Justervesenet

Report on Electromagnetic Metrology Activities at JV, Norway Prepared for the 33st Meeting of the CCEM 2023

Staff

Dr. Helge Malmbekk – **ACI/ACV,** AC/DC Josephson – Group leader, convenor of the TC-EM Subcommittee for low frequency – *will leave JV 01.05.2023* - hma@justervesenet.no
Dr. Bjørnar Karlsen – **Power and Energy,** AC/DC Josephson, ACI/ACV – bka@justervesenet.no
Mr. Kristian Ellingsberg – Power and Energy – kbe@justervesenet.no
Dr. Susmit Kumar – **Resistance**, QHR, CCC – sku@justervesenet.no

During the last year Ilia Kolevatov left JV for a job at Nordic Semicondutor and was replaced by Susmit Kumar who came from a position as researcher at the University of Oslo. At the end of February, Tore Sørsdal retired after almost 30 years at JV, and Susmit Kumar will take over the responsibility of the resistance lab. At the end of April, Helge Malmbekk will leave JV for a new job at Institute for Energy Technology.

During the last two years, our group has focused on research related to Josephson standards and power & energy.

Bjørnar Karlsen has continued the work to demonstrate LHe operation of InGaAs photo diodes for generating fast current pulses used for operation of Josephson junction arrays. Mach-Zehnder modulation of a continuous-wave laser has been performed to generate photo-current pulses with full-width-at-half-maximum (FWHM) as short as 45 ps and peak heights up to 16 mA. It was demonstrated that identical pulse waveforms can be produced by a fast photodetector in the range 1.25 - 10 GPulse/s where the reverse voltage bias was induced electrically and optically (via photodiodes) at room temperature. The measured pulse peaks exceeded 2 mA, which could be used to cover the first Shapiro step of Josephson junction arrays with critical currents up to 650 µA. The next step was to put together a fully optical cryogenically viable pulse-drive consisting of a balanced bipolar photodiode module together with the biasing photodiodes, and have this immersed into liquid helium. While in a cryo-cooled state, it was demonstrated that this pulse-drive could put out overlapping positive and negative photo-current pulses with pulse peaks up to 4 mA and FWHM as short as 62 ps, and for pulse rates up to 5 GPulse/s. This pulse-drive has also been demonstrated sufficient to bias a 100 Josephson-junction-long array to synthesize quantum-accurate ac voltage waveforms of up to 500 µV and 10 kHz from a purely optical input. This project is a long term collaboration between JV, PTB and others, building on previous EMPIR projects such as Q-Wave and QuADC.

Our old DC Josephson system has been replaced by a new 10 V PJVS system and during 2020-2022 the system was upgraded with a pulse tube cryostat for continuous operation. The cryostat will be used for both PJVS and JAWS, with a testbed for optical generation of current pulses based on the work of Dr. Bjørnar Karlsens PhD thesis. In the future, we plan to start investigating if a QHE standard based on Graphene could be operated inside the cryostat and samples investigating the Quantum Anomalous Hall Effect.

In 2020 we started the EMPIR project QuantumPower, coordinated by Dr. Helge Malmbekk, where the overall objective of the project is to develop a quantum sampling standard for electrical power which is open to the whole Metrology community and provides direct traceability to the new quantum SI. The use of quantum standards in sampling of electrical power enables direct traceability not only for power measurements, but also for PQ and phasors. The project has developed an open-source hardware multiplexer that is synchronised with the sampling system. It is able to switch the input of the analogue-to-digital convertors (ADCs) between the voltage, current and PJVS channels, in order to provide real-time calibration of the ADCs and substantially decrease the uncertainties of the power measurements. The multiplexer enables using a single PJVS chip for measurement of both current and voltage components of the electric power using differential sampling, or to provide calibration of ADCs before and after the direct sampling of electric power.

The software for performing the measurements is open source and can be found here: https://github.com/KaeroDot/QPsw. It is based on three separate components, which can be operated together or on their own:

1. The sampling software TWM first developed during the TracePQM project samples data from commercial digitizers such as the HP3458A or NI5922.
2. The algorithm toolbox QWTB performs waveform analysis on the sampled data.
3. The newly developed QPScontrol sets up commercial PJVS bias source hardware such as the NPL bias source, the Supracon AC Quantum Voltmeter and configures commercial trigger hardware.

A YouTube-channel has been created to share information about the project: https://www.youtube.com/@quantumpowerempirproject9560?themeRefresh=1

In June 2023 the EPM project True8DIGIT will start, focusing on the development of a digitiser with a state-of-the-art ADC, operating from DC to 100 kHz, to meet the demands for linearity, noise, and overall accuracy of current applications in NMIs and research which cannot be met using currently available DMMs, digitizers or ADCs.

During the last few years, we have been discussing technical solutions for calibration and control of fast DC charging of electrical vehicles. A Nordic cooperation on the legal metrology issues related to this (NordCharge) and a EURAMET project (LegalEVcharge) has been initiated to investigate the issues related to fair and correct billing of electrical vehicle charging as well as coordinated work on providing a standard for testing of DC charging stations. The work has resulted in a guide for metrological requirements for EV charging stations. In addition, we are developing measurement equipment for calibration commercial test equipment used for measurement systems at DC charging stations. This will be tested at EV charging stations operated in arctic winter condition.

Publications – oppdatere ned relevante siste årene

- van den Brom, Helko E., Malmbekk, Helge, Kolevatov, Ilia, et al. "EMC Testing of Electricity Meters Using Real-World and Artificial Current Waveforms." IEEE Transactions on Electromagnetic Compatibility 63.6 (2021): 1865-1874.

- Ireland, J., Malmbekk, H. et al. "A method for using Josephson voltage standards for direct characterization of high performance digitizers to establish AC voltage and current traceability to SI." Measurement Science and Technology 34.1 (2022): 015003.
- Karlsen, B. et al. “A Fully Optical Pulse-Drive To Bias Josephson Arrays: Progress Report”. CPEM 2022, New Zealand.
- Kraus, M., Karlsen, B., Malmbekk, H., et al. “Progress on PTB’s Optical Pulse Transmission for Pulse-Driven Josephson Voltage Standards”. CPEM2022, New Zealand.
- Bierzychudek, M., Malmbekk, H., et al. “An SSR-Based Multiplexer for Power Measurement“. CPEM2022, New Zealand.
- Mester, C., Malmbekk, H., et al. “LegalEVcharge - Practical legal metrology framework for electric vehicle charging stations”. CPEM2022, New Zealand.
- Sira, M., Malmbekk, H., et al. “Multiplexing schemes for quantum power systems”. CPEM2022, New Zealand.