Progress Report to CCEM

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Electrical and magnetic measurements

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DC voltage (A. Katkov)

The equipment of VNIIM primary voltage standard based on Josephson effect consists of laboratory made devices that can use 1 V and 10 V SIS and SINIS arrays made in PTB, Germany and 1 V SIS array made in Russia.

VNIIM developed 1 V and 10 V transportable Josephson standards that are used for key comparisons of national voltage standards in COOMET and EURAMET.

VNIIM is pilot laboratory of the bilateral key comparison with BelGIM in the frame of COOMET project 542/RU/11. Draft B report of the key comparison between two Josephson voltage standards (COOMET.EM.BIPM-K10.b) is prepared. The final result is in very good agreement.

VNIIM is a collaborator within the Q-WAVE project:

- model practical sampling measurement methods;
- analyse experimental measurement set-up;
- suggest testing methods to investigate possible error sources.

Publications

A. S. Katkov, P. A. Chernyaev. Key Comparisons of the Standards of the Volt of the Russian Federation and the Republic of Belarus. // Measurement Techniques, 2013, Vol. 56, No. 5, P. 570-575.

Jinni Lee, Ralf Behr, Luis Palafox, Alexander Katkov, Marco Schubert, Michael Starkloff and Andreas Charles Böck. An ac quantum voltmeter based on a 10 V programmable Josephson array. 2013 // Metrologia 50 (6) 612-622.

A. Katkov, G. Gubler, J. Lee, R. Behr, J. Nissilä. Influence of Harmonics on AC Measurements Using a Quantum Voltmeter. // Conference Digest CPEM 2014. Rio-de-Janeiro. 2014. P. 526-527.

J. Lee, J. Nissilä, A. Katkov, R. Behr. A quantum voltmeter for precision AC measurements. // Conference Digest CPEM 2014. Rio-de-Janeiro. 2014. P. 732-733.

Comparison

VNIIM and BelGIM. COOMET.EM.BIPM-K10.b. Comparison of Josephson voltage standards by using portable JVS. (Draft B).

Comparison planned

EURAMET, EM- K10.b. Comparison of Josephson voltage standards by using portable JVS.

DC HTS voltage standard (A. Klushin, a_klushin@ipmras.ru)

A practical automated DC voltage standard based on an array of high-temperature superconductor (HTS) Josephson junctions suitable for metrological, scientific and industrial applications has been developed and its performance has been characterized. In the new instrument, the quantum voltage equal to 25 mV or 50 mV of the cryocooled up to liquid nitrogen temperatures HTS array is converted by a resistive divider into an output voltage up to 10 V with a relative uncertainty smaller than 5×10^{-8}. This voltage standard consists of three units with dimensions of 450 × 500 × 185 mm. The work has been supported by the Ministry of Industry and Trade of the Russian Federation (Minpromtorg Russia).

DC current (O. Pavlov)

VNIIM maintains and develops the state primary standard of DC current in the range of $1\cdot10^{-16}$ A - 1 A. VNIIM holds unique transportable standard of DC current in the range $1\cdot10^{-15}$ A - $1\cdot10^{-9}$ A.

Investigation of the accuracy of serial electronic sources/meters in the range of 100 pA to 1 μA are performed. Experimental results show accuracy limitation in reproduction of DC current by thermal noise, shot noise, which originates from the discrete nature of electric charge, and 1/f noise. Type A uncertainties of measurements of serial electronic device in the DC current range from 100 pA to 1 μA were from 0.0025 % to 0.00005%.

Publications

A.Katkov, O. Pavlov, V. Gerasimenko. Influence of noise in DC current measurements in the range of 0.1 nA - 1 mA. // Conference Digest CPEM 2014. Rio-de-Janeiro. 2014. P. 246-247.

V.S. Alexandrov, A.S. Katkov, I.V. Korotkova, V.E. Lovtsyus, O.M. Pavlov, A.V. Pokusaev, G.P. Telitchenko, V.I. Shevtsov. Measurement and Reproduction Low DC Currents by means Electron Multiplier. // Conference Digest CPEM 2014. Rio-de-Janeiro. 2014. P. 552-553.

O. M. Pavlov, P. A. Chernyaev. Reproduction and Measurement of Attoampere Direct Currents with the Highest Accuracy. // Measurement Techniques. 2014, Vol. 57, Issue 7, pp. 805-811.

Comparison

VNIIM took part in the comparison of Ultra-low DC currents in the range from ± 100 fA to ± 100 pA under Euromet project EM-S24.

DC Voltage electrostatic field (O. Pavlov)

VNIIM has designed a calibrator of electrostatic field. The calibrator is designed to reproduce the electrostatic field and electrostatic potential of a charged surface, and can be used for testing and calibration of the intensity measurements of the electrostatic field and electrostatic potential of a charged surface.

The range of the electrostatic field in free space is ± 200 kV / m. The range of electrostatic potential is ± 30 kV. Limits of relative error of reproduction setpoint electrostatic field strength is 1.5%. Limits of a relative error of reproduction setpoint charged surface potential is 0.4%.

AC Voltage (V.I. Shevtsov)

State primary AC voltage standard consists of:

- special primary standard for the unit of electrical voltage in the frequency range from 10 to $3\cdot10^7$ Hz at voltage from 0.1 to 1000 V;
- special primary standard for the unit of electrical voltage in the frequency range from $3\cdot10^7$ to $2\cdot10^9$ Hz at voltage from 0.1 to 10 V.

Calibration manual for new secondary AC voltage standard in the frequency range from $3\cdot10^7$ to $2\cdot10^9$ Hz for the voltage from 0.1 to 3 V was developed.

Publications

GOST R 8.886-2014. The state system of measurement assurance. Standard AC voltage and current thermal converters. Methods and instruments of verification (in Russian).

Comparison

Comparison of AC voltage standards in the frequency range 10 – 10^6 Hz (COOMET project 566/UA/12) was finished.

Comparison of high frequency AC voltage standards in 2013 (COOMET project 567/UA/12) in progress.

AC current (V.I. Shevtsov)

VNIIM established the new state primary AC current standard in the range of frequency 20 Hz - $1\cdot10^6$ Hz. It includes a unique set of thermo-converters that directly convert the AC current up to 20 A.

Investigation of AC current shunts parameters was performed in the range up to 100 A at frequency up to 100 kHz.

Publications

GOST R 8.886-2014. The state system of measurement assurance. Standard ac voltage and current thermal converters. Methods and instruments of verification.

LF Power (G. Gubler)

Sampling power standard was deployed at VNIIM in 2012. New calibration system for non-traditional transformers was developed on the base of the sampling system and DSP algorithms that were explored for the power standard. New system provides calibration of non-traditional (optical and electronic) current and voltage transformers and transducers with digital outputs. The system includes DVM, waveform generator and synchronization module. It has analog input and digital input according to IEC 61850-9-2LE (communication protocol for digital substation). Estimated expanded uncertainty for amplitude error is 10 μA/A (10 μV/V) and for phase error is 40 μrad. The uncertainty budget does not include amplitude and phase errors of reference transformer.

Sampling system of power standard is also used as a core of new calibration system for PMU (phasor measurement units) that is under development.

DSP algorithms and system control procedures were organized as separate software products. It can operate with typical set of equipment that popular in NMI labs and available for trial usage.

Current to voltage transducer is under development with input current up to 40 Amps and output voltage of 0.8 V to replace squirrel-cage shunt for low frequency measurement (40 - 400 Hz). The main idea of the transducer (electronic current transformer) was popularized by Ilya Budovsky [APMP 2013 TCEM workshop]. Target uncertainty of 5 μA/A in-phase and 3 μrad quadrature.

Joint work on experimental comparison of methods used to process the signals in the power standards of NMIA and VNIIM were conducted in 2014. Participants from NMIA: I. Budovsky. The comparison of two systems based on different principles shows good agreement (5 μW/W).

Publications

Gubler G.B., Shapiro E.Z. Implementation of Sampling Measurement System for new VNIIM power standard. Conference Digest CPEM 2012. Washington. 2012. P. 294 – 295.

G. Gubler, A. Katkov. Investigation of ADC-Aided AC Measurement through the use of PJVS. // Conference Digest CPEM 2012. Washington. 2012. P. 64-65.

A. Katkov, G. Gubler, J. Lee, R. Behr, and J. Nissilä Influence of Harmonics on AC Measurements Using a Quantum Voltmeter. // Conference Digest CPEM 2014. Rio de Janeiro. 2014. P. 526 – 527.

Comparison

APMP.EM-K5.1 Key comparison AC Power at 50/60 Hz.

Comparison planned

CCEM-K5. Key comparison of electrical power standards.

CCEM-K13. Key comparison K13 on Power Harmonics.

DC Resistance (A. Ploshinsky)

During the years from 2011 to 2014 we investigated the temporal instability of the 1 kΩ resistance standards (ZIP, Krasnodar) via QHR with the PTB heterostructure with high mobility. To improve temperature conditions the polymethylsiloxane fluid PMS-10 (viscosity 10 units) was used. We controlled the value of each resistance as a mean value for the group of four such resistances as well. The temporal instability of the mean value during one year does not exceed 20 nΩ/Ω. We have also carried out preparatory work to be able to use in the near future the CCC bridge (Magnicon) to compare QHR and resistance standards with an uncertainty less than 1 nΩ/Ω.

Magnetic measurements (V.Ya. Shifrin)

The first international comparisons in the field of earth-level DC magnetic flux density measurement with participation of six National Metrology Institutes (NMIs) and four geomagnetic observatories (GOs) have been carried out under the auspices of the Regional Metrology Organization, Asia Pacific Metrology Programme (APMP), in 2013 and 2014.

VNIIM was the pilot laboratory for this comparison, registered in the Key Comparisons Data Base (KCDB) under the index APMP.EM-S14.

The Technical Protocol of the comparison is provided for the use of a transportable quantum standard magnetometer (transfer standard). It was circulated unattended among the participants and was subjected to a triple calibration by the pilot laboratory primary standard for the basic magnetic units - in the beginning, in the middle and after the comparison - to monitor its stability.

The transfer standard (TS) provided by the pilot laboratory was a portable quantum magnetometer based on the proton magnetic resonance method combined with the Overhauser effect. Corrections for the results of measurements by the transfer standard were determined by the pilot laboratory over the entire measurement range from 20 to 100 μT, which made it possible to carry out the measurements with a type B uncertainty better than 0.05 nT (coverage factor k = 2) and a type A (random) uncertainty close to 0.01 nT.

Another important aim of this project is to set-up metrological service system for global network of geomagnetic observatories. Practically, applying the corrections to measurements performed in the GO's will allow to lower measurement uncertainties to a level less than 0,1 nT (a 5-fold reduction).

The certification by comparison of the quantum magnetometers in the geomagnetic observatories network can be organized using the experience gained in this project. Similar experience in other measurement fields, for example in the field of electric measurements with a long tradition in metrology service, can be used.

The project organizers expect proposals from International Association of Geomagnetism and Aeronomy (IAGA) and geomagnetic observatories expressing their wish to participate in the expanded programme for gradual coverage of all GO's network

Publications

V. Ya Shifrin, V N Khorev, J Rasson and Po Gyu Park. International comparisons to establish the traceability in the global network of geomagnetic observatories to SI units, 2014, Metrologia, 51 01015 doi:10.1088/0026-1394/51/1A/01015

V. Ya. Shifrin, V. N. Khorev, V. N. Kalabin, S. L. Voronov, A. E. Shilov. State primary standard for the units of magnetic induction, magnetic flux, magnetic moment, and magnetic induction gradient, Measurement Techniques, 2012, Vol. 55, Issue 7, pp. 739-744. http://www.springerlink.com/openurl.asp?genre=article&id=doi:10.1007/s11018-012-0031-y

HV measurements (VNIIMS, dubrovskaya_ta@mail.ru)

From 2010 to 2013 – State Standard complex for reproduction and storage of electric voltage units of switching and lightning impulses in the range from 1 to 1000 kV was developed.

Till the beginning of 2015 VNIIMS is the developer and holder of 4 state primary standards (SPS) in the field of HV measurements. Below there is some information about the State primary special standards of the institute:

SPS 175-2009 of the units of ratio error and phase displacement of AC voltage of power frequency;

SPS 181-2010 of DC voltage unit – volt – in the range ±(1…500) kV;

SPS 191-2011 of AC voltage of power frequency unit in the range from 1 to 500 kV;

SPS 204-2012 of voltage unit of standard switching and lightning impulses in the range from 1 to 1000 kV.

In the field of metrology the department deals with:

- research, development and improvement of the national (state) standards,
- international comparisons of the state standards of the units of the measured quantities (all information is reflected on IBMW website);
- metrological assurance of designed and operated potentially hazardous objects. Systematic approach to metrological assurance of industrial safety facilities, starting from the design phase. A particular attention is paid to the stages of manufacturing, construction, installation, maintenance and control of technical devices with the use of measuring instruments.