EURAMET European Association of National Metrology Institutes

EMRP European Metrology Research Programme
Programme of EURAMET

Publishable JRP Summary for Project T4 J01 (Power & Energy). The Next generation of power and energy measuring techniques

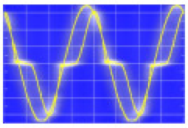
Society demands electricity supplies that are secure, sustainable and of high quality. In the next decade, Europe is facing potential energy shortages as oil and gas supplies run down and nuclear power facilities age. Pressure to reduce the green house gas emissions will lead to a requirement for more renewable energy generation, efficient appliances, energy management and improved electricity distribution efficiencies. Commerce will demand an electricity supply of the highest quality, free from momentary voltage interruptions or interference sources.

This project has developed an array of new measurement equipment, algorithms and software which forms the necessary infrastructure to enable the measurement of the complex electrical parameters associated with power, energy and power quality to ensure that technologists, energy suppliers and regulators can work towards an energy secure future within a metrology framework.

Impact in Images

Renewable Energy Performance

Transmission & Distribution Efficiency



Power Quality Compliance

Energy Saving Evaluation

Accurate Electricity Metering

To achieve this framework the project has undertaken the following research and development:

- Designed and built metrology grade digitisation hardware suitable for laboratory and on-site use suitable for measurement of signals ranging from three phase power to transients and impulses.
- Developed and characterized precision transducers for laboratory measurements of power and power quality.
- Formulated accurate sampling techniques and analysis algorithms in support of power quality including asynchronous sampling and noise reduction algorithms.
- Developed and characterized high current and high voltage transducers for non-invasive use on the high voltage grid.
- Applied this new technology within a harmonised methodology for the traceable measurement of power quality parameters in the laboratory and on-site.

To ensure exploitation and assure a timely and smooth take-up of the outcomes of this project, a “User Committee” consisting of 19 representatives of electricity suppliers, generation/distribution equipment manufacturers, legislation bodies and end-users have monitored the progress of the project suggesting approaches and methodologies that will ensure that the project has real impact in their industrial sectors.

Working together with this committee, the project has developed and disseminated a metrology infrastructure consisting of equipment designs, algorithms, procedures and techniques that will enable the measurement of Power Quality parameters under realistic conditions and develop on-site capabilities that provide traceable measurements on fixed power grid installations.

Summary of Technical Achievements

A full account of the technical activities of the project is available in the "Final Publishable JRP report" and in the technical presentations available at http://projects.npl.co.uk/power_energy/meeting.html

The first challenge tackled in this project is to build new transducers for lab based power measurements. WP3 concentrated on the development of voltage and current transducers with accurate phase and amplitude characteristics for laboratory metrology of power quality. A detailed examination of the performance of their shunt designs has been undertaken and the result has been a comprehensive comparison of the figures of merit that determine the performance of these devices. Modelling, the selection of materials and experimental characterization have been carried out to develop optimized designs of shunts for 5 A, 20 A and 100 A ranges. New characterization methods including phase and impedance methods have been developed to ensure traceability.

The development and characterization of non-conventional current and voltage transducers were required to enable traceable measurements over the necessary ranges suitable for on-site measurements on the medium voltage grid. Non-invasive current transducers such as split core Rogowski coils will allow measurements without interrupting the high voltage circuits. The coils have been characterized and their performance optimized for temperature.

Accurate voltage divider systems were developed to step down the grid voltages to a working level. These were designed and computer modelled and the constituent component elements have been individually characterized. The final assembly has been assembled tested and on-site measurements at 33 kV have been performed at two separate sub-stations.

Transducers have been exchanged between partners for these various parameters to be measured at the relevant expert laboratory. In light of the results designs are adjusted and the iterative design process resulting in world leading transducer technology. The project has developed the following transducers:

- Precision voltage dividers for laboratory use.
- Lab current shunts ranging 100 mA to 100 A at the highest accuracy.
- Systems and methodology for phase, level dependence and temperature coefficient of shunts.
- Characterized non-invasive current transducers for kA measurements.
- Selection and characterization of impulse (fault) current transducers.
- A portable precision MV voltage divider for on-site measurements.

The output signals from these transducers will then be applied to digitizer hardware to convert the signals to data for computer processing. Three designs have been completed each looking to design and build/acquire instruments for the highest precision lab measurements; portable multiphase measurements and high frequency measurements respectively. The following digitizers systems have been completed and characterized:

- A high precision laboratory digitizer and associated synchronization software.
- A portable high-resolution digitizer system based on a commercial solution.
- A new portable 24-bit system with on-board digital signal processor and Ethernet (wireless) data connection for safety isolation.
- A high frequency digitizer, suitable for 1 MHz power measurements, based on a commercial solution.

The digitized data is processed to determine the all important Power Quality parameters (e.g. harmonics, flicker) and the project is engaged in the development of novel waveform analysis techniques and signal processing algorithms to enable meaningful sample based measurements of arbitrary, fluctuating signals under noisy, asynchronous conditions, such as those that prevail on high voltage sites. The following methods have been developed:

- Windowed Fourier transform and Wavelet methods for fluctuating harmonic measurement.
- Measurement of flicker in the presence of phase jumps.
- Four independent new asynchronous sampling algorithms have been developed and inter- compared.
- Noise reduction techniques using adaptive filters applied to power system scenarios.
- Application of Bayesian techniques to power quality algorithms and noise reduction

This technology was brought together and implemented in a harmonized metrology infrastructure to underpin EU regulation. This includes the compilation of uncertainties which must be carried out for complex multiple input systems. Methodologies for pan-European working are also essential to ensure a harmonized approach to the implementation of directive of Power Quality. The project has:

- Modelled the effect of localized finite grid impedance on various power quality parameters.
- Completed a flicker uncertainty model and is carrying out computationally intensive Monte Carlo runs to determine uncertainties
- Agreed a protocol on EU power quality measurements
- Completed an on-site power loss measurement at low power factor.
- Integrated WP2 digitizers, WP4 algorithms and WP5 transducers into an on-site measurement system. Including real time measurements of a wide range of power quality measurements suitable for remote long-term data collection to determine PQ events and energy patterns.
- Completed two on-site Power Quality measurements at substations.

The impact WP has delivered close ties with some of the main industrial participants in this field. Working through its User Committee, the JRP can ensure its outputs are both relevant and taken-up by industry. Nineteen such members committed to the project and representatives attended and contributed to meetings in the UK, Sweden, Austria, Denmark and the Netherlands. This represents a significant commitment by these organizations that it is hoped will eventually be in a position to implement its outputs on real measurement problems on real systems. Seven separate on-site measurements have been carried out at substations with the support of personnel from various companies.

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JRP Contract Number:	T4.J01
JRP Title - JRP Acronym:	Power and Energy.
JRP start date and duration:	Next generation of power and energy measuring techniques.
Date of this Publishable JRP Summary:	1st April 2008 for 3 years.

JRP-Coordinator:

Name, Title, Organisation:	Paul Wright, Dr, National Physical Laboratory (UK).
Tel.:	+44 (0)208 943 6367
E-mail:	paul.wright@npl.co.uk
JRP website address:	http://projects.npl.co.uk/power_energy/

Other JRP partners:

Organisation, Country:	BEV (AT), EJPD (CH), CMI (CZ), PTB(DE), TRESCAL (DK), CEM (ES), MIKES (FI), LNE (FR), INRIM (IT), VSL (NL), JV (NO), BRML INM (RO), SP (SE), MIRS/SIQ (SI), SMU (SK).

The research within this EURAMET joint research project receives funding from the European Union Seventh Framework Programme, ERA-NET Plus, under the iMERA-Plus Project – Grant Agreement No. 217257.