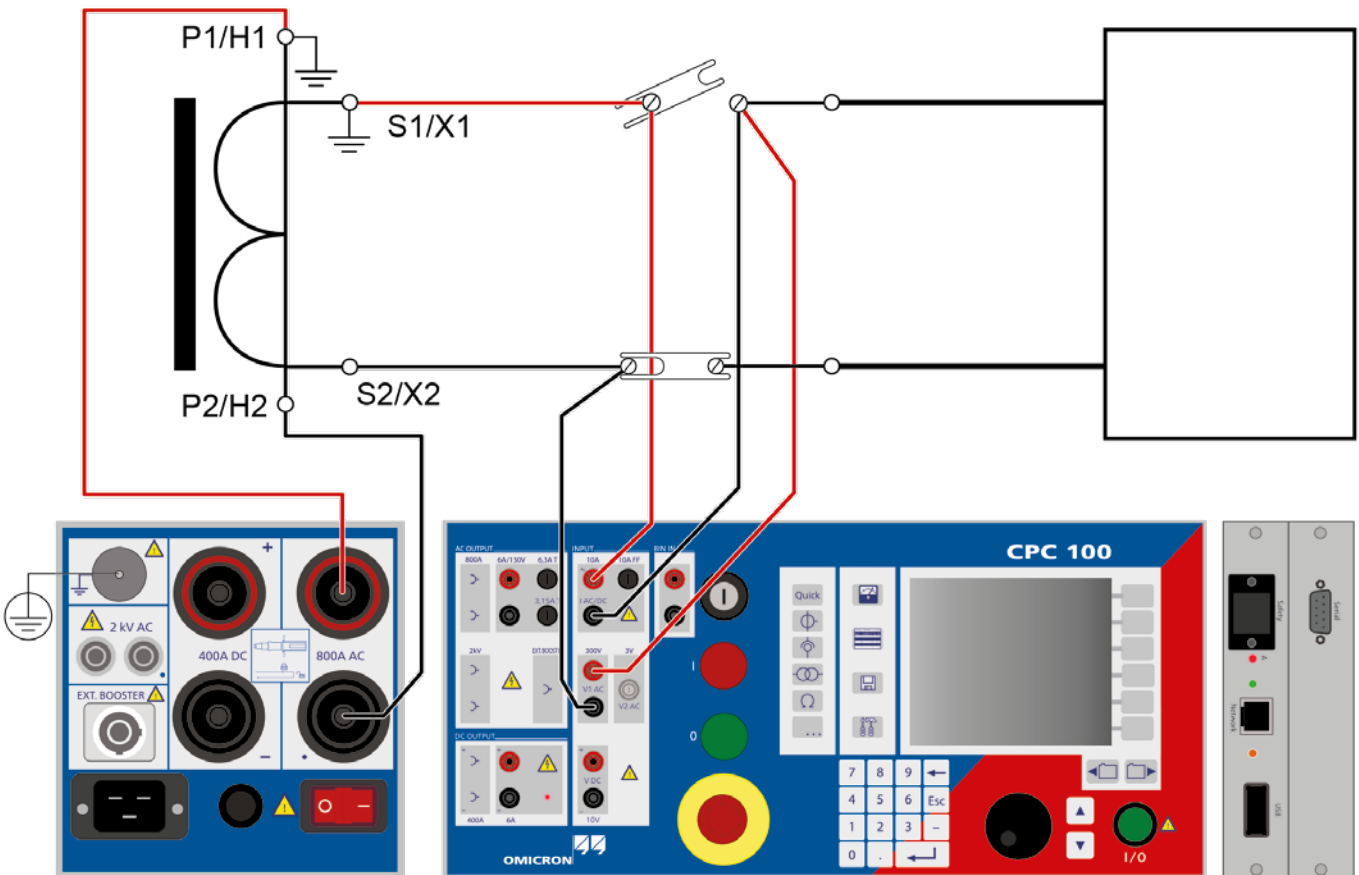


Figure 3. Testing of ratio and operating burden via primary injection

charged following the measurement, so they should be grounded briefly. Checking the transformation ratio, the winding direction, operating burden, and internal burden can be carried out through a primary injection (for example, using OMICRON's CPC 100) as well as a secondary injection [1].

For the test involving a primary injection, the test of ratio, winding direction, and operating burden can be performed in a single step via primary injection, as depicted in Fig. 3.

The test involving a secondary injection (for example, with CT Analyzer from OMICRON) is carried out in two stages. Firstly, a measurement is taken on the burden side of the secondary circuit (Fig. 4).

In the second stage, the transformer side of the secondary circuit has to be rewired (Fig. 5).

Using the CT Analyzer can reduce the testing time to around 5 minutes per core. A further advantage of using the CT Analyzer to carry out this test is

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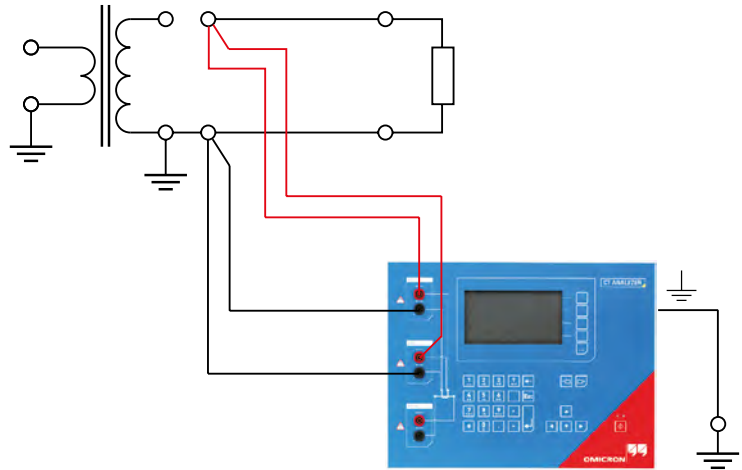


Figure 4. Connection diagram for measurement of operating burden

Equipment designed for the CT commissioning is the CT analyzer, and its use can reduce the testing time to around 5 minutes per core

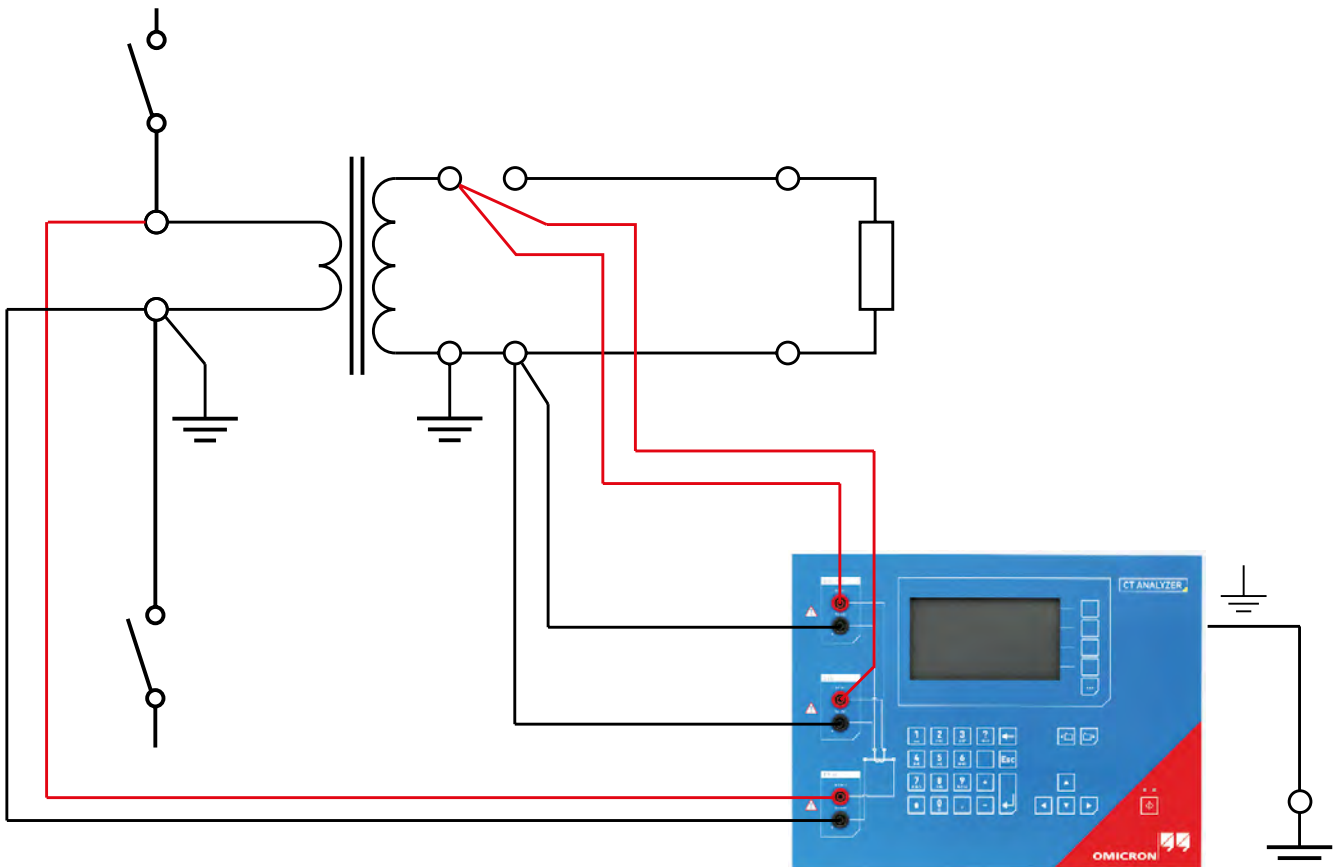


Figure 5. Connection diagram for transformer measurement

Another advantage of using the integrated approach of CT Analyzer is that a demagnetization is inherent in the test sequence

automatic evaluation in the test report, assuming that all the required data from the rating plate are entered in the test template of the CT Analyzer [1].

Demagnetization

Another advantage of using the integrated approach of CT Analyzer is that a demagnetization is inherent in the test sequence. DC measurements, such as winding-resistance measurements, can saturate the

core, so it is important that the demagnetization is not forgotten [4].

Evaluating the results of the current transformer test

The evaluation involves comparing the measured values with those specified in the corresponding standard. The tester should look at the results and carry out a cross-check on a similar core from a different phase or bay. Measuring the mag-

netization characteristic is a simple way of demonstrating that the core assignment is correct [1].

After the test - final checks

After completing the test, all the grounds must be reconnected, and the electrical circuits closed again. To check this, another primary injection at about 50 % of the nominal current should be carried out, and the display referred to in order to monitor the measured values for every installed device. Using a polarity checker and injecting a square-wave signal with the same measuring configuration and primary injection, it's then a simple matter to locate any wiring faults as far as the protection device is concerned. In contrast to the old, conventional battery method, the advantage of using a square-wave signal is that it prevents saturation of the current transformer [1].

Creating the final documentation

Time and overhead costs to create the final documentation can be saved by using preformatted test reports. In addition, these automatically-generated test reports simplify the evaluation and documentation of the test and help identify problems and anomalies [1].

Most frequently, these problems are found during commissioning:

- Wiring faults (phases swapped)
- Multiple grounding of the electrical circuits
- Insulation faults due to incorrectly laid cables (cutting into the individual cores)
- Overloading of the protection circuits
- Incorrect installation orientation of the current transformer or individual transformer cores
- Connection of measuring instruments to protection transformer cores and vice versa.

Summary

We have presented some ideas on how a consistent test quality and level of documentation can be achieved without taking too much time during the commissioning test. This test plan is put forward as a recommendation and invitation to discuss alternative proposals.



Figure 6. Measuring configuration of the CT Analyzer in the field

The CPC 100 injects a special polarity check signal

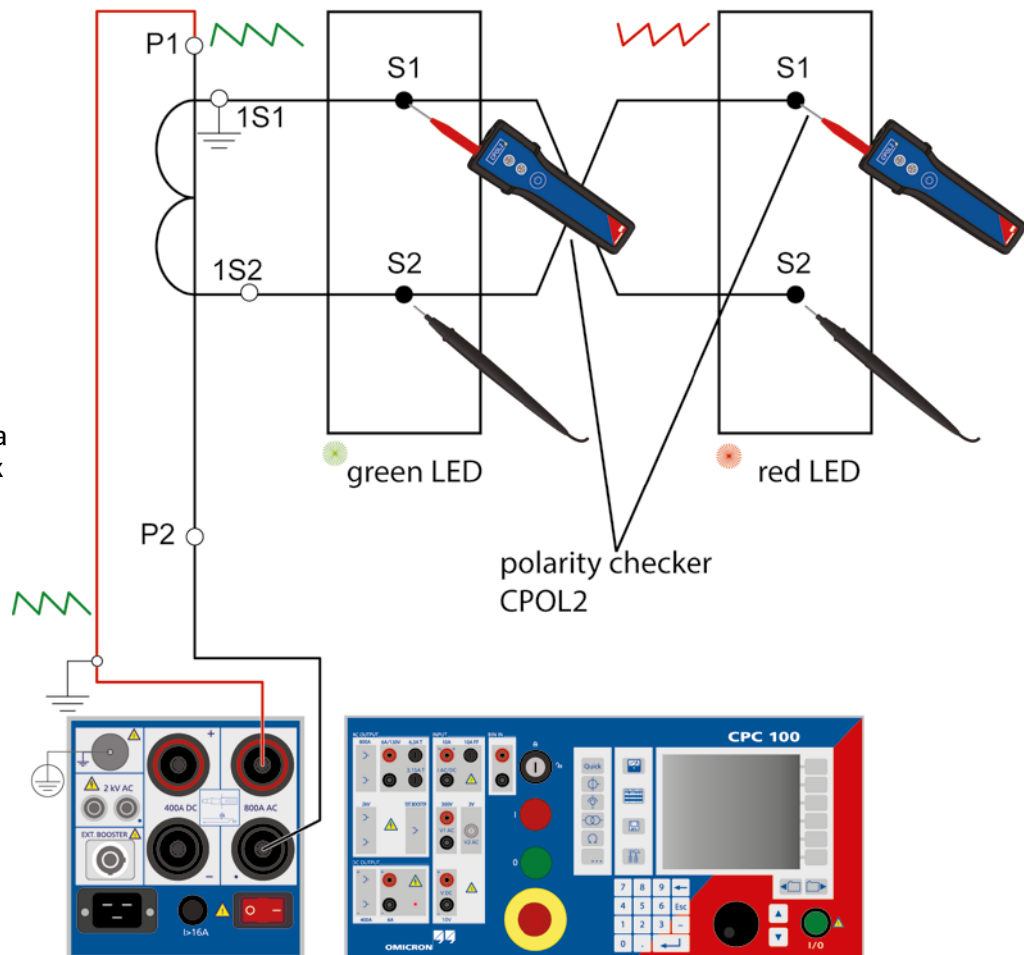


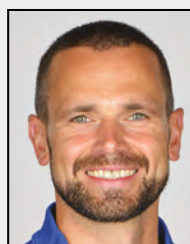
Figure 7. Wiring testing with the CPOL2

Automatically-generated test reports simplify the evaluation and documentation of the test and help identify problems and anomalies

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