Publishable Summary for 19RPT01 QuantumPower
Quantum traceability for AC power standards

Overview

The electrical power industry is undergoing a rapid transformation from fossil fuels to renewable energy generation. Precise and traceable measurements are required to guarantee stable supply, prevent blackouts and ensure a fair electricity market. The aim of the project is to improve quantum traceability for AC power standards. To achieve this, the project will design and build an open access Quantum Power measurement System (QPS), also known as quantum sampling electrical power standard, for electrical power and power quality (PQ), which will be distributed within the metrology community. This will provide developing institutes with the best calibration and research capabilities, improve uncertainties in power measurement, ensure a direct link to the new quantum SI, decrease development costs and reduce the gap in electrical measurement capabilities among the European institutes.

Need

Over the last decade, there has been substantial interest in AC quantum voltage references to meet the demand for applied AC measurements, which affect around 70 % of NMIs' calibrations. Additionally, quantum effects play an important role in the redefinition of the SI units e.g. the volt can now be directly realised by the quantum effect. The primary (electrical) power is one of the electrical quantities that has traceability to the volt and the ampere, typically through complicated calibration of thermal voltage converters, current shunts and digitizers, which only a few NMIs in Europe can provide with uncertainties approaching a few µV/V. In order to ensure a secure and robust development of interconnected smart grids in Europe, it is crucial that the developing NMIs increase their competence, capabilities and traceability within the field of electrical power measurements. Commercial Programmable Josephson Voltage Standards (PJVS) are not used for straightforward power measurements due to the complexity of integrating them into a QPS. Although most of the components for this integration are commercially available, a single NMI cannot conduct the whole development on this topic, and the power industry needs support and collaboration in order to assemble a working system and validate it against national standards. An open system for direct quantum traceability for electrical power is therefore necessary as a solid metrological platform for a future smart monitoring of the electrical grids, which can only be achieved by validated methods, developed within the metrological community.

Objectives

The overall objective of the project is to develop a quantum sampling standard for electrical power which is open to the whole metrology community and provides direct traceability to the new quantum SI.

1. To design and realise a practical quantum sampling electrical power standard based on programmable Josephson voltage standards, traceable digitizers and transducers. The quantum sampling standard should be able to measure electrical power, power quality (PQ) parameters and phasor. The target uncertainties are better than 20 µW/VA for power measurements and less than 2 µW/VA for the contribution of the digitizers.
2. To develop software for the operation of the quantum sampling electrical power standard developed in Objective 1. The software should enable measurement control, data processing and uncertainty estimation. Additionally, it should be open source and easily modifiable to control different AC quantum systems.
3. To develop new methods and algorithms for the measurement of electrical power using quantum systems, validate these methods and algorithms using a transfer standard and develop a protocol for future comparison of QPSs.

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

4. For each participant, to develop an individual strategy for the long-term operation of the capacity developed, including regulatory support, research collaborations, quality schemes and accreditation. Additionally, to develop a strategy for offering calibration services from the established facilities to their own country and neighbouring countries. The individual strategies should be discussed within the consortium and with other EURAMET NMIs/DIs including members of relevant EMNs, JRPs and EURAMET TCs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Progress beyond the state of the art and results

Practical quantum sampling electrical power standard based on PJVS

The use of quantum standards in sampling of electrical power enables direct traceability not only for power measurements, but also for PQ and phasors. The project will develop an open-source hardware multiplexer that will be synchronised with the sampling system. It will be able to switch the input of the analogue-to-digital convertors (ADCs) between the voltage, current and PJVS channels, in order to provide real-time calibration of the ADCs and substantially decrease the uncertainties of the power measurements. The multiplexer will enable using a single PJVS chip for measurement of both current and voltage components of the electric power using differential sampling, or to provide calibration of ADCs before and after the direct sampling of electric power. This will result in a flexible system useful for both industry and NMIs. The newly developed methods will also extend traceability to time-varying signals, which are becoming more relevant for the electrical power community.

Software for the operation of the new quantum sampling electrical power standard

Currently, no commercial products for quantum based electrical power measurements are available, but during EMRP project SIB59 Q-WAVE and EMPIR project 15RPT04 TracePQM, joint algorithms and software for sampling of electrical power were written and verified by the participating NMIs. An open-source approach was considered the best way to spread the load of developing a joint system and reduce the amount of overlapping development. This project will build on this earlier research to include the traceability to quantum standards, in a collaboration that goes beyond what a single NMI can achieve. Different PJVS sources will either be controlled or run in parallel to the quantum sampling software, and a description of the algorithms will be published and available as open source.

New methods and algorithms for the measurement of electrical power using quantum systems

Over the last decades there has been a rapid development of analogue-to-digital converters and implementation of digital measurements of electrical power, but the community is not yet widely utilising quantum voltage standards technology. This project will make significant advances in power measurement systems and implementation of the quantum systems traceable to the new quantum SI, where the fundamental electrical units are now defined by physical constants and realised by quantum standards. This will be achieved through the development of new methods and algorithms for the measurement of peak amplitude and phasor tailored to PJVSs. This project will build on the work in previous iMERA, EMRP and EMPIR projects such as ProVolt, SIB59 Q-WAVE, 14RPT01 ACQ-PRO, SIB59 Q-WAVE, 15SIB04 QuADC, 17RPT03 DIG-AC, 15RPT04 TracePQM, ENG04 SmartGrids and 15NRM04 ROCOF.

Impact

Impact on industrial and other user communities

This project will enable industrial stakeholders to establish direct traceability of electrical power measurements to the new quantum SI, by providing an open design system that will connect commercial products together to provide direct quantum traceability to the SI. The collaboration with European manufacturers of quantum standards and high precision DACs and ADCs, represented as stakeholders in the project and within the EURAMET European Metrology Network for Smart Energy Grids (EMN SEG) and EURAMET European Metrology Network for Quantum Technology (EMN-Q), will ensure that the project is aligned with industrial needs from the start. By sharing the knowledge gathered in numerous EMRP/EMPIR projects and making quantum traceability for electrical power widely available, this project will ensure that high quality type approval (certification) and calibrations can be offered more widely.

As a result of the modular and open-source approach to be developed in this project, many calibration laboratories and DIs will be able to use results of the project independently and incorporate validated hardware or software into their quantum systems and services. This will thereby expand the number of NMIs and calibration laboratories with the ability to provide very low uncertainty calibration of electrical power.

Impact on the metrology and scientific communities

The new QPS to be developed in this project will be used as basis for workshops which members of EURAMET technical committees will be invited to, in order to disseminate the work to the European metrology community. A close collaboration between this project and EURAMET EMN-SEG will ensure that the knowledge is spread to stakeholders within the field and that the increased capacity for high-quality electrical power measurements will benefit end-users. Additionally, this project will increase capacity and decrease the existing technological and scientific gap in power measurements among the different NMIs of the consortium. The demonstration of quantum electrical power sampling, which will accessible to all NMIs and calibration laboratories, will promote the development of PJVS systems across Europe, and will lead to more robust traceability, not just for electrical power, but also DC and AC voltage and impedance measurements. At the end of this project, the participating NMIs will be able to deliver power measurements with lower uncertainties than today.

Impact on relevant standards

The project will engage with relevant technical committees of regional metrology organisations such as i) EURAMET TC-EM (Technical Committee for Electricity and Magnetism), ii) EURAMET TC-EM SC Low Frequency, iii) EURAMET TC-EM SC DC Quantum Metrology, iv) EURAMET TC-EM SC Power and Energy and v) BIPM-CCEM (Consultative Committee for Electricity and Magnetism) to ensure knowledge transfer and exchange with the community primarily responsible for maintaining references for electrical power. The documentation of the open-source software and hardware multiplexer will be disseminated to the community, in order to ensure that emerging NMIs can benefit from the work developed in the project. Furthermore, the reduced uncertainties for power measurements will support the MID mandated under EU directive 2014/32/EU which has been challenged by recent electromagnetic interference (EMI) issues with approved smart meters and investigated in the EMPIR project 17NRM02 MeterEMI.

Longer-term economic, social and environmental impacts

This project will significantly enhance the development of a coordinated European electric power metrology infrastructure, which will support EU power industry, estimated to have been approximately €155 billion in 2017. Extending cutting-edge research technologies to the European NMIs and calibration laboratories, by publicly releasing the project results, will lead to higher efficiency in measurement services, which will contribute to increasing economic welfare in Europe. Measurement of electric power is essential to the management of power quality and stability through the balance of variable demand and variable distributed generation caused by renewable sources.

List of publications

<table>
<tr><td colspan="2">Project start date and duration:</td><td>01 September 2020, 36 months</td></tr>
<tr><td colspan="3">Coordinator: Dr. Helge Malmbekk, JV Tel: +47 64 84 84 27 E-mail: hma@justervesenet.no
Project website address: under construction</td></tr>
<tr><td>Internal Funded Partners:
1. JV, Norway
2. CEM, Spain
3. CMI, Czech Republic
4. INRIM, Italy
5. PTB, Germamy
6. VTT, Finland</td><td>External Funded Partners:
7. INTI, Argentina
8. UMA, spain</td><td>Unfunded Partners:</td></tr>
<tr><td colspan="3">RMGs: -</td></tr>
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