National Measurement Institute, Australia
Report on Research and Development Activities in Electricity and Magnetism
CCEM Meeting, March 2023

DC AND LOW FREQUENCY

Quasi-continuous dc voltage standard using sinusoidal and pulse-driven Josephson junction arrays

We have combined two continuous wave driven Josephson Junction Arrays and two pulse-driven Josephson Junction Arrays, supplied from two microwave inputs to one chip, to generate quasi-continuous dc voltages up to the sum of the full-scale voltages of both arrays that are robust to the imperfections of the Josephson junctions and have relaxed requirements on the radio frequency electronics driving the Josephson Junction Arrays, compared to the existing Josephson Voltage standards. By use of the Josephson Junction Arrays chip available at the National Measurement Institute Australia, we have demonstrated its feasibility to generate voltages up to 1 V. Preliminary evaluation of the system shows that the voltage uncertainty can be 11 nV (k=2) or better and the theoretical resolution is better than 1 nV from 0 V to 1 V.

Calibration of dc resistive voltage dividers and dc voltage calibrators up to 1000 V

The new method to calibrate resistive voltage dividers and dc voltage calibrators has been refined and applied to practical calibrations. The new technique takes advantage of the combination of:

an inductive voltage divider (IVD) with an ultimate life-time stability of its ac voltage ratio,

a resistive voltage divider (Transfer RVD) with low and stable ac-dc difference but relatively large voltage dependence and modest long-term stability of the dc ratio,

a programmable Josephson voltage standard

The target uncertainty of dc voltage ratio is 1 x 10^{-7} at voltages up to 1000 V.

Calibration of Precision Inductive and Resistive Voltage Dividers by Comparison using Two Sampling Digital Voltmeters

NMIA has developed a new highly efficient technique for the calibration of inductive and resistive voltage dividers by comparison with a reference divider. Two sampling digital voltmeters, equipped with buffer amplifiers having a selectable gain of either 1 or 0.8 (to maximise the dynamic range of the sampling multimeters are used to measure the voltage output of each divider. The target calibration uncertainty is below calibration uncertainty is below 10^{-7} of ratio for both in-phase and quadrature errors at frequencies up to 1 kHz and a few parts in 10^{-6} at frequencies up to 10 kHz.

IMPEDANCE

Calculable capacitor and precision four-port ac capacitance bridge

A new calculable capacitor and associated impedance measurement chain is being designed and built at NMIA with a target accuracy below 5 nF/F. All components will be configured as four-port devices, and measured at ten frequencies from 200 Hz to 2 kHz.

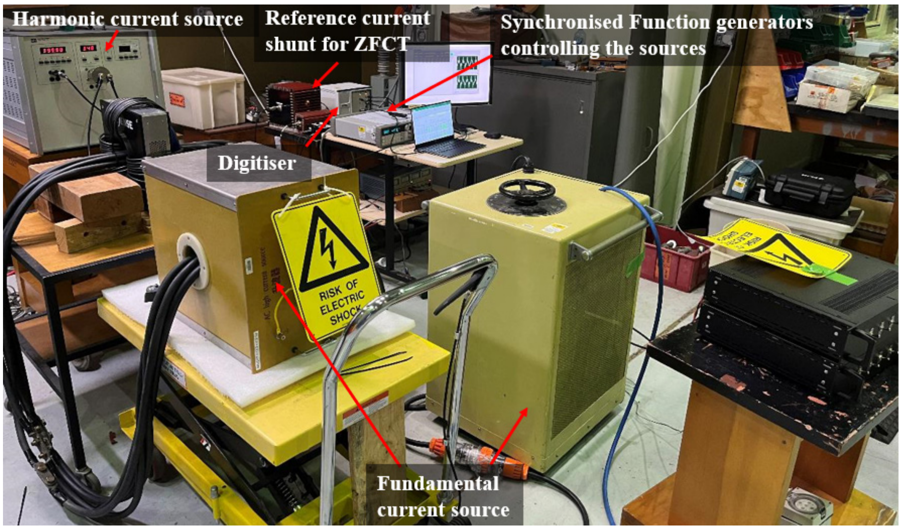
Three new staff have recently been appointed to the team to assist with the completion of the project. Dr Douglas Little has refined the design of the calculable cross-capacitor optical interferometry system, in particular resolving the challenge of aligning the optical cavity with the electrical axis with a precision adequate to meet the demanding target uncertainty. Modifications to the calculable cross-capacitor to accommodate the alignment procedure have been completed, and the alignment is currently in progress. Brady Shearan and Scott Ho are working on the remaining components for the associated capacitance ratio bridge, and for the ratio transformer calibration system.

HIGH VOLTAGE

Development of the wideband high-voltage current transformer calibration system

NMI has completed the development of measurement system for calibration of high-voltage current transformers with composite current waveforms that contain the fundamental power frequency and harmonic frequencies up to 10 kHz. The system is capable of performing calibration with a composite current that contains the rated current of 4000 A at the fundamental frequency and 2% to 20% of the rated current at harmonic frequencies. The measurement uncertainties have been verified to be less than 0.02% for current ratio error at all frequencies up to 10 kHz, and 0.06 crad for phase displacement at frequencies from the fundamental to the 9th harmonics and 0.39 crad from the 11th to the 198th harmonics. The linearity of current ratio and phase displacement with test current from 25% to 100% of the rated current of 4000 A have been verified to be less than 0.05% and 0.039 crad.

The development is a part of the Global Linkage Project, Power Quality of Future Electricity Networks, that involves 5 Australian power utilities, 3 Australian Universities, Tsinghua University in China, National Measurement Institute Australia, National Institute of Metrology China, ARCMesh Australia and SMA Solar Technology AG Germany.



Development of the wideband high-voltage voltage transformer calibration system

NMI is near to complete the development of a measurement system for calibration of high-voltage voltage transformers with composite voltage waveforms that contain the fundamental power frequency and harmonic frequencies up to 10 kHz. The system has been tested at the primary voltage of 4 kV with uncertainties of 0.02% and 0.04 crad for the fundamental frequency of 50 Hz, and 0.13% and 0.15 crad for harmonic frequencies of 100 Hz to 10 kHz. The aim is to complete a system that is capable of performing calibration at fundamental voltages up to 100 kV, with the uncertainties less than 0.1% and 0.1 crad for fundamental frequencies and 1% and 1 crad for harmonic frequencies up to 10 kHz.

The development is also a part of the Global Linkage Project, Power Quality of Future Electricity Networks, that involves 5 Australian power utilities, 3 Australian Universities, Tsinghua University in China, National Measurement Institute Australia, National Institute of Metrology China, ARCMesh Australia and SMA Solar Technology AG Germany.

NMI High-Voltage laboratory is upgrading its AC high-voltage capabilities.

- A 240 kV resonant voltage source has been acquired for on-site calibrations of capacitive voltage transformers.
- A 600 kV/3.4 nF coupling capacitor has been acquired to replace the existing 400 kV coupling capacitor to enable partial discharge measurement at voltages up to 600 kV.
- A 800 kV / 0.5 A AC voltage source has been ordered to replace the 600 kV / 0.5 A existing AC voltage source.

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