# REPORT OF THE RESEARCH AND DEVELOPMENT ACTIVITIES OF INMETRO ELECTRICAL METROLOGY DIVISION (2022-2023)

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March 8-9, 2023

## 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 μV/V) using the Programmable Josephson Voltage System (PJVS) and digital sampling techniques. The system will be also used to ensure the traceability for ac power and energy measurements and to characterize thermal converters at low frequencies with reduced uncertainties.

(b) Current

- A model for the transimpedance amplitude and phase of cage-type current shunts for nominal currents from 0.5 A to 20 A and frequencies from dc to 10 MHz using two-port network theory was developed by the end of 2022.
- A measuring system based on the charging and discharging times of reference capacitors was developed in May 2022 to increase the measurement range by reducing the old minimum value of 10 μA to the new minimum value of 100 fA.

(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 1 GΩ to 100 TΩ.

(d) Impedance

- Traceability chain to derive the capacitance unit from the dc quantum Hall effect. The calculable resistor, the quadrature bridge, and the inductive voltage divider calibration system based on the bootstrap method are under development.
- An accurate system for measuring impedances at frequencies up to 300 kHz is under development. The system comprises a digital bridge to compare impedances both in-phase and in quadrature, high-stability digital signal synthesizers, analog-to-digital converter with control software, and auxiliary circuits.

(e) Power

- A PMU calibration system is under development to provide traceability to our Fluke 6135A PMU calibration system.
- 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 HV measurements to LV measurements based on the 'binary step-up' procedure is under development.
- Traceability of ac HV 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 is under development. Two standard current transformers (CT) are compared with the reference bridge and 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) Digitalization

- Development of an integrated web system for data processing related to calibration and lab management.

**Regional Project**

(i) 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.

**International Comparisons**

(a) Bilateral comparison of 1 Ω and 10 kΩ standards (ongoing BIPM key comparisons BIPM.EM-K13.a and 13.b) between the INMETRO (Brazil) and the BIPM - Inmetro e BIPM – from Nov-2020 to Sept-2021.
(b) CCEM-K6a/K9 Key Comparison of AC-DC Voltage Transfer Standards (Ac-dc voltage transfer at 3 V, 500 V e 1000 V) – from 2018 to 2023.
(c) SIM.EM-S13: Comparison of voltage, current and resistance – from 2017 to 2022.
(d) CCEM-K5 Key comparison of electric power. Inmetro's measurement report sent in January, 2021.

**Publications**


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