Measuring-Network of Wind Energy Institutes

Calibration Procedure for Transducers

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1 Scope

This document presents a calibration procedure for the measurement devices/transducers used in electrical characteristics test campaigns on wind turbines according to the standard IEC 61400-21-1 [3]. If applicable it can be used also for other standards for the measurement of electrical characteristics.

Calibration of transducers is required for:

- All kind of measurements for the fundamental frequency
- Measurement of harmonic currents and voltages in the frequency range above fundamental until 9 kHz. However, the mandatory measurements according to IEC 61400-21-1 do not cover voltage harmonics. The voltage harmonics are only important for investigations of the background noise, as given in Annex D of this standard. Thus, without any information or calibration of the voltage harmonics it will not be possible to follow these specific measurement procedures of the Annex D.

The existing types of transducers used on those measurements, to which the calibration procedure is relevant, are:

- For current measurements, generally Rogowski coils are used. They are considered as active transducers.
- For voltage measurements, electronic voltage transducers, voltage transformers and directly the data acquisition are used. They could be active or passive transducers.

For carrying out an appropriate calibration, the following factors have been taken into account, since accuracy is affected:

- Positioning of the current transducers including the angle of the positioning and deformation. Rogowski coils are sensitive to the position of the conductor within the measurement window
- Load of the transducer

2 Reference Standards

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[1] ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*
[2] ISO/IEC Guide 98-3:2008, *Uncertainty of Measurement-Part 3: Guide to the expression of uncertainty in measurement (GUM 1995)*
[3] IEC 61400-21-1, Wind energy generation systems – Part 21-1: Measurement and assessment of electrical characteristics – Wind turbines, Ed.1
[4] IEC 61869-2, Instrument transformers – Part 2: Additional requirements for current transformers
[5] European Accreditation (EA) Publication EA-4/02 M: 2013, Evaluation of the Uncertainty of Measurement in Calibration
[6] ILAC P10:01/2013, ILAC Policy on the Traceability of Measurement Results.
[7] IEC 61000-4-30 Electromagnetic compatibility (EMC) – Part 4-30, "Testing and measurement techniques – Power quality measurement methods", Ed. 3.0, 2015-02.
[8] IEC 61000-4-7 Electromagnetic compatibility (EMC) – Part 4-7, "Testing and measurement techniques – General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto", Ed. 2.1, 2009-10.

3 Definitions

3.1 Fundamental frequency

50 Hz or 60 Hz

3.2 Harmonic frequency

Frequency which is an integer multiple of the fundamental frequency

3.3 Root-mean-square value (RMS)

Square root of the arithmetic mean of the squares of the instantaneous values of a quantity taken over a specified time interval and a specified bandwidth

[SOURCE: IEC 60050-103:2009, 103-02-03]

3.4 Reference signal

Current or voltage signal designated as the reference signal for the calibration of the relevant device/transducer

3.5 Measurement uncertainty

Parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand.

3.6 Standard uncertainty

Uncertainty of the result of a measurement expressed as a standard deviation

3.7 Expanded uncertainty

Quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand.

3.8 Typ A uncertainty

Type A uncertainty is the evaluation of a component of measurement uncertainty by statistical analysis of measured quantity values obtained under defined measurement conditions.

3.9 Typ B uncertainty

Type B uncertainty is the evaluation of a component of measurement uncertainty determined by means other than the Type A evaluation of measurement uncertainty. The information for the Type B uncertainty may come from data provided in calibration certificates or others.

Abbreviations and acronyms

EA	European Accreditation
ILAC	International Laboratory Accreditation Cooperation
ISO	International Organization for Standardization
IEC	International Electrotechnical Commission

5 Reference equipment

High quality requirements for a product mean that there must be an adequate quality system. The control, calibration and maintenance of measuring and test equipment is an important part of quality systems and provides an assurance that measurements will be made properly during production processes. To this end, all measurement results must be traceable to national standards.

This measurement procedure shall follow the relevant policies and guidelines of ILAC and EA, with regards to the control, calibration and maintenance of measuring and test equipment as well as the traceability and calibration hierarchy and uncertainty of the test – and reference equipment.

The reference equipment shall be calibrated and traceable to a national standard, whereas the calibration is done by a calibration laboratory, which is accredited for this calibration service according to the ISO/IEC 17025 [1].

Reference equipment like transducer, shunt, burden etc. shall meet the requirements given in IEC61869-1, IEC61869-2, IEC61869-3.

5.1 Test layout

The signals for voltage and current shall be produced by an output signal source. The signals for current and voltage can be tested separately - there is no need for a simultaneous recording respective calibration of all three phases. The recording from reference signals and measurand signals need to be simultaneous. Typical simplified layouts for the calibration of current and voltage transducers are given in Figure 1. The calibration setup shall consist of one calibrated signal generator (calibrator) or a calibrated reference current/voltage transducer, the measurand equipment and a calibrated measurement system. The output signals of the calibrator/reference transducer and the measurand shall be recorded, analysed and reported as described in the next paragraphs.

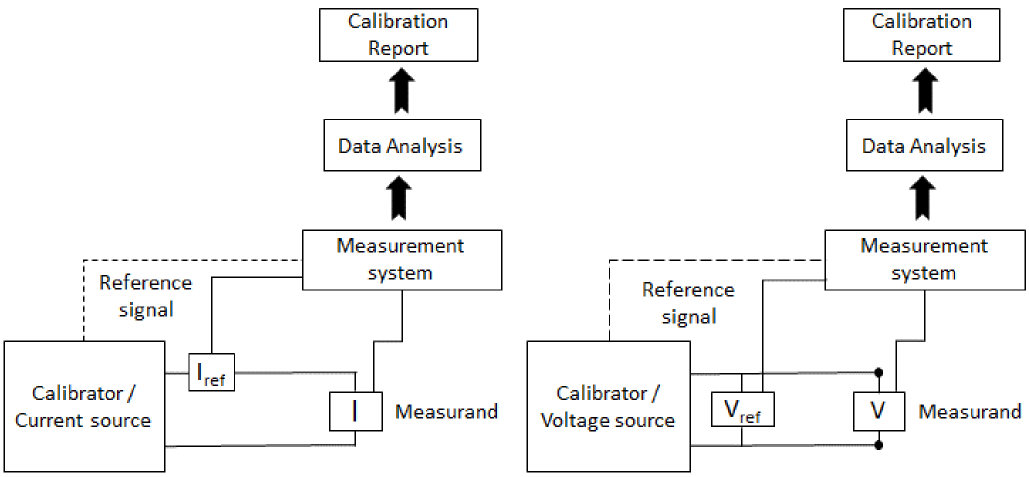

Figure 1 Typical test layout of calibrator, reference and measurand equipment

6 Calibration procedure

6.1 General procedure

The calibration is carried out to determine the difference between the device under test and a reference transducer or a reference signal. The used reference has to have an uncertainty which is better or equal to the one third (1/3) of the uncertainty from the device under test.

The calibration interval of passive transducers shall be maximum 5 years, the interval of active transducers shall be maximum 2 years.

All measurement values for magnitude shall be averages over at least 3-second windows. In case of harmonics, the calculation method mentioned in IEC 61000-4-30 [7] and IEC 61000-4-7 [8], including subgrouping and aggregation method shall be used.
Although the temperature might not influence the accuracy for every type of transducers, it has to be ensured that the environmental conditions are stable and within the specification of the transducer under test. Therefore, the temperature, humidity and pressure (in case the altitude is above 1000m) have to be stated prior or in parallel to each calibration. Typical temperature range is 23°C ±5°C and typical humidity range is 30% to 70%. Generally, the pressure should have no influence as long as the altitude is below 1000m.

It must be ensured that the impedances or loads at the output of the transducers are within the manufacturer specifications.

The transducer has to be placed in an ideal position for the general calibration tests, if applicable. For current transducers that means a centered position in a 90° angle to the line. It has to be ensured, that negative effects due to external electromagnetic fields on the device under tests are avoided.

If a Rogowski coil is used with two windings around the conductor/cable, then a calibration of this mode should be performed.

If the transducer uses a burden, it has to be ensured that the burden is within +/-3% of the required value (according to IEC 61869-2) or within the required range. This has to be checked with a 4 wire measurement.

6.2 *Calibration Tests – General Tests*

The general calibration tests consist of the following two subtests:

- Calibration of the fundamental
- Calibration of harmonics

6.2.1 General Calibration Tests – Fundamental

The calibration shall be carried out at the specific fundamental frequency of interest. That means that no combined calibration for 50 Hz and 60Hz is allowed.

For the calibration of the magnitudes, at least 5 test points over the whole operation range for current transducers and 3 test points over the relevant operation range for voltage transducers have to be tested.

Example:

- 1%, 10%, 50%, 100% and 110% of the measurement range for current transducers.
- 90, 100% and 120% of the measurement range for voltage transducers.

In each step, at least a 3-second average value of the measured RMS of the current is calculated. To avoid influences by transient oscillations, the signal has to be active at least 1 second before the averaging starts at each step.

The deviation will be presented as value in Ampere or Volt and/or in % of the measurement range.

For the determination of the phase error, at least a measurement at 1 current or voltage level in the upper range is sufficient.

Example: 90%

The phase angle deviation will be either presented in ° or in rad.

6.2.2 General Calibration Tests – Harmonics

The calibration of harmonic currents can be carried out without a present fundamental frequency.

For the calibration of the harmonics at least 5 test points over the whole frequency range up to a frequency of 9 kHz have to be tested. The current or voltage output value has to be between 0.1% and 1% of the transducers' measurement range and has to be the same for each of the chosen frequency test points.

If the calibration is done without a fundamental frequency, the current or voltage output value has to be in the specified measurement range of the sensor taking into account the typical linearity error.

Example: 250 Hz, 350 Hz, 1 kHz, 3 kHz and 9 kHz

At each step, at least a 3-second average value of the sub-grouped harmonic current/voltage is calculated. To avoid influences by transient oscillations, the signal has to be active at least 1 second before the averaging starts at each step.

The deviation will be presented as value in Ampere or Volt and as % of the measurement range.

Optional: If possible, the phase deviation at each frequency step has to be determined and stated either in ° or rad.

6.3 Calibration Tests – Enhanced Tests

The enhanced calibration tests are used to determine the accuracy of the current transducers under non-ideal conditions.

6.3.1 Enhanced Calibration Tests – Positioning

This test shall show the influence of a non-centered position on the fundamental.

For the calibration of the magnitudes at least 2 test points over the whole operation range of the transducer have to be tested. At least three positions have to be used. Each position has to be documented with a photo.

Example:

Current: 30% and 100 % of the measurement range.

Position: Centered, junction close to the conductor and junction far away from the conductor

At each step and deformation, at least a 3 second average value of the measured RMS of the current is calculated. To avoid influences by transient oscillations, the signal has to be active at least 1 second before the averaging starts at each step.

The deviation compared to the results at centered position will be presented as value in Ampere and as % of the measurement range.

For the determination of the phase error, a measurement at 1 current level in the upper measurement range is sufficient.

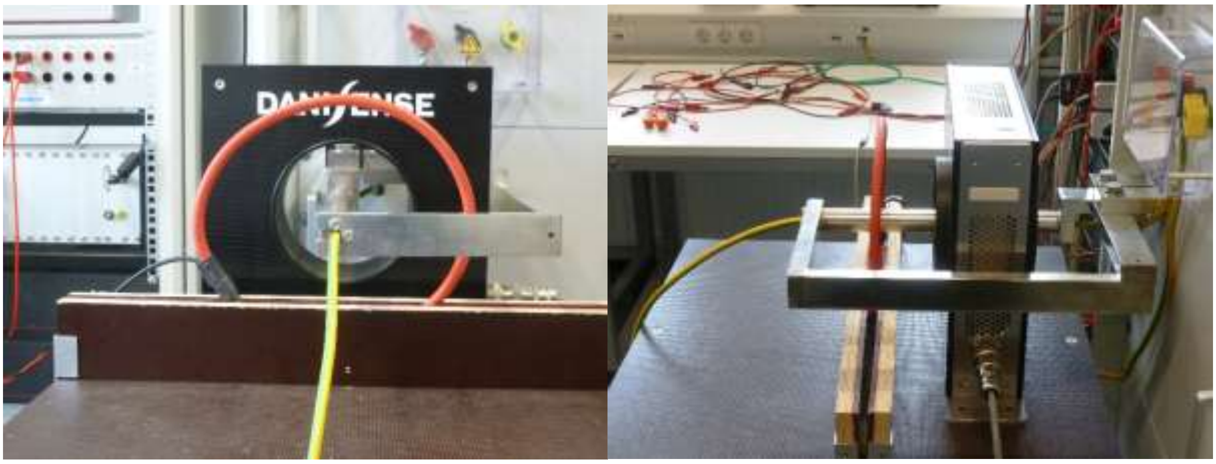

Figure 2: Example set-up: Calibration of a Rogowski current transducer in a centered position.

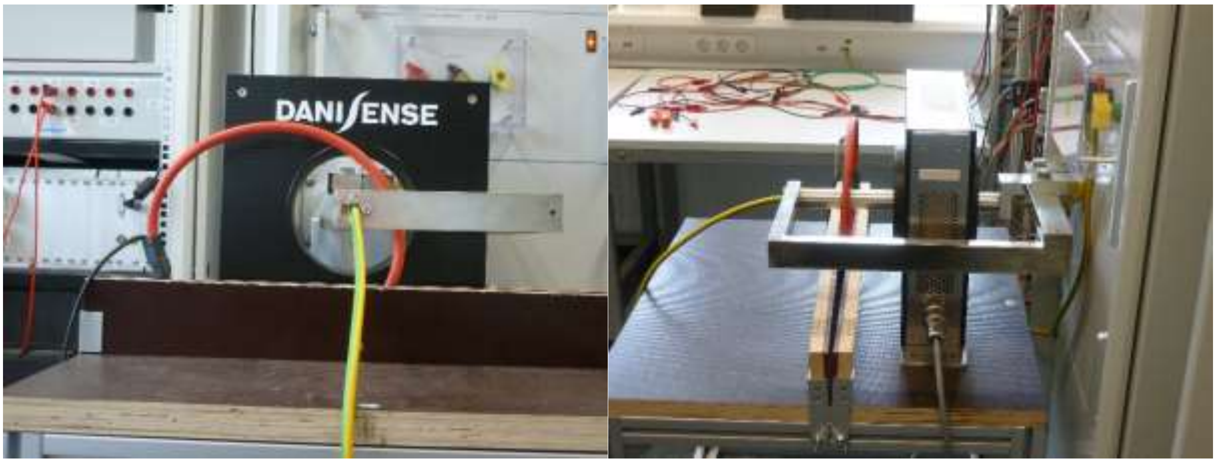

Figure 3: Example set-up: Calibration of a Rogowski current transducer with the junction far away from the conductor.

6.3.2 Enhanced Calibration Tests – Deformation

This test shall show the influence of a deformation of the current transducer.

For the calibration of the magnitudes at least 2 test points over the whole operation range of the transducer have to be tested. At least two deformations have to be used. Each position has to be documented with a photo or a drawing.

Example:

Current: 30% and 100 % of the measurement range.

Deformation: Normal position, Deformation from the top, Deformation from the side

At each step and deformation, at least a 3 second average value of the measured RMS of the current is calculated. To avoid influences by transient oscillations, the signal has to be active at least 1 second before the averaging starts at each step.

The deviation compared to the centered position will be presented as value in Ampere and as % of the measurement range.

For the determination of the phase error, a measurement at 1 current level at the upper measurement range is sufficient.

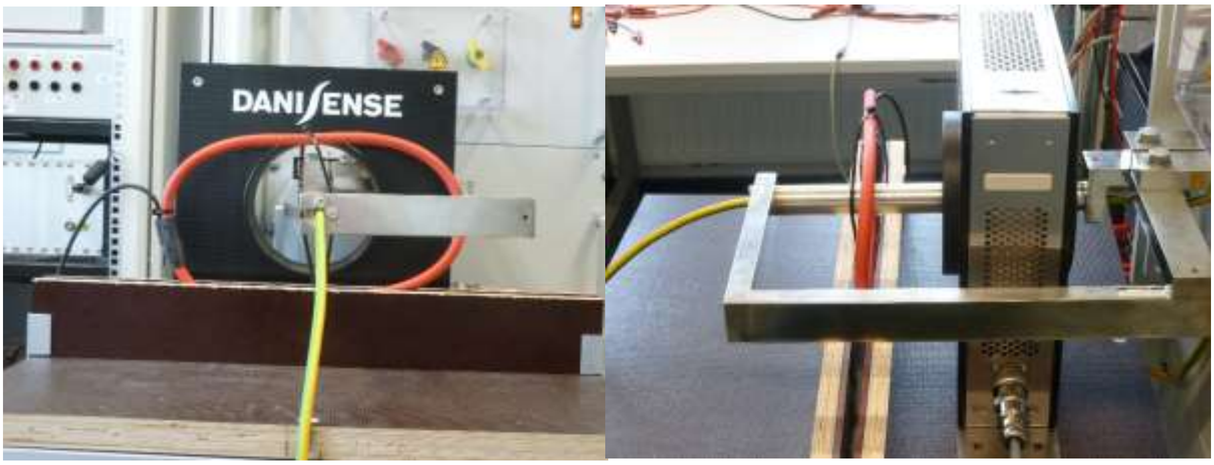

Figure 4: Example set-up: Calibration of a Rogowski current transducer, where the coil is deformed from the top.

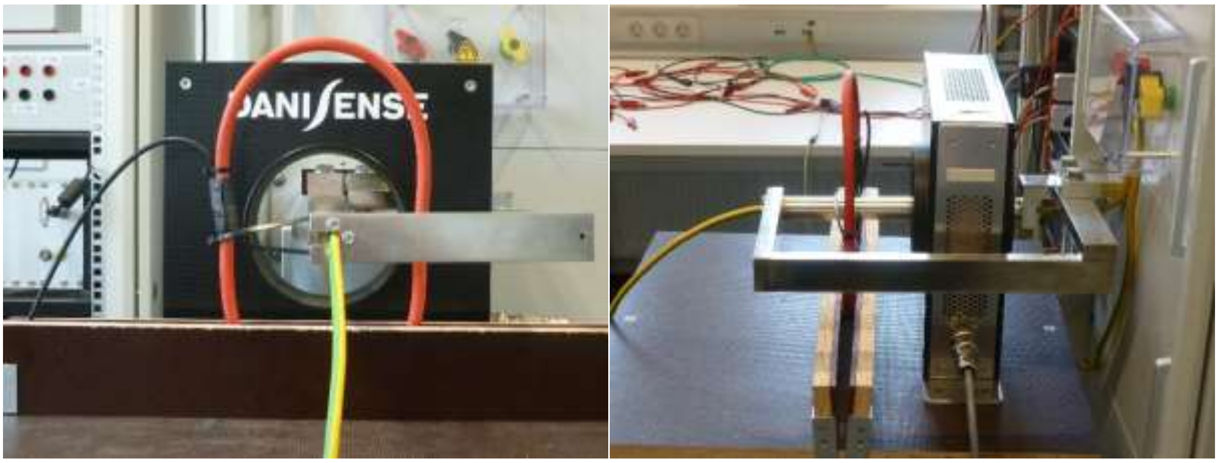

Figure 5: Example set-up: Calibration of a Rogowski current transducer, where the coil is deformed from the side.

6.3.3 Enhanced Calibration Tests – Angle

This test shall show the influence of a non-ideal angle of the transducer.

For the calibration of the magnitudes at least 2 test points over the whole operation range of the transducer have to be tested. At least two angles have to be used. Each position has to be documented with a photo or a drawing.

Example:

Current: 30% and 100 % of the measurement range.

Deformation: Normal position, 45°, 60°

At each step and angle, at least a 3 second average value of the measured RMS of the current is calculated. To avoid influences by transient oscillations, the signal has to be active at least 1 second before the averaging starts at each step.

The deviation will be presented as value in Ampere and as % of the measurement range.

For the determination of the phase error, a measurement at 1 current level at the upper measurement range is sufficient.

Figure 6: Example set-up: Calibration of a Rogowski current transducer in a centered position, but where the current transducer is not at right angle.

7 Calibration Report

Based on the ISO/IEC 17025 the following data has to be stated at least on the calibration report:

1. General data
    a. Date of calibration
    b. Location of calibration
    c. Method used

2. Device under test
    a. Manufacturer
    b. Type
    c. Serial Number and/or Inventory number
    d. Nominal Ratio

3. Reference devices. For each device
    a. Manufacturer
    b. Type
    c. Serial number
    d. Purpose of use
    e. Calibration number and date

4. Meteorological data
    a. Temperature
    b. Humidity
    c. Air pressure

5. Uncertainty analysis of the reference equipment
    a. Extended uncertainty for each used measurement range
    b. Statement on procedure of extended measurement uncertainty (level of confidence, k-factor)

6. Calibration results for magnitude (for each range / Step / Frequency)
    a. Testing point (Level of current or voltage / frequency / position / deformation / angle)
    b. Measurement range of transducer
    c. True value (from reference)
    d. Measured value (from device under test)
    e. Absolute deviation
    f. Deviation as error of range

7. Calibration results for phase angle (for each range / Step / Frequency)
    a. Testing point (Level of current or voltage / frequency)
    b. Measurement range of transducer
    c. Determined absolute phase angle deviation

8 Calibration Uncertainty

Evaluation of measurement uncertainty is a requirement of ISO/17025 standard for accredited laboratories. For the calculation of the uncertainty in the calibration of current and voltage transducers, the general rules described in ISO/IEC Guide 98-3: 2008 [2] should be followed. It includes the Typ B uncertainty (accuracy of the source, of the reference and of the measurement equipment) and the type A uncertainty of the measurements. The procedure to be followed, should be also in accordance with the requirements of the European Accreditation [5] .

Unless otherwise requested, the calibration of current transducers should be performed using a proper test setup so that the influence of the positioning, angle of positioning and deformation of the head of the transducers is minimized and the relevant uncertainty is negligible (ideal position). In order to identify the uncertainty in case of non-ideal installation conditions, the calibration at special positions could also be taken into account.

The used reference transducer or reference signal from a calibrator has to have an uncertainty which is better or equal to the one third (1/3) of the uncertainty from the device under test.