Publishable Summary for 15RPT04 TracePQM
Traceability routes for electrical power quality measurements

Overview

The diversification of electric power generation to include sources with fluctuating output power such as solar and wind and the growing number of appliances employing switched-mode power supplies, has led to increased demands for traceable, accurate measurement of electrical power and power quality (PQ) parameters. Conventional power measurements based on thermal converters only provide information about the root-mean-square (RMS) value which is not sufficient for PQ measurements that need to address complex waveforms. New measurement setups based on alternative measurement techniques are required and whilst a few national metrology institutes (NMIs) have developed metrology grade power and PQ measurement systems based on sampling techniques, these systems are not generally available and no laboratories can offer calibration services for all the required PQ tests. This project will help to address this issue by developing and validating a modular metrology grade system for the measurement of power and PQ parameters using digital sampling techniques.

Need

Traceable measurement of PQ parameters requires the establishment of an appropriate measurement setup, software to control the instruments and collect the data, and algorithms to process the data including the calculation of the power, the PQ parameters and their associated uncertainties. The development of all parts of a sampling power and PQ measurement system with associated software and the calibration and validation of the system requires significant effort and time and is generally beyond the capacity of individual institutes such as smaller or emerging NMIs/DIs, universities, calibration laboratories and manufacturers of PQ instrumentation etc. Furthermore the independent development of all parts of the sampling power and PQ measurement system from scratch in every institute would result in duplication of existing designs and devices and waste resources. In addition traceability has not been fully established for all components of the PQ measurement setup, and harmonised calibration methods with extended ranges for transducers and wideband digitizers are therefore required.

Successful implementation of such a power and PQ measurement system requires knowledge and expertise in at least four fields. Firstly it is essential to design a proper, interference-free interconnection scheme of the components of the measurement system, i.e. the digitizers, current shunts and voltage dividers. Secondly it is necessary to design software capable of controlling the digitizers that will, among other things, ensure synchronization of particular digitizer channels. Thirdly the sampled voltage and current waveforms must be mathematically processed to obtain the required parameters such as power, power factor, and various PQ parameters. The waveform processing also needs to incorporate the calculation of the measurement uncertainties. Finally performance of the measurement setup needs to be validated to ensure traceability to the SI. The design of the measurement setup must be flexible and allow new digitizers or PQ algorithms to be easily incorporated without the need to rebuild the entire system in order to cater for continuously developing customer's needs and to reflect documentary standards which define requirements for PQ meters. Ideally any solution should focus on maximising the use of the capabilities of existing hardware components such as the bandwidth for wideband digitizers and the record length extension for sampling multimeters which are now limiting factors for complex PQ parameter measurements.

Objectives

The overall aim of this project is to develop and validate a modular metrology grade system for the measurement of power and PQ parameters using digital sampling techniques. The specific scientific and technical objectives of the project are:

1. To design a modular, metrology grade measurement setup for sampled electrical power and PQ parameters measurements, including a review of existing measurement and calibration methods,

associated hardware and software, investigation of the optimum use of equipment already available within the NMIs/DIs and extension of traceability for power and PQ measurements up to 1 MHz.

2. To develop and validate a modular measurement setup for sampled electrical power and PQ parameters measurements, which can be easily established at NMIs/DIs and at other organisations. The target uncertainties of the modular measurement setup are at least four times smaller than the tolerances specified in documentary standards for PQ meters, e.g. the target expanded uncertainties for the amplitude of voltage harmonics of the modular measurement setup are 1.25 % of the measured voltage harmonic for measured values higher or equal to 1 % of the nominal voltage and 0.012 % of the nominal voltage for measured values lower than 1 % of the nominal voltage.
3. To develop an open software tool for instrumentation control, data acquisition and the calculation of electrical power and PQ parameters with full uncertainty estimation.
4. To develop and make available a good practice guide for the assembly and operation of the modular measurement setup including the calibration of all components so as to establish full traceability to the SI of the electrical power and PQ parameters measured. The guide will include the manual for the open software tool to assist users in the extension and modification of the modular measurement setup.
5. For each partner to develop an individual strategy for the long-term operation of the research capability developed during the project, including regulatory support, research collaborations, quality schemes and accreditation, together with a strategy for offering calibration services from the facilities established to customers in their own country and neighbouring countries. The individual strategies will be discussed within the consortium and with other EURAMET NMIs/DIs, to ensure that a coordinated and optimised approach to the development of traceability in this field will be implemented for Europe as a whole.

Progress beyond the state of the art

The project will go beyond the state of the art by making innovative and optimum use of equipment that is already available within the NMIs/DIs and maximising the capabilities of the chosen hardware components in order to develop a modular measurement system for power and PQ parameters. The possibility of implementing continuous sampling with sampling multimeters for measurements that require long interval waveform records will be investigated. Methods to improve the stability and temperature dependence of wideband digitizers will be studied. Traceable methods for the calibration of particular components for frequencies up to 100 kHz will be developed together with an extension of the frequency range up to 1 MHz.

The modular power and PQ measurement setup will be accompanied by an open software tool for instrumentation control, data acquisition and data processing, so that the end user community can add functionality for any other digitizers or PQ algorithms by simply adding new modules. A unified system of calibration datasets for every component used in the setup (i.e. digitizers, current shunts and voltage dividers) will be implemented so that adding or interchanging the components will only require different datasets to be loaded into the system. The algorithms implemented for calculation of the PQ parameters will be accompanied by a numerical calculator of the measurement uncertainty and, for computationally expensive algorithms, by a quick uncertainty estimator based on a previous Monte Carlo uncertainty analysis.

In addition the project will extend the research capabilities and calibration services in power and PQ metrology across more European countries. Coordinated activities of the participating NMIs/DIs will speed up the research in this field and reduce unnecessary parallel investigations and developments, thus saving resources.

Results

The overall goal of this project is to develop and validate a modular and well documented metrology grade system for the measurement of power and PQ parameters by means of digital sampling techniques. This goal can be achieved only by completion of particular scientific and technical objectives listed above. The progress made during first nine months in scope of these objectives is as follows:

Design of a modular, metrology grade measurement setup

A review of existing measurement setups, calibration methods and voltage and current transducers for the measurement of power and PQ parameters in use by most worldwide NMIs/DIs and already published in literature was conducted. Moreover, an international survey of existing methods and their main features has been circulated, targeting European and international NMIs. Answers from 17 NMIs have been collected and

analysed. The existing measurement set-ups have been described and categorized based on their measuring principles and/or the hardware used. The contradictory requirements on the setup design (to ensure both the lowest possible uncertainties and the highest possible bandwidth) cannot be met by a single measurement setup. Therefore the new design needs to consist of two setups, one of which will cater for low frequency (LF) measurements at the best accuracy level and the other for wideband (WB) measurements, but with reduced accuracy. The review of existing measurement setups identified three candidates for the new LF system and one candidate for the new WB system.

Traceable calibration methods of voltage dividers and current shunts in terms of amplitude and phase were developed up to 1 MHz for dividers and up to 100 kHz for the shunts. The first trial software versions for the long duration data sampling with 3458A have been implemented. The measurement of short term stability, temperature dependence and input admittance of several pieces of NI 5922 was performed. An interchannel phase shift calibration method of NI 5922 up to 1 MHz was completed.

Development and validation of a modular measurement setup

There was no progress in scope of this objective during the first nine months of the project. The new modular measurement set up will be developed later in the project after completion of the report on the most suitable setup design and development of the open SW tool.

Development of an open software tool

The review of existing systems and the “first-pass” design of the two proposed measuring set-ups - (LF and WB), have led to the proposal of a concept for the software structure able to satisfy the different demands in terms of clock and trigger and to allow the handling of different samplers involved in the design of the two setups. LabVIEW (LV) and/or LabWindows/CVI provided by National Instruments were considered and agreed as the most suitable software environments for development of an open modular SW tool for PQ measurement.

A concept for the interface between LV/CVI to GNU Octave/Matlab for runtime data processing was proposed considering the possibility of integrating as many PQ algorithms as possible. Based on the concept the DLL library for runtime communication with GNU Octave console process was developed to be used by both LV and CVI.

Production of good practice guide

There was no progress in scope of this objective during the first nine months of the project.

Development of individual strategies of the partners

There was no progress in scope of this objective during the first nine months of the project.

Impact

An abstract describing the project progress was submitted to CIM 2017 conference. The information about the project and the results has been regularly disseminated via international and European electricity related technical committees, and presented to relevant legal metrology organisations. So far the project was presented to the OIML TC 12 committee, EURAMET SC Power and Energy and was also introduced during 26th National Scientific Symposium “Metrology and Metrology Assurance 2016”. Contact is being made with IEC TC77, WG9 “Power Quality Measurement Methods” to determine if the results of the research can be of use to the working group.

The project incorporates early phase knowledge transfer from experienced NMIs to the less experienced NMIs. A half day Workshop on Power and Power Quality Metrology for consortium was organised in conjunction with the kick-off meeting to provide the partners with the necessary knowledge to progress with the activities of the project. Next, the active participation of less experienced NMIs in the development of the new system is planned to further extend their knowledge.

The project’s stakeholder committee, which provides an enduring link between the project and interested parties, includes representatives from instrument manufacturers; distribution service operators, accredited test laboratories, and academic research departments.

Impact on the metrology and scientific communities

The open software tool and good practice guide will be publicly available to all interested parties, i.e. NMIs/DIs, calibration laboratories, industry, universities and individual practitioners. They will serve both as a quick

starting point for the establishment of an expandable modular sampling power and PQ measurement system and as a reference to speed up the design of a new system if required. The universal access to the open software tool and good practice guide and the easy to implement modular design of the power and PQ measurement setup will lead to the improvement of the power and PQ measurement capabilities within Europe, not only within the partner NMIs/DIs but also through the early uptake of the knowledge and project outputs by other interested parties, such as other NMIs/DIs or calibration laboratories.

The strategies for the long-term development and use of partners' capabilities will ensure fast uptake and maximum use of the project's results that will lead to the establishment of new calibration services or to the improvement of existing measurement capabilities in every participating country.

The preparation of a supplementary comparison in the field of power and PQ will support the validation of the new measurement setups after the end of the project.

Impact on industrial and other user communities

The strong interaction with stakeholders through a stakeholder committee helps the project to focus on the end-user's needs. So far 11 organisations of different fields of activities related to power and PQ (universities, test laboratories, distribution service providers, PQ test instruments manufacturers etc.) have joined the Stakeholders committee. Efforts are continued to expand the stakeholder committee. Moreover, a half day workshop related to the power quality was organized by SIQ in Slovenia to give the lectures to more than 30 participants from different Slovenian electricity distribution companies and companies that produce PQ instruments. Another four collaborators have joined the project to directly contribute to the technical and scientific objectives.

The improved European power and PQ measurement capabilities will contribute to the metrological basis necessary for policy makers and energy suppliers in all European countries to guarantee a stable and secure energy supply to customers. This project will also assist with the growth and development of the energy infrastructure by providing wider European access to traceable measurement capabilities for power and PQ quantities. The modular design and open software tool will enable straightforward future expandability of the measurement setup to cater for continuously developing customer's needs.

At the end of the project a stakeholder workshop will be organised that will be open to anyone and which will help to ensure the uptake of the project's outputs by potential end-users.

Impact on relevant standards
The working group WG9 of IEC sub-committee SC77A "Power Quality Measurement Methods" has been informed about the project.

List of publications

No publications so far.

Project start date and duration:	01 June 2016, 36 months	
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