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Publishable Summary for 14RPT01 ACQ-PRO
Towards the propagation of AC Quantum Voltage Standards

Overview

The overall objective of the project is to develop the European measurement and research capacity in AC, by providing European National Metrology Institutes (NMIs) the access to AC quantum voltage standards and therefore contributing to spread the capacity to countries or regions in Europe where access to these facilities is currently limited. The project will also establish the basis for the future collaboration between metrological institutes working on AC quantum voltage standards.

Need

Much effort has been devoted to the development of AC quantum voltage standards. Work carried out in the last two decades resulted in very complex AC quantum voltage standards systems, difficult to develop and operate. Current infrastructure and level of knowledge present a barrier for most of the NMIs to develop their own AC quantum voltage standards, the consequence being that only a few institutes in Europe have access to these standards and the technological gap between NMIs is increasing. Traceability to AC quantum voltage standards can only be provided by a few NMIs and the dimension of the European research capacity on AC quantum voltage metrology is not large enough to keep up with the societal challenges associated with energy, environment and health. In addition, when raising the profile of basic scientific metrology, knowledge and technology transfer into industry and pre-/co-normative research, not even the most established institutes in Europe will be able to exploit the full potential of their AC quantum voltage standards. The European research capacity in AC quantum voltage metrology needs therefore to be improved.

Objectives

The specific scientific and technological objectives of the project are:

- **To transfer experience and expertise in different and specific technologies to enable the integration, operation and modification of AC quantum voltage standards.** The purpose is not only to provide the infrastructure but also the capacity to improve the measurement technology through continuing research and development.
- **To design a new practical AC quantum voltage infrastructure accessible to all NMIs**, which is easy to implement and operate, maintaining the potential research capacity.
- **To produce a Good Practice Guide** on the use of AC quantum voltage standards including guidance on development and validation of measurement methods for different specialised applications.
- **To establish the basis for future cooperation** between European NMIs working on AC quantum voltage standards research and the further propagation of their use.
- T**o create an individual strategy for the long-term development of the research capability in AC quantum voltage metrology** for each partner developing capability in project. This will include a strategy for offering calibration services from the established facilities to their own country and neighbouring countries.

Progress beyond the state of the art

The current state of art of AC quantum metrology research in Europe illustrates the huge gap between different NMIs. While some of them are among the most advanced in the world, others lack not only AC but also DC quantum voltage standards. This project will facilitate an increase in the number of AC quantum

voltage infrastructures in Europe as a result of the collaboration between NMIs. More experienced NMIs will transfer their knowledge to other institutes, enabling them to carry out research on AC quantum voltage standards. The collaboration will make smart specialisation possible, not only in the new infrastructures but also in the research carried out, thereof improving the European research capacity.

The availability of AC quantum voltage standards would improve the electrical measurement capabilities of the European NMIs and industrial laboratories. For AC voltage and current measurement the uncertainty can be reduced from several ppm to the sub-ppm level. For power measurements, the calibration of the digital power measurement systems using AC quantum voltage standards will enable uncertainties to be achieved at the ppm level. In addition, AC quantum voltage standards will allow the precise calibration in amplitude and phase of analogue to digital converters, which can be used to develop accurate measurement systems of power quality parameters and provide metrological support to the “Smart Grid” concept. For impedance measurements, the use of automated bridges based on quantum standards will significantly reduce the measurement times (from one day for a single frequency point to two hours for a frequency band covering typically 50 Hz to a few kHz) and therefore will reduce the cost.

Results

The expected final results of the project are as follows:

Transfer of experience and expertise in different and specific technologies
This will enable the less experienced NMIs the integration, operation and modification of AC quantum voltage standards. The purpose is not only to provide the infrastructure but also the capacity to improve the measurement technology through continuing research and development.

Design of a new practical AC quantum voltage infrastructure
The design should be for a consolidated AC quantum voltage standard based on the knowledge acquired in previous research projects, where different types of approaches were followed. The objective is to define a simplified subsystem that could be used for all AC quantum voltage applications (e.g. thermal voltage calibration, digital impedance bridge). The interoperability of this subsystem is a key requisite. In addition, the consortium will define the requirements to use common software for the AC quantum voltage infrastructures.

Produce a Good Practice Guide
Guidance on the use of AC quantum voltage standards will consolidate the practical knowledge into one document. The guide will include guidance on development and validation of measurement methods for different specialised applications

Establish the basis for future cooperation between European NMIs
For this, a working group on AC quantum voltage standards will be created that will work in close collaboration with the relevant existent technical groups and committees, specifically with the EURAMET TC-EM: on “DC & Quantum Metrology”, “Low Frequency” and “Power and Energy”.

Create individual strategies for the long-term development of research capability
Individual strategies for each NMI/DI partner developing capability in project will include priorities for collaborations with the research community in the respective country, the establishment of appropriate quality schemes and accreditation. Future plans will consider the possible cooperation of some NMIs to build and use shared AC quantum infrastructures depending on the particular needs of each country.

Impact

This project will enable a number of NMIs to access AC quantum voltage standards, thereof reducing the technological gap between NMIs. Furthermore, the partners will work towards a basis for a future European collaboration. The combined efforts between NMIs will enable specialisation in the new infrastructures developed and on the research topics defined in the EURAMET roadmap for metrology. This will improve the European research capacity and contribute to achieve the EURAMET research targets.

Impact on relevant standards
Quantum effects play an important role in the redefinition of the SI electrical units and over the last decade there has been a substantial research activity on AC quantum voltage references to meet the demand for applied AC measurements in industrial and scientific research. This project responds to the following documents: i) A Resolution on the possible future revision of the International System of Units (SI), adopted by the CGPM (General Conference on Weights and Measures) and ii) a draft *mise en pratique* for the ampere and other electric units, prepared by the CCEM (Consultative Committee for Electricity and Magnetism).

Impact on industrial and other user communities
This project addresses the industry need for lower Calibration and measurement capabilities (CMCs) in AC electrical properties. The improvement of uncertainties of AC electrical quantities in several NMIs will increase the measurement quality and, in the long-term, the high automation and high speed of AC quantum standards are expected to decrease the price of calibrations. In industry, many of the electrical measurements are directly traceable to AC quantities; so the wide introduction of AC quantum voltage standards is expected have a larger impact than the introduction of DC quantum voltage standards that by the time improved the uncertainties of calibration services by three orders of magnitude. The increasing demand for calibration of analogue-to-digital converters with better precision can only be met with the fast spread of AC quantum standards. Furthermore, due to the traceability of waveforms enabled by AC quantum voltage standards, the industrial community involved in the measurement of dynamic quantities will benefit with the increased calibration capabilities of the NMIs. For example, the dynamic force and pressure are quantities where a strain gauge or other sensor converts instantaneous force or pressure into a voltage waveform; and in the health industry complicated waveforms such as cardiac waveforms also require calibration.

Impact on the metrological and scientific communities
AC quantum voltage standards will give the European NMIs direct traceability for AC measurements to the new SI definition. A few laboratories (e.g. CMI, TUBITAK) are already in the process of establishing AC quantum voltage standards and this project will shorten the development time. A future inter-comparison of the systems will be arranged during the lifetime of this project. It is expected that the comparison demonstrates a significant improvement of their measurement and calibration capabilities. NMIs with top-level calibration services usually collaborate with universities and institutes of technology towards the development of new instruments or measurement methods. With a larger adoption of AC quantum voltage standards, research in this field is expected to increase substantially, as a large fraction of electrical quantities will be traceable to these standards.

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<tr><td colspan="2">Project start date and duration:</td><td>01 June 2015 (36 months)</td></tr>
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Partner 1 CEM, Spain
Partner 2 BEV-PTP, Austria
Partner 3 CMI, Czech Republic
Partner 4 FER, Croatia
Partner 5 GUM, Poland
Partner 6 INRIM, Italy
Partner 7 IPQ, Portugal
Partner 8 JV, Norway
Partner 9 NPL, United Kingdom
Partner 10 PTB, Germany
Partner 11 SIQ, Slovenia
Partner 12 TUBITAK, Turkey</td><td>External Funded Partners:
Partner 13 FCT- UNL, Portugal</td><td>Unfunded Partners:
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