Title: Advanced classical standards for electrical metrology

Abstract

In recent years, electrical metrology has improved significantly by the development and implementation of quantum-based standards. However, in the same time, classical standards used for maintaining and disseminating the units among laboratories have become outdated. Without research into and development of new classical standards industry will not be able to benefit from the recent advances in quantum metrology. The increasing metrology gap is caused by stricter regulations, loss of long-standing knowledge, and cost pressure on new developments. Research is needed on the development, characterisation and verification of advanced classical standards to maintain precision calibration services at NMIs and industrial calibration laboratories. Proposals addressing this SRT should focus on developing new or revised electrical standards that are application oriented.

Keywords

Calibration, traceability, electrical standards, waveform measurements, sampling techniques, electricity metering equipment.

Background to the Metrological Challenges

Calibration standards used in industrial calibration laboratories for electrical metrology are mainly based on well-established products which are mostly dated back to the 1990s. Their functionality is limited and repair in case of damage is no longer possible. To replace them with new available standards is difficult, since those companies, having produced such standards, are either no longer existing or have changed the focus of their product line. Improved electrical standards are needed to reduce the overall number of calibration steps resulting in reduced uncertainties to meet the increasing demands of customers in industry, accredited calibration laboratories, and the research community, including in the fields of renewable energies and electromobility. Moreover, improved automatic calibration methods and instruments which significantly increase sensitivity, precision and calibration range in terms of amplitude and phase angle error must be developed and investigated.

In power and power quality measurements there is the need to calibrate high currents. The accuracy of common shunts is limited by their change in value with the applied power level, and solutions need to be investigated. Coaxial high current shunts are nowadays the main standards suitable to extend the measurement range for AC-DC current transfer standards up to 100 A and frequencies up to 100 kHz. However, today's uncertainties of NMIs using coaxial shunts for AC current measurements from 10 mA to 100 A range from a few µA/A to 100 µA/A, which increases at the level of calibration and industrial laboratories. During the last decade, there has been a substantial research activity to expand the use of electrical quantum standards for electrical AC quantities. Despite these efforts, such quantum standards practically cover only a small range of values (resistance around 10 kΩ and voltage around 1 V). Thus, NMIs as well as calibration laboratories have to trace electrical AC quantities, e.g. voltage, current and derived quantities to the SI units through a long chain of measurements which involves AC-DC transfer standards. Additionally, in the characterisation of power transformers, higher harmonics are of interest, requiring the development of shunts for the use at frequencies up to 100 kHz. One of the main challenges will deal with specialised coaxial AC-current sensing standards allowing higher bandwidth and dynamic range. This could be accomplished by partly applying existing technologies and novel equipment for their characterisation under sinusoidal and distorted waveforms. A major drawback again concerns the long chain of measurements required to trace RMS (root-mean-squared) and non-RMS quantities such as harmonics, distortion, phase, etc., to electrical quantum standards.

Furthermore, the world of electricity is no longer described by analogue DC or sinusoidal AC quantities but in most cases is converted into the digital domain, often by direct sampling of a signal of interest. In recent years, analogue-to-digital-converter technology (ADC) has not only pushed the barriers in the sampling speed, but also in the ADC resolution, and especially in overall accuracy. These new developments have challenged the AC voltage calibration capabilities at the highest levels. AC-DC transfer measurements using thermal converters cannot directly cope with all ADC characteristics to be calibrated. Additionally, ADCs should be calibrated for complex signals, such as those required for power quality and transient measurement applications. For that reason, new techniques and instrumentation are needed to properly calibrate fundamental ADC parameters for complex signals. For disseminating SI units for time-dependent electrical signals, the development of a classical arbitrary waveform generator covering a frequency range from 1 mHz to 100 kHz with long-term stability (1 x 10^{-6}) and negligible glitch-type distortions is not available but will be highly useful for research and industry.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on developing new or revised electrical standards that are application oriented.

The specific objectives are

1. To develop and validate new active standards including a remote controllable isothermal AC-DC transfer device (1 mV to 1000 V, at 10 Hz to 1 MHz, best uncertainty 5 ppm), new types of voltage references with lower noise (< 0.05 µV/V), synthesised impedances: high inductances, range 1 H to 10 kH (0.1 %), high capacitance / low R-C impedance (1 F to 50 F, 0.1 mΩ to 10 mΩ, 1 %), and high current shunts (< 1 mΩ, 1 kA, 1 ppm), for application in precision measurements of power and energy as well as for the characterisation of instrumentation in electromobility.
2. To develop and validate new passive standards including shunts for high current up to 100 A and frequencies up to 100 kHz with an uncertainty level < 5 ppm for the AC-DC difference, and < 0.1 µrad for the phase, and high precision resistance standards, which allow transfer at an uncertainty level < 0.01 ppm.
3. To develop, validate and apply novel sampling methods for the realisation and analysis of voltage waveforms, ranging from 1 mV to 10 V at frequencies from 1 mHz to 100 kHz. The analysis methods should achieve optimal noise performance (close to the theoretical limit) and a processing bias < 1 x 10^{-8}, and in particular, determine the characteristics of continuous non-sinusoidal and transient signals and the frequency response and linearity of new active and passive standards.
4. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (NMIs, research and calibration laboratories), standards developing organisations (CEN, ISO, ETSI) and end users (e.g. instrument manufacturers, automotive industry, battery manufacturers).

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution across all selected projects in this TP.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the calibration laboratories, automotive and manufacturing sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Time-scale

The project should be of up to 3 years duration.