

**REPORT OF THE RESEARCH AND DEVELOPMENT ACTIVITIES OF  
INMETRO ELECTRICAL METROLOGY DIVISION  
(2017-2019)**

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## Scope

This report presents the recent research activities in electricity and magnetism performed at Inmetro to support the confidence-building mentioned in the CIPM Mutual Recognition Arrangement (CIPM MRA).

## Research and Development

### (a) Voltage

- Dissemination of the ac voltage unit from near dc to 1 kHz with reduced uncertainties (typically less than  $1 \mu\text{V}/\text{V}$ ) using the Programmable Josephson Voltage System (PJVS) and digital sampling techniques. The system will also be used to characterize thermal converters at low frequencies with reduced uncertainties.
- An automated measuring system is under development to measure dc voltages from  $1 \mu\text{V}$  to 100 mV with reduced uncertainties.

### (b) Current

- Modelling the ac-dc transfer difference of wideband cage-type current shunts for nominal currents from 0.5 A to 20 A is under development. A lumped equivalent circuit model for current shunts assembled according to this design was conceived. The ac-dc transfer difference of shunts with nominal currents from 0.5 A to 20 A are computed using standard two-port network theory. Cage-type current shunts were constructed and tested to validate the model. The model will help on future design decisions.
- A measuring system based on the charging and discharging times of reference capacitors is under development to measure dc currents from 1 fA to 10  $\mu\text{A}$ .

### (c) Resistance

- Several actions have been implemented to provide international recognition for our dc quantum Hall system. See below Inmetro's participation in comparisons run by BIPM.
- A measuring system based on the modified Wheatstone bridge is under development to measure dc resistance from 100 M $\Omega$  to 1 T $\Omega$ . The measuring system can be extended to measure dc resistance up to 100 T $\Omega$ .

### (d) Impedance

- Traceability chain to derive the capacitance unit from the dc quantum Hall effect. Development of the quadrature bridge and the inductive voltage divider calibration system based on the bootstrap method.
- There are 3 (three) impedance bridges in operation at Inmetro: a two terminal-pair coaxial bridge, a four terminal-pair coaxial bridge and a digital quadrature bridge. They were compared among themselves in the nanofarad capacitance range. These comparisons were aimed at checking the performance and reliability of the coaxial bridges among themselves and to infer about the capabilities of a digital one, recently put in operation. The results obtained indicated that the more accurate coaxial systems are compatible with one another in the  $10^{-7}$  level. The digital bridge is in agreement with the coaxial ones within a few parts in  $10^6$  or even less in some cases.

- Development of a five-terminal (four-terminal with shield) digital impedance bridge aided by digital adaptive phase regulation. It allows the comparison of ac resistances and capacitances with outstanding accuracy and with measurement uncertainties bearing only some  $10^{-6} \Omega/\Omega$ , as corroborated by extensive experimental investigations. The system was devised to be used in daily routine calibrations (in the resistance range from 10  $\Omega$  to 100 k $\Omega$  and capacitances from 1 nF to 1  $\mu$ F).

(e) Power

- A PMU calibration system is under development to measure amplitude modulation and voltage sags under low modulation indexes and slow voltage variations. The voltage signals are generated by a power quality calibrator used as a voltage source and conditioned by a resistive voltage divider before being acquired by a digital voltmeter. To estimate the voltage signal phasors at each time stamp, an iterative algorithm is applied to some fitting functions after the digital sampling. The results can be used as reference values, so they can be compared with the PMU values to determine the PMU errors.
- Acquisition of a commercial PMU calibrator for the routine calibration for PMU calibrators and the testing of commercial PMUs. Characterization of the PMU calibrator purchased and implementation of procedures.
- Development of a measuring system for electrical disturbances related to power quality.

(f) High voltage

- Traceability of ac high voltage (HV) measurements to low voltage (LV) measurements. The methodology adopted aims at characterizing a reference HV potential transformer with a HV capacitance bridge and HV and LV standard capacitors. The values of capacitance and dissipation factor of the standard capacitors need to be known by the time of the reference potential transformer characterization. The voltage coefficients will need to be estimated and the overall uncertainty evaluated.
- Traceability of dc high voltage measurements to low voltage measurements based on the 'binary step' procedure is under development.
- Extension of the ac high voltage range to 500 kV and implementation of a system for measuring impulsive voltages are under development.
- Traceability of ac high voltage measurements at harmonic frequencies (initially from 50 Hz to 2 kHz) is under development.

(g) High current

- Traceability of ac high current measurements based on model-based calibration where two standard current transformers (CT) are compared with the reference bridge and the several parameters of the two CT are measured to conceive the theoretical model for the CTs. The model is validated and employed to calibrate the reference bridge. Both single- and double-stage CTs will be evaluated.

(h) Magnetic field

- Improvement of the magnetic field metrology with the acquisition of new equipment.
- Implementation of field measurements of static and alternating magnetic fields (at network frequencies) according to Brazilian standards.

## Regional Project

- Regional project among Inmetro (Brazil), INTI (Argentina) and UTE (Uruguay), funded by the Brazilian government, to build a reference system for measuring electric power up to 100 kHz. Inmetro already constructed and tested 24 current shunts ranging from 20 mA to 100 A. INTI is currently constructing additional 36 current shunts for the same ranges. UTE already constructed and tested 27 resistive binary voltage dividers ranging from 4 V to 1024 V. Inmetro is currently constructing 3 (three) power amplifiers up to 240 V and 9 (nine) transconductance amplifiers with the ranges: 20 mA, 200 mA and 20 A. INTI is currently constructing 3 (three) Sigma-Delta

digitizers and 3 (three) DDS signal generators. The modules constructed will be distributed among the NMIs so that one unit of the reference measuring system can be integrated in each country.

### International Comparisons

- Inmetro is participating in the key-comparison of resistance standards (BIPM.EM.K13.a) as a preliminary step for her participation in the key-comparison on Quantum Hall resistance standards and their scaling to other resistance values (BIPM.EM.K12).
- Inmetro is also participating in the CIPM Key Comparison of AC-DC Voltage Transfer Standards (CCEM-K6a/K9).
- Inmetro is also participating in the regional supplementary comparison of voltage, current and resistance measurement (SIM.EM.S13).

### Publications

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#### **Book chapter**

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