Progress Report to CCEM

(The 32th meeting of the CCEM, April 2021)

Electrical and magnetic measurements

Submitted by G. Gubler, VNIIM (St. Petersburg, Russia)
March 2021

DC and AC voltage

The primary voltage standard of VNIIM based on Josephson effect consists of the laboratory-made devices that can use 1 V and 10 V SIS and SINIS.

VNIIM has 10 V transportable Josephson standard for a key comparison of DC national voltage standards.

VNIIM in collaboration with PTB created the pulse driven JVS system (ACJVS). The sinusoidal output voltage with RMS up to 0.5 V at frequency of 62.5 Hz was obtained.

A precision DVM in conjunction with a specially developed software was used as an AC measurement sampling system (ACMSS). The ACJVS was used for ACMSS calibration in the range up to 0.5 V (RMS) in the range from 62.5 Hz to 3750 Hz. A new technique to find current margins by using the ACMSS was investigate. It provides measurements of the step inclination with a resolution of 0.015 μV. The short-term stability of the AC measurement by the ACMSS is less than 0.03 μV/V within 5 minutes.

It was show that ACMSS is competitive with a lock-in amplifier in the frequency range from 10 – 400 Hz.

VNIIM maintains and develops 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.

VNIIM takes part in key comparisons CCEM-K6a and CCEM-K9 of ac-dc voltage transfer difference at frequency up to 100 kHz and CCEM-K6c in the frequency range 1 MHz and 100 MHz.

Publications

A. Katkov. The status of and prospects for development of voltage quantum standards. 2019. J. Phys.: Conf. Ser. 1379 012076. doi:10.1088/1742-6596/1379/1/012076

A.S Katkov, V.E. Lovtsyus, A.I. Bykov, V.I. Schevtsov, A.N. Petrovsrkaya, R. Behr, O.F. Kieler . Electrical Quantum Metrology Standard for the Synthesis of AC Voltages. *Meas Tech* **63,** 295–300 (2020). https://doi.org/10.1007/s11018-020-01786-0

A. Katkov, G. Gubler, V. Shevtsov, A. Petrovskaya, R. Behr and O. Kieler, "Pulse-driven AC Josephson voltage standard at VNIIM,"2020 Conference on Precision Electromagnetic Measurements (CPEM), Denver (Aurora), CO, USA, 2020, pp. 1-2, doi: 10.1109/CPEM49742.2020.9191742

DC current

VNIIM maintains and develops the state primary standard of dc current in the range of $1{\cdot}10^{-16}$ A to 1 A. VNIIM uses a unique 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 and develops 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. Limits of relative error of reproduction set point electrostatic field strength is 1.5%. Limits of a relative error of reproduction set point charged surface potential is 0.6%.

A method for calibrating the potential meters of a charged surface in the range of ± 50 kV is developed.

AC current

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

Research is being carried out on the developed current shunts from 1 mA to 100 A in the frequency range up to 100 kHz using strip transmission lines.

Publication

M.L. Gurevich., V.I. Shevtsov, "The use of strip line transmission lines of an electrical signal in measuring current shunts blocks" Legal and Applied Metrology, N 2, 2019. P. 42 – 44 (in Russian)

LF power

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

VNIIM extended functionality of AC power primary standard. New functions include 3-phase voltage or current measurements (symmetrical components, inter-phase angles) on the base of 3-channel electronic current transformer, 3-phase resistive voltage divider and three synchronized DVM 3458A.

New project was started to build up reference multifunctional system with digital inputs/outputs via IEC 61850-9-2 protocol to provide traceability for reference instruments with only digital inputs/outputs via IEC 61850-9-2 (meters, power quality analyzers and calibrators, phasor measurement units).

In collaboration with AC voltage lab of VNIIM a series of experiments was conducted to calibrate voltage channel of primary power standards with JAWS. This work was presented on CPEM 2020.

Comparisons

VNIIM has been participating in the following comparisons:

AC power at 50/60 Hz: APMP.EM-K5.1; COOMET.EM-K5;

Ongoing comparisons

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

AC power harmonics: CCEM-K13.

Publications

A. Katkov, G. Gubler, V. Shevtsov, A. Petrovskaya, R. Behr and O. Kieler, "Pulse-driven AC Josephson voltage standard at VNIIM," 2020 Conference on Precision Electromagnetic Measurements (CPEM), Denver (Aurora), CO, USA, 2020, pp. 1-2, doi: 10.1109/CPEM49742.2020.9191742

S. Solve, M. -S. Kim, L. Palafox, R. Behr, I. Budovsky and G. B. Gluber, "Update on the future BIPM on-site comparison program for Josephson ac voltage standards", 2020 Conference on Precision Electromagnetic Measurements (CPEM), Denver, CO, USA, 2020, pp. 1-2, September 2020 DOI: 10.1109/CPEM49742.2020.9191727

Gubler G.B., Nikitin A.Yu., Shapiro E.Z., Alekseeva N.S. Multifunctional state primary power standard in the frequency range from 1 to 2500 Hz, GET 153-2019. *Measurement Standards. Reference Materials*. 2020;16(1):7-16. (In Russ.) https://doi.org/10.20915/2687-0886-2020-16-1-7-16

Magnetic measurements

The latest research of the VNIIM magnetic laboratory is aimed at expanding the range of reproduction of the unit of magnetic induction of a constant field to the region of average fields. A set of equipment was created to reproduce the unit of magnetic induction of a constant field in the range of 1-25 mT. The inclusion of this complex in the State Primary Standard of units of magnetic induction, magnetic flux, magnetic moment and magnetic induction gradient GET 12-2011 provides reproduction and direct transmission of a unit of magnetic induction of a constant field in the ranges of not only weak (10^{-3}-1 mT), but medium (1-25 mT) and strong (0.025–1 T) magnetic fields. To transfer the unit of magnetic induction to the region of medium fields, a quantum caesium magnetometer based on the resolved structure of caesium atoms was created. A method of calibration and calculation of the frequency-to-magnetic induction conversion coefficients of the created quantum caesium magnetometer was developed. The influencing factors were investigated and the uncertainty budget for reproducing the unit of magnetic induction of a constant field was estimated using the created complex.

Publications

Shifrin V.Ya., Belyakov D.I., Kosenkov D.D., Shilov A.E.”Research on expanding the range of reproduction of magnetic flux density of the dc field of the state primary standard GET12-2011”, Measurement Techniques T.63, № 4, 2020.

Shifrin V.Ya., Belyakov D.I., Kosenkov D.D., Shilov A.E. “precise definition of γ 133CS with resolved structure in magnetic fields higher than 0.8 mT”, Magnetic Resonance and its Applications. Proceedings 16th International School-Conference. 2019. C. 252-254.

V.Ya. Shifrin, A.E. Shilov, D.I. Belyakov, D.D. Kosenkov. "Application a quantum cesium magnetometer for the transmission of a magnetic flux density unit in the range of “mean fields” ($1 \cdot 10^{-3}$– $2 \cdot 10^{-2}$ T), Proceedings of the V international conference "laser, plasma research and technologies." LAPLACE-2019, Moscow, February, 2019.

High AC and DC voltage

VNIIMS, Ozernaya str. 46, Moscow, Russia, Victor Kiselev, Tatiana Dubrovskaya (dubrovskaya_ta@mail.ru, dubrovskaya_ta@vniims.ru)

FSUE «VNIIMS» continued to perform modernization in the field of HV metrology.

Some works had been finished before 2015 and the results were included to the brief report of VNIIMS for the 29th Meeting of the CCEM in 2015.

Still the process of updating the equipment for HV measurements is being continued by now:

1) From 2012 to 2018 the specialists of FSUE "VNIIMS" expanded the scope of measurements of State primary standard (SPS) 175 in terms of reproducing and measuring the electrical capacitance and tangent of loss angle (tan δ), improved and put into operation State primary special standard of units of ratio error and phase displacement of AC voltage of power frequency in the range of 0.1/√3…750/√3 kV and units of the electric capacitance and tangent of the loss angle at AC voltage of power frequency in the range from 1 to 500 kV (SPS 175-2019).

2) By 2021, State primary special standard for the unit of DC electrical voltage – volts – in the range of ± (1...500) kV (SPS 181-2010) has been improved and is being prepared for approval, including a reference complex developed in the course of improvement based on a new component base (low-voltage thermostable reference sources of integrated design) in the range from 1 kV to 100 kV of both polarities.

3) By 2019, the specialists of FSUE "VNIIMS" expanded the scope of measurements of SPS 191 in terms of reproducing and measuring composite voltage signal with harmonic components, improved and put into operation the State primary special standard for units of AC electrical voltage of power frequency and composite voltage in the range from 1 to 500 kV with harmonic components from 0,3 to 50 order, in the frequency range from 15 to 2500 Hz (SPS 191-2019).

4) From 2021, it is planned to improve the State Primary special standard for the unit of electrical voltage of standardized lightning and switching impulses in the range from 1 to 1000 kV (SPS 204-2012).

Finished Comparisons:

1) COOMET 707/RU-a/16 (COOMET.EM-S21) Bilateral comparisons of reference switching impulse voltage measuring systems in the range from 1 to 100 kV.

Participants: VNIIMS – pilot laboratory, PTB - Physikalisch-Technische Bundesanstalt, Germany.

2) COOMET 761/RU-a/18 Pilot comparisons of reference systems for reproduction and measuring AC high voltage (above 1 kV) of power frequency (50 Hz) with extended frequency range from 15 Hz to 2.5 kHz and with composite harmonic signal from 0,3 to 50 order

Participants: VNIIMS – pilot laboratory, Università di Bologna – UNIBO, Italy.

3) EURAMET.EM-S42 Supplementary comparison of lightning impulse (LI) reference measuring systems

Coordinator and working group members: VTT Technical Research Centre of Finland Ltd, MIKES (Centre for Metrology - MIKES), Finland, AB (RISE Research Institutes of Sweden), Sweden, LCOE (Laboratorio Central Oficial de Electrotecnia, Spain;

Participants: PTB (Physikalisch-Technische Bundesanstalt, Germany, INRIM (Istituto Nazionale di Ricerca Metrologica), Italy, TUBITAK – UME (Ulusal Metroloji Enstitusu), Turkey, JHILL (National Metrology Institute of Japan (NMIJ), Japan, NMIA (National Measurement Institute), Australia, IATTE, Argentina, VNIIMS (Russian Research Institute for Metrological Service), Russia, NRC National Research Council, Canada, LNE - Laboratoire national de metrologie et d'essais, France, NIM - National Institute of Metrology, China.

Ongoing Comparisons:

4) COOMET 821/RU/20 Pilot comparisons of DC high voltage measuring reference instruments in the voltage range ± (1…100) kV

Participants: VNIIMS – pilot laboratory, BelGIM (Republic of Belarus), NIM (National Institute of Metrology) (People's Republic of China), interested NMIs of COOMET member-countries.

Publications

Kiselev V.V., Dubrovskaya T.A., Gromochkova E.V., Grishin M.V., Leonov A.V., Shkabura V.V., Melekhin A.Yu. "Metrological support of electrical measurements". Chief metrologist. 2020. No. 4 (115). S. 40-55 (in Russian).

Kiselev V.V., Voinov V.N., Smolyaninova M.A. "Improvement of the standard of high voltage AC power frequency before reproducing and measuring harmonic components". Legal and applied metrology. 2019. No. 2 (159). S. 30-34 (in Russian).

Kiselev V.V., Grishin M.V., Dubrovskaya T.A. "Results of international supplementary comparisons of kU and φU measurement standards within the framework of COOMET project 411 / RU-A / 07 (COOMET.EM-S6)". Legal and applied metrology. 2016. No. 2 (141). S. 21-26 (in Russian).

Boyarin N.A., Boyarsky A.I., Dubrovskaya T.A., Kiselev V.V., Leonov A.V., Zergenidze A.D., Melkumyan E.V. "Supplementary comparisons of reference measuring systems of electrical capacity and dielectric loss tangent of NMIs of the Russian Federation (VNIIMS) and Georgia (GEOSTM) within the framework of COOMET comparisons 604 / RU / 13". Legal and applied metrology. 2016. No. 3 (142). S. 12-17 (in Russian).

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 152-2018 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 2017, the primary standard was upgraded and now its measurement capabilities allow the unit to be transferred to DC and AC measurement transducers.

In 2019, work began on its improvement in terms of expanding the measuring capabilities to the frequency range up to 2500 Hz.

GET 152-2018 includes two standard systems:

1 Sinusoidal current standard system:

During the work on expanding the measuring capabilities of the GET 152, a reference standard was developed for comparing the range of nominal primary currents from 5 to 1000 A, the nominal secondary current of 5 A, the operating frequency range from 40 to 2500 Hz.

2 High direct current standard system:

Currently, work is underway to develop and create a high direct current converter in the range of rated primary currents from 1000 to 10000 A, rated secondary current of 5 A

UNIIM has been participating in the following comparisons:

(2020-2022) COOMET.EM-S25 (COOMET 813/RU/20) Supplementary Comparison of measuring Current Transformers (CTs). Pilot laboratory UNIIM

Publications

Ekaterina Voronskaya «Metrological assurance of current measuring transducers», The role of technical regulation and standardization in the digital economy, Digests of the II International Scientific and Practical Conference of Young Scientists, 2020, pp. 317-323.

Pulsed high voltage and current (VNIIOFI, Moscow, Russia)

A. Sukhov (sukhov@vniiofi.ru)

In 2020, the upgrade of the state primary standard GET 148-2020 was completed. As a result of the work carried out, the reproduction of a high impulse electric voltage unit was realized. The step voltage pulses are reproduced using a set of semiconductor generators (FID GmbH). To determine the amplitude-time parameters of the reproduced pulses, the generator is connected to a TEM cell (50 Ohm), which houses a pulsed electric field intensity converter (capacitor antenna with an optical unit). The transducer is pre-calibrated in the standard of the pulsed electric field strength.

Studies of the standard have shown that the range of reproduction of a high-pulsed electric voltage unit is from 1 to 50 kV, the rise time of reproduced pulses is in the range from 0.1 to 8.0 ns, and the pulse duration is in the range from 0.02 to 150 μs. The expanded uncertainty of reproducing a unit is 5.8 % ($p = 0.95$, $k = 2$).

This year, work began on the modernization of the lightning discharge impulse current unit standard GET 202-2012. It is planned to reduce the rise time of the reproduced pulses to 1 ns; the extended amplitude range should be from 1 A to 100 kA.

Publications

Sukhov, A.V., Sakharov, K.Y., Zolotarevsky, Y.M. et al. A Study of High Transient Voltage Unit Realization Uncertainty. Meas Tech 63, 823–827 (2021). https://doi.org/10.1007/s11018-021-01859-8.

Sakharov, K.Y., Mikheev, O.V., Turkin, V.A. et al. Get 148–2013: State Primary Special Standard of Units of Electric and Magnetic Pulse Field Strengths with Pulse Rise Time in the Range from 0.1 to 10.0 ns. Meas Tech 61, 967–972 (2019). https://doi.org/10.1007/s11018-019-01534-z

Sukhov, A.V., Sakharov, K.Y., Mikheev, O.V. et al. Microwave Photonic Detector for Measuring Pulsed Electric Field Strengths in the Sub-Nanosecond Region. Meas Tech 61, 627–632 (2018). https://doi.org/10.1007/s11018-018-1475-5