Measuring-Network of Wind Energy Institutes

Procedure for Acceptance of Medium-Voltage Transducers

Created by MEASNET Electrical Characteristics Expert Group

Coordinator: Sokratis Tentzerakis (UL Solutions)

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1. Scope

This procedure primarily applies to testing of Electrical Characteristics according to the IEC 61400-21 series of standards, but can also be applied to other relevant standards/guidelines/grid codes as long as it does not contradict any other specific requirements.

2. Acceptance criteria

2.1. Types of medium-voltage transducers

Medium-voltage transducers shall meet the following criteria:

- have an accuracy class of 1 or better (if not otherwise stated in the relevant guideline)
- are compliant with IEC 61869-3 ([3])
- exhibit characteristics as given in IEC 61400-21-2 Annex D ([4]) or FGW TG3 Rev. 26 Annex C.5 (e.g. inductive transformer or RC divider) ([6])

2.2. Traceability

The traceability of the measured voltages to international standards shall be ensured by applying one of the two procedures:

2.2.1. Procedure 1: Calibration by a calibration laboratory accredited acc. to ISO/IEC 17025 [1] (recommended)

The calibration certificate shall cover the voltage and frequency range of the intended use of the transducer of interest. The accreditation of the calibration laboratory must be awarded by an ILAC recognized accreditation body. For the calibration procedure, the general rules of the MEASNET Calibration Procedure for Transducers ([5]) can be followed, taking into account any technical constraints for the calibration at MV level (e.g. the maximum possible harmonic range).

2.2.2. Procedure 2: In-house verification

The testing laboratory may apply transducers without an ISO/IEC 17025 compliant calibration certificates as long as some of the following statements a) to h) are true. It is the responsibility of the testing laboratory to select, justify and document the applicable ones for a specific measurement campaign.

a) Unmounting and sending the transducers to a calibration laboratory is prohibitive.
b) There is no possibility for onsite calibration (e.g. no availability of mobile calibration).
c) A factory calibration certificate or acceptance test report by the manufacturer or other adequately qualified provider exists.
d) Historical records of the transducers are made available to the measuring institute (including damage/repair information if any).
e) An additional verification is performed according to chapter 3 of this document.
f) The conditions and outcome (from statements a-e) are documented in the test report.
g) The uncertainty is increased as per chapter 4 and documented in the test report.
h) Higher frequency harmonic voltages (above 2.5 kHz) are only reported up to the frequency range stated in the data sheet of the used type of transducer. Care shall be taken in the interpretation of the reported results due to possible resonances at higher frequencies ([7]).

3. Example protocol for the acceptance of medium-voltage transducers

3.1. Review of documentation of the medium-voltage transducers

Prior to the execution of the tests, the measuring institute shall review the documentation of the medium-voltage transducers thereby completing Table 1.

Table 1: Review of available documentation of medium-voltage transducers

	Description	Accepted
Type of voltage transducer		Y/N
Manufacturer		Y/N
Class	shall be ≤ 1.0	Y/N
Other specifications		Y/N
Factory calibration certificate or acceptance test report	Number / Date / Comments	Y/N

3.2. Onsite verification of the condition of medium-voltage transducers

A list of verification steps is given in Table 2, which are recommended to be performed by the measuring institute after the installation of the measurement system and before the start of the test campaign. It is under the responsibility of the measuring institute to select the suitable verification checks depending on the needs of the specific campaign.

3.2.1. Recommended verification checks

The recommended verification checks to be done onsite are listed in Table 2. It is the responsibility of the testing laboratory to select, justify and document the applicable ones for a specific measurement campaign.

Table 2: Recommended verification checks

Check	Description	Done	Comments
1	**Visual check of transducers** (check for visible wear/damages etc.)	Y/N	Example text below: No visible wear or damage was identified. Photos of the VTs are shown in the figures shown below.
2	**Check of installation of the transducers as well as connection points** (common neutral on secondary side, phase to phase, etc.)	Y/N	
3	**Compare voltage signal with other available signals** (for example compare the 3 phases to assure that the differences between phases are in the normal range, or compare with another voltage transducer, if available, for example temporarily from an FRT system)	Y/N	
4	**Injection of a low voltage signal at the primary of the transducer to verify the ratio** (measure input and output of transducer with a calibrated measurement system)	Y/N	See Table 4: Example table of results

Placeholder for Figure 1

Figure 1: Photo of Voltage Transducer (phase 1-2)

Placeholder for Figure 2

Figure 2: Photo of Voltage Transducer (phase 2-3)

Placeholder for Figure 3

Figure 3: Photo of Voltage Transducer (phase 3-1)

Placeholder for Figure 4

Figure 4: Photo of verification test setup

3.2.2. Injection of a low voltage signal at the primary of the medium-voltage transducer

The aim of this check is to verify the ratio of the windings of the medium-voltage transducers used for the measurement at the medium-voltage terminals of the DUT. The check can be used as a supplement to the available routine test reports, to increase the level of confidence in the calculated voltage related parameters. The results of this verification are considered for the calculation of uncertainty in 4.

The check can be performed by supplying a low AC voltage signal (e.g. 230 V) to the primary winding of the relevant transducer and comparing the measured voltages between the primary and the secondary side. The supply can be done using the normal supply from the public grid or using a signal generator. The input and output voltages (at the primary and the secondary windings) shall be measured with a calibrated measurement system using a sampling rate of ≥ 10 kHz.

The check is performed for each transducer. The duration of each check should be ≥ 1 min. Table 3 (check information) and Table 4 (example table of results for the fundamental and for selected harmonics) shall be included in the test report. Additionally, details of the measured waveforms shall be shown for each phase (see Figure 5 to Figure 10, as example).

Table 3: Check information

<table>
<tr><td rowspan="3">Date of check</td><td rowspan="3">DD.MM.YYYY</td><td>Phase 1: HH:MM – HH:MM (UTC)</td></tr>
<tr><td>Phase 2: HH:MM – HH:MM (UTC)</td></tr>
<tr><td>Phase 3: HH:MM – HH:MM (UTC)</td></tr>
<tr><td>Site</td><td colspan="2"></td></tr>
<tr><td>Test engineer</td><td colspan="2"></td></tr>
<tr><td>Test Items</td><td colspan="2">• Type:
• Manufacturer:
• Ratio:
• Serial number U1:
• Serial number U2:
• Serial number U3:</td></tr>
<tr><td>Measurement equipment used</td><td colspan="2">• Type:
• Serial number:
• Manufacturer:
• Calibration: Number / Date</td></tr>
<tr><td>Sampling rate of measurements</td><td colspan="2"></td></tr>
</table>

Table 4: Example table of results

Fundamental frequency	U1_primary (rms)	U1_secondary (rms)	Measured ratio = U1_prim./U1_sec.	Deviation in %
	U2_primary (rms)	U2_secondary (rms)	Measured ratio = U2_prim./U2_sec.	Deviation in %
	U3_primary (rms)	U3_secondary (rms)	Measured ratio = U3_prim./U3_sec.	Deviation in %
5th harmonic order	U1_primary (rms)	U1_secondary (rms)	Measured ratio = U1_prim./U1_sec.	Deviation in %
	U2_primary (rms)	U2_secondary (rms)	Measured ratio = U2_prim./U2_sec.	Deviation in %
	U3_primary (rms)	U3_secondary (rms)	Measured ratio = U3_prim./U3_sec.	Deviation in %
7th harmonic order	U1_primary (rms)	U1_secondary (rms)	Measured ratio = U1_prim./U1_sec.	Deviation in %
	U2_primary (rms)	U2_secondary (rms)	Measured ratio = U2_prim./U2_sec.	Deviation in %
	U3_primary (rms)	U3_secondary (rms)	Measured ratio = U3_prim./U3_sec.	Deviation in %
11th harmonic order	U1_primary (rms)	U1_secondary (rms)	Measured ratio = U1_prim./U1_sec.	Deviation in %
	U2_primary (rms)	U2_secondary (rms)	Measured ratio = U2_prim./U2_sec.	Deviation in %
	U3_primary (rms)	U3_secondary (rms)	Measured ratio = U3_prim./U3_sec.	Deviation in %
13rd harmonic order	U1_primary (rms)	U1_secondary (rms)	Measured ratio = U1_prim./U1_sec.	Deviation in %
	U2_primary (rms)	U2_secondary (rms)	Measured ratio = U2_prim./U2_sec.	Deviation in %

Table 4: Example table of results

	U3_primary (rms)	U3_secondary (rms)	Measured ratio = U3_prim./U3_sec.	Deviation in %
1 kHz	U1_primary (rms)	U1_secondary (rms)	Measured ratio = U1_prim./U1_sec.	Deviation in %
	U2_primary (rms)	U2_secondary (rms)	Measured ratio = U2_prim./U2_sec.	Deviation in %
	U3_primary (rms)	U3_secondary (rms)	Measured ratio = U3_prim./U3_sec.	Deviation in %
1.5 kHz	U1_primary (rms)	U1_secondary (rms)	Measured ratio = U1_prim./U1_sec.	Deviation in %
	U2_primary (rms)	U2_secondary (rms)	Measured ratio = U2_prim./U2_sec.	Deviation in %
	U3_primary (rms)	U3_secondary (rms)	Measured ratio = U3_prim./U3_sec.	Deviation in %
2 kHz	U1_primary (rms)	U1_secondary (rms)	Measured ratio = U1_prim./U1_sec.	Deviation in %
	U2_primary (rms)	U2_secondary (rms)	Measured ratio = U2_prim./U2_sec.	Deviation in %
	U3_primary (rms)	U3_secondary (rms)	Measured ratio = U3_prim./U3_sec.	Deviation in %
2.5 kHz	U1_primary (rms)	U1_secondary (rms)	Measured ratio = U1_prim./U1_sec.	Deviation in %
	U2_primary (rms)	U2_secondary (rms)	Measured ratio = U2_prim./U2_sec.	Deviation in %
	U3_primary (rms)	U3_secondary (rms)	Measured ratio = U3_prim./U3_sec.	Deviation in %
Note 1. RMS voltage in each phase is calculated as average over the actual time frame of recording (e.g. 10 min) Note 2. Only harmonic orders with magnitude above __% of the nominal voltage to be presented				

Placeholder for Figure 5

Figure 5: Transducer 1: Measured primary vs. secondary voltage over a few cycles (ratio: __)

Placeholder for Figure 6

Figure 6: Transducer 1: Measured primary vs. secondary voltage (ratio: __): Zoom

Placeholder for Figure 7

Figure 7: Transducer 2: Measured primary vs. secondary voltage over a few cycles (ratio: __)

Placeholder for Figure 8

Figure 8: Transducer 2: Measured primary vs. secondary voltage (ratio: __): Zoom

Placeholder for Figure 9

Figure 9: Transducer 3: Measured primary vs. secondary voltage over a few cycles (ratio: __)

Placeholder for Figure 10

Figure 10: Transducer 3: Measured primary vs. secondary voltage (ratio: __): Zoom

4. Uncertainty analysis

If all the verification steps described in the previous chapters are performed, measurements of voltage can be used for the analyses described in the test report, as long as the uncertainty is multiplied by a factor of 2 as given in Table 1.

Table 1: Increased Type B (as defined in GUM [8]) uncertainty in the voltage measurement

Accuracy class of the transducer according to the manufacturer's specifications	Standard uncertainty (k=1) (% of the measured value)	Expanded uncertainty (k=2) (% of the measured value)
0.2 or better	$\frac{0.5}{\sqrt{3}}$	$2 \cdot \frac{0.5}{\sqrt{3}}$
≥ 0.3 and ≤ 1.0	$2 \cdot \frac{Accuracy\ Class}{\sqrt{3}}$	$2 \cdot \left(2 \cdot \frac{Accuracy\ Class}{\sqrt{3}}\right)$

The uncertainty result included in the test report, will be the combined uncertainty of voltage measurement and software uncertainty, as shown in Table 2. The calculation shall be done according to the MEASNET procedure [2]. A relevant note shall be added in the test report, explaining the increase in the uncertainty. In the case where specific uncertainty limits are specified in the applicable guidelines (e.g. Table 7-1 of TG3 Rev26 [6]), these must be also observed.

Table 2: Uncertainty analysis of the voltage measurement

Parameter	Standard uncertainty (k=1) (% of the measured value)	Expanded uncertainty (k=2) (% of the measured value)
Voltage	Value from Table 1	Value from Table 1
Voltage integer harmonics		

5. References

[1] ISO/IEC 17025: 2017: General requirements for the competence of testing and calibration laboratories

[2] MEASNET, Procedure for Measurement of Electrical Characteristics, Version 1, June 2019

[3] IEC 61869-3, Instrument transformers – Part 3: Additional requirements for inductive voltage transformers

[4] IEC 61400-21-2: 2023, Wind energy generation systems – Part 21-2: Measurement and assessment of electrical characteristics – Wind power plants, Ed.1.

[5] MEASNET, Calibration Procedure for Transducers, Revision 1, 16th April 2019

[6] Technische Richtlinien für Erzeugungseinheiten und -anlagen, Teil 3 (TR3), Bestimmung der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen, Speicher sowie für deren Komponenten am Mittel-, Hoch- und Höchstspannungsnetz, Revision 26, Stand 05.04.2022, FGW e.V. Fördergesellschaft Windenergie und andere Dezentrale Energien (FGW)

[7] https://www.schutztechnik.com/posts/spannungswandler-und-sensoren-fur-power-quality-messungen-in-der-mittelspannung

[8] ISO/IEC GUIDE 98-3:2008, Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement" (GUM:1995)