Research of metrological characteristics of national standard of electrical resistance unit

Filipchik I.V.
Republican Unitary Enterprise “Belarusian State Institute of Metrology”, BelGIM
Minsk, Belarus, 2017, (375 17) 233 52 55, fax (375-017) 288-09-38,
filipchik@belgim.by

In 2013-2015 the Belarusian State Institute of Metrology established the national standard of electrical resistance unit. The paper presents the prerequisites for creating a national standard, the composition of the standard, its metrological characteristics, as well as research results and prospects at the resistance measurements area.

The priority directions of our institute are to establish of the national standards base and to ensure a system of international traceability for its standards.

The main reasons for establishing the national standard of electrical resistance unit were the necessity of:

- improving measurements accuracy, allowing us to take part in international comparisons and to place calibration and measurement capabilities (CMC’s) at the international database KCDB;
- replacement and improvement the existing equipment;
- meeting the requirements of our industry in expanding the reproduction and measuring range;
- metrological control of up-to-date high-precision equipment (multimeters and calibrators);
- metrological support of scientific inventions in Belarus.

Besides, we had no measuring equipment at low ohms with nominal current up to 100 A and *at high ohms* from 10 GOhms to 100 TOhms.

The development of standards of electrical resistance unit is carried out in two steps, as a rule. At first the system of store and transfer the unit is created. In this case the basis of standard is a group of resistance standards. At the second stage a quantized Hall resistance standard is established [1]. We finished the first stage at 2015.

The structure of national standard and the scheme of transfer the electric resistance unit are represented at figure 1.

The unit is transfer from the resistance group to reference standard and further to working measurement standards.

The national standard of electrical resistance unit consists of two complexes.

1 A set of reference equipment for reproduction and storing the basic value of the electric resistance unit.

For creation of a reference group four primary standard resistors 9210A/1 (figure 2) were manufactured according to our technical task by Measurement International (MI), Canada. These standards have the best metrological characteristics at present. The stability in year is less then 0.2 ppm, temperature coefficients are less then 0.05 ppm.

2 A set of reference equipment for the storing and transfer units consists of:

- the system 6242B (measurement range from 100 mkOhm to 1 MOhm, the best accuracy is less then 0.05 ppm, measurement current up to 100 A);
- the system 6600A (measurement range from 100 kOhm to 100 TOhm, the best accuracy is less then 7 ppm, measurement voltage up to 1000 V)
- high resistance standard 9331G (nominal values from 10 GOhm to 100 TOhm, stability from 25 ppm to 0.5 %)

Besides, the available set of reference resistance standards with nominal values from 1 mOhm to 1 GOhm became a part of national standard. These standards have a long history of researches and high stability.

3 Ancillary equipment

To provide temperature control system calibration Bath OB-50/2, temperature controlled standard resistor air bath 9300A and 9300 are used.

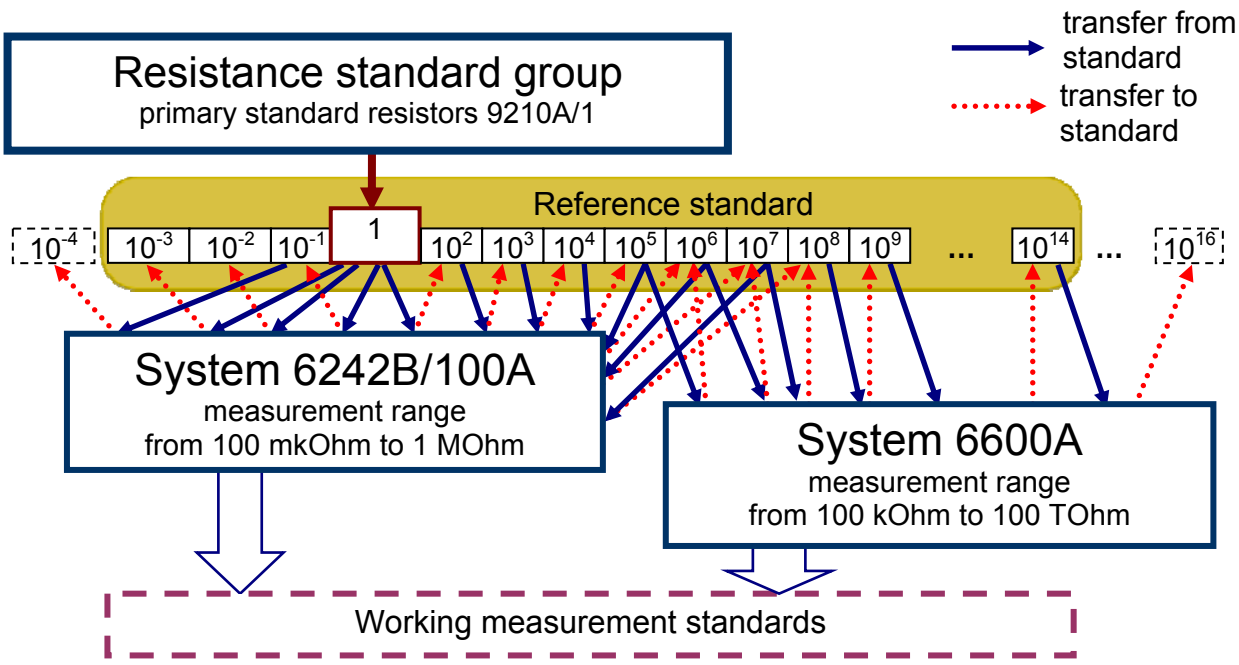

Figure 1

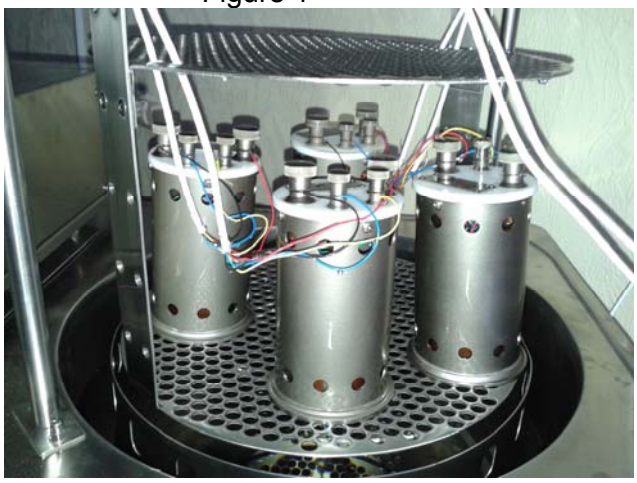

Figure 2

The results of* national standard of electrical resistance unit *researches

The researches of metrological characteristics of national standard were conducted during the 2014-2016. The researches *of the primary resistance standard group* and transfer of resistance unit to reference standard are the most significant. Earlier the reference standard was calibrated at VNIIM, Russia.

Primary standard resistors 9210A/1 (resistance standard group)

The actual values of standard resistors 9210A/1 during 2015-2016 are shown at the table 1. These values are calculated as an average meaning from 25 measurements, obtained relatively to reference standard P321 which was calibrated at VNIIM with expanded uncertainty 0.3 ppm.

Table 1

Serial Numbers	Actual Values				
	06.2014 г. (certificate MI)	02.2015	11.2015	02.2016	11.2016
1102314	1,00000105	1,00000149	1,00000139	1,00000148	1,00000125
1030603	0,99999790	0,99999822	0,99999810	0,99999822	0,99999805
1101044	0,99999658	0,99999690	0,99999684	0,99999696	0,99999680
1101047	1,00000038	1,00000081	1,00000081	1,00000092	1,00000063

Based on the measurement results standard deviation and stability were determined (table 2, figure 3).

Table 2

Serial Numbers	Standard deviation, $\times 10^{-2}$ ppm	Standard deviation according to technical task, $\times 10^{-2}$ ppm	Stability, ppm	Stability according to specification, ppm
1102314	0,8	5	0,00	0,2
1030603	0,6	5	0,01	0,2
1101044	0,6	5	0,06	0,2
1101047	0,7	5	0,11	0,2

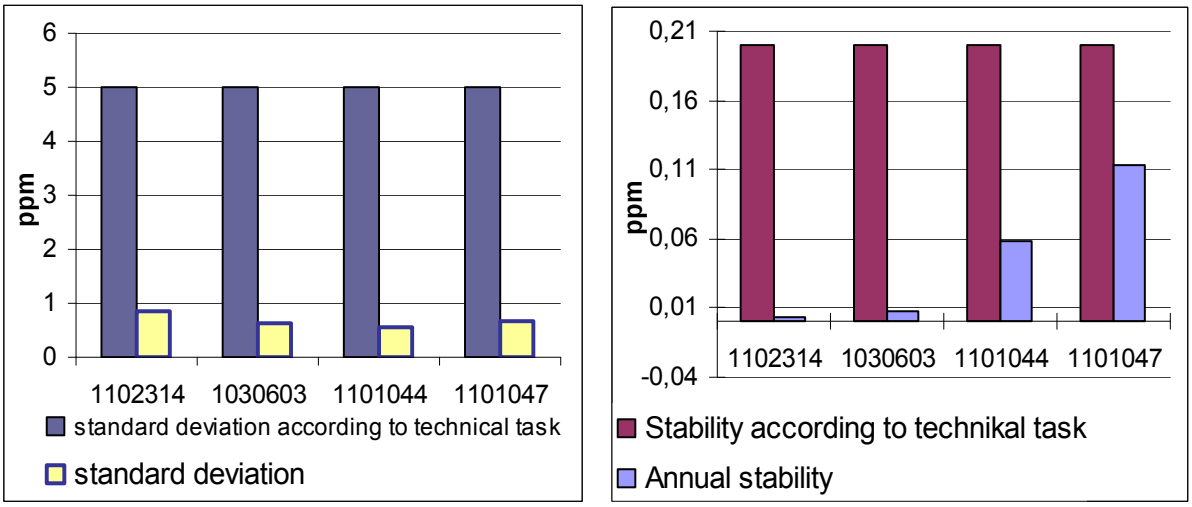

Figure 3

The obtained values do not exceed the values given in the technical documents.

The transfer the electrical resistance unit to the reference standard

The results of measurement are shown at tables 3, 4.

Table 3

Nominal value	Actual Value (VNIIM), 2014	Actual Value (BelGIM), 2016	Annual stability
	Ohm	Ohm	ppm
0,001 Ohm	0,000999997	0,000999999	1,0
0,01 Ohm	0,01000066	0,01000068	1,0
0,1 Ohm	0,1000033	0,1000035	1,0
10 Ohm	9,99945	9,99945	0,0
100 Ohm	99,9977	99,9976	-0,5
1 kOhm	1000,049	1000,048	-0,5
10 kOhm	9999,15	9999,11	-2,0
100 kOhm	100001,7	100001,2	-2,5
	MOhm	MOhm	ppm
1 MOhm	1,000302	1,000303	0,5
10 MOhm	9,99976	9,99969	-3,5
100 MOhm	99,9977	99,9969	4,0
1 GOhm	1000,079	1000,086	-3,5

On the basis of the results, these set of resistance standards can be used as a reference standard and the measurement systems allow transferring the unit with the required accuracy.

International Comparisons

In 2015 BelGIM took part in the COOMET Supplementary Comparison of Resistance at 100 Ohm and 100 kOhm (COOMET.EM- S19) which was conducted in the framework of the project COOMET 624/GE-a/13.

Conclusions

Thus the national standard of electrical resistance unit is capable to store and transfer unit of electric resistance with the highest accuracy in Belarus. The main metrological characteristics are presented in Table 5.

Table 5

Metrological characteristics	Value	
	in accordance with a technical task	in accordance with the results of research
Reproduction and storing the basic value	1 Ohm	1 Ohm
RMS	$5 \cdot 10^{-8}$	$(0{,}6\text{-}0{,}8) \cdot 10^{-8}$
Systematic error	$5 \cdot 10^{-7}$	$4{,}6 \cdot 10^{-7}$
Unit transfer range	from $1 \cdot 10^{-3}$ to$1 \cdot 10^{9}$ Ohm	from $1 \cdot 10^{-4}$ to $1 \cdot 10^{16}$ Ohm

The equipment made on the basis of the technical project is fully consistent with the technical task and provide an additional opportunities. They are:

- extended measuring range of electrical resistance unit;
- the possibility of low ohms measurements at the nominal current up to 100 A;
- the possibility of the temperature coefficient of resistance determination.

Development prospects:

- introduction CMC's to an international database KCDB;
- inclusion of Quantum Hall Resistance into national standard of electrical resistance unit, which will allow to rise resistance reproducing accuracy up to $2 \cdot 10^{-8}$ [2].

References:

[1] Создать эталон единицы электрического сопротивления: отчет о НИР № ГР 20131974, 2015.

[2] T.A. Colomiets, E.A. Kazakova, I.N. Lukhverchik, T.G. Sosnovskaya, I.V. Filipchik. Creation of national standard of electrical resistance unit. Metrologia and instrument-making, 2016, 76

I.V. Filipchik