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Interlaboratory comparisons of calibration results for electrical capacity measures and inductance measures

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Abstract

The article is dedicated to the organization and performance of bilateral interlaboratory comparisons of calibration results for electrical capacity measures and inductivity measures at the frequency of 1 kHz. Interlaboratory comparisons of measuring instruments calibration results for electric quantities are presented. Evaluation of the laboratory calibration results bias is provided by means of functioning statistics E_n number. Analysis and conclusions concerning laboratory competence are obtained.

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1. Introduction

At the modern science and technique development level, one of the widespread electromagnetic quantities measurements is the measurement of electrical impedance parameters, particularly electrical capacity, and inductance. They are performed in the process of development, production, adjustment, operation, and repair of electric and electronic schemes and their components in such fields as telecommunication, energetics, transport, telematics, navigation, radiolocation, protection, security, defense, etc.

To ensure impedance parameters measurement accuracy, measuring equipment manufacturers recommend equipment calibration at regular intervals in accredited according to [1] laboratories. National Accreditation Agency of Ukraine (NAAU) evaluates meeting the requirements of [1] by testing and calibrating laboratories. This standard requires laboratories to have a quality assurance system for testing and/or calibration results. Laboratories should participate in proficiency testing (PT) within this system.

NAAU considers PT as a tool for competency demonstration and maintaining laboratorys technical quality and requires that the laboratory participates in such PTs before and after accreditation [2]. PT is the participants functioning conformity assessment according to the established requirements by means of interlaboratory comparisons [3]. Interlaboratory comparisons (ILCs) are the organization, performance assessment, and measurement of the same or similar

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sample testing by two or several laboratories according to set requirements [3].

ILCs are widely used for particular tasks and are more often used at the international level. ILCs are one of the validation techniques for calibration methods in the laboratory [4, 5]. Reliable measurement results guarantee is necessary not only for laboratory and metrological services customers but also for inspection and accreditation bodies and other organizations which set requirements for laboratories [3]. ILCs are an urgent task for calibrating laboratories.

2. ILCs general characteristics

SE «Ukrmetrteststandart» as national metrological center initiated and performed ILCs for P 597 electrical capacity measures and P 596 inductivity measures calibration from April to October 2021. ILCs were organized according to [1, 3, 8] standards on order for testing accuracy of measurement results in calibrating laboratories.

P 597 electrical capacity measures and P 596 inductivity measures were chosen as samples for calibration. Those measurement standards are used to verify, calibrate and test measurement standards and measuring instruments.

Basic technical characteristics of P 597 electrical capacity measures are:

- nominal values – 100 pF, 200 pF, 1000 pF;
- accuracy class – 0,05;
- normal frequency of AC power – 1000 Hz.

Basic technical characteristics of P 596 inductivity measures are:

- nominal values – 5 mHn, 50 mHn, 500 mHn;
- accuracy class – 0,05;
- normal frequency of AC power – 1000 Hz.

ILCs aim is proficiency testing by electrical capacity and inductivity measures calibration.

ILCs program was realized according to requirements [3]. Calibrating laboratory and ILCs provider took part in ILCs. Calibration was performed in normal conditions.

ILCs provider used the comparison method for electrical capacity and inductivity measurements performance. Used electrical capacity and inductivity measurement standards are traceable to world-leading laboratories (BIPM, France; NIST, USA). ILCs participating laboratory used the direct measurements method.

Measurement uncertainty evaluation in calibration was performed according to requirements [6, 7]. Detailed measurement uncertainty evaluation budgets of ILCs provider are presented in [4, 5]. Participating laboratory provided similar to ILCs provider detailed measurement uncertainty evaluation budgets.

3. ILCs calibration results

ILCs provider performed measurements according to block diagrams in Fig. 1. a, b, Fig. 2. Comparator adjustments were provided according to manual before the electric capacity measurement started; this includes automated testing function and its internal blocks and elements adjustment.

Comparator adjustments are provided according to the manual before the inductivity measurement start.

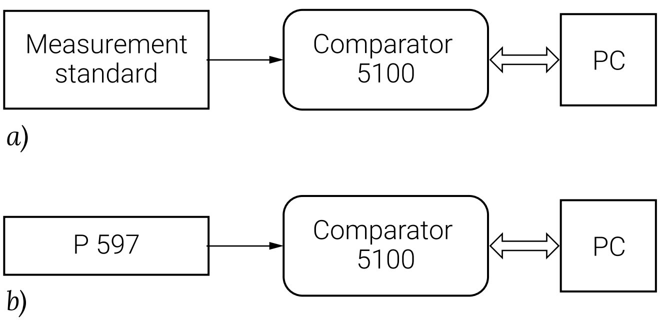

Fig. 1. *Block diagram of electrical capacity measurements by provider*
a – comparator adjustment stage for electric capacity measurement;
b – electric capacity measurement stage by comparator

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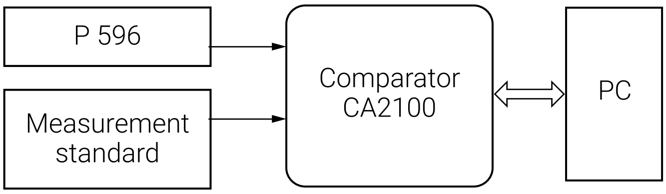

Fig. 2. *Block diagram of inductivity measurements by provider*

Participating laboratory used RLC-meter for electrical capacity and inductivity measurement. Adjustments for the selection of measured value and measurement range according to nominal values of measurement standards were performed at the beginning of measurements, and initial parameters were taken into account.

The design of measurement systems used for electrical capacity and inductivity measurement by provider is presented in Fig. 3, 4.

Measurement results bias performed by the laboratory is calculated by the formula:

Fig. 3. *Providers measurement system for electrical capacity measurement (1 – comparator 5100; 2 – measurement standard; 3 – P 597 measure)*

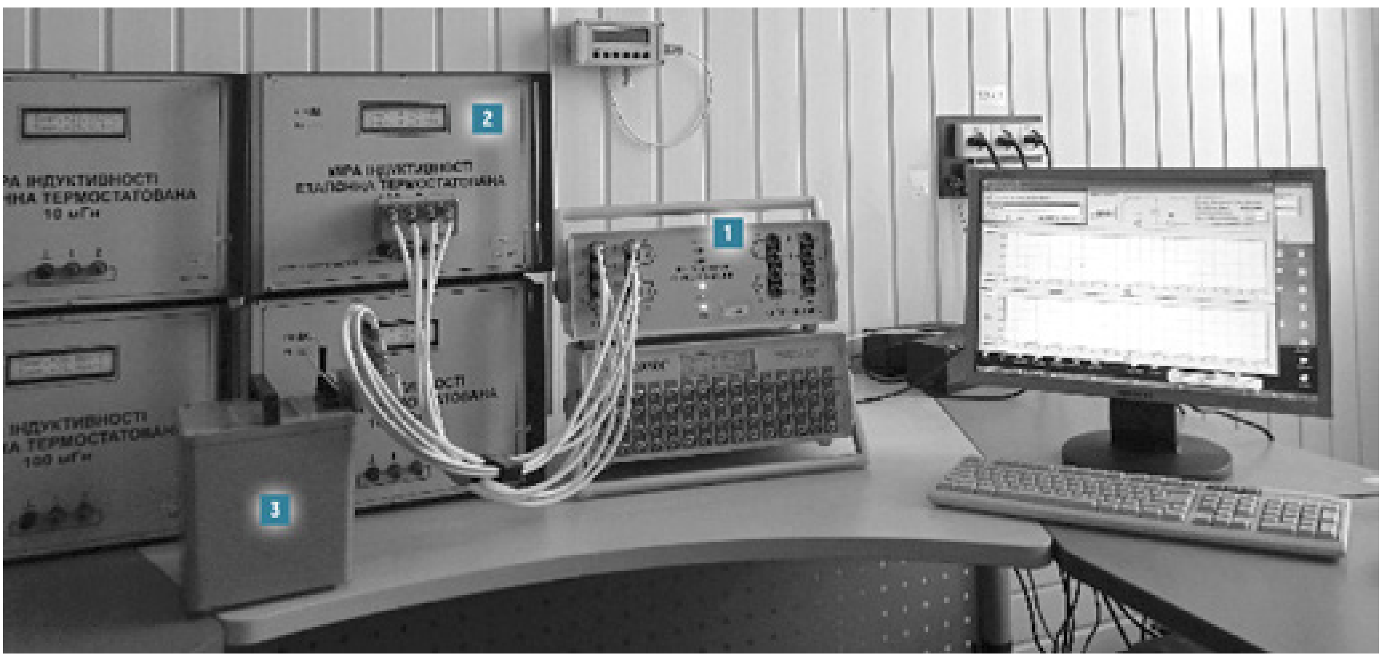

Fig. 4. *Providers measurement system for inductivity measurement (1 – comparator CA2100; 2 – inductivity measurement standard; 3 – P 596 measure)*

$$D_{lab} = x_{lab} - X_{ref}, \quad (1)$$

where

x_{lab} – measurement result average value performed by the laboratory;

X_{ref} – measurement result average value performed by the ILCs provider.

Participants measurement results are evaluated by means of E_n value, which is calculated by formula [3, 8]:

$$E_n = \frac{x_{lab} - X_{ref}}{\sqrt{U_{lab}^2 + U_{ref}^2}}, \quad (2)$$

where

U_{lab} – expanded measurement uncertainty performed by the laboratory;

U_{ref} – expanded measurement uncertainty performed by the ILCs provider.

Herewith, if:

$|E_n| \leq 1{,}00$ – the result does not require correction or any other actions;

$|E_n| > 1{,}00$ – the result requires correction or any other actions.

Measurement results, measurement results biases D_{lab}, expanded measurement uncertainties, U_{lab} and E_n values are presented in Tables 1-2.

Laboratory	Nominal electrical capacity value, pF	Electrical capacity measurement result, pF	D_{lab}, pF	U_{lab}, pF	E_n
Ref	100	100,05065	0	0,00056	-
Lab		100,0470	-0,00361	0,0100	-0,36
Ref	200	199,9271	0	0,0011	-
Lab		199,9240	-0,0031	0,0200	-0,15
Ref	1000	1000,2899	0	0,0055	-
Lab		1000,3200	0,0301	0,0600	0,50

Table 1. *Electrical capacity measurement results of P 597 measure*

Laboratory	Nominal inductivity value, mHn	Inductivity measurement result, mHn	D_{lab}, mHn	U_{lab}, mHn	E_n
Ref	5	5,01189	0	0,00059	-
Lab		5,01280	0,00091	0,00097	0,80
Ref	50	50,0647	0	0,0022	-
Lab		50,0620	-0,0027	0,0096	-0,27
Ref	500	500,389	0	0,03700	-
Lab		500,376	-0,0130	0,2500	-0,05

Table 2. *Inductivity measurement results of P 596 measure*

Measurement results $\left|E_n\right|$ for participating laboratory is changed within limits:

- from 0,15 to 0,50 in the process of electrical capacity measures calibration;
- from 0,05 to 0,80 in the process of inductivity measures calibration, that completely corresponds to the mentioned ($\left|E_n\right| \leq 1{,}00$) criterion.

4. Conclusion

Taking into account ILCs results, their participants meet the requirements of ($\left|E_n\right| \leq 1{,}00$) criterion in the result of electrical capacity and inductivity measurement at the frequency of 1 kHz. This proves participants competency in the calibrating process.

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