

Progress Report to CCEM
(The 34th meeting of the CCEM, March 2025)

Electrical and magnetic measurements

Submitted by G. Gubler, VNIIM (St. Petersburg, Russia)
February 2025

DC and AC voltage (VNIIM, St. Petersburg, Russia)

(a.s.katkov@vniim.ru)

The VNIIM primary DC voltage standard based on Josephson effect consists of two system with 10 V SIS and SNS arrays which produce voltage in the range from 1 mV to 10 V. VNIIM have the DC 10 V transportable Josephson standard for a key comparisons.

At November 2024 VNIIM took part in key comparisons of voltage unit standards on the Josephson effect COOMET.EM.BIPM-K10.b with Republican Unitary Enterprise "Belarusian State Institute of Metrology" (BelGIM). Report B of the comparison is prepared.

VNIIM maintains the State primary AC voltage standard consisting of:

- special primary standard for the unit of electrical voltage in the frequency range from 10 to $3 \cdot 10^7$ Hz at voltage from 0,1 to 1000 V;
- special primary standard for the unit of electrical voltage in the frequency range from $3 \cdot 10^7$ to $2 \cdot 10^9$ Hz at voltage from 0,1 to 10 V.

Research in the field of AC voltage measurements by means programmable Josephson voltage standard is continued. Investigation in the range from 1 mV to 7 V and frequency from 10 Hz to 1 kHz was performed. It was noticed that in the range from 0,2 V to 2 V there is influence of output voltage produced by voltage calibrator when PJVS is connected to calibrator. It is possible to reduce this effect by control output voltage using ADC.

Publications

Katkov, A.S., Shevtsov, V.I. & Gromova, J.A. State primary voltage standard of the fourth generation. Meas Tech (2023). <https://doi.org/10.1007/s11018-023-02246-1>

DC current

VNIIM maintains the state primary standard of DC current in the range of $1 \cdot 10^{-16}$ A to 1 A. VNIIM uses transportable standard of DC current in the range of $1 \cdot 10^{-15}$ A to $1 \cdot 10^{-9}$ A.

DC Voltage electrostatic field

VNIIM maintains the State standard for the unit of the electrostatic field. The range of the electrostatic field in free space is up to ± 1000 kV/m. The range of electrostatic potential is ± 30 kV. Relative uncertainty of reproduction set point electrostatic field strength is 1,5%. The standard allows to calibrate the potential meters of a charged surface in the range of ± 50 kV. Relative uncertainty of charged surface potential is 0.6%.

AC current

VNIIM maintains the State Primary AC current Standard in the frequency range of 20 Hz to $1 \cdot 10^6$ Hz. It consists of a set of thermo-converters that directly convert the AC current up to 20 A. AC current shunts parameters is used in the range up to 100 A at frequencies up to 100 kHz.

LF Power (VNIIM, St. Petersburg, Russia)

G. Gubler (g.b.gubler@vniim.ru)

State Primary Standard for LF power and related quantities was upgraded in 2024. It includes two new reference setups. First of them provides traceability for merging units, digital meters, power quality analyzers and calibrators with inputs/outputs via IEC 61850-9-2 protocol. Second one provides traceability for phasor measurement units. New software released for finding parameters

of multicomponent chirp signals. Development of reference setup for DC power (current up to 500 A, voltage up to 1000 V) and energy have been started in 2024 to calibrate with uncertainty 50 μ W/W reference instruments for electrical vehicle charge station.

Comparisons

VNIIM has been participating in the following comparisons:

AC power at 50/60 Hz: CCEM-K5.

High AC and DC current (UNIIM, Ekaterinburg, Russia)

A.A. Akhmeev (lab262@uniim.ru), E.V. Voronskaya (ekaterina@uniim.ru)

The State Primary Standard for electric current (AC, DC) conversion coefficients units GET 152-2023 is responsible for the transfer of the electric current conversion coefficients units to current measurement transducers (metrological assurance of measurement transducers) in the Russian Federation.

In 2023, the primary standard was upgraded and now its measurement capabilities allow the unit to be transferred to DC and AC (frequency range from 40 to 2500 Hz) measurement transducers.

GET 152-2023 includes four standard systems:

- 1 Sinusoidal current standard system for industrial frequency;
- 2 Sinusoidal current standard system for frequency range from 40 to 2500 Hz;
- 3 High direct current standard system up to 1000 A;
- 4 High direct current standard system up to 10000 A.

UNIIM has been participating in the following comparisons:

COOMET 855/RU-a/22 " Pilot comparisons in the field of high DC current measurements"

Publications

Supplementary comparison of the measurement of current transformers (CTs). A A Akhmeev; E V Voronskaya; V N Kikalo; E V Melkumyan; O Dzhasinbekov; G Gantumur; D M Volozhinskii // Metrologia 2024, Volume 61, Number 1A, DOI: [10.1088/0026-1394/61/1A/01006](https://doi.org/10.1088/0026-1394/61/1A/01006)

Magnetic measurements (VNIIM-UNIIM, Ekaterinburg, Russia)

In 2023-2024, work was carried out on improving the State primary standard of units of magnetic loss power, magnetic flux density of a constant magnetic field in the range from 0.1 to 2.5 T and magnetic flux in the range from $1 \cdot 10^{-5}$ to $3 \cdot 10^{-2}$ Wb GET 198 in order to expand the measurement capabilities in the field of reproduction and transmission of dynamic magnetic characteristics of samples of magnetic materials. Completion of works in 2025.

As a part of the performance of the work:

- purchase and installation of equipment;
- conducting research and calculating the uncertainty of reproducing the unit of magnetic flux density of an alternating magnetic field in samples of magnetic materials of various shapes.

Publications:

Supplementary comparison of national standard instruments in the field of magnetic flux density and magnetic flux measurements by sensing coils. Tatiana I Maslova, Sergey V Serdiukov, Ekaterina A Volegova, Martin Albrecht, Michal Ulvr, Stuart Harmon and Jian He. Published 27 April 2023. BIPM & IOP Publishing Ltd Metrologia, Volume 60, Number 1A DOI [10.1088/0026-1394/60/1A/01004](https://doi.org/10.1088/0026-1394/60/1A/01004)

<https://iopscience.iop.org/article/10.1088/0026-1394/60/1A/01004>

Ultrafast Pulse Waveform Measurement (VNIIFTRI, Moscow, Russia)

A. Kleopin (kleopin@vniiftri.ru)

In 2024, the development of an electro-optic sampling (EOS) measuring system has been carried out in the Russian Metrological Institute of Technical Physics and Radio Engineering Measurements (VNIIFTRI). An EOS-based standard will enable the modernization and improvement of the State primary special standard of pulse electrical voltage GET 182-2010 after additional research on metrological characteristics.

Currently, the EOS measuring system model at VNIIFTRI is capable of generating optical pulses with durations no more than 100 fs and converting them into ultrafast electrical pulses with duration not more than 9 ps. The EOS measuring system model has been assembled and tested. The purpose of this development is metrological traceability in measuring the parameters of electro-optical and optoelectronic converters. As a result, a complex transmission coefficient of a broadband photodiode was obtained. It was established that the photodiode has linear amplitude and phase transmission coefficients and its characteristics are stable in the frequency range up to 67 GHz.

Publications

M.A. Zenchenko, A.V. Kleopin, V.V. Makarov, L.N. Selin, A coplanar waveguide with a gallium arsenide substrate for an electro-optic sampling system with a bandwidth over 110 GHz // Measurement Techniques, Vol. 65, No. 1, April, 2022, pp. 70–76.

A.V. Kleopin, A.A. Beloborodov and K.O. Suslova, Model of Synchronous Signal Processing for Electro-Optical Stroboscopic Measurement System // 2024, 26th International Conference on Digital Signal Processing and its Applications (DSPA), Moscow, Russian Federation, 2024, pp. 1-4, doi: 10.1109/DSPA60853.2024.10510062.

S-parameters of microelectronic devices on a wafer (VNIIFTRI, Moscow, Russia)

In order to ensure the uniformity of measurements, a special standard of units of reflection coefficients and transmission coefficients of microelectronic devices implemented on a wafer is being developed from 2022 to the present. In cooperation with technology partners, the production of calibration plates and measuring probes is being established.

The standard must consist of a vector network analyzer, a probe station, probes, calibration plates and measuring devices for linear-angular quantities, permittivity, and surface resistance. The standard is based on the comparison with a standard method. The vector network analyzer together with the probe station is used as a comparator. Coplanar structures made on the wafer in the form of Short (Short or Reflect), Open, matched load (Load or Match), and coplanar line segments (Thru and Line) are used as measures.

Publications

Bondarenko A.S., Borovkov A.S., Malay I.M., Mikhailov P.D., Rakov A.V., Semyonov V.A., Smotrova D.A.. Method for Determination of Metrological Characteristics of Calibration Standards on a Wafer. 2024 IEEE 9th All-Russian Microwave Conference (RMC). DOI: 10.1109/RMC62880.2024.10846901

Bondarenko A.S., Borovkov A.S., Malay I.M., Mikhailov P.D., Rakov A.V., Semyonov V.A., Smotrova D.A.. Methodology for Determining the Characteristics of Measuring Probes Based on the Calibration Comparison Method. 2024 IEEE 9th All-Russian Microwave Conference (RMC). DOI: 10.1109/RMC62880.2024.10846869

Research Center for Applied Metrology - Rostest in the field of high AC and DC voltages, impulse voltage

Center 201: Center for Research, Development, Testing, Metrological support of
Measuring Systems, Electric and Magnetic Measurements
Victor Kiselev, Tatiana Dubrovskaya (TatyanaAD@rostest.ru)

At the end of 2024, the reorganization of the federal budgetary institution «State Regional Center for Standardization, Metrology and Testing in Moscow and the Moscow Region» and the federal state budgetary institution «Russian Research Institute for Metrological Service» (VNIIMS) in the form of joining the second institution to the first one, with the name of the first institution changed after the completion of the reorganization process to the federal budgetary institution «Research Center for Applied Metrology - Rostest» (RCAM-Rostest) was completed.

Some works on modernization of the reference base were completed before 2023, and its results were included in the summary reports for previous CCEM meetings.

The authority of the Center for state standards in the field of high and ultrahigh voltage measurements was transferred to RCAM-Rostest.

After the reorganization, performing of works on improving the reference base in the field of metrological support for electric measurements continue.

High AC voltage, lightning and switching impulse voltage

The process of upgrading the equipment for high-voltage measurements is currently ongoing:

1) From 2020 to 2022 works in terms of modernization and improvement of the State primary special standard of units of ratio error K_U and phase displacement φ_U of AC voltage of power frequency in the range of $0,1/\sqrt{3} \dots 750/\sqrt{3}$ kV and units of the electric capacitance and dielectric dissipation factor ($\tan \delta$) at AC voltage of power frequency frequency in the range from 1 to 500 kV in order to expand its functionality, providing reproduction and transmission of units of K_U and φ_U to digital electronic voltage transformers, as well as analog and digital low-power voltage transformers (sensors) – LPVT were performed. The modernization was completed, and the improved SPS 175-2023 standard was approved in the new composition.

2) In 2025, it is planned to complete works on improving of the State Primary special standard of the units of electric voltage of standardized lightning and switching impulses in the range from 1 to 1000 kV (SPS 204-2012) in order to expand its functionality in order to meet the needs of industry in the field of reproduction and transmission of the units of electric voltage of standardized lightning and switching impulses in the range from 50 to 2000 V.

Comparisons (2022-2024):

1) COOMET 821/RU-a/20 Pilot comparisons of DC high voltage measuring reference instruments in the voltage range $\pm (1 \dots 100)$ kV (SPS 181-2022)

Participants: RCAM-ROSTEST – pilot laboratory, BelGIM (Republic of Belarus), NIM (National Institute of Metrology) (People's Republic of China).

Measurements under the comparisons are completed in 2022. In 2023 protocol (report) of comparisons with BelGIM was agreed. NIM provided the results of measurements to the pilot laboratory with a delay caused by COVID restrictions in China. Protocol (report) of comparisons is being prepared for further agreement with the second participant of the comparisons NIM.

2) COOMET 862/RU/22 Pilot comparisons of reference instruments measuring AC high voltage above 1 kV when transmitting units of ratio error and phase displacement to analogue low-power voltage sensors (transformers - LPVT) (SPS 175-2023)

Participants: RCAM-ROSTEST – pilot laboratory, BelGIM (Republic of Belarus).

Protocol (report) of comparisons was sent to the secretariat of TC 1.3 COOMET «Electricity and Magnetism». The comparisons were completed with a positive result.

3) COOMET 919/RU-a/24 Pilot comparisons of reference measuring systems transmitting units of ratio error (K_U) and phase displacement (φ_U) of AC electric voltage above 1 kV to electronic voltage transformers, as well as digital voltage transformers (sensors) (SPS 175-2023).

Participants: RCAM-ROSTEST – pilot laboratory, BelGIM (Republic of Belarus).

The comparisons are completed. Protocol (report) of comparisons is sent to COOMET secretariat.

Publications

Kiselev V.V., Kucobin A.A., Dubrovskaya T.A. «Digital sampled value stream calibrator for performing metrological work at digital substations», OIML BULLETIN VOLUME LXIV, number 3 July 2023 p. 5.

Kiselev V.V., Grishin M.V., Dubrovskaya T.A., Kucobin A.A. «Development of a reference complex for metrological assurance of digital automated information and measurement systems for commercial electricity accounting», Legislative and Applied Metrology, issue 2, p. 3, 2023 (in Russian).

Kiselev V.V., Rogozhin S.Yu., Grishin M.V., Dubrovskaya T.A., Kucobin A.A. «Improvement of the state primary special standard SPS 175-2019». Legislative and Applied Metrology, issue 3, p. 5, 2023 (in Russian).

Kiselev V.V., Kucobin A.A., Grishin M.V., Dubrovskaya T.A. «SV- stream calibrator for performing metrological works at digital substations». Journal «ENERGOEXPERT», № 3 (87), p. 70, 2023 (in Russian).