GULFMET.EM-S2

AC Power at Power Frequencies

Bilateral comparison between SASO NMCC and TÜBİTAK UME

Final Report

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Abstract

A supplementary bilateral comparison measurement on AC Power at 50/60 Hz between SASO NMCC (GULFMET) and TÜBİTAK UME (EURAMET) was performed with the primary power standards of each partner. Measurement methods and setups which are very similar of the participants, measurement results, calculation of differences in the results, evaluation of uncertainties are given within this report.

Contents

1. Introduction

A bilateral comparison on AC Power was organised between SASO NMCC and TÜBİTAK UME, in the frame of the Project of Development and Realization Measurement and Calibration System for the National Measurement and Calibration Center (NMCC) at Saudi Standards, Metrology and Quality Organization (SASO). And, it was approved by GULFMET as a supplementary comparison (GULFMET.EM-S2).

A well-known travelling standard was provided by the pilot Institute (TÜBİTAK UME). Comparison measurements were performed at several AC power values according to the Technical Protocol of Bilateral Comparison (Annex B).

TÜBİTAK UME was responsible for monitoring standard performance during the circulation and the evaluation and reporting of the comparison results. The comparison was carried out in accordance with the CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons [1].

2. Travelling Standard

The travelling standard, MTE C1-2 Power Converter (Figure 1), has identification as follows:

MTE C1-2 Serial No: 23875

Figure 1. Front panel of the travelling standard MTE C1-2.

The selected travelling standard is a MTE C1-2, based on a time-division-multiplication scheme. The instrument is configured as an AC power to DC voltage transducer, with a nominal full-scale DC output of 10 V.

The travelling standard was supplied by TÜBİTAK UME. This standard was chosen for its high accuracy and stability in time. The general specifications of MTE C1-2 are given in Table 1.

Table 1. The general specifications of MTE C1-2 Power Converter

Inputs	
Nominal Current **Nominal Voltage** **Frequency Range**	5 A AC 120 V AC 45 - 65 Hz
Outputs	
Nominal Voltage **Nominal Frequency**	10 V DC 10 kHz and 10 Hz
Accuracy **(P_n=nominal power)**	P_n - 0.5*P_n : 0.005% 0.5*P_n - 0.1*P_n : 0.01% 0.1*P_n – 0*P_n : 0.001%
Warm up time	2 h
Power	220 - 240 V at 50 Hz
Temperature Range	10 °C to 30 °C
Dimensions	255 mm x 165 mm x 315 mm
Weight	7.5 kg

3. Participant Laboratories

The pilot laboratory for this comparison was TÜBİTAK UME (Turkey). The contact details of the coordinator are given below:

Pilot Institute	**:**	TÜBİTAK Ulusal Metroloji Enstitüsü (UME)
Coordinator	**:**	Özlem Yılmaz Tel: +90 262 679 50 00 Fax: +90 262 679 50 01 E-mail: ozlem.yilmaz@tubitak.gov.tr

The participating laboratories and contact persons with their addresses are given in Table 2.

Table 2. Participant laboratories

Country	Institute	Acronym	Shipping Address	Contact Person
Turkey	TÜBİTAK Ulusal Metroloji Enstitüsü	TÜBİTAK UME	TÜBİTAK Ulusal Metroloji Enstitüsü (UME) TÜBİTAK Gebze Yerleşkesi Barış Mah. Dr. Zeki Acar Cad. No:1 41470 Gebze-Kocaeli, TURKEY	Özlem Yılmaz ozlem.yilmaz@tubitak.gov.tr Tel: +90 262 679 50 00
Saudi Arabia	SASO The National Measurement and Calibration Center	SASO NMCC	Saudi Standards, Metrology and Quality Organization of The Kingdom of Saudi Arabia (SASO) Riyadh 11471, P.O. Box 3437 KINGDOM of SAUDI ARABIA	Abdullah M. Alrobaish a.robaish@saso.gov.sa Tel: +966 11 252 97 30

4. Time Schedule

The time schedule for the comparison is given in the Table 3. The circulation of travelling standard was organized so that to monitor the performance of the travelling standard. Each laboratory had 1 week to carry out the measurements. There was not any deviation in the agreed schedule during the measurements and the transportation.

Table 3. Circulation Time Schedule

Acronym of Institute	Country	Starting Date	Time for measurement and transportation
TÜBİTAK UME	Turkey	16.01.2017 - 20.01.2017	7 days
SASO NMCC	Saudi Arabia	05.02.2017 - 09.02.2017	7 days
TÜBİTAK UME	Turkey	06.03.2017 - 10.03.2017	7 days

5. Measurement Quantities and Points

The measurement points are given in Table 4.

Table 4. Measurement quantity & points

Measurement Points			
Voltage	**Current**	**Power Factor**	**Frequency**
120 V	5 A	1	53 Hz
120 V	5 A	0.8i	53 Hz
120 V	5 A	0.8c	53 Hz
120 V	5 A	0.5i	53 Hz
120 V	5 A	0.5k	53 Hz
120 V	5 A	0.25i	53 Hz
120 V	5 A	0.25c	53 Hz
120 V	5 A	0.01i	53 Hz
120 V	5 A	0.01c	53 Hz
120 V	1 A	1	53 Hz
120 V	1 A	0.5i	53 Hz
120 V	1 A	0.5c	53 Hz
60 V	5 A	1	53 Hz
120 V	5 A	1	60 Hz
120 V	5 A	0.5i	60 Hz
120 V	5 A	0.5c	60 Hz
120 V	1 A	1	60 Hz
120 V	1 A	0.5i	60 Hz
120 V	1 A	0.5c	60 Hz

6. Methods of Measurement

6.1 Reference Measurement System

The operating principle of this well-known DSWM, shown in the figure below, is based on the use of two sampling voltmeters and on computerized evaluation by means of discrete integration (DI) or discrete Fourier transform (DFT). Similar to others, it consists of two digital sampling voltmeters (DVMs), a precision voltage divider, a set of AC current shunts, a power source, a triggering unit and software.

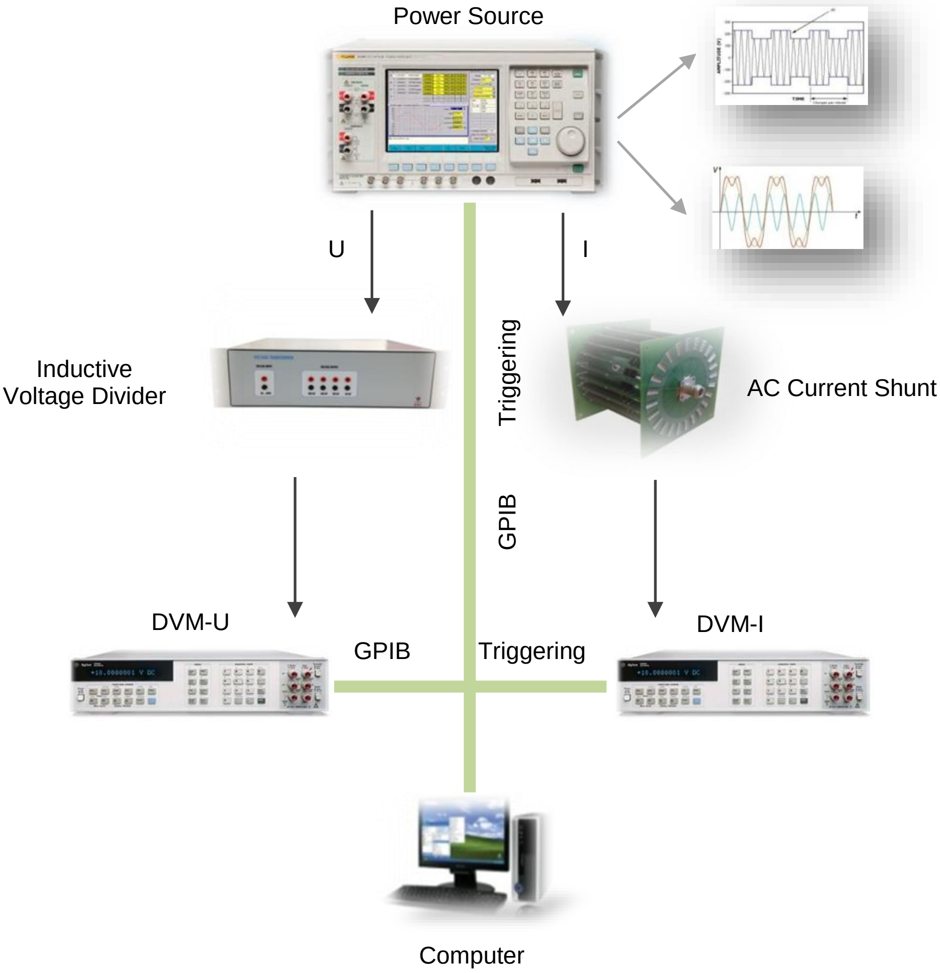

Figure 2. Block diagram of DSWM

The voltage and current signals from a phantom power source are applied to the relevant input terminals of the voltage divider and of the AC current shunts. A regulated voltage from secondary terminals of the voltage divider and a voltage obtained from the selected AC current shunt are then applied to the DVMs. With the help of the software, DVMs are programmed with the calculated appropriate aperture times for the selected samples per period. Each programmed DVM samples the applied voltage signals with the help of trigger signal which is synchronized to the power source.

The data from both DVMs are then transferred to the computer via IEEE488. The ratio and phase angle errors of the voltage divider and current shunts were corrected by the software. The amplitudes of both signals, the phase angles between them and the calculated results are displayed during the measurements.

Calibration of the travelling standard was performed by measuring the DC voltage output of the power converter with a precision voltmeter and multiplying the measured value with a scale factor to find the measured active power.

6.2 Travelling Standard

The travelling standard has separate (electrically isolated) voltage and current inputs on the front panel with the voltage range of 120 V and the current range of 5 A. The input frequency capability of the instrument is between 45 Hz to 65 Hz. The internal DC reference voltages (nominally +7.044... V and -7.044... V) can be monitored at the front panel. The nominal full scale DC output of 10 V is also available on the front panel (Volt OUT). It has also nominal full scale frequency outputs of 10 kHz and 10 Hz which are available with BNC connectors on the front panel (f-OUT).

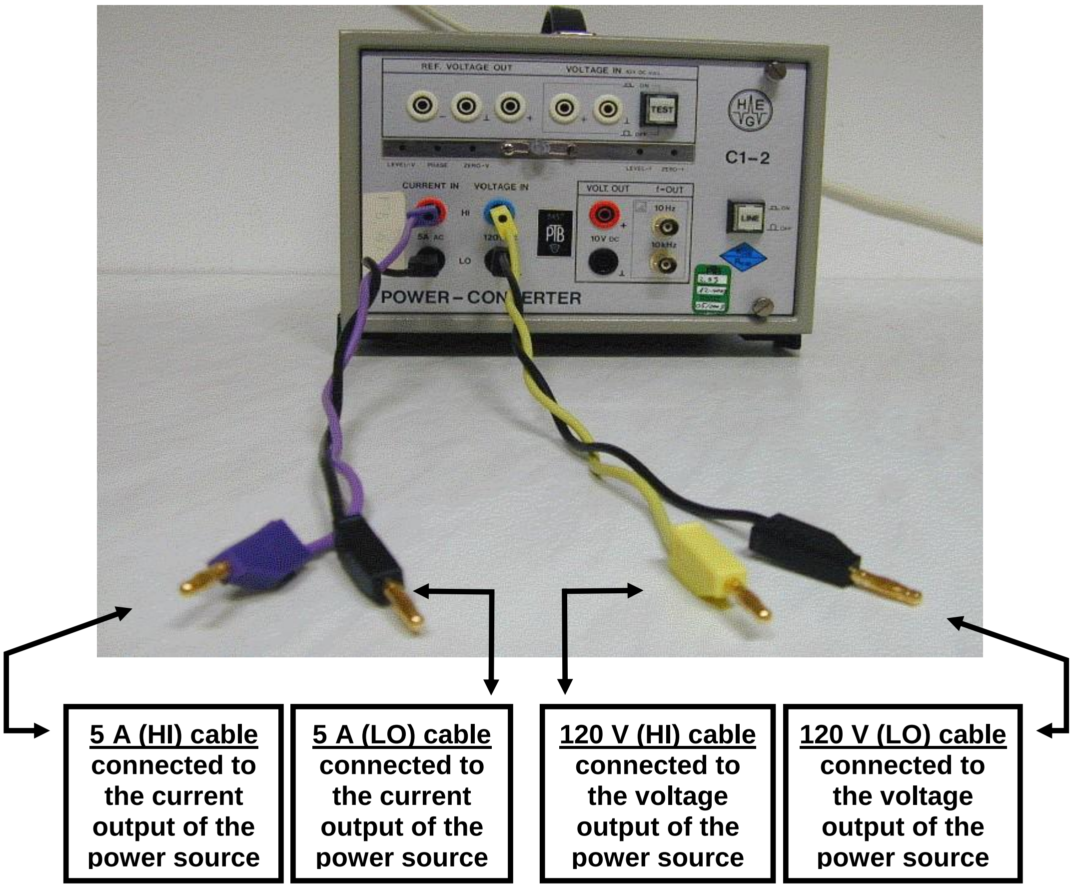

Figure 3. Current and voltage input connections of the travelling standard.

A digital multimeter with a high input impedance shall be used to measure the DC voltage. The voltmeter shall be calibrated with a DC voltage standard immediately before measurements.

An Agilent 3458A digital multimeter is given in the Figure 4, to show a sample connection for the measurement of DC voltage values from the travelling standard. Voltage and current input connections are not shown in the figure.

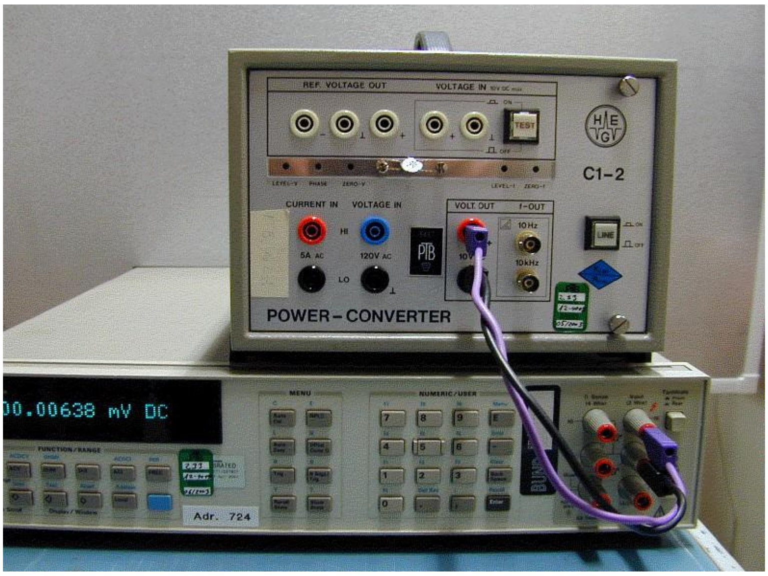

Figure 4. Connections and DC voltage measurement from the voltage output (VOLT.OUT) of the travelling standard.

The internal DC reference voltages can be measured before comparison measurements. Only positive output connection is given in the Figure 5. Negative reference voltage can be measured by removing the cable used for HI connection and reconnecting it to the next banana connector which is signed with (-) negative.

The multimeter were programmed to measure the DC reference values with the best resolution and accuracy.

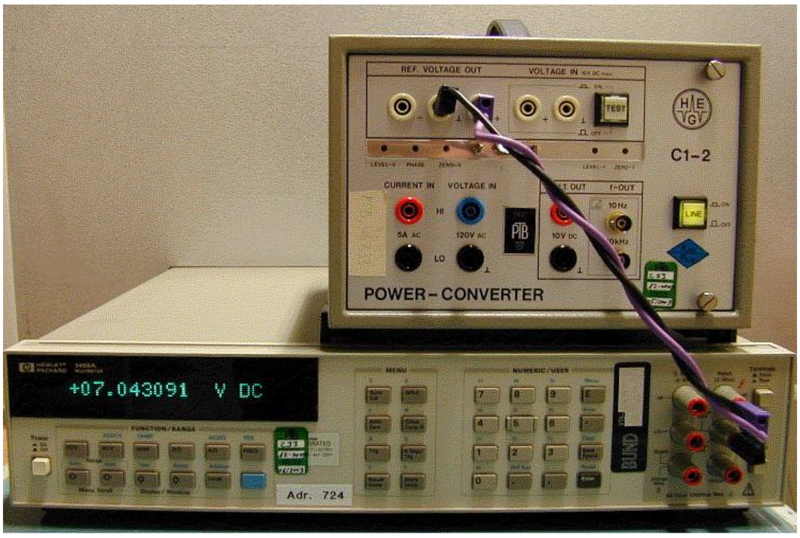

Figure 5. DC reference voltage measurements from the reference voltage output (REF. VOLTAGE OUT) of the travelling standard by means of a digital multimeter.

7. Discussion of the Results

The comparison was organised in a single loop of two laboratories. The uncertainties of measurement were calculated according to the JCGM 100 “Guide to the Expression of Uncertainty in Measurement” [2] for the coverage probability of approximately 95%. All contributions to the measurement uncertainty listed in the report submitted by each participant. Participant was also asked to provide detailed uncertainty budget and the combined standard uncertainty for the aforementioned measurands. The measurement results and uncertainties are given in Table 5**.**

To evaluate the equivalence degree of the AC Power Measurement Systems, the E_N factor is calculated according to:

$$\mathrm{E_N}(\Delta \mathrm{P}_i) = \frac{\Delta P_{NMCC-UME}}{U_C(\Delta P_i)}$$

where $\Delta P_{NMCC\text{-}UME}$ is the active power difference of the results of SASO NMCC and TÜBİTAK UME and

$$U_C(\Delta P_i) = \sqrt{U^2(P_{UME}) + U^2(P_{NMCC}) + U_{Std}^2(P)}$$

represent the combined uncertainties of the calculated active power. The term U_{Std} represents an additional uncertainty contribution of the travelling standard power converter.

The laboratory measurement results can be utilized according to the criteria of E_n value which is given below.

If $|E_n| \leq 1$ then it is successful
If $|E_n| > 1$ then it is unsuccessful

For all of the active power measurements there is a close agreement between TÜBİTAK UME and SASO NMCC. It can therefore be concluded that the result of each laboratory agree very well within the calculated measurement uncertainties. No outliers were observed. The laboratory measurement results meet the criteria of $E_n \leq 1$.

Uncertainty budget provided by the participants can be found in Appendix A.

8. Measurement Results

The measurement results, uncertainties and En values can be found in Tables 5 and Figures 6 to13.

Table 5. Measurement results and uncertainties of TÜBİTAK UME and SASO

Nominal Value				Measurement Results			
Voltage	Current	Power Factor	Frequency	P_{UME} µW/(V·A)	U_{UME} µW/(V·A)	P_{NMCC} µW/(V·A)	U_{NMCC} µW/(V·A)
120 V	5 A	1	53 Hz	-77	25	-71	40
120 V	5 A	0.8i	53 Hz	-59	25	-53	40
120 V	5 A	0.8c	53 Hz	-65	25	-66	40
120 V	5 A	0.5i	53 Hz	-35	25	-32	40
120 V	5 A	0.5k	53 Hz	-46	25	-41	40
120 V	5 A	0.25i	53 Hz	-17	25	-17	40
120 V	5 A	0.25c	53 Hz	-29	25	-24	40
120 V	5 A	0.01i	53 Hz	-5	25	-9	40
120 V	5 A	0.01c	53 Hz	-19	25	-10	40
120 V	1 A	1	53 Hz	-98	25	-102	40
120 V	1 A	0.5i	53 Hz	-50	25	-49	40
120 V	1 A	0.5c	53 Hz	-65	25	-64	40
60 V	5 A	1	53 Hz	-65	25	-61	40
120 V	5 A	1	60 Hz	-59	28	-65	40
120 V	5 A	0.5i	60 Hz	-16	28	-27	40
120 V	5 A	0.5c	60 Hz	-50	28	-45	40
120 V	1 A	1	60 Hz	-87	28	-98	40
120 V	1 A	0.5i	60 Hz	-33	28	-39	40
120 V	1 A	0.5c	60 Hz	-71	28	-57	40

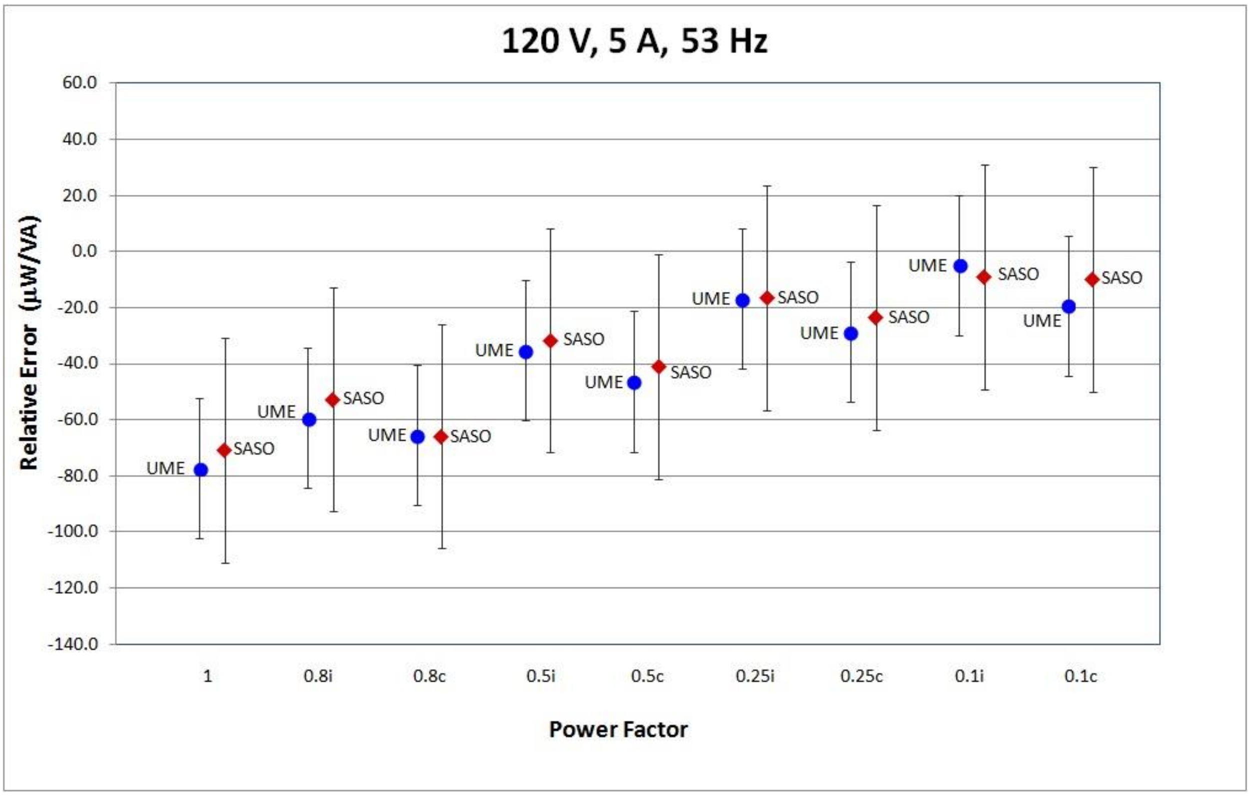

Figure 6. The comparison results and its uncertainty for 120 V, 5 A, 53 Hz (%95, k=2)

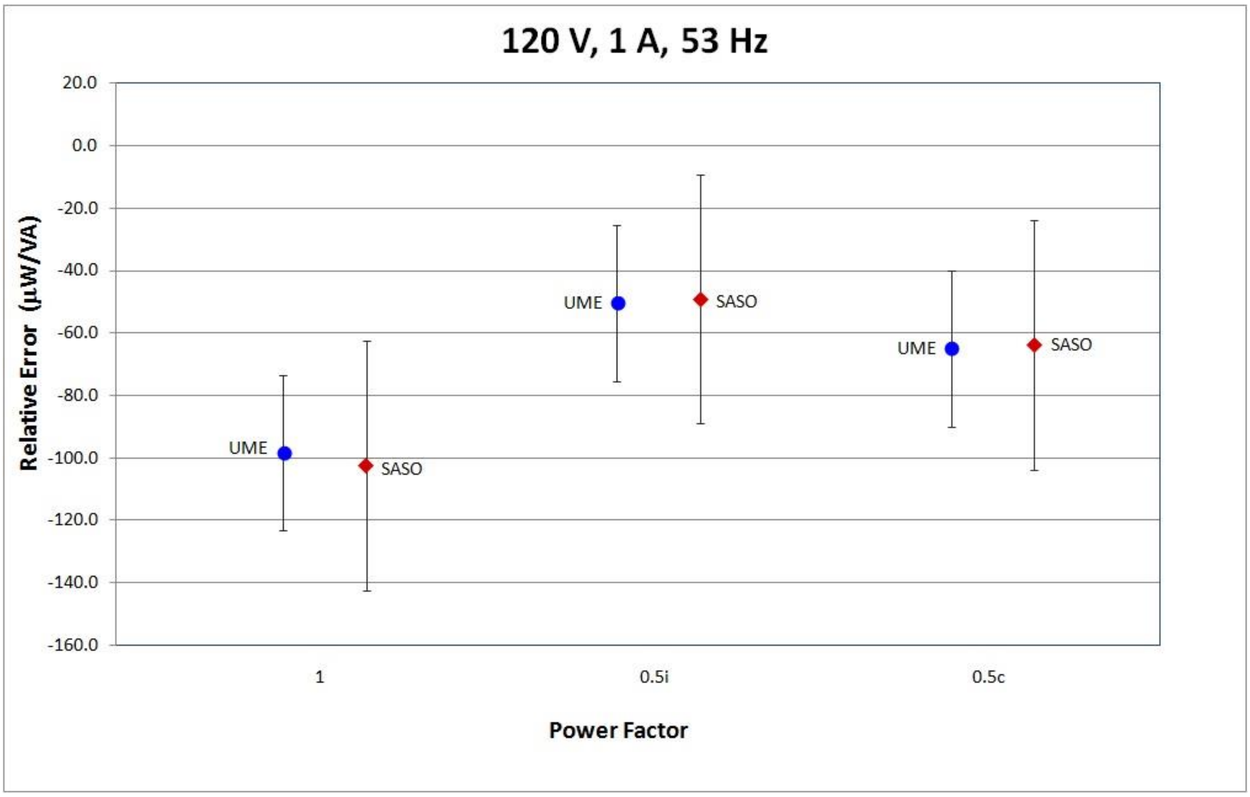

Figure 7. The comparison results and its uncertainty for 120 V, 1 A, 53 Hz (%95, k=2)

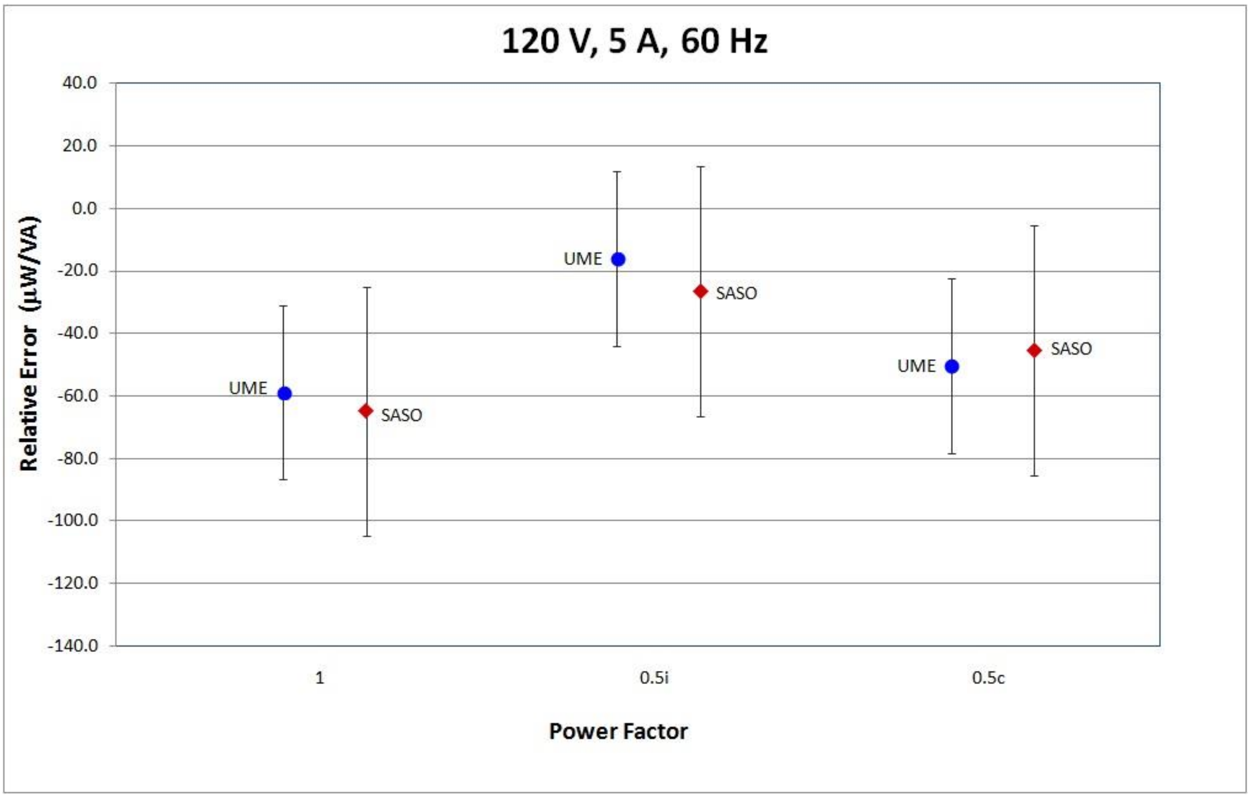

Figure 8. The comparison results and its uncertainty for 120 V, 5 A, 60 Hz (%95, k=2)

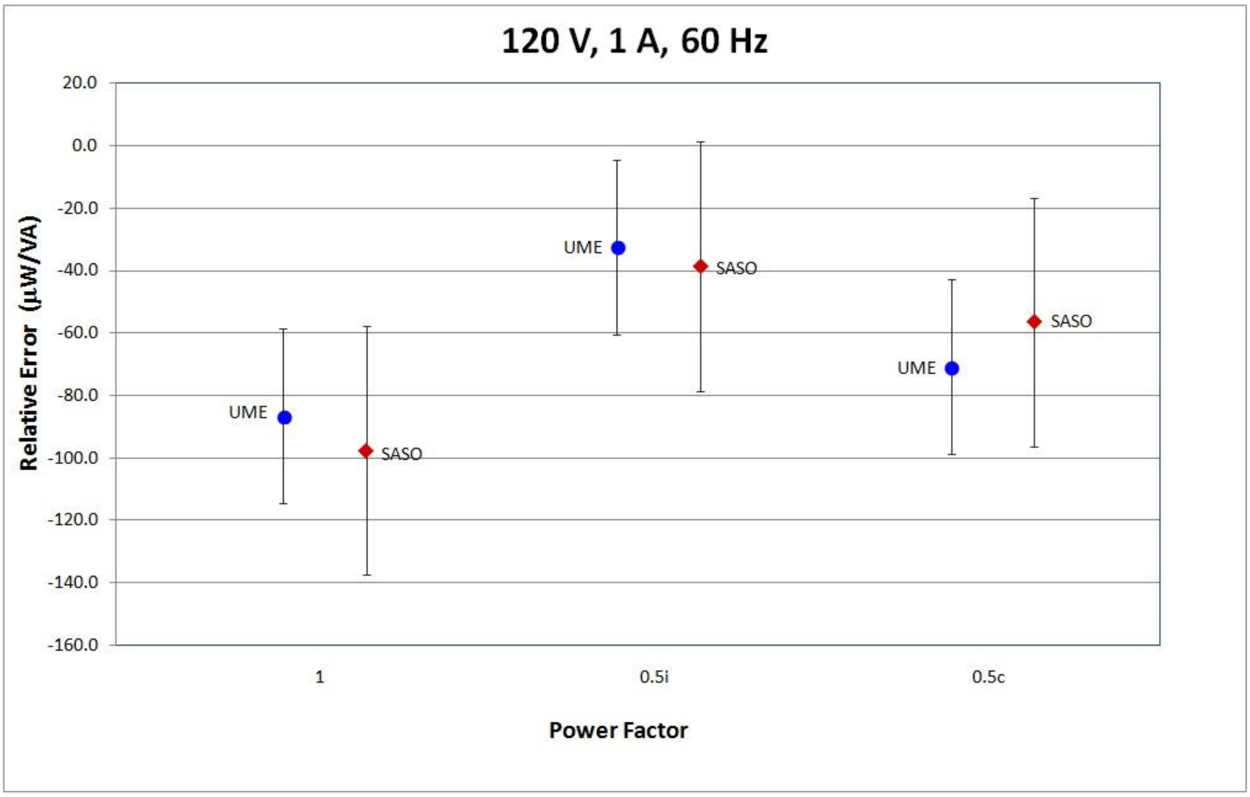

Figure 9. The comparison results and its uncertainty for 120 V, 1 A, 60 Hz (%95, k=2)

Table 7. Measurement results and uncertainty of SASO and En values

Nominal Value				X_{lab}	U_{lab}	D	U_D	E_n
Voltage	Current	Power Factor	Frequency	(μW/VA)	(μW/VA)	(μW/VA)	(μW/VA)	
120 V	5 A	1	53 Hz	-71	40	6	47	0.1
120 V	5 A	0.8i	53 Hz	-53	40	7	47	0.1
120 V	5 A	0.8c	53 Hz	-66	40	0	47	0.0
120 V	5 A	0.5i	53 Hz	-32	40	3	47	0.1
120 V	5 A	0.5k	53 Hz	-41	40	5	47	0.1
120 V	5 A	0.25i	53 Hz	-17	40	0	47	0.0
120 V	5 A	0.25c	53 Hz	-24	40	5	47	0.1
120 V	5 A	0.01i	53 Hz	-9	40	-4	47	-0.1
120 V	5 A	0.01c	53 Hz	-10	40	9	47	0.2
120 V	1 A	1	53 Hz	-102	40	-4	47	-0.1
120 V	1 A	0.5i	53 Hz	-49	40	1	47	0.0
120 V	1 A	0.5c	53 Hz	-64	40	1	47	0.0
60 V	5 A	1	53 Hz	-61	40	4	47	0.1
120 V	5 A	1	60 Hz	-65	40	-6	49	-0.1
120 V	5 A	0.5i	60 Hz	-27	40	-10	49	-0.2
120 V	5 A	0.5c	60 Hz	-45	40	5	49	0.1
120 V	1 A	1	60 Hz	-98	40	-11	49	-0.2
120 V	1 A	0.5i	60 Hz	-39	40	-6	49	-0.1
120 V	1 A	0.5c	60 Hz	-57	40	14	49	0.3

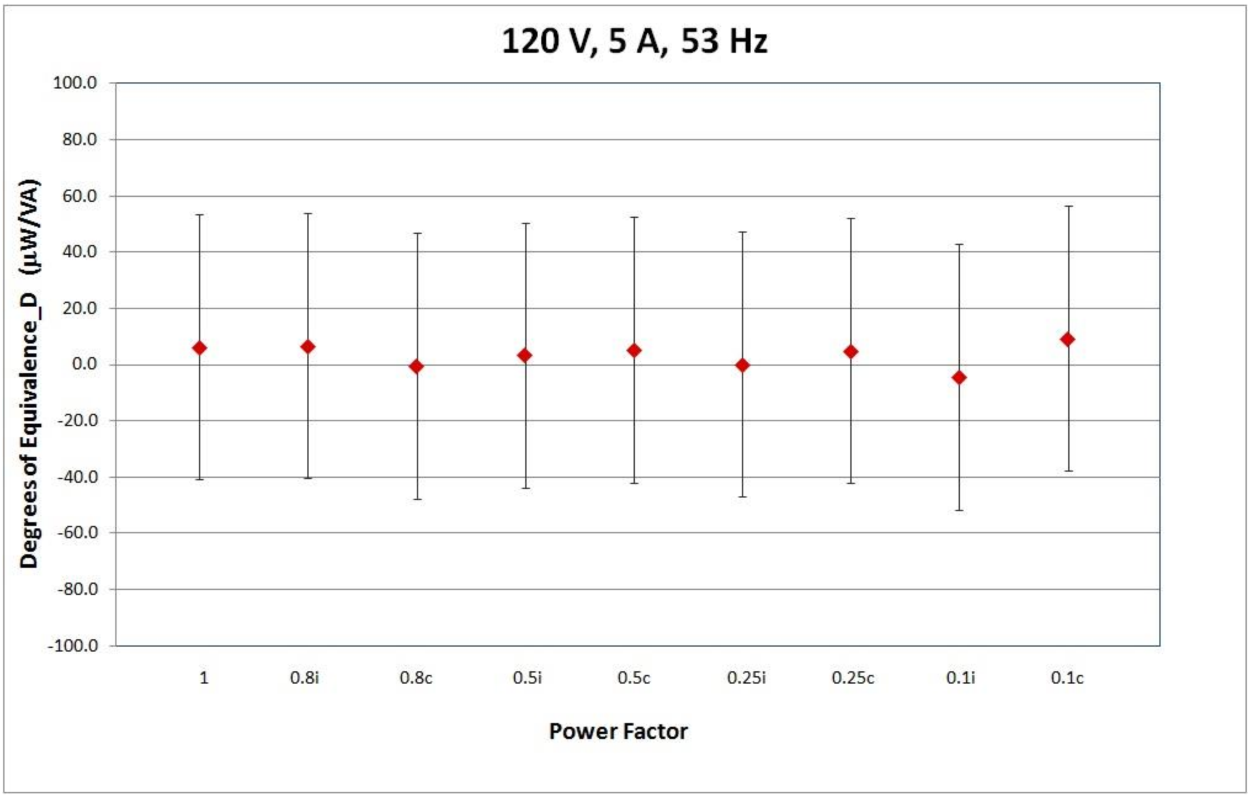

Figure 10. Degrees of Equivalence and its uncertainty for 120 V, 5 A, 53 Hz (%95, k=2)

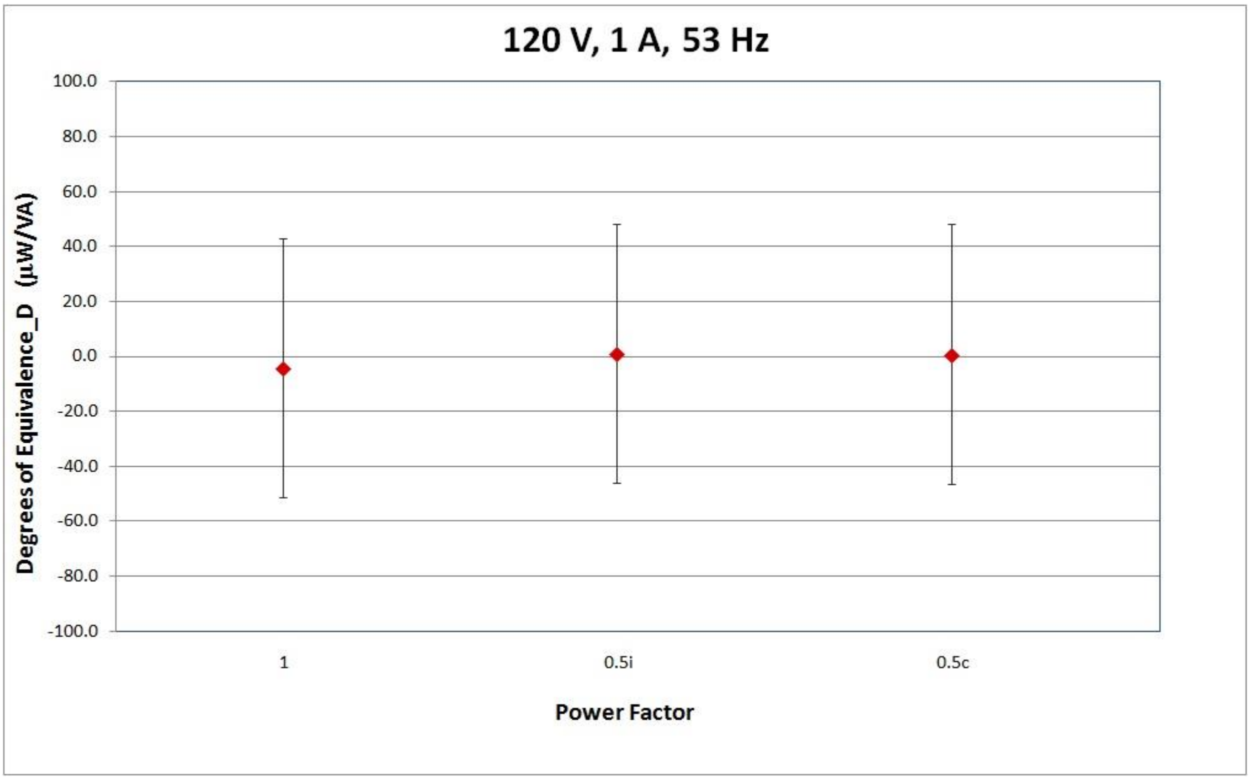

Figure 11. Degrees of Equivalence and its uncertainty for 120 V, 1 A, 53 Hz (%95, k=2)

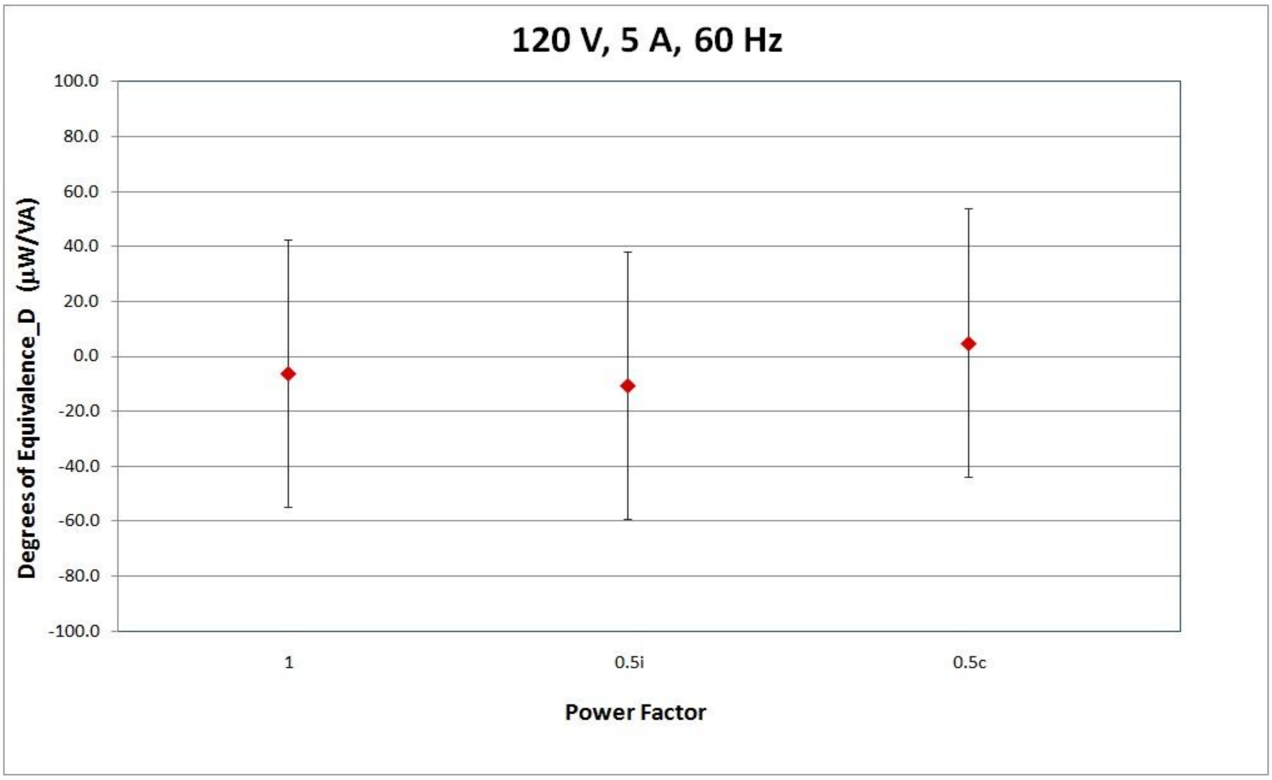

Figure 12. Degrees of Equivalence and its uncertainty for 120 V, 5 A, 60 Hz (%95, k=2)

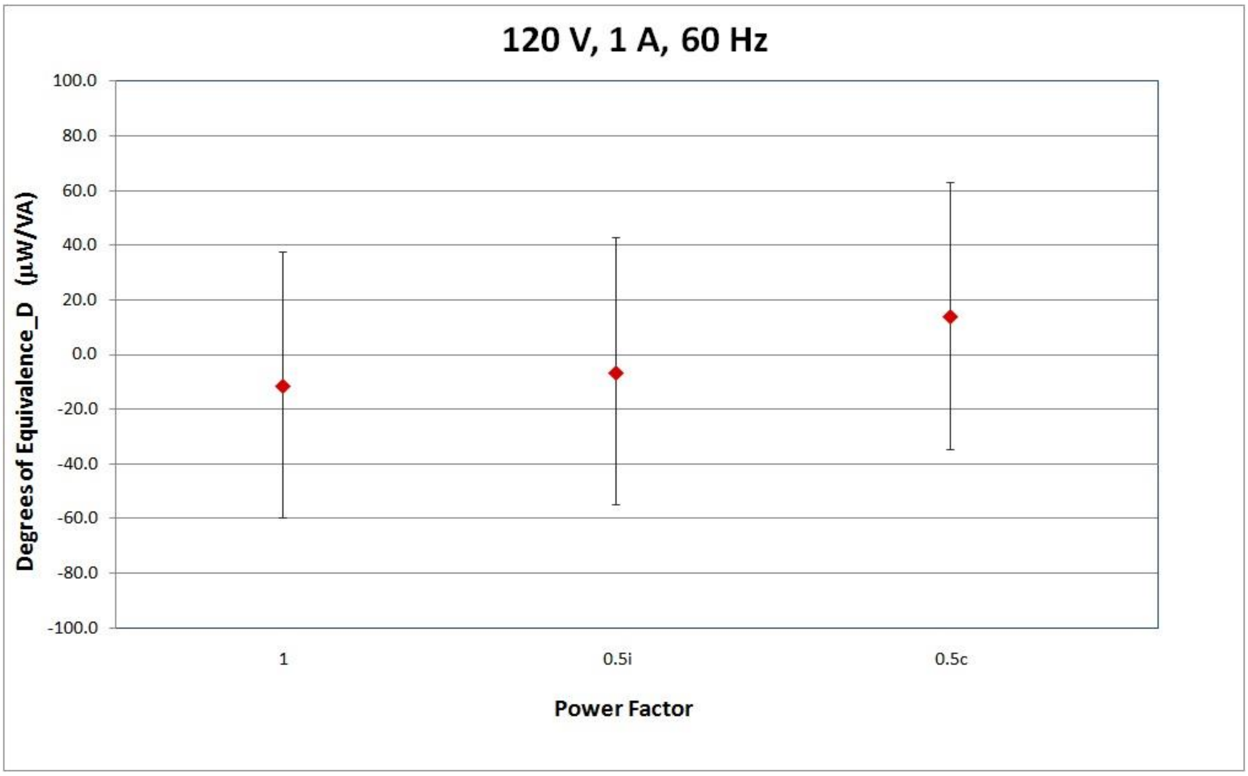

Figure 13. Degrees of Equivalence and its uncertainty for 120 V, 1 A, 60 Hz (%95, k=2)

Conclusions

Bilateral comparison schedule was planned for a very short circulating time of the travelling standard between the participants to eliminate the long-term drifts and any other behaviour of it. And, those effects were successfully declared with the repetitive measurements on the travelling standard, by the pilot laboratory. The measurand and the parameters (voltage, current, power factor, and frequency) were selected carefully to be able compare each participant's measurement capabilities as wider as possible.

The results for each measurement points are found very close each other and show a good agreement with the given uncertainties. Both measurement standards used by the participants are based on the digital sampling method but with minor differences in the hardware. In this point of view, this comparison might have a meaning of a direct check of two similar primary power measurement standards.

References

[1] CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons, 2007 (available on the BIPM website: http://www.bipm.org/utils/common/pdf/CC/CCEM/ccem_guidelines.pdf).

[2] Evaluation of measurement data - Guide to the Expression of Uncertainty in Measurement (GUM), JCGM 100, First edition, September 2008 (available on the BIPM website: http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf).

[3] Hüseyin Çaycı, "Final Report of Key Comparison EUROMET.EM-K5.1 Comparison of 50/60 Hz Power," March 2011.

[4] Technical Protocol, "Bilateral Comparison of AC Power Standards Between TÜBİTAK UME and SASO NMCC", UME-EM-D3-2.22.6.a, 2016.

ANNEX A. UNCERTAINTY BUDGET

A.1. Uncertainty budget of TÜBİTAK UME

The following sample tables show a typical uncertainty budget used by UME in the calculation of its uncertainty values. The uncertainty budget given shows the contributions associated with the measurements made in the 120 V voltage range and 5 A current range, and for an ambient temperature of (23 ± 1) °C.

Frequency: 53 Hz

Source of Uncertainty (At power factor 1)	Standard uncertainty (μW/VA)	Probability distribution	Sensitivity coefficient	Uncertainty Contribution (μW/VA)
Voltage measurement	6.0	Normal	1	6.0
Current measurement	10.0	Normal	1	10.0
Phase measurement	7.5	Normal	0	0.0
Measurement set up	2.5	Rectangular	1	2.5
Standard uncertainty of measurement	3.0	Normal	1	3.0
Combined Uncertainty				**12.3**
Expanded Uncertainty (k=2)				**24.6**

Source of Uncertainty (At power factor 0.5)	Standard uncertainty (μW/VA)	Probability distribution	Sensitivity coefficient	Uncertainty Contribution (μW/VA)
Voltage measurement	6.0	Normal	0.5	3.0
Current measurement	10.0	Normal	0.5	5.0
Phase measurement	7.5	Normal	0.87	6.5
Measurement set up	2.5	Rectangular	1	2.5
Standard uncertainty of measurement	3.0	Normal	1	3.0
Combined Uncertainty				**9.6**
Expanded Uncertainty (k=2)				**19.2**

Source of Uncertainty (At power factor 0)	Standard uncertainty (µW/VA)	Probability distribution	Sensitivity coefficient	Uncertainty Contribution (µW/VA)
Voltage measurement	6.0	Normal	0	0.0
Current measurement	10.0	Normal	0	0.0
Phase measurement	7.5	Normal	1	7.5
Measurement set up	2.5	Rectangular	1	2.5
Standard uncertainty of measurement	3.0	Normal	1	3.0
Combined Uncertainty				**8.5**
Expanded Uncertainty (k=2)				**16.9**

The expanded uncertainty for any power factor is rounded to 25 µW/VA relative to the apparent power (k=2)

Frequency: 60 Hz

Source of Uncertainty (At power factor 1)	Standard uncertainty (µW/VA)	Probability distribution	Sensitivity coefficient	Uncertainty Contribution (µW/VA)
Voltage measurement	7.0	Normal	1	7.0
Current measurement	11.0	Normal	1	11.0
Phase measurement	7.5	Normal	0	0.0
Measurement set up	2.5	Rectangular	1	2.5
Standard uncertainty of measurement	3.0	Normal	1	3.0
Combined Uncertainty				**13.6**
Expanded Uncertainty (k=2)				**27.2**

Source of Uncertainty (At power factor 0.5)	Standard uncertainty (µW/VA)	Probability distribution	Sensitivity coefficient	Uncertainty Contribution (µW/VA)
Voltage measurement	7.0	Normal	0.5	3.5
Current measurement	11.0	Normal	0.5	5.5
Phase measurement	7.5	Normal	0.87	6.5
Measurement set up	2.5	Rectangular	1	2.5
Standard uncertainty of measurement	3.0	Normal	1	3.0
Combined Uncertainty				**10.0**
Expanded Uncertainty (k=2)				**20.0**

Source of Uncertainty (At power factor 0)	Standard uncertainty (µW/VA)	Probability distribution	Sensitivity coefficient	Uncertainty Contribution (µW/VA)
Voltage measurement	7.0	Normal	0	0.0
Current measurement	11.0	Normal	0	0.0
Phase measurement	7.5	Normal	1	7.5
Measurement set up	2.5	Rectangular	1	2.5
Standard uncertainty of measurement	3.0	Normal	1	3.0
Combined Uncertainty				**8.5**
Expanded Uncertainty (k=2)				**16.9**

The expanded uncertainty for any power factor is rounded to 28 µW/VA relative to the apparent power (k=2)

A.2. Uncertainty budget of SASO NMCC

The following sample tables show a typical uncertainty budget used by SASO NMCC in the calculation of its uncertainty values. The uncertainty budget given shows the contributions associated with the measurements made in the 120 V voltage range and 5 A current range, and for an ambient temperature of (23 ± 2) °C.

Frequency: 53 Hz and 60 Hz

Source of Uncertainty (At power factor 1)	Standard uncertainty (μW/VA)	Probability distribution	Sensitivity coefficient	Uncertainty Contribution (μW/VA)
Voltage measurement	10.0	Normal	1	10
Current measurement	16.0	Normal	1	16
Phase measurement	9.5	Normal	0	0
Measurement set up	5.0	Rectangular	1	5
Standard uncertainty of measurement	4.0	Normal	1	4
Combined Uncertainty				**19.9**
Expanded Uncertainty (k=2)				**39.8**

Source of Uncertainty (At power factor 0.5)	Standard uncertainty (μW/VA)	Probability distribution	Sensitivity coefficient	Uncertainty Contribution (μW/VA)
Voltage measurement	10.0	Normal	0.5	5.0
Current measurement	16.0	Normal	0.5	8.0
Phase measurement	9.5	Normal	0.87	8.3
Measurement set up	5.0	Rectangular	1	5.0
Standard uncertainty of measurement	4.0	Normal	1	4.0
Combined Uncertainty				**14.1**
Expanded Uncertainty (k=2)				**28.2**

Source of Uncertainty (At power factor 0)	**Standard uncertainty (μW/VA)**	**Probability distribution**	**Sensitivity coefficient**	**Uncertainty Contribution (μW/VA)**
Voltage measurement	10.0	Normal	0	0.0
Current measurement	16.0	Normal	0	0.0
Phase measurement	9.5	Normal	1	9.5
Measurement set up	5.0	Rectangular	1	5.0
Standard uncertainty of measurement	4.0	Normal	1	4.0
Combined Uncertainty				**11.5**
Expanded Uncertainty (k=2)				**22.9**

The expanded uncertainty for any power factor is rounded to 40 μW/VA relative to the apparent power (k=2)

ANNEX B. Technical Protocol

TECHNICAL PROTOCOL
Bilateral Comparison of AC Power Standards Between TÜBİTAK UME and SASO NMCC

UME-EM-D3-2.22.6.a

TÜBİTAK UME

(Rev. 0)
August 19, 2016

Contents

1. Introduction

It was planned to organise a bilateral comparison on AC Power between SASO NMCC and TÜBİTAK UME, in the frame of the Project of Development and Realization Measurement and Calibration System for the National Measurement and Calibration Center (NMCC) at Saudi Standards, Metrology and Quality Organization (SASO).

The bilateral comparison will be performed by measuring a power converter at several AC power values.

UME is acting as the pilot institute. The travelling standard will be provided by TÜBİTAK UME. TÜBİTAK UME will be responsible to monitoring standard performance during the circulation and the evaluation and reporting of the comparison results.

The comparison will be carried out in accordance with the CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons [1].

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Figure 1. Front panel of the travelling standard MTE C1-2.

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The travelling standard will be supplied by TÜBİTAK UME. This standard was chosen for its high accuracy and stability in time. The general specifications of MTE C1-2 are given in Table 1.

Table 1. The general specifications of MTE C1-2 Power Converter

Inputs	
Nominal Current **Nominal Voltage** **Frequency Range**	5 A AC 120 V AC 45 - 65 Hz
Outputs	
Nominal Voltage **Nominal Frequency**	10 V DC 10 kHz and 10 Hz
Accuracy **(P_n=nominal power)**	P_n - 0.5*P_n : 0.005% 0.5*P_n - 0.1*P_n : 0.01% 0.1*P_n – 0*P_n : 0.001%
Warm up time	2 h
Power	220 - 240 V at 50 Hz
Temperature Range	10 °C to 30 °C
Dimensions	255 mm x 165 mm x 315 mm
Weight	7.5 kg

Powering of the standard

The travelling standard shall be plugged to the mains supply for 24 hours and signal voltage and current shall be connected to the instrument for at least 2 hours before starting the measurements. After these procedures have been performed, one may find out that the travelling standard will remain extremely stable even if the voltage and current input signals are shut down for a moment. Particularly, if the power supply of the travelling standard will be shut down in any time, then the warm-up time procedure shall be performed once more.

3. Participant Laboratories

The pilot institute for this comparison is TÜBİTAK UME (Turkey). The contact details of the coordinator are given below:

Pilot Institute	:	TÜBİTAK Ulusal Metroloji Enstitüsü (UME)
Coordinator	:	Özlem Yılmaz Tel: +90 262 679 50 00 Fax: +90 262 679 50 01 E-mail: ozlem.yilmaz@tubitak.gov.tr

The participating institutes and contact persons with their addresses are given in Table 2.

Table 2. Participants

Country	Institute	Acronym	Shipping Address	Contact Person
Turkey	TÜBİTAK Ulusal Metroloji Enstitüsü	TÜBİTAK UME	TÜBİTAK Ulusal Metroloji Enstitüsü (UME) TÜBİTAK Gebze Yerleşkesi Barış Mah. Dr. Zeki Acar Cad. No:1 41470 Gebze-Kocaeli, TURKEY	Özlem Yılmaz ozlem.yilmaz@tubitak.gov.tr Tel: +90 262 679 50 00
Saudi Arabia	SASO The National Measurement and Calibration Center	SASO NMCC	Saudi Standards, Metrology and Quality Organization of The Kingdom of Saudi Arabia (SASO) Riyadh 11471, P.O. Box 3437 KINGDOM of SAUDI ARABIA	Abdullah M. Alrobaish a.robaish@saso.gov.sa Tel: +966 11 252 97 30

4. Time Schedule

The time schedule for the comparison is given in the Table 3. The circulation of travelling standard will be organized so that to monitor the performance of the travelling standard. Each laboratory will have 1 week to carry out the measurements and transportation. Any deviation in the agreed plan should be approved by the pilot institute.

Table 3. Circulation Time Schedule

Acronym of Institute	Country	Starting Date	Time for measurement and transportation
TÜBİTAK UME	Turkey	November 2016	7 days
SASO NMCC	Saudi Arabia	December 2016	7 days
TÜBİTAK UME	Turkey	January 2017	7 days

5. Transport Case

The travelling standard is packed in a transport case of size (55 x 30 x 40) cm and a total weight of 13 kg. The transport case can easily be opened for customs inspection.

The content of the transport case is given below:

1. MTE C1-2 Power Converter (Serial No: 23875)
2. Power cord
3. User Manual of MTE C1-2 Power Converter

6. Transportation of Travelling Standard

The comparison will be organised in a single loop of two laboratories in order to allow close monitoring of the behaviour of the standard.

Participants will be responsible for arranging transportation to the next participant.

After arrival in the participant’s laboratory, the standard should be allowed to stabilise in a temperature and possibly, humidity controlled room for at least one day before use.

Each institute will have one week available. This includes the measurements and the transportation of the standard to the next participant.

6.1. Failure of Travelling Standard

In case of any damage or malfunction of the travelling standard, the comparison will be carried out after the travelling standard is repaired.

6.2. Financial aspects

Each participant institute is responsible for its own costs for the measurements as well as any damage that may occur within its country.

The overall costs for the organisation of the comparison are covered by the pilot institute. The pilot institute has no insurance for any loss or damage of the travelling standard.

7. Measurement Quantities and Points

The quantities to be measured and the measurement points are given in Table 4.

Table 4. Measurement quantity & points

Measurement Points			
Voltage	**Current**	**Power Factor**	**Frequency**
120 V	5 A	1	53 Hz
120 V	5 A	0,8i	53 Hz
120 V	5 A	0,8k	53 Hz
120 V	5 A	0,5i	53 Hz
120 V	5 A	0,5k	53 Hz
120 V	5 A	0,25i	53 Hz
120 V	5 A	0,25k	53 Hz
120 V	5 A	0,01i	53 Hz
120 V	5 A	0,01k	53 Hz
120 V	1 A	1	53 Hz
120 V	1 A	0,5i	53 Hz
120 V	1 A	0,5k	53 Hz
60 V	5 A	1	53 Hz
120 V	5 A	1	60 Hz
120 V	5 A	0,5i	60 Hz
120 V	5 A	0,5k	60 Hz
120 V	1 A	1	60 Hz
120 V	1 A	0,5i	60 Hz
120 V	1 A	0,5k	60 Hz

Also the quantities given below must be measured;

- Ambient temperature
- Ambient humidity

No correction will be applied for the ambient temperature and relative humidity.

8. Calculation of the Comparison Reference Value

The Comparison Reference Value (CRV) for each measurement point will be calculated using the results of the pilot institute.

9. Measurement Instructions

The travelling standard has separate (electrically isolated) voltage and current inputs on the front panel with the voltage range of 120 V and the current range of 5 A. The input frequency capability of the instrument is between 45 Hz to 65 Hz. The internal DC reference voltages (nominally +7.044... V and -7.044... V) can be monitored at the front panel. The nominal full scale DC output of 10 V is also available on the front panel (Volt OUT). It has also nominal full scale frequency outputs of 10 kHz and 10 Hz which are available with BNC connectors on the front panel (f-OUT).

Participants shall use twisted cables for both current and voltage input connections.

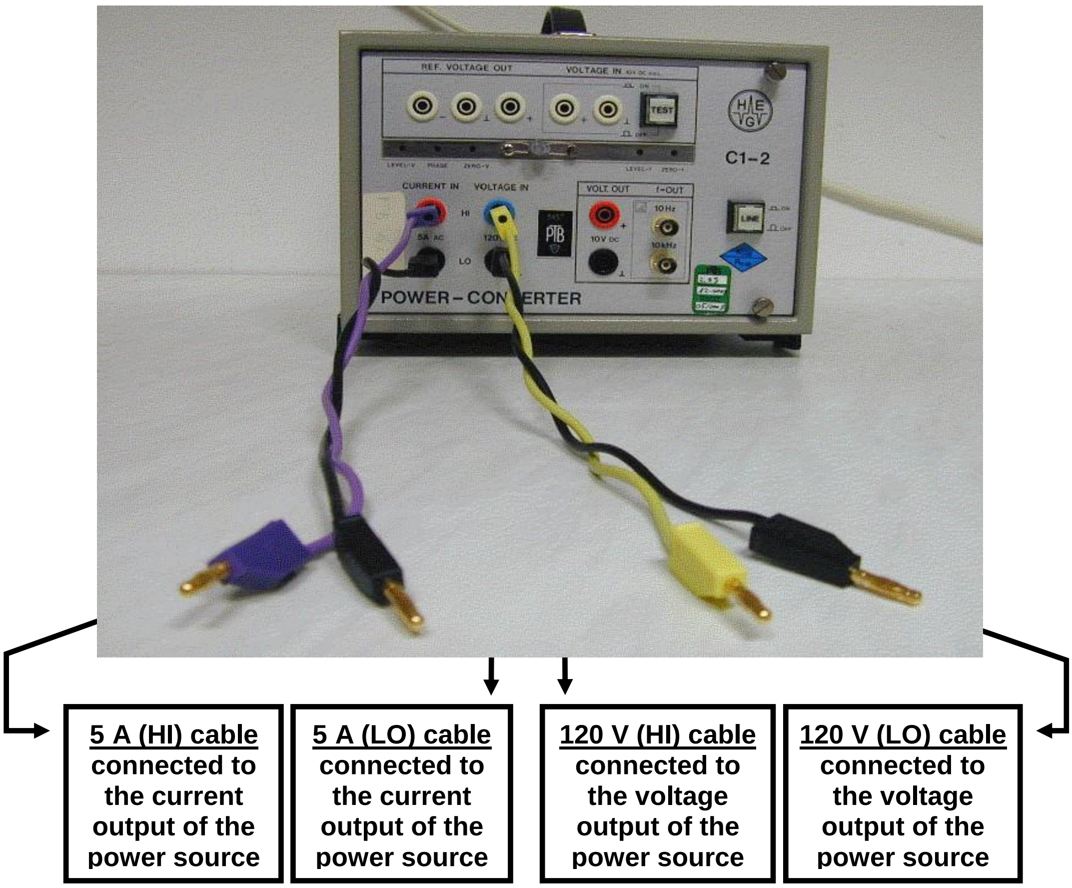

Figure 2. Current and voltage input connections of the travelling standard.

A digital multimeter with a high input impedance shall be used to measure the DC voltage. The voltmeter shall be calibrated with a DC voltage standard immediately before measurements.

An Agilent 3458A digital multimeter is given in the Figure 3, to show a sample connection for the measurement of DC voltage values from the travelling standard. Voltage and current input connections are not shown in the figure.

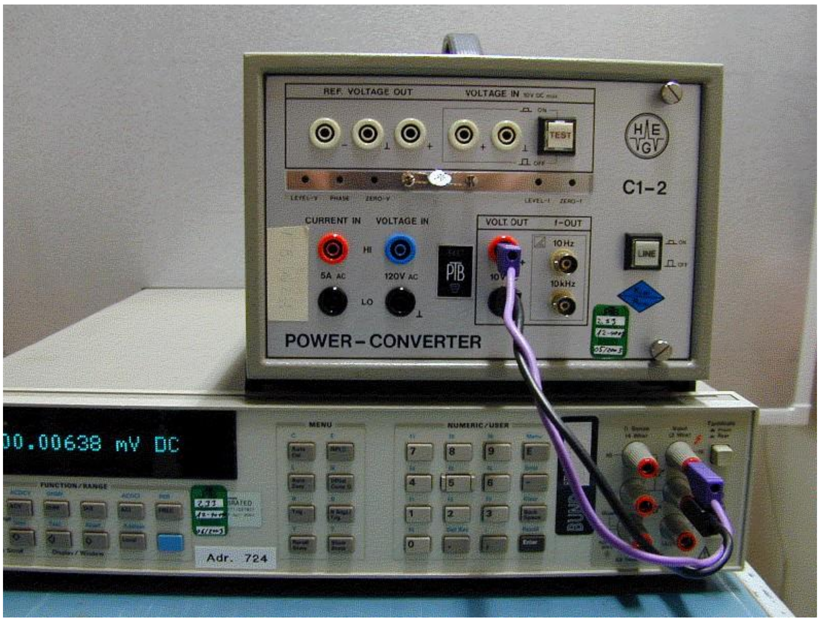

Figure 3. Connections and DC voltage measurement from the voltage output (VOLT.OUT) of the travelling standard.

The internal DC reference voltages can be measured before comparison measurements. Only positive output connection is given in the Figure 4. Negative reference voltage can be measured by removing the cable used for HI connection and reconnecting it to the next banana connector which is signed with (-) negative.

The multimeter shall be programmed to measure the DC reference values with the best resolution and accuracy.

During the measurement of DC reference voltages, no AC signal shall be connected to the travelling standard.

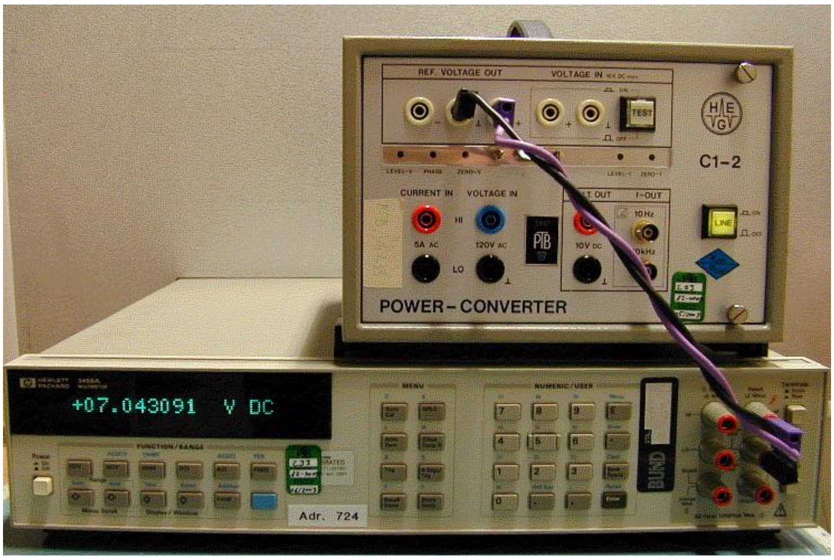

Figure 4. DC reference voltage measurements from the reference voltage output (REF. VOLTAGE OUT) of the travelling standard by means of a digital multimeter.

10. Measurement Uncertainty

The uncertainty of measurement must be calculated according to the JCGM 100 “Guide to the Expression of Uncertainty in Measurement” [3] for the coverage probability of approximately 95%.

All contributions to the measurement uncertainty should be listed in the report submitted by each participant.

Even though the contributions to the uncertainty are specific to the measurement method used, it may be useful to consider the list of uncertainty sources given below.

1. Type A
2. AC Power Measurement Standard uncertainty

This is not a complete list and should be extended with uncertainty contributions that are specific for the participant’s measurement system.

11. Reporting of Results

The results should be communicated to the pilot institute within 30 days of completing the measurements.

The participant shall report their results using the standard certificate that they would normally issue to a customer.

However, results shall also be reported in the pilot institute. The report must contain at least:

- Details of participating institute,
- The date and time of the measurements,
- A detailed description of the method used,
- The measurement standards used in the comparison measurements,
- Software used in the comparison measurements
- The environmental conditions during the measurements,
    - ambient temperature
    - relative humidity
- Results of measurement; The measurement results shall be provided in the following format (Table 5).

Table 5. The table for reporting the measurement results

Measurement Points				Reference Value (W)	Measured Value (W)	Measurement Result (μW/VA)	
Voltage	**Current**	**Power Factor**	**Frequency**	P_{REF} (1)	P_{UUT} (2)	**Error**	**Uncertainty**
120 V	5 A	1	53 Hz				
120 V	5 A	0.8i	53 Hz				
120 V	5 A	0.8c	53 Hz				
120 V	5 A	0.5i	53 Hz				
120 V	5 A	0.5k	53 Hz				
120 V	5 A	0.25i	53 Hz				
120 V	5 A	0.25c	53 Hz				
120 V	5 A	0.01i	53 Hz				
120 V	5 A	0.01c	53 Hz				
120 V	1 A	1	53 Hz				
120 V	1 A	0.5i	53 Hz				
120 V	1 A	0.5c	53 Hz				
60 V	5 A	1	53 Hz				
120 V	5 A	1	60 Hz				
120 V	5 A	0.5i	60 Hz				
120 V	5 A	0.5c	60 Hz				
120 V	1 A	1	60 Hz				
120 V	1 A	0.5i	60 Hz				
120 V	1 A	0.5c	60 Hz				

Absolute error of transfer device is calculated in the formulas below for all measurement points.

$$E = \frac{P_{UUT} - P_{REF}}{S_{REF}} \quad (1)$$

E : Measurement error.

P_{UUT} : Measured value on MTE C1-2 Power Converter = 60 x V_{3458A}

V_{3458A} = Measured value on Agilent 3458A multimeter connected to the output of Power Converter

P_{REF} : Measured active power value on the Reference Standard

S_{REF} : Measured apparent power value on the Reference Standard

- A statement of traceability,
- The Type A standard uncertainty;
- Detailed uncertainty budget with the different sources of uncertainty and their values, as;
- Expanded measurement uncertainty, estimated for the coverage probability of approximately 95%.

12. Final Report of the Comparison

The pilot institute is responsible for the preparation of a comparison report.

The draft version of the comparison report will be issued within two months after receiving the participant report by the pilot institute. Draft report will be sent to the SASO NMCC for discussion and approval. This draft will be confidential to the participants.

The participant will have one week to send their comments on Draft Report. After approval, Draft Report will become the Final Report. The Final Report will form the basis for the publication of results.

13. References

[1] CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons, 2007 (available on the BIPM website: http://www.bipm.org/utils/common/pdf/CC/CCEM/ccem_guidelines.pdf)

[2] Evaluation of measurement data - Guide to the Expression of Uncertainty in Measurement (GUM), JCGM 100, First edition, September 2008 (available on the BIPM website: http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf)

[3] Hüseyin Çaycı, "Final Report of Key Comparison EUROMET.EM-K5.1 Comparison of 50/60 Hz Power," March 2011.