

Active power quality assessment through interlaboratories comparison

Maria Magdalena Poenaru¹, Fănel Iacobescu¹, Albert-Ciprian Anghel², Alexandru Sălceanu³,
Mirela-Adelaida Anghel⁴

¹ *University of Craiova, Craiova, Romania, poenaru_magdalena@yahoo.com,*

² *“Dimitrie Cantemir” Christian University, Bucharest, Romania, albert.ciprian@gmail.com,*

³ *Gheorghe Asachi Technical University of Iasi, Iasi, Romania, asalcean@tuiasi.ro,*

⁴ *Romanian Bureau of Legal Metrology, Bucharest, Romania, mirela.a.anghel@gmail.com.*

Abstract – Nowadays, an independent assessment of the technical performance of laboratories is necessary, in order to assure the validity of measurement results. The article presents the assessment of laboratories which participated at an inter-laboratories comparison (ILC) within active power field. This interlaboratories comparison had been performed on a period of 8 months and a number of 17 laboratories participated. The main goal of this intercomparison was the assessment of laboratories capabilities that perform verifications of active electrical energy meters and a travelling measurement standard was used.

Keywords – proficiency testing, interlaboratories comparison, active power meters

I. INTRODUCTION

Correct and traceable measuring instruments can be used for a variety of measurements tasks. Those responding to reasons of public interest, public health, safety and order, protection of the environment and the customer, of levying taxes and duties and of fair trading, which directly and indirectly affect the daily life of citizens in many ways, may require the use of legally controlled measuring instruments.

The basic use of PT for a laboratory is to assess its performance for the conduct of specific measurements or calibrations. The results and information received from the participation in PT schemes will provide laboratories with either a confirmation that the laboratory's performance is satisfactory or an indication that there are potential problems and corrections should be performed. One of the basic elements in all PT's is the evaluation of the performance of each participant. In order to do so, the PT provider has to establish basically two values, which are used for the performance evaluation:

1. The assigned value.
2. The standard deviation for proficiency assessment.

The main purpose of this comparison was the evaluation

of metrological laboratories performance in the field of active electrical energy meters.

The active electrical energy meters comply with 2014/32/EU Directive regarding the harmonization of the laws of the Member States relating to the making available on market of measuring instruments. The scope of PT was the determination of relative errors of current values (I_{max} , I_n , $0.1 I_n$ and $0.01 I_n$) at which the verification of active electrical energy meters is performed, the most common being $I_n = 5 A$.

II. TRAVELING MEASURING STANDARD

Type of proficiency testing scheme was quantitative sequential participation scheme, which had involved the proficiency test item being circulated successively from the one participant, circulated back to the proficiency testing provider for rechecking, to the next.

- *Sequential scheme* - PT item to be measured is circulated successively from one participant to the next. In this case the PT item has returned to the PT provider before being passed on to the next participant in order to determine whether any changes have taken place to the PT item.
- *Quantitative scheme* - the results of quantitative measurements are numeric and are reported on an interval or a ratio scale.

Proficiency test item was a 3-phase (rotary) active electrical energy meter, 1800 type, Elster Rometrics manufacturer, having the following characteristics:

- the specified reference voltage
 $U = 3 \times (57,7 V / 100 V \dots 230 V / 400 V)$;
- the specified reference current: 1 A;
- maximum current: 10 A;
- specified reference frequency: 50 Hz;
- accuracy class: 0,2S;
- constant value: 5 000 imp/kWh;
- 4 wire energy meter connection.

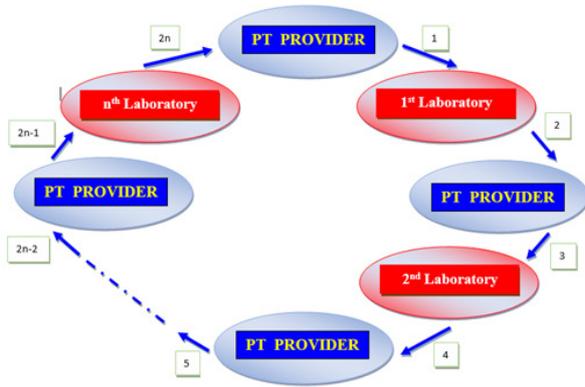


Fig. 1. Route of traveling measurement standard

III. RESULTS & DISCUSSION

The purpose of interlaboratory comparisons for the determination of laboratory performance includes:

- Evaluation and monitoring of laboratories performance for specific tests or measurements;
- Identification of problems within laboratories and initiation of improvement actions;
- Establishing of efficacy and comparability of test or measurement methods;
- Providing an additional confidence to laboratories' customers;
- Identifying of differences between participating laboratories;
- Training of personnel belonging to participating laboratories based on the results of such comparisons.

The reference laboratory of provider performed the characterization of traveling measurement standard 5 times. The assigned values taken into account were the means of measurement values by the reference laboratory for each established point/value.

The relative measurement errors at each established point of active electrical energy were calculated using the following formula:

$$e_x(\%) = \frac{E_x - E_e}{E_x} \cdot 100 = \left(\frac{N_x}{N_e} \cdot \frac{C_e}{C_x} - 1 \right) \cdot 100, \quad (1)$$

where:

- E_x = active electrical energy registered by energy meter;
- N_x/C_x - the number of pulses counted by meter;
- C_x - constant, for this case $C_x = 5000 \text{ imp./kWh}$;
- E_e = active electrical energy registered by standard energy meter of bench
- N_e/C_e - the number of pulses, from standard energy meter of bench, counted by energy meter of travelling measurement standard;
- C_e - constant of standard energy meter of bench.

Measurement results obtained by reference laboratory of provider is presented in Table 1

Table 1 - Measurement results obtained by reference laboratory

measurement point / value (phase values)			connection, loading	$e_x, \%$	
voltage, V	current, A	Cos ϕ			
57.7	0.05	1	star, L1L2L3	0.00	
	0.5	0.5i	star, L1L2L3	0.00	
	5	1	1	star, L1L2L3	-0.01
		0.5i	0.5i	star, L1L2L3	-0.06
		0.8c	0.8c	star, L1L2L3	0.01
		1	1	star, L1	-0.02
		0.5i	0.5i	star, L1	-0.07
		1	1	star, L2	0.00
		0.5i	0.5i	star, L2	-0.04
		1	1	star, L3	-0.02
	0.5i	0.5i	star, L3	-0.07	
	10	1	star, L1L2L3	-0.01	
	230	0.05	1	star, L1L2L3	0.00
		0.5	0.5i	star, L1L2L3	0.00
5		1	1	star, L1L2L3	0.00
		0.5i	0.5i	star, L1L2L3	-0.06
		0.8c	0.8c	star, L1L2L3	0.01
		1	1	star, L1	-0.01
		0.5i	0.5i	star, L1	-0.08
		1	1	star, L2	0.00
		0.5i	0.5i	star, L2	-0.04
		1	1	star, L3	-0.01
0.5i		0.5i	star, L3	-0.07	
10		1	star, L1L2L3	0.00	

The evaluation of acceptance criteria for each laboratory was made using the following formula

$$z_{score} = \frac{x_i - X_i}{\sigma}, \quad (2)$$

where:

- z -score - standardized measure of laboratory bias, calculated using the assigned value and the standard- deviation for proficiency assessment
- x_i - measurement result of i laboratory, for each measurement point;
- X_i - assigned value of PT object;
- σ - assigned PT standard deviation.

Z score criteria:

- $|z| \leq 2$;
the score indicates "satisfactory" performance
- $2 < |z| < 3$;
the score indicates "questionable" performance
- $|z| \geq 3$;
the score indicates „unsatisfactory" performance.

The assigned PT value of PT object was the mean of the measurement results of reference laboratory, for each measurement point, taken in 5 stages, 1st at the beginning,

3 times during the PT scheme performing and the last at the end of PT scheme.

The participating laboratories had the accuracy request requirements. The MPE (maximum permissible errors) have to be between $\pm 1.0\%$ & $\pm 0.5\%$, according to the applied correct and power factor.

For 57.7 V & 230 V, the measurement results of each participating laboratory, are presented in Table 2 and score $|z|$ of each laboratory are presented in Table 3.

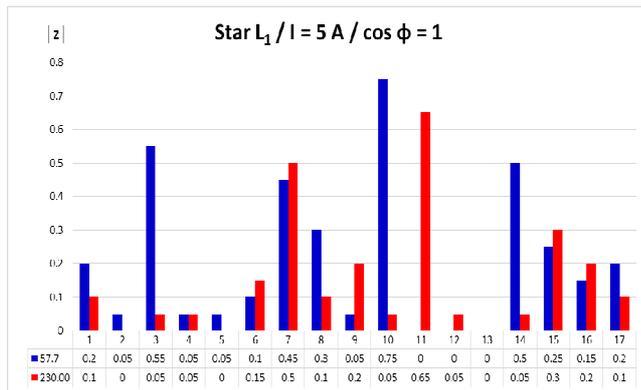


Fig. 2. $|z|$ score for L_1 , $I=5$ A, $\cos \phi = 1$

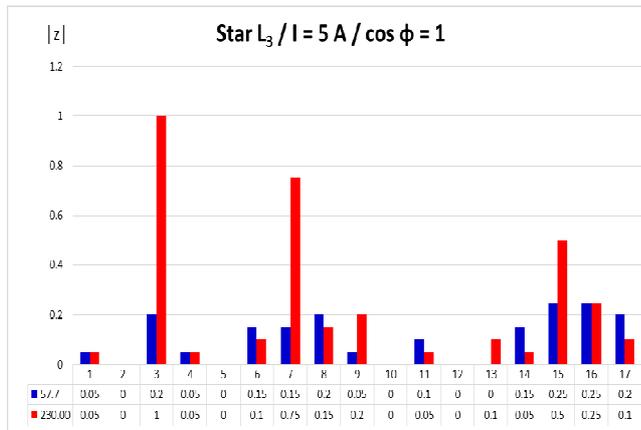


Fig. 4. $|z|$ score for L_3 , $I=5$ A, $\cos \phi = 1$

Some results from mentioned tables, corresponding to 5A and 57.7 V, respectively 230 V are graphically presented in Figures 2 to 5.

IV. CONCLUSIONS

The measurement results of this inter-laboratory comparison proved that all participants meet the acceptance criteria of competence with the exception of only one, which has to make an improvement.

Laboratories with unsatisfactory $|z|$ have to identify problems, initiate improvement actions and train the personal in order to achieve the results according to the standards requirements.

A number of 16 laboratories obtained good results, having the scores z less than 1.5, and a percent of 75 % of these laboratories obtained very good results with a z score less than 0.5.

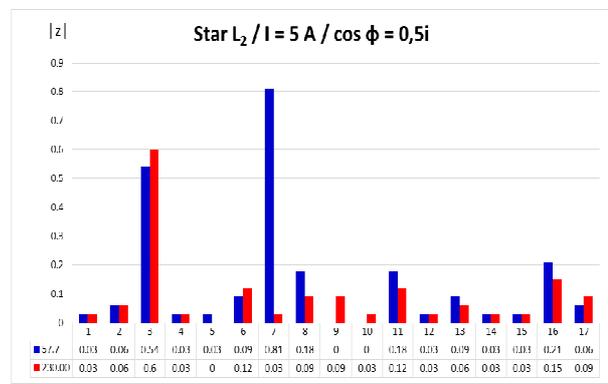


Fig. 3. $|z|$ score for L_2 , $I=5$ A, $\cos \phi = 0,5i$

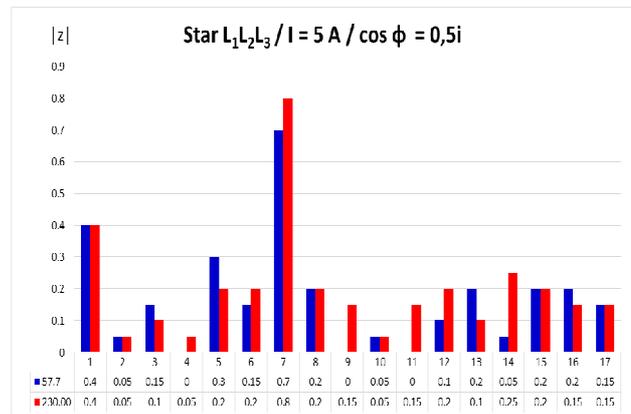


Fig. 5. $|z|$ score for $L_1L_2L_3$, $I=5$ A, $\cos \phi = 0,5i$

Table 2 - Measurement results of each laboratory for 57.7 V & 230 V

Measurement point (phase values)			Load connection	Error, % (of measurement results of active electrical energy for each laboratory)																
Voltage V	Current A	cosφ		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
57.7	0.05	1	Star, L1L2L3	-0.05	0.01	-0.06	-0.01	-0.67	0.08	0.37	-0.02	0.05	0.01	0.00	-0.01	-0.02	-0.03	-0.03	-0.10	0.04
	0.5	0.5i	Star, L1L2L3	0.00	-0.01	-0.07	-0.02	0.01	0.03	0.12	-0.07	-0.03	-0.02	-0.06	-0.04	-0.03	-0.03	-0.05	-0.10	0.01
	5	1	Star, L1L2L3	-0.05	-0.02	-0.03	-0.02	-0.51	0.02	0.02	-0.02	0.00	-0.11	-0.03	-0.01	-0.02	-0.04	-0.03	-0.06	0.02
		0.5i	Star, L1L2L3	0.02	-0.07	-0.09	-0.06	-0.12	-0.03	0.08	-0.10	-0.06	-0.07	-0.06	-0.04	-0.10	-0.07	-0.10	-0.10	-0.03
		0.8c	Star, L1L2L3	-0.03	0.01	-0.01	-0.01	-0.68	0.05	0.03	-0.02	0.01	0.01	-0.03	-0.01	-0.01	-0.03	-0.03	-0.04	0.04
		1	Star, L1	-0.06	-0.01	0.09	-0.03	-0.03	0.00	0.07	-0.08	-0.01	-0.17	-0.02	-0.02	-0.02	-0.12	-0.07	-0.05	0.02
		0.5i	Star, L1	-0.05	-0.08	0.04	-0.09	-0.08	-0.03	0.25	-0.12	-0.07	-0.09	-0.10	-0.04	-0.07	-0.10	-0.11	-0.09	-0.04
		1	Star, L2	-0.02	-0.02	0.11	-0.02	-0.01	0.04	0.27	-0.07	0.00	0.00	0.04	-0.02	-0.06	-0.07	-0.03	-0.07	0.01
		0.5i	Star, L2	-0.03	-0.06	0.14	-0.05	-0.05	-0.01	0.23	-0.10	-0.04	-0.04	0.02	-0.03	-0.07	-0.05	-0.03	-0.11	-0.02
		1	Star, L3	-0.03	-0.02	0.02	-0.03	-0.02	0.01	0.01	-0.06	-0.01	-0.02	-0.04	-0.02	-0.02	-0.05	-0.07	-0.07	0.02
	0.5i	Star, L3	-0.02	-0.06	0.05	-0.07	-0.05	-0.04	-0.29	-0.15	-0.08	-0.07	-0.07	-0.04	-0.08	-0.09	-0.19	-0.10	-0.04	
10	1	Star, L1L2L3	-0.03	-0.02	-0.02	-0.02	-0.52	0.01	0.03	-0.03	-0.01	-0.01	-0.02	-0.01	-0.02	-0.03	-0.07	-0.08	0.02	
230	0.05	1	Star, L1L2L3	-0.05	0.01	-0.02	-0.02	-0.61	0.10	0.20	-0.01	0.02	-0.01	-0.01	0.02	0.01	0.00	-0.04	-0.09	0.03
	0.5	0.5i	Star, L1L2L3	-0.02	-0.02	-0.02	-0.01	0.23	0.04	0.12	-0.06	0.05	-0.01	0.01	0.01	-0.01	-0.01	-0.04	-0.09	0.02
	5	1	Star, L1L2L3	0.01	-0.01	0.04	-0.02	-0.50	0.02	0.05	-0.02	0.04	-0.01	-0.04	0.01	0.01	0.00	-0.03	-0.06	0.02
		0.5i	Star, L1L2L3	0.02	-0.05	-0.04	-0.05	-0.02	-0.02	0.10	-0.10	-0.03	-0.05	-0.03	-0.02	-0.04	-0.01	-0.10	-0.09	-0.03
		0.8c	Star, L1L2L3	0.03	0.02	0.03	0.01	-0.71	0.04	0.07	0.02	0.04	0.01	-0.05	0.01	0.06	0.01	-0.04	-0.04	0.04
		1	Star, L1	-0.03	-0.01	-0.02	-0.02	-0.01	0.02	0.09	-0.03	0.03	-0.02	-0.14	-0.02	-0.01	-0.02	-0.07	-0.05	0.01
		0.5i	Star, L1	-0.05	-0.07	0.13	-0.07	-0.06	-0.03	0.31	-0.07	-0.01	-0.07	-0.05	-0.04	-0.06	-0.07	-0.11	-0.10	-0.04
		1	Star, L2	0.00	0.01	0.14	0.01	0.00	0.04	0.17	0.01	0.03	0.01	0.04	-0.01	0.01	-0.06	-0.07	-0.06	0.02
		0.5i	Star, L2	-0.05	-0.06	0.16	-0.03	-0.04	0.00	-0.05	-0.01	-0.01	-0.03	-0.08	-0.03	-0.02	-0.03	-0.03	-0.09	-0.01
		1	Star, L3	-0.02	-0.01	0.19	-0.02	-0.01	0.01	0.14	0.02	0.03	-0.01	0.00	-0.01	0.01	0.00	-0.11	-0.06	0.01
	0.5i	Star, L3	-0.03	-0.03	0.10	-0.07	-0.02	0.04	0.02	-0.15	-0.03	-0.06	-0.04	-0.04	-0.07	-0.07	-0.15	-0.10	-0.05	
10	1	Star, L1L2L3	-0.02	-0.02	0.09	-0.01	-0.51	0.01	0.05	-0.02	0.03	-0.01	-0.05	0.01	0.01	-0.01	0.00	-0.06	0.02	

Table 3 - Score $|z|$ of each laboratory for 57.7 V & 230 V

Measurement point (phase values)			Connection loading	Score $ z $ for each laboratory																
Voltage, V	Current, A	cosφ		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
57.7	0.05	1	Star, L1L2L3	0.15	0.03	0.18	0.03	2.01	0.24	1.11	0.06	0.15	0.03	0.00	0.03	0.06	0.09	0.09	0.30	0.12
	0.5	0.5i	Star, L1L2L3	0.00	0.05	0.35	0.10	0.05	0.15	0.60	0.35	0.15	0.10	0.30	0.20	0.15	0.15	0.25	0.50	0.05
	5	1	Star, L1L2L3	0.24	0.06	0.12	0.06	3.00	0.18	0.18	0.06	0.06	0.60	0.12	0.00	0.06	0.18	0.12	0.30	0.18
		0.5i	Star, L1L2L3	0.40	0.05	0.15	0.00	0.30	0.15	0.70	0.20	0.00	0.05	0.00	0.10	0.20	0.05	0.20	0.20	0.15
		0.8c	Star, L1L2L3	0.20	0.00	0.10	0.10	3.45	0.20	0.10	0.15	0.00	0.00	0.20	0.10	0.10	0.20	0.20	0.25	0.15
		1	Star, L1	0.20	0.05	0.55	0.05	0.05	0.10	0.45	0.30	0.05	0.75	0.00	0.00	0.00	0.50	0.25	0.15	0.20
		0.5i	Star, L1	0.06	0.03	0.33	0.06	0.03	0.12	0.96	0.15	0.00	0.06	0.09	0.09	0.00	0.09	0.12	0.06	0.09
		1	Star, L2	0.10	0.10	0.55	0.10	0.05	0.20	1.35	0.35	0.00	0.00	0.20	0.10	0.30	0.35	0.15	0.35	0.05
		0.5i	Star, L2	0.03	0.06	0.54	0.03	0.03	0.09	0.81	0.18	0.00	0.00	0.18	0.03	0.09	0.03	0.03	0.21	0.06
		1	Star, L3	0.05	0.00	0.20	0.05	0.00	0.15	0.15	0.20	0.05	0.00	0.10	0.00	0.00	0.15	0.25	0.25	0.20
		0.5i	Star, L3	0.15	0.03	0.36	0.00	0.06	0.09	0.66	0.24	0.03	0.00	0.00	0.09	0.03	0.06	0.36	0.09	0.09
		10	1	Star, L1L2L3	0.12	0.06	0.06	0.06	3.06	0.12	0.24	0.12	0.00	0.00	0.06	0.00	0.06	0.12	0.36	0.42
230	0.05	1	Star, L1L2L3	0.15	0.03	0.06	0.06	1.83	0.30	0.60	0.03	0.06	0.03	0.03	0.06	0.03	0.00	0.12	0.27	0.09
	0.5	0.5i	Star, L1L2L3	0.10	0.10	0.10	0.05	1.15	0.20	0.60	0.30	0.25	0.05	0.05	0.05	0.05	0.05	0.20	0.45	0.10
	5	1	Star, L1L2L3	0.06	0.06	0.24	0.12	3.00	0.12	0.30	0.12	0.24	0.06	0.24	0.06	0.06	0.00	0.18	0.36	0.12
		0.5i	Star, L1L2L3	0.40	0.05	0.10	0.05	0.20	0.20	0.80	0.20	0.15	0.05	0.15	0.20	0.10	0.25	0.20	0.15	0.15
		0.8c	Star, L1L2L3	0.10	0.05	0.10	0.00	3.60	0.15	0.30	0.05	0.15	0.00	0.30	0.00	0.25	0.00	0.25	0.25	0.15
		1	Star, L1	0.10	0.00	0.05	0.05	0.00	0.15	0.50	0.10	0.20	0.05	0.65	0.05	0.00	0.05	0.30	0.20	0.10
		0.5i	Star, L1	0.09	0.03	0.63	0.03	0.06	0.15	1.17	0.03	0.21	0.03	0.09	0.12	0.06	0.03	0.09	0.06	0.12
		1	Star, L2	0.00	0.05	0.70	0.05	0.00	0.20	0.85	0.05	0.15	0.05	0.20	0.05	0.05	0.30	0.35	0.30	0.10
		0.5i	Star, L2	0.03	0.06	0.60	0.03	0.00	0.12	0.03	0.09	0.09	0.03	0.12	0.03	0.06	0.03	0.03	0.15	0.09
		1	Star, L3	0.05	0.00	1.00	0.05	0.00	0.10	0.75	0.15	0.20	0.00	0.05	0.00	0.10	0.05	0.50	0.25	0.10
		0.5i	Star, L3	0.12	0.12	0.51	0.00	0.15	0.33	0.27	0.24	0.12	0.03	0.09	0.09	0.00	0.00	0.24	0.09	0.06
		10	1	Star, L1L2L3	0.12	0.12	0.54	0.06	3.06	0.06	0.30	0.12	0.18	0.06	0.30	0.06	0.06	0.06	0.00	0.36

REFERENCES

- [1] International Vocabulary of Metrology, Basic and General Concepts and Associated Terms VIM, 3rd edition, JCGM 200:2008 (2008)
- [2] ISO/IEC 17043:2010, Conformity assessment – General requirements for proficiency testing, (2010)
- [3] ISO 13528:2005, Statistical Methods for Use in Proficiency Testing by Interlaboratory Comparisons, (2005)
- [4] Eurachem Guide, The fitness for purpose of analytical methods, 2nd edition, (2014)
- [5] Evans, M., Hastings, N. and Peacock, B. “Statistical distributions”, Wiley, 2000
- [6] Rice, J. R. “Mathematical Statistics and Data Analysis”, second ed. Duxbury Press, Belmont, Ca., USA, 1995