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Reference

Report from RISE Research Institutes of Sweden within the field of Electrical Metrology

Organisation

RISE Research Institutes of Sweden is organized in five divisions: Bioeconomi and Helth, Digital Systems, Materials and Production, Saftey and Transport, and Built Environment. RISE operates from some 35 sites all over Sweden plus a few abroad and the headquarter is located in Gothenburg. RISE has a staff of 3100 and a yealy turnover of 360 M€. The Swedish state is the sole owner of RISE.

RISE have the asignment as Swedens Nationl Metrology Institut (NMI). The activities as NMI is coordinated by the Department for Measurement Science and Technology which is part of the Safety and Transport Division. This Department also holds most of the staff working in the field of metrology or quality assured measurements, about 150 employees. Professor Jan Johansson is the NMI director.

Technical news since CCEM meeting in 2021

Subfield DC, LF and Quantum metrology

RISE have completed our work in the EMPIR project LibForSecUse, which was aimed at developing methods to characterize the performance of second life Li-ion batteries. RISE focused on calibration methods and traceability for impedance measurements in ranges typical of vehicle Li-ion battery cells (~1 mΩ, ~1 F, 10 mHz – 5 kHz) [D1].

We have also participated in the EMPIR project, GIQS. In this project we were constructing a Josephson voltage standard to be integrated in our cryostat for quantum Hall measurements. The aim was to demonstrate simultaneous operation of a Josephson voltage standard (JVS) and a quantum Hall resistance standard (QHR) in the same cryostat. At the end of the project, we could demonstrate excellent QHR operation and good magnetic shielding of the JVS while operating the cryostat magnet at high field. Work will continue after the project to acieve full operation of JVS by improving the cooling of the JVS chip.

Our collaboration with Chalmers University of Technology on the use of graphene in quantum metrology have continued. One key development, which began in 2021, is the development of graphene array devices with hundreds of interconnected hall bars. We demonstrated for the first time that a large graphene quantum Hall array, consisting of over 250 connected hall bars, can have as high quantization accuracy as a single Hall bar quantum standard, paving the way for improved resistance calibrations. [D2]. We also demonstrated that the array device can take bias currents close to 10 mA, which makes it suitable for direct use in a Kibble balance, eliminating the need for a secondary resistance standard.

The first design of array used only parallel connections, reaching a resistance value of around 109 Ω. We have since improved the design and created an exact 100 Ω array, which deviates from nominal value by less than 0.2 nΩ/Ω per design (limited by the number of connected devices in the array). The quantization accuracy of this array has been confirmed via multiple precision comparison measurements, and the initial results were presented during CPEM 2022 [D3].

In collaboration with the NMIs of United Kingdom and South Africa, RISE continues the development of a new Kibble balance for realization of the new kilogram. The electricity group is working with the JVS part of the setup for the measurement of the electrical signals.

For ac voltage we have extended the frequency range of our in-house realization at the primary level 3 V to 1 MHz, earlier limit was 1 kHz. The method we have used in the range >1 kHz to 1 MHz is similar to the one described by Budvsky in 1999 but with some modifications. The influence of skin effect and conductance is determined using intermediate standards with unknown but reproducible ac-ac difference and the inductance is determined by realization of the henry using the individual parts of the TVCs and an LCR-meter [D4].

References

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[D2] H. He, K. Cedergren, N.Shetty, S. Lara-Avila, S. Kubatkin, T. Bergsten, and G. Eklund, “Accurate graphene quantum Hall arrays for the new International System of Units,” Nat. Commun., vol. 13, no. 1, pp. 1–9, 2022, doi: 10.1038/s41467-022-34680-0.

[D3] H. He, K. Cedergren, T. Bergsten, and G. Eklund, ”Towards a Primary Standard of 100 Ω using Graphen Quantum Hall Arrays,” 2022 Conference on Precision Electromagnetic Measurements (CPEM 2022), Wellngton, 2022.

[D4] K.-E. Rydler, and T. Bergsten, "Realization of AC-DC Voltage Transfer Difference in the Frequency Range 1 kHz to 1 MHz at RISE," 2022 Conference on Precision Electromagnetic Measurements (CPEM 2022), Wellngton, 2022.

Subfield High voltage, Power and Energy

RISE is coordinating an EMPIR project 19ENG02 FutureEnergy [1]. The project is extending the traceable calibration of Ultra-High Voltage Direct Current (UHVDC) up to 1600 kV, developing a new modular voltage divider with a claim for an expanded measurement uncertainty better than 100 µV/V at 1600 kV, and have extended the 1000 kV modular divider from EMRP ENG07 HVDC to 1200 kV with claims for expanded measurement uncertainty of 20 µV/V at 1200 kV. A stability study of the Modular HVDC measurement system was published at CPEM 2022 [2] with an unprecedented stability of the scale factor < 0.7 µV/V/yr of the RISE 1000 kV modular HVDC divider. The project has extended linear extension methods for lightning impulse voltage calibration for testing of UHV equipment. It will provide new input to IEC 60060-2 for time parameters and voltage measurement on ultra-high voltages above 2.5 MV with an uncertainty for peak voltage better than 1 %. It has developed a new method for linearity determination of HV capacitors with a target calibration uncertainty for HVAC of 80 µV/V at 800 kV. The project has developed demonstrated implementation of partial discharge (PD) measurement techniques for testing of equipment under d.c. stress [3], with specific emphasis on detection and prevention of insulation failures in HVDC cables, GIS and convertors.

RISE is piloting the Supplementary Comparison EURAMET.EM-S46 and EURAMET.EM-S47 “High voltage comparison of DC ratio and high resistance” together with VTT and VSL. The comparison started in Feb 2022 and will be completed 2023. Five systems 200 kV HVDC systems PTB, RISE, TUBITAK, VSL and VTT were collected at RISE for the 200 kV intercomparison. This was done in preparation of a 1200 kV intercomparison of EMPIR 19ENG02 FutureEnergy, from which new and improved CMCs will be claimed for HVDC for RISE, PTB and TUBITAK.

RISE is participating in the EMPIR 19NRM07 $HVcom^2$ where traceability for composite and combined waves has been developed [4]. This research has realized the necessary metrology required for the standardization of high voltage testing with composite and combined wave shapes [5, 6]. In order to address the current lack of traceability, traceable measurement systems and calibration services has been developed for composite and combined wave shapes, and the relationship between impulse voltages with High Voltage Alternating Current (HVAC) or High Voltage Direct Current (HVDC) measurements was determined. The project has provided input to the current revision of IEC 60060-2. RISE has developed metrology for composite wave up to 1400 kV and combined wave up to 700 kV.

References

[1] EMPIR 19ENG02 FutureEnergy, https://www.ptb.de/empir2020/futureenergy/home/, accessed 27 February 2023

[2] A.-P. Elg, E. Houtzager, G. Rietveld, A. Merev, J. Hällström, J. Havunen, J. Meisner, S. Dedeoglu, and A. Bergman “On the Stability of a Modular 1000 kV HVDC divider design” CPEM 2022 Special Section of IEEE Transactions on Instrumentation and Measurement.

[3] Joni V. Klüss, Alf-Peter Elg and Claes Wingqvist, “High-Frequency Current Transformer Design and Implementation Considerations for Wideband Partial Discharge Applications”, IEEE Transactions on Instrumentation and Measurement, Vol. 70, 2021

[4] EMPIR 19NRM07 $HV\text{-}com^2$: https://www.ptb.de/cms/en.html, accessed 27 February 2023

[5] “Contribution to the standardisation of measurement of composite and combined high voltages”, Paper ID 1115 CIGRE Session 2022, Study Committee D1 - Materials and Emerging Test Techniques

[6] J. Havunen, J. Hällström, J. Meisner, F. Gerdinand, A.-P. Elg, “Design and Verification of a Calculable Composite Voltage Calibrator”, NordIS-22, Trondheim, Norway, June 13-15 2022.

Subfield RF and MW

The high frequency laboratory at RISE is participating in two EPM projects. The first one is 21NRM06 EMC-STD, a project that does research in new electromagnetic emissions test methods for harsh environments, fully traceable time-domain measurement techniques, new calibration methods for the response to pulses of receivers and the statistical evaluation of interferences in compliance assessments. RISE is the leader for WP5 in this project. The second EPM project is 21NRM03 MEWS, a project that aims to develop practical and efficient measurement methods to better match rapidly emerging radio technologies for 5G/6G product and system over-the-air testing, for wireless channels up to sub-THz, and for radio frequency exposure assessment. Both of these projects started in 2022.

RISE also had two internal projects during this time period. The first one was a project for a comparison of the methods from HF theory and the ones employed by traditional DC-LF theories in the frequency range 9 kHz-45 MHz. This project also included implementations of knowledge developed within the 2018 closed EMPIR project 15RPT01 RF Microwave. This project ended in 2021. The second project was running in 2021-2022 with the aim of development of traceable S-parameter calibrations for the 2.4 mm cable interface. This project was an important step for future calibrations above 40 GHz.

The high frequency laboratory is participating in an ongoing comparison, EURAMET.RF-S46, for the calibration of magnetic field strength in the frequency range up to 30 MHz. This comparison started in 2022 and is expected to end in 2023.

Since several years we are partners in the GHz Centre, which is a microwave research Centre of excellence financed by Vinnova and operated by Chalmers in collaboration with industry and RISE. Within the GHz Centre at Chalmers we are working on S-parameter measurements on membrane circuits suitable for THz frequencies, cryogenic S-parameters measurements on HEMTs as well as measurements of broadband S-parameters [F1].

In December 2018 we were awarded funding for a PhD student to work on THz Metrology. The project will focus on measurement of S-parameters at frequencies from 0,3 – 3 THz and will be executed in close collaboration with Chalmers.The aim of the research project is to develop terahertz mixers for future space missions (ESA, DLR, PDI, VDI) and to demonstrate precise and traceable terahertz characterization methods for next generation of wireless systems (SSF, TEMMT).

RISE participated in the ChaseOn centre, which was an antenna centre of excellence financed by Vinnova, and operated by Chalmers in collaboration with industry and research institutes. Within the centre RISE participated in development of characterization methods of vehicular 5G systems. ChaseOn did end in 2021.

References:

[F1] K. Karlsson, A. Lundberg, N. Arabäck and B. Bergqvist, "Test Level in Reverberation Chamber EMC Immunity Assessment Based on the Quantile to Average Ratio," *2022* International Symposium on Electromagnetic Compatibility – EMC Europe, Gothenburg, Sweden, 2022, pp. 178-182, doi: 10.1109/EMCEurope51680.2022.9901226.

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