Interlaboratory Comparison for Electric Power Measurements at Industrial Frequency in Ukraine

O. Velychko[1], S. Karpenko[2]

State Enterprise "All-Ukrainian research and production centre for standardization, metrology, certification and consumers rights protection" (SE "UKRMETRTESTSTANDARD"), Kyiv, Ukraine
e-mail: velychko@ukrcsm.kiev.ua[1] , s.r.karpenko86@gmail.com[2]

Abstract – SE "UKRMETRTESTSTANDARD" provided and carried out the interlaboratory comparison (ILC) as reference measurements provider for all Ukraine accredited calibration laboratories (CL's) for electric power (EP) measurements at industrial frequency. This paper presents the assessment of CL's which participated at ILC within EP measurements at industrial frequency. The main goal of this ILC was the assessment of CL's capabilities that perform calibration in EP measurement.

Keywords – interlaboratory comparison, electric power, measurement uncertainty, calibration laboratory

I. INTRODUCTION

The implementation of the ILC is the most effective technical inspection requires [1]. Participation in ILC provides independent verification of CL's competence and demonstrate to the publics, customers, accreditation bodies, regulators and management that procedures are under control and gives technical confidence in the service which CL's provide [2].

Nowadays the EP measurements at industrial frequency has a practical importance as it become the main basis of commercial relations between consumer of electricity and electricity supplier. It should be noted that the main purpose of legal metrology is to control the measuring instruments which are used in commercial transactions and to ensure and guarantee the accuracy of the measurement results throughout the period of use under operating conditions within the limits of the allowed permissible errors [3].

It is very important for understanding that only participation in ILC can gauge where CL's measurements may stand in the community of similar CL [4]. Definitely ILC reports [2] can provide information on where a participation CL may need improvement.

It should be noted that comparison between different results can only be done correctly if the measurement uncertainty of the results is taken into account [5].

II. TRAVELLING STANDARD OF THE INTERLABORATORY COMPARISON

A. Brief review of travelling standard

Selected travelling standard (TS) is Radian Research RM 15-04 precision EP standard. TS is single-phase EP meter, works on principles of digital processing of electrical current and voltage signals.

The measure process of measuring EP is fully automatically with the help of connector output count number of pulses which is directly proportional to the measured EP.

Note that stability is included within the maximum accuracy specifications for all measurement functions.

B. Calibration conditions

The TS is calibrated as a single-phase precision EP meter. It is important that calibration had to be carried out current phase A.

Before starting EP measurements the TS must be warmed up for 24 hours (connected to the main power supply). Also current and voltage signals must be connected for 4 hours before measurement. Following these procedures, short-term shutdown signal current or voltage from TS will not lead to loss of the standard's characteristics.

Main measurements should be performed with the input signals and environmental conditions such as: voltage: from 119.76 V to 120.24 V; current: from 4.99 A to 5.01 A; power factor (PF): 1.0, 0.5 Lag, 0.5 Lead, 0.866 Lag, 0.866 Lead deviation from the nominal value not exceeding 0.002%; frequency: from 49.9 Hz to 50.1 Hz and from 52.9 Hz to 53.1 Hz; temperature: from 17 ˚C to 23 ˚C; humidity: from 30 % to 80 %; supply voltage: from 209 V to 231 V; frequency of the supply voltage: from 49.9 Hz to 50.1 Hz.

III. PARTICIPANTS OF INTERLABORATORY COMPARISON

Currently there are about twenty Ukrainian accredited CL's. But only seven CL's (Lab1-7) are obligated to

participate in ILC organized by SE "UKRMETRTESTSTANDARD" to maintain their accreditation. All the participated CL's did measurements according the Technical Protocol which was sent before the execution of ILC. But evaluation of expanded uncertainty was done according to calibration procedures developed by participated CL's [6]. The main goal of this ILC was the assessment of CL's capabilities that perform calibration in EP measurement. This ILC helped to verify first of all technical competence of the staff of participated CL's, their technical and calibration procedures, environmental conditions.

All Ukrainian CL's are accredited according to [1] and are equipped with single/three-phase watt meters with accuracy classes 0.02 %, 0.05 %, 0.1 %, 0.2 %.

IV. EVALUATION OF THE RESULTS

The measurement points were established according the participated CL's accreditation schedules and international practice of organizing comparisons. The most critical measurement points of the instruments ranges were checked.

The radial scheme was used so the TS is returned to the SE "UKRMETRTESTSTANDARD" as the reference laboratory (RL) after each measurement at a participated CL [7,8]. The assigned values taken into account were the means of measurement values by the RL for each established point [2].

The following deviations of CL measurement results D_{CL_i} for each point were evaluated as:

$$D_{CL_i} = X_{CL_i} - X_{AV},\qquad(1)$$

where X_{CL_i} – the measurement results of participated CL, X_{AV} – the assigned value (AV) of the EP, defined as the arithmetic mean of the values measured by the RL.

The evaluation of the results for each participated CL was carried out with the help of a modified criterion for the functioning statistics E_n according to [2], which is determined by (2):

$$E_n = \frac{X_{CL_i} - X_{AV}}{\sqrt{U_{CL_i}^2 + U_{AV}^2}},\qquad(2)$$

where U_{CL} – expanded uncertainty of EP measurements of participated CL, U_{AV} – extended uncertainty of EP measurements of AV of the EP and is determined by (3):

$$U_{AV} = 2\sqrt{u^2(X_{AV}) + u^2(X_{TS})},\qquad(3)$$

where $u(X_{AV})$ – standard uncertainty obtained during calibration by the RL for the corresponding power factor, $u(X_{TS})$ – standard uncertainty from the instability of TS [9] during the time of ILC.

An ILC result is satisfactory if $|E_n| \le 1$ implying the compatibility of the measurement results. In other way if $|E_n| > 1$ the result of ILC is unsatisfactory.

Table 1 and Fig. 1 show only the results for 50 Hz measurements of the ILC.

Table 1. Results for measurement points 120 V, 5 A, PF, in mW.

Lab-code	RL	Lab1	Lab2	Lab3	Lab4	Lab5	Lab6
50 Hz, 1.0							
X_{lab}	600,02	600,03	600,59	600,10	592,66	600,07	600,07
D_{lab}	0,00	6,00	566,00	76,0	-7364,00	46,00	46,00
U_{lab}	12,30	82,20	150,60	145,00	574,10	104,50	100,00
E_n	-	0,07	3,71	0,52	-12,82	0,43	0,45
50 Hz, -1.0							
X_{lab}	600.04	600.05	600.35	600.35	619.36	600.07	600.08
D_{lab}	0.00	10.00	310.00	310.0	19320.00	30.00	40.00
U_{lab}	12.30	82.00	150.60	148.00	564.10	104.90	100.00
E_n	-	0.12	2.03	2.07	34.22	0.28	0.39
50 Hz, 0.5 Lag							
X_{lab}	300.06	300.08	300.34	300.17	-	300.04	300.05
D_{lab}	0.00	22.00	282.00	112.0	-	-18.00	-8.00
U_{lab}	13.00	82.00	150.60	152.00	-	101.10	70.00
E_n	-	0.26	1.85	0.73	-	-0.17	-0.11

| Lab-code	RL	Lab1	Lab2	Lab3	Lab4	Lab5	Lab6
50 Hz, 0.5 Lead							
X_{lab}	300.06	300.08	300.37	300.14	-	300.04	300.05
D_{lab}	0.00	18.00	308.00	78.0	-	-22.00	-12.00
U_{lab}	13.00	82.00	150.60	140.50	-	101.10	70.00
E_n	-	0.21	2.02	0.55	-	-0.21	-0.16
50 Hz, 0.866 Lag							
X_{lab}	519.65	519.65	519.97	519.97	596.37	519.64	519.68
D_{lab}	0.00	0.00	320.00	320.00	76720.00	-10.00	30.00
U_{lab}	12.40	82.00	150.60	152.70	560.10	102.60	100.00
E_n	-	0,23	1,97	-1,25	-118,89	0,09	0,29
50 Hz, 0.866 Lead							
X_{lab}	519.65	519.67	519.95	519.43	587.97	519.66	519.68
D_{lab}	0.00	20.00	300.00	-220.0	68320.00	10.00	30.00
U_{lab}	12.40	82.00	150.60	174.00	574.10	103.40	100.00
E_n	-	0,00	2,10	2,07	136,84	-0,09	0,29
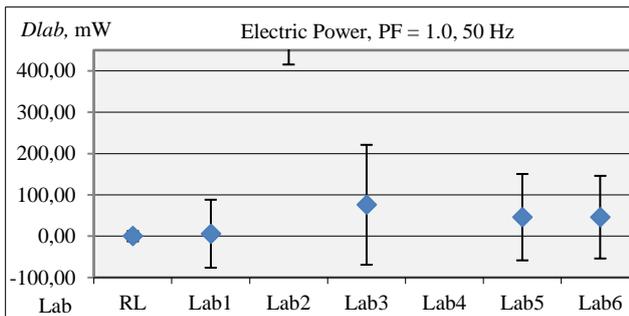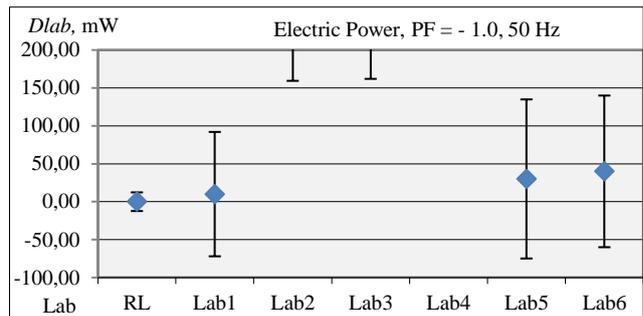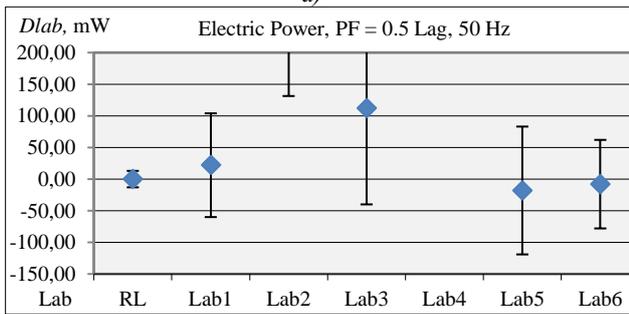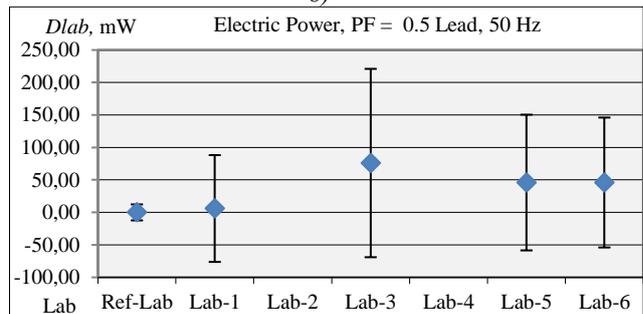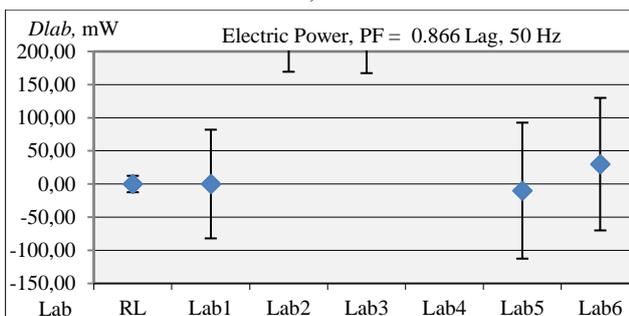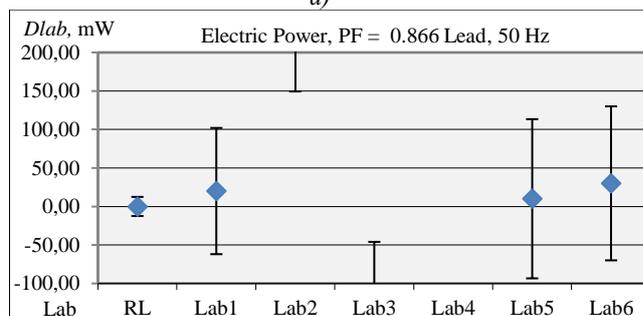
Fig.1. Calibration results of interlaboratory comparison for power factor: 1.0, 0.5 Lag, 0.5 Lead, 0.866 Lag, 0.866 Lead

13

V. ANALYSIS OF INTERLABORATORY COMPARISON

The preliminary analysis of the results of provided by the relevant CL's allow the following general conclusions to be drawn:

Lab7 was unable to calibrate the TS and, accordingly, did not provide the results of calibration;

Lab4 failures were detected in measurements at PF's 0.5 Lead and 0.5 Lag at a frequency of 50 Hz.

The analysis of the results evaluation of each participaited CL, which was carried out with the help of modified criterion E_n, allows to formulate the following conclusions:

Lab1, Lab3, Lab5 and Lab6 meet the requirements of the criterion ($\left|E_n\right| \leq 1$) when calibrating the TS at 120 V, 5 A, PF 1.0, 50 Hz, confirming the qualification of the participated CL's in accordance with [1]. Lab2 and Lab4 do not meet the requirements of the criterion ($\left|E_n\right| \leq 1$), calibration results require correction or response measures;

Lab1, Lab5 and Lab6 meet the requirements of the criterion ($\left|E_n\right| \leq 1$) when calibrating the TS at 120 V, 5 A, PF -1.0, 50 Hz, which confirms the qualification of the participated CL's. Lab2, Lab3 and Lab4 do not meet the requirements of the criterion ($\left|E_n\right| \leq 1$) calibration results require correction or response measures;

Lab1, Lab3, Lab5 and Lab6 meet the requirements of the criterion ($\left|E_n\right| \leq 1$) when calibrating TS at 120 V, 5 A, PF's 0.5 Lead and 0.5 Lag, 50 Hz, confirming the qualification of the participated CL's. Lab2 does not meet the requirements of the criterion ($\left|E_n\right| \leq 1$) calibration result requires correction or response measures; Lab1, Lab5, and Lab6 meet the requirements of the criterion ($\left|E_n\right| \leq 1$) when calibrating the TS at 120 V, 5 A, PF's 0.866 Lead and 0.866 Lag, 50 Hz, which confirms the qualification of the participated CL's.

Lab2, Lab3 and Lab4 do not meet the requirements of the criterion ($\left|E_n\right| \leq 1$) calibration results require correction or response measures.

VI. CONCLUSIONS

Foremost the report of the ILC provided by SE "UKRMETRTESTSTANDARD" for EP at industrial frequency was prepared. It should be noted that compatibility has been achieved between the RL and measurements from accredited participated CL's.

General notes and recommendations for Lab2-4:

to review existing or develop new calibration procedures in accordance with the requirements of [1];

to reconsider the approaches of evaluating the uncertainty of the measurement results in the applied calibration procedures in accordance with which the evaluation of expanded uncertainty was performed;

to carry out systematically technical training for laboratory staff [9] to perform calibration of measuring equipment and pay special attention to the provisions of international and national documents for the evaluation of uncertainty.

Participation in ILC provides independent verification of CL's competence and demonstrates to the publics, customers, accreditation bodies, regulators and management that procedures are under control and gives technical confidence in the service which CL provide [2].

The positive result for some participated CL's of the ILC means that the traceability transfers from SE "UKRMETRTESTSTANDARD" [10] to the accredited participated CL's through the periodical calibration of their standards [11].

REFERENCES

[1] ISO/IEC 17025:2017. General requirements for the competence of testing and calibration laboratories.

[2] ISO/IEC 17043:2014. Conformity assessment. General requirements for testing laboratory qualifications.

[3] Muravyov, S and Marinushkina, I, *General problems of metrology and measurement technique: Processing data from interlaboratory comparisons by the method of preference aggregation*, Measurement Techniques, vol 6, no. 2, 2016, pp. 118-126.

[4] Chunovkin, A, Zviagin, N and Burmistrova, N, *Interlaboratory comparisons. Practical approach for data evaluation*, Proc. of 20th IMEKO World Congress, Busan, July 15-17, 2012, 5 p.

[5] Muravyov, S and Marinushkina, I, *Largest consistent subsets in interlaboratory comparisons: preference aggre-gation approach*, Proc. of 14th Joint Interna-tional IMEKO TC1, TC7, TC13 Symposium, Jena, August 31 - September 2, 2011, pp. 69-73.

[6] Sandu, I, Dragomir, L and Pantelimon, B, *Interlaboratory comparison*, Proc. of 15th IMEKO TC 4 Symposium, Iasi, July 15-17, 2007, 4 p.

[7] Velychko, O, Karpenko, S and Gachok, V, *Evaluation of the uncertainty of calibration of the three phase high precision comparator of the electrical power*, Proc. of 19th Symp. IMEKO TC 4 Symposium and 17th IWADC Workshop Adv. in Instrumentation and Sensors Interoperability, Barcelona, July 18-19, 2013, pp. 41-46.

[8] Velychko, O and Karpenko, S, *Linking results of key and supplementary comparisons of regional metrology organization for electrical power*, International Journal of Metrology and Quality Engineering, vol 7, no. 3, 2016, 301, pp. 1-7.

[9] Claudio, J and Costa, M, *Brazilian energy interlaboratory program applicative*, Proc. of 20th IMEKO World Congress, Busan, July 15-17, 2012, 6 p.

[10] Velichko, O., *Traceability of measurement results at different levels of metrological work*, Measurement Techniques, vol 52, 2009, pp. 1242-1248.

[11] Briggs, P., *Proficiency testing for calibration laboratories*, Proc. of 20th IMEKO World Congress, Busan, July 15-17, 2012, 5 p.