REPORT OF THE RESEARCH ACTIVITIES OF INMETRO ELECTRICAL METROLOGY DIVISION (2015-2017)

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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

- Development of a system for generating and measuring extremely accurate phase angles that combines digital synchronous signal generation with the synchronous subsampling technique, aided by digital phase regulators. The system was set up with commercially available instrumentation with a minimum of hardware development. Experimental evidences suggest that the phase between two generated sinusoidal signals can be resolved to a few μrad up to the MHz range.
- Development of an automated ac current-comparator-based resistance measurement system that uses precise and accurate phase synchronization of frequency-locked ac signals aided by adaptive digital regulators. The aimed frequency range lies between 1 Hz and 20 Hz.
- Development of a technique for digitally calibrating an ac signal against another one taken as reference, which is not necessarily of the same frequency as the first. The requirements of this technique are: knowledge of the spectrum of the ac reference signal, coherent generation of the signals with respect to a single time-base, a well-known bandwidth characteristic of a digitizer over frequency, and the ability to phase-align signals accurately.
- Development of a four terminal-pair 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 a few μΩ/Ω.
- Development of a primary single-phase sampling ac power standard, which uses a programmable Josephson voltage standard (PJVS) in its core. Magnetic transducers are used to scale down to low levels the ac signals to be compared with the PJVS by digital sampling. Independent digital adaptive regulators in the form of algorithms in control software guarantee stable and accurate phase alignment of the ac signals up to a few nanoradians.
- Investigation on a method to extend the frequency range of Programmable Josephson Voltage Standard based ac voltage calibrations. It requires coherent (synchronous) signal generation and sampling to a common reference time-base of a digitizer and accurate phase alignment of ac signals. Experimental investigations corroborate its feasibility in the range of some hertz towards audio and well up to the MHz-range.
- Development of a thermal converter (TC) with frequency output. The TC uses commercially available discrete components, eliminating the need for special environments (clean rooms) for its construction. Today's available SMD resistors for high frequency applications display nearly pure resistive behavior up to the GHz range, enabling the operation of the TC in a wide frequency range. A thermistor is used as temperature sensor, connected to an oscillator in order to provide a frequency output proportional to the input power.

- Development of a new calibration system to ensure traceability of low-frequency alternating current (ac) voltage calibrations (< 1 kHz) to a programmable Josephson ac waveform synthesizer. The automated full-synchronous system allows the synchronization of a commercial calibrator or signal synthesizer with a programmable Josephson voltage synthesizer system to be made by employing digital sampling and signal processing techniques, aided by adaptive digital control. It allows accurate determination of the spectral content of ac signals with minimum human intervention.
- Development a digital ac quadrature bridge for impedance measurements. This bridge is primarily intended to allow the comparison of ac resistors with standard capacitors. It is aimed at attaining measurement uncertainties of about 10 μΩ/Ω at 1 kHz under sinusoidal conditions, it has prospects for further improvements.
- Investigation of two proposals for extending the sampling rate and thus the frequency range of highly accurate ac voltage and power measurements at frequencies below 1 MHz. These are based on full-synchronous measurement techniques.
- Development of a setup for investigating the programmable ac voltage standard with thermal converters. Of primary interest was the validation of differential ac voltage calibrations of the Josephson system with thermal converters and their calibration against the quantum system.
- The four terminal-pair coaxial bridge, in operation at Inmetro, was recently modified to improve the coaxiality of the bridge, significantly reducing the net current in the coaxial cables, thus reducing both electromagnetic noise and possible systematic errors. The reliability and repeatability of impedance measurements were improved enabling us to achieve uncertainties as low as parts in 10^8.
- Reevaluation of Inmetro conventional (CJVS) and programmable (PJVS) Josephson Voltage Standards uncertainty budgets for Zener calibration. An intralaboratory indirect comparison between the two systems was made in order to check the consistency of the uncertainties. The achieved uncertainties are ±40 nV (at 1.018 V) and ±250 nV (at 10 V), k=2.
- 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.
- A method for estimating parameters of combined amplitude and phase modulation signals from digital sampling data was proposed. It can be employed with advantage to analyze combined modulation functions of commercial function generators. Though this problem of inference has applications in communication technology, it has also become a concern to the power industry in issues related to phasor measurement unit tests. Prior information available to metrologists about the signal components allows the reduction of the dimensionality of the search algorithm with consequent time savings.

Regional Project

- Development of a reference system for measuring electric power up to 100 kHz. Regional project between Inmetro (Brazil), INTI (Argentina) and UTE (Uruguay) funded by the Brazilian government. Each country will receive a complete reference system.

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