29th meeting of the CCEM
12 – 13 March 2015 at BIPM

Activities from
CEM Electricity and Magnetism Division

The activities of the Electricity and Magnetism Division are mainly directed to give fulfilment to the following fundamental points:

a) Establishment, maintenance, conservation, development and dissemination of the national standards of/for the measurement units corresponding to the electrical quantities in DC and LF. Therefore, the requirements established in the Mutual Recognition Arrangement are fulfilled in their entirety:
- Participation in international key comparisons.
- Declaration of the optimal Calibration and Measurement Capabilities, CMC.
- Implantation of a quality system in the laboratories of the Electricity Division.

b) Execution of research, development and technological innovation projects: National and EMRP projects.
c) Search and optimisation of methods for the improvement of uncertainty values, the extension of the existing measurement ranges and the beginning of activities in new quantities.

The technical activities can be summarised as follows:

DC Voltage

The laboratory continues making calibrations of Zener references and high accuracy voltmeters with the Josephson conventional standard. Additionally, we routinely calibrate DC voltage and current meters and sources.

CEM organised the last EURAMET DC&QUANTUM METROLOGY Experts Meeting in May 2013.

In the framework of its participation in the EMRP project JRP SIB53 AIM QuTE, *Automated impedance metrology extending the quantum toolbox for electricity*, the laboratory has developed a new system in order to generate very low AC voltage with phase controlled. This system is being used to verify the linearity of AC null detector, especially lock-in amplifiers. The development of an AC impedance ratio bridge based on a single programmable Josephson array is ongoing.

The new service to calibrate charge meters is now fully operational. It is essentially used to calibrate ionising radiation dosimeters.

DC Resistance

A new high resistance measurement system has been developed based on a reference standard, an electrometer and a voltage calibrator as a source. This system is an alternative to the teraohmeter.

The resistance laboratory has finished a new procedure for the calibration of resistance bridges based on a resistance bridge calibrator RBC 400 designed by the MSL, of New Zealand.

A new service of resistance meter calibration will be proposed in the next EURAMET CMC review process.

The laboratory has participated in the "*EURAMET.EM-S32 Comparison of Resistance Standards at 1 TΩ and 100 TΩ* ", obtaining good results at 1 TΩ. Errors in results at 100 TΩ have been studied and their causes have been detected, allowing us to improve our measurement method.

Calibration of standard resistors and reference groups is still ongoing.

AC-DC Transfer

The laboratory is participating in the on-going "*EURAMET.EM-K12 key comparison of AC-DC current transfer standards*" at 10 mA and 5A from 10 Hz to 100 kHz.

In cooperation with 14 European NMIs, CEM has coordinated a successful proposal for the EMPIR CALL 2014 research potentials. This project, named "*ACQ-PRO. Towards the propagation of AC Quantum Voltage Standards*", focuses on extending the use of the AC Quantum Voltage Standards within the European NMIs. The project will start on June 2015 and will be coordinated by CEM.

The laboratory participates in the EMRP CALL 2012 project SIB59, Q-Wave, *A quantum standard for sampled electrical measurements"*. The project started on June 2013. CEM participates in four work packages and is responsible for the improved characterisation of analogical to digital converters.

New CMCs were approved in the recent CMC review EURAMET.EM.12.2014. In particular, the service of "AC voltage up to 1 000 V" for sources and meters has improved the uncertainties and range. Furthermore, a new entry on "AC current up to 100 A", for sources and meters, was also approved.

The laboratory has actively participated in the CPEM 2014 held in Rio de Janeiro (Brazil) with two oral presentations and cooperating in a poster. It has also been the chairman of a session.

Additionally, the laboratory has participated in the EURAMET Low Frequency Experts Subcommittee Meeting held at the PTB in May 2013.

Power and Energy Standards

New services, with improved ranges and uncertainty values and based on the power and energy digital sampling system, have been approved in the last review process in EURAMET.

Further work has begun in order to optimise the measurement period and the uncertainty values of the primary power standard by using the digital sampling method. This method is based on Artificial Neural Networks (ANNs) for spectrum analysis and fundamental frequency estimation of asynchronously sampled signals.

On the other hand, we continue with our Measurement Assurance Program (MAP) in order to ensure the traceability of the electrical energy measurement in Spain. This program is based on a set from RADIAN travelling standards.

Impedance

A new four-terminal-pair coaxial bridge has been developed for AC resistance measurement. It consists on a ratio bridge which compares the value of an unknown AC resistance standard with the reference resistance, which is a calculable resistor. Figure 1 shows the two calculable resistors employed as a reference in the bridge. This system allows the determination of AC resistances standards between 1 Ω and 100 kΩ, in a wide range of frequencies (from 40 Hz to 5 kHz), with an expanded uncertainty from 1 μΩ/Ω to 5 μΩ/Ω, depending on the nominal value of the resistance and the measurement frequency.

A new calibration service for 10 mH inductance measurement has been approved in the last EURAMET CMC review process.

The recent development of a measurement system for AC voltage ratio based on the Straddling method has allowed the calibration of the standard transformer employed in the AC resistance bridge for all the above-mentioned frequencies with an uncertainty value of order one part in 10^{-7}.

Fig. 1. Photos of the CEM bifilar calculable resistor (on the left) and quadrifilar calculable resistor (on the right) used as a reference for AC resistance measurements.

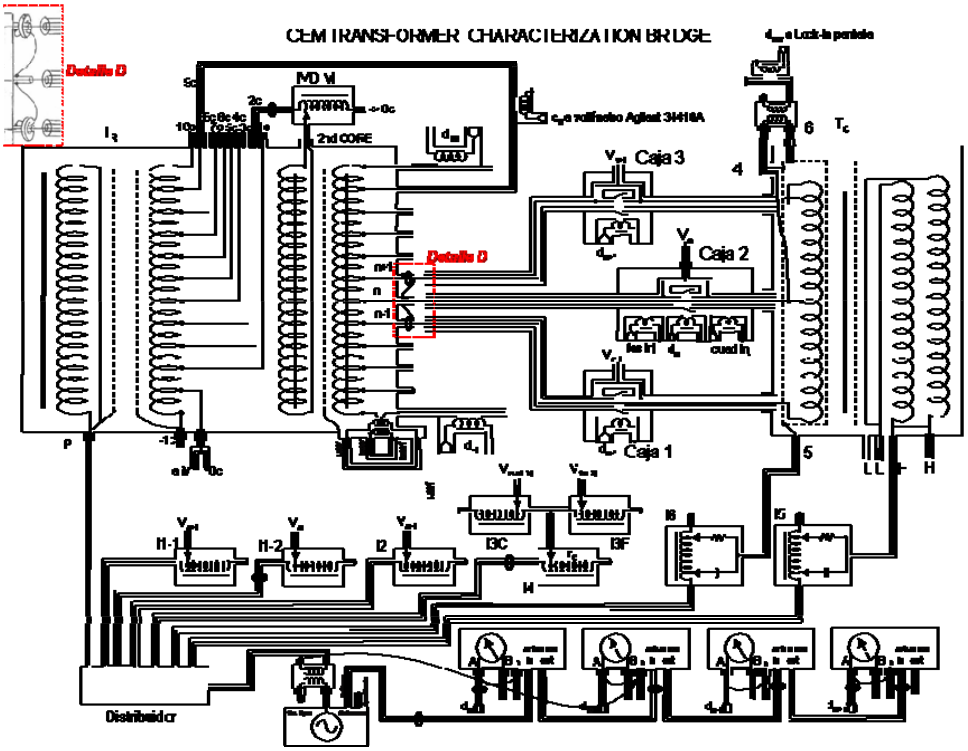

Fig. 2. Scheme of the new CEM AC voltage ratio bridge

CMCs

The Electricity and Magnetism Division is currently participating in the CMC review processes. First CEM participated in the EURAMET.EM.9.2013 review process (simplify procedure) published at BIPM in August 2013. Then CEM has participated in the EURAMET.EM.12.2014 review process: 8 new CMCs and 9 modified CMCs, in DC current low values, AC voltage up to 1 000 A, AC current up to 100 A and AC power and energy, single and three phase, based on the primary standard by using sampling digital. These new services, ranges and uncertainty values have significantly improved the DC and AC services.

EMRP projects

CEM is participating in the following EMRP or EMPIR projects:

EMRP CALL 2012. SI Broader Scope:

- SIB59, Q-Wave. *A quantum standard for sampled electrical measurements*.
- SIB53, AIM QuTE. *Automated impedance metrology extending the quantum toolbox for electricity*.

EMPIR CALL 2014. Research Potentials, capacity building:

- "*ACQ-PRO. Towards the propagation of AC Quantum Voltage Standards*", focuses on to extent the use of the AC Quantum Voltage Standards within the European NMIs. The project will start on June 2015 and will be coordinated by CEM in cooperation with 14 European NMIs.

New publications

- *The national measurement standards at CEM and their role in MRA and EMRP projects*. Miguel Neira. 19th IMEKO TC-4, Plenary Session, Pub.nº 14, 0001, ISBN-13:978-84-616-5438-3. Barcelona, 18 July 2013.
- *Calibration System for Electric Charge at Centro Español de Metrología*. Manuel L. Cervantes, Félix Raso. 19th IMEKO TC-4, Pub.nº 14, 01DC020. Barcelona, 18 July 2013.
- *Realization and validation of the 10 mA-100 A current standards at CEM*. J. Díaz de Aguilar, R. Caballero and Y. Álvarez Sanmamed. IEEE Transactions on Instrumentation and Measurement, (Volume: PP, Issue: 99), ISSN: 0018-9456, 19 December 2013.
- *Design and installation of a novel multi-point measurement system for a renewable energy grid*. J. Bruna, J.J. Melero, D. Cervero, R. Caballero, J. Díaz-de-Aguilar, M. Neira. Renewable Energy and Power Quality Journal (RE&PQJ), ISSN 2172-038 X, No.11. March 2013.
- *Multi-point PQ measurement system for a renewable energy grid*. J. Bruna, J.J. Melero, D. Cervero, R. Caballero, J. Díaz-de-Aguilar, M. Neira. Smart Grid Metrology final workshop, Noordwijk, Netherlands. June 2013.
- *Design and installation of a novel multi-point measurement system for a renewable energy grid.* J. Bruna, J.J. Melero, D. Cervero, R. Caballero, J. Díaz-de-Aguilar, M. Neira. International Conference on Renewable Energies and Power Quality (ICREPQ'13). Bilbao, 20-22 March 2013.
- *Nuevos patrones nacionales en el CEM en CC y baja frecuencia*. Miguel Neira. 5º Congreso Español de Metrología. Madrid, 12-14 June 2013.
- *Proyecto sistema de medida patrón de resistencia corriente alterna. Estado actual y resultados preliminares*. Yolanda A. Sanmamed, Antonio Sánchez, Javier Díaz de Aguilar y Miguel Neira. 5º Congreso Español de Metrología. Madrid, 12-14 June 2013.

- *Los convertidores digitales como futuro patrón de corriente alterna. El proyecto europeo Q-WAVE*. J. Diaz de Aguilar Rois, M. Anguas Ballesteros, Y. A. Sanmamed, R. Caballero Santos, K. Schweiger Gallo y M. Neira. 5º Congreso Español de Metrología. Madrid, 12-14 June 2013.
- *Sistema de calibración para carga eléctrica*. Manuel Cervantes y Félix Raso. 5º Congreso Español de Metrología. Madrid, 12-14 June 2013.
- "Medida de resistencias de muy alto valor". L. Matías, A. Hortelano, F. Raso y M. Neira. 5º Congreso Español de Metrología. Madrid, 12-14 June 2013.
- *Puesta en servicio y evaluación del nuevo sistema de medida de parámetros de calidad de red en el Centro Español de Metrología*. M. Mar Izquierdo, M. Luisa Romero y Miguel Neira. 5º Congreso Español de Metrología. Madrid, 12-14 June 2013.
- *Evaluation and compensation of the Analog-to-Digital Converters and transducer influence in the CEM digital sampling wattmeter*. J. Díaz de Aguilar, José R. Salinas, María L. Romero, Francisco García Lagos, Yolanda A. Sanmamed y Miguel Neira, 29th Conference on Precision Electromagnetic Measurements (CPEM). Rio de Janeiro (Brazil). August 2014.
- *A quantum standard for sampled electrical measurements – main goals and first results of the EMRP project Q-WAVE*. J. Kohlmann , R. Behr , O. Kieler , J. Diaz De Aguilar Rois , M. Šíra, A. Sosso et al., 29th Conference on Precision Electromagnetic Measurements (CPEM). Rio de Janeiro (Brazil). August 2014.
- *Spectrum analysis of asynchronously sampled signals by means of an ANN Method.* J.R. Salinas, Javier Díaz de Aguilar, F. García-Lagos, G. Joya, F. Sandoval, and María L. Romero, 29th Conference on Precision Electromagnetic Measurements (CPEM). Rio de Janeiro (Brazil). August 2014.

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