# Interlaboratory Comparison LF-Power

**Evaluation Report Round 1 version 2.0**

**Report number ILC-028A**

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|---|---|---|
| **This work has been carried out by** | R.P. van Otterloo | Coordinator |
| | VSL employees | Technician |
| **In the period** | May 2011 – September 2012 | |
| **On request of** | VSL B.V. Department of Calibration & Reference Materials | |

***Confidentiality statement***

VSL keeps all data regarding the performance of individual participants, or groups of participants, strictly confidential. Data is accordingly protected and stored in areas on networks with restricted access. The relationship between results and the laboratories that submitted them will never be disclosed. Only the laboratory is granted access to its performance through the assigned code number.

This report cancels and replaces report with number ILC-028.

| | |
|---|---|
| Signature | Approved by |
| R.P. van Otterloo | C. van 't Wout |
| Coordinator | Manager K&R |
| Date 2012-10-30 | Date 30/10/12 |

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# 1 Introduction

The first round of the interlaboratory comparison programme “LF-Power” has been carried out in the period between May 2011 and January 2012. The purpose of the comparison is to allow calibration laboratories to assess their performance with respect to the calibration of Power meters this objective is achieved by comparing their calibration results with the reference calibrations performed by the coordinating laboratory, VSL.

The evaluation of the performance has been carried out using the reported deviations and/or corrections and corresponding uncertainties of the participants with respect to the measured deviations/corrections and corresponding uncertainties by the reference laboratory. From these values we calculated the normalized errors ($E_n$ Numbers).

*During re-evaluation of the measurement results obtained by VSL a mistake has been discovered in all 5 A measurements.*

*After carefully analyzing the obtained data there seemed to be an interference caused by crosstalk between the voltage and current channels. The results were corrected for this interference and recalculated for the 100V, 5 A measurements.*

# 2 Travelling standard and measurand

For this comparison we have selected a Yokogawa WT3000.


| | | |
|---|---|---|
| Item | : | Precision power analyser |
| Manufacturer | : | Yokogawa |
| Model | : | 760304-04 (1-element) |
| S/N | : | 27E116812 A |

For more information please visit: http://tmi.yokogawa.com/products/digital-power-analyzers/digital-power-analyzers/wt3000-precision-power-analyzer/

Quantities to be measured:

Input alternating voltage of 100V RMS combined with input alternating current of 1 A RMS

Input alternating voltage of 100V RMS combined with input alternating current of 5 A RMS

Both at the following phase angles 0°, +36.87°, -36.87°, +60.00°, -60.00°, +84.26°, -84.26° and at the frequency of 53 Hz.

| Frequency | Voltage | Current | Phase Angle φ |
|---|---|---|---|
| [Hz] | [V] | [A] | [Degrees °] |
| 53 | 100 | 1 | 0.00 |
| 53 | 100 | 1 | +36.87 |
| 53 | 100 | 1 | -36.87 |
| 53 | 100 | 1 | +60.00 |
| 53 | 100 | 1 | -60.00 |
| 53 | 100 | 1 | +84.26 |
| 53 | 100 | 1 | -84.26 |
| 53 | 100 | 5 | 0.00 |
| 53 | 100 | 5 | +36.87 |
| 53 | 100 | 5 | -36.87 |
| 53 | 100 | 5 | +60.00 |
| 53 | 100 | 5 | -60.00 |
| 53 | 100 | 5 | +84.26 |
| 53 | 100 | 5 | -84.26 |

# 3 Stability assessment and determination of the Interlaboratory Comparison Reference Value

## 3.1 Stability assessment

Before the start of the interlaboratory comparison, the travelling standard was analysed to determine the expected long term stability. While the stability measurements were being made, conditions were simulated that approximated as closely as possible those that would be encountered while the artefact was being circulated. This means the artefact was transported several times during this period to investigate the effect this would have. On the basis of the results of the stability study, it was decided to use the artefact for the interlaboratory comparison.

At the start of the interlaboratory comparison, the artefact was dispatched in an undamaged state and was subsequently returned in an undamaged state at the end of the interlaboratory comparison.

## 3.2 Interlaboratory Comparison Reference Values (ICRV)

The Interlaboratory Comparison Reference Values (ICRV) has been determined based on three sets of measurements by VSL before, in the middle and after the comparison. For this purpose we use the simple average of the three independent determinations of the Interlaboratory Comparison Reference value. The formulas below show the calculation of the average deviation:

$$\overline{\Delta E_{ref}} = \frac{\Delta E_{ref,1} + \Delta E_{ref,2} + \Delta E_{ref,3}}{3}$$

Where

$$\overline{\Delta E_{ref}} = \overline{E_{calc} - E_{IEC}}$$

is the Interlaboratory Comparison Reference Value used for consequent determination of all $E_n$ values. See table 1.

## 3.3 Metrological traceability

The calibrations by VSL is consistent with the Calibration and Measurement Capabilities (CMCs) that are included in Appendix C of the Mutual Recognition Arrangement (MRA) drawn up by the International Committee for Weights and Measures (CIPM). Under the MRA, all participating institutes recognize the validity of each other's calibration and measurement certificates for the quantities, ranges and measurement uncertainties specified in Appendix C (for details see http://kcdb.bipm.fr).

## 3.4 Measurement uncertainty

The uncertainty of the Interlaboratory Comparison Reference value is determined according to:

$$\mathrm{U_C}(\overline{\Delta E_{ref}}) = \sqrt{[\overline{U(\Delta E_{ref1,2,3})}]^2 + [U(E_{drift})]^2}$$

Where $\mathrm{U_C}(\overline{\Delta E_{ref}})$ is the (*k*=2) combined uncertainty for the Interlaboratory Comparison Reference value,

Where $\mathrm{U}(\overline{\Delta E_{ref1,2,3}})$ is the (*k*=2) average uncertainty of the 3 Interlaboratory Comparison Reference values (before, in the middle and after the comparison),

$\mathrm{U}(E_{drift})$ is the (k=2) uncertainty related to the drift of the Interlaboratory Comparison Reference value and calculated at each measurement point by taking the standard deviation of the three measurements.

## 3.5 Results of the Interlaboratory Comparison Reference Value

*Table 1 – ICRV*

| Frequency | Voltage | Current | Phase Angle φ | Measured Power | Uncertainty |
|---|---|---|---|---|---|
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] |
| 53 | 100 | 1 | 0 | 100.001 | 0.011 |
| 53 | 100 | 1 | +36.87 | 80.001 | 0.010 |
| 53 | 100 | 1 | -36.87 | 80.001 | 0.011 |
| 53 | 100 | 1 | +60.00 | 50.000 | 0.010 |
| 53 | 100 | 1 | -60.00 | 50.000 | 0.010 |
| 53 | 100 | 1 | +84.26 | 10.000 | 0.010 |
| 53 | 100 | 1 | -84.26 | 10.000 | 0.010 |
| | | | | | |
| 53 | 100 | 5 | 0 | 500.193 | 0.033 |
| 53 | 100 | 5 | +36.87 | 400.125 | 0.033 |
| 53 | 100 | 5 | -36.87 | 400.122 | 0.031 |
| 53 | 100 | 5 | +60.00 | 250.049 | 0.031 |
| 53 | 100 | 5 | -60.00 | 250.047 | 0.030 |
| 53 | 100 | 5 | +84.26 | 50.002 | 0.030 |
| 53 | 100 | 5 | -84.26 | 50.002 | 0.030 |

*During re-evaluation of the measurement results obtained by VSL a measurement error has been discovered in all 5 A measurements.*

*After carefully analyzing the obtained data there seemed to be an error caused by crosstalk between the voltage and current channels. This error has been investigated and new results have been calculated for the 100V, 5 A measurements see table 2.*

Table 2 – Renewed ICRV for 100V, 5 A measurements

| Frequency | Voltage | Current | Phase Angle φ | Measured Power | Uncertainty |
|---|---|---|---|---|---|
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] |
| 53 | 100 | 5 | 0 | 500.189 | 0.030 |
| 53 | 100 | 5 | +36.87 | 400.152 | 0.030 |
| 53 | 100 | 5 | -36.87 | 400.152 | 0.030 |
| 53 | 100 | 5 | +60.00 | 250.092 | 0.030 |
| 53 | 100 | 5 | -60.00 | 250.097 | 0.030 |
| 53 | 100 | 5 | +84.26 | 50.019 | 0.030 |
| 53 | 100 | 5 | -84.26 | 50.023 | 0.030 |

# 4 Report and analysis of the participants measurements

The participants were asked to report their measurements in a by VSL prepared excel sheet with the results as a normal calibration.

Paragraph 4.1 lists the deviations observed by the participants, together with the associated sum of uncertainties. The normalized error ($E_n$) was also calculated to enable the results to be evaluated.

The $E_n$ number is calculated according to:

$$E_n = \frac{x_i - X_{ref}}{\sqrt{U_{lab,i}^2 + U_{ref}^2}}$$

where

| | |
|---|---|
| $x_i$ | is the result of laboratory i, |
| $X_{ref}$ | is the result of reference laboratory, |
| $U_{lab,i}$ | is the expanded uncertainty ($k$=2) given by laboratory i, |
| $U_{ref}$ | is the expanded uncertainty ($k$=2) given by the reference laboratory |

The qualification of the results is the following:

| | |
|---|---|
| $\lvert E_n \rvert \leq 1$ | Satisfactory result |
| $\lvert E_n \rvert > 1$ | Unsatisfactory result |

## 4.1 Reported results, uncertainty and $E_n$ numbers

### 4.1.1 Results @ 53 Hz, 100 V, 1 A

| L001 | | | | | | |
|---|---|---|---|---|---|---|
| Frequency | Voltage | Current | Phase Angle φ | Measured | Uncertainty | $E_n$ |
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] | |
| | | | | | | |
| 53 | 100 | 1 | 0 | 100.000 | 0.025 | -0.03 |
| 53 | 100 | 1 | +36.87 | 80.004 | 0.260 | 0.01 |
| 53 | 100 | 1 | -36.87 | 80.002 | 0.260 | 0.00 |
| 53 | 100 | 1 | +60.00 | 50.001 | 0.380 | 0.00 |
| 53 | 100 | 1 | -60.00 | 50.002 | 0.380 | 0.00 |
| 53 | 100 | 1 | +84.26 | 10.011 | 0.430 | 0.03 |
| 53 | 100 | 1 | -84.26 | 10.012 | 0.430 | 0.03 |

| L002 | | | | | | |
|---|---|---|---|---|---|---|
| Frequency | Voltage | Current | Phase Angle φ | Measured | Uncertainty | $E_n$ |
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] | |
| | | | | | | |
| 53 | 100 | 1 | 0 | 99.999 | 0.004 | -0.17 |
| 53 | 100 | 1 | +36.87 | 79.999 | 0.004 | -0.18 |
| 53 | 100 | 1 | -36.87 | 79.999 | 0.004 | -0.20 |
| 53 | 100 | 1 | +60.00 | 50.000 | 0.004 | -0.04 |
| 53 | 100 | 1 | -60.00 | 50.000 | 0.004 | -0.03 |
| 53 | 100 | 1 | +84.26 | 10.001 | 0.004 | 0.09 |
| 53 | 100 | 1 | -84.26 | 10.002 | 0.004 | 0.18 |

| L003 | | | | | | |
|---|---|---|---|---|---|---|
| Frequency | Voltage | Current | Phase Angle φ | Measured | Uncertainty | $E_n$ |
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] | |
| | | | | | | |
| 53 | 100 | 1 | 0 | 100.002 | 0.125 | 0.01 |
| 53 | 100 | 1 | +36.87 | 79.999 | 0.125 | -0.02 |
| 53 | 100 | 1 | -36.87 | 80.006 | 0.125 | 0.04 |
| 53 | 100 | 1 | +60.00 | 49.998 | 0.125 | -0.02 |
| 53 | 100 | 1 | -60.00 | 50.002 | 0.125 | 0.01 |
| 53 | 100 | 1 | +84.26 | 10.002 | 0.125 | 0.02 |
| 53 | 100 | 1 | -84.26 | 10.002 | 0.125 | 0.02 |

| L004 | | | | | | |
|---|---|---|---|---|---|---|
| Frequency | Voltage | Current | Phase Angle φ | Measured | Uncertainty | $E_n$ |
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] | |
| | | | | | | |
| 53 | 100 | 1 | 0 | 100.002 | 0.021 | 0.05 |
| 53 | 100 | 1 | +36.87 | 80.002 | 0.021 | 0.05 |
| 53 | 100 | 1 | -36.87 | 80.004 | 0.021 | 0.11 |
| 53 | 100 | 1 | +60.00 | 50.002 | 0.021 | 0.06 |
| 53 | 100 | 1 | -60.00 | 50.002 | 0.021 | 0.05 |
| 53 | 100 | 1 | +84.26 | 10.000 | 0.021 | 0.00 |
| 53 | 100 | 1 | -84.26 | 10.001 | 0.021 | 0.04 |

| L005 | | | | | | |
|---|---|---|---|---|---|---|
| Frequency | Voltage | Current | Phase Angle φ | Measured | Uncertainty | $E_n$ |
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] | |
| | | | | | | |
| 53 | 100 | 1 | 0 | 100.019 | 0.020 | 0.80 |
| 53 | 100 | 1 | 36.87 | 80.016 | 0.036 | 0.40 |
| 53 | 100 | 1 | -36.87 | 80.016 | 0.036 | 0.39 |
| 53 | 100 | 1 | 60.00 | 50.009 | 0.023 | 0.34 |
| 53 | 100 | 1 | -60.00 | 50.009 | 0.023 | 0.34 |
| 53 | 100 | 1 | 84.26 | 10.003 | 0.005 | 0.27 |
| 53 | 100 | 1 | -84.26 | 10.000 | 0.005 | -0.01 |

### 4.1.2 Results @ 53 Hz, 100 V, 5 A

| L001 | | | | | | |
|---|---|---|---|---|---|---|
| Frequency | Voltage | Current | Phase Angle φ | Measured Power | Uncertainty | $E_n$ |
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] | |
| | | | | | | |
| 53 | 100 | 5 | 0 | 500.215 | 0.120 | 0.21 |
| 53 | 100 | 5 | +36.87 | 400.235 | 1.300 | 0.06 |
| 53 | 100 | 5 | -36.87 | 400.153 | 1.300 | 0.00 |
| 53 | 100 | 5 | +60.00 | 250.196 | 1.900 | 0.05 |
| 53 | 100 | 5 | -60.00 | 250.067 | 1.900 | -0.02 |
| 53 | 100 | 5 | +84.26 | 50.146 | 2.200 | 0.06 |
| 53 | 100 | 5 | -84.26 | 50.007 | 2.200 | -0.01 |

| L002 | | | | | | |
|---|---|---|---|---|---|---|
| Frequency | Voltage | Current | Phase Angle φ | Measured Power | Uncertainty | $E_n$ |
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] | |
| | | | | | | |
| 53 | 100 | 5 | 0 | 500.186 | 0.020 | -0.08 |
| 53 | 100 | 5 | +36.87 | 400.150 | 0.020 | -0.06 |
| 53 | 100 | 5 | -36.87 | 400.147 | 0.020 | -0.14 |
| 53 | 100 | 5 | +60.00 | 250.094 | 0.020 | 0.06 |
| 53 | 100 | 5 | -60.00 | 250.092 | 0.020 | -0.14 |
| 53 | 100 | 5 | +84.26 | 50.025 | 0.020 | 0.17 |
| 53 | 100 | 5 | -84.26 | 50.022 | 0.020 | -0.03 |

| L003 | | | | | | |
|---|---|---|---|---|---|---|
| Frequency | Voltage | Current | Phase Angle φ | Measured Power | Uncertainty | $E_n$ |
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] | |
| | | | | | | |
| 53 | 100 | 5 | 0 | 500.155 | 0.625 | -0.05 |
| 53 | 100 | 5 | +36.87 | 400.103 | 0.625 | -0.08 |
| 53 | 100 | 5 | -36.87 | 400.133 | 0.625 | -0.03 |
| 53 | 100 | 5 | +60.00 | 250.056 | 0.625 | -0.06 |
| 53 | 100 | 5 | -60.00 | 250.099 | 0.625 | 0.00 |
| 53 | 100 | 5 | +84.26 | 49.991 | 0.625 | -0.04 |
| 53 | 100 | 5 | -84.26 | 50.04 | 0.625 | 0.03 |

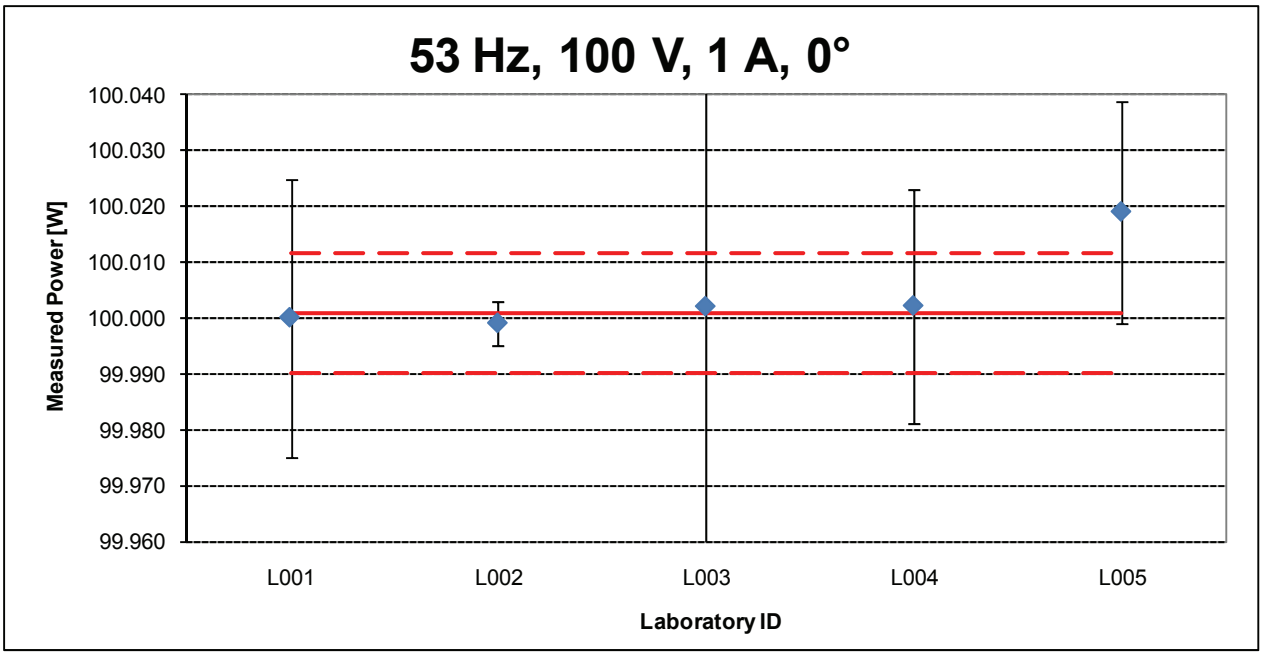
| L004 | | | | | | |
|---|---|---|---|---|---|---|
| Frequency | Voltage | Current | Phase Angle φ | Measured Power | Uncertainty | $E_n$ |
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] | |
| | | | | | | |
| 53 | 100 | 5 | 0 | 500.200 | 0.101 | 0.11 |
| 53 | 100 | 5 | +36.87 | 400.170 | 0.101 | 0.17 |
| 53 | 100 | 5 | -36.87 | 400.166 | 0.101 | 0.13 |
| 53 | 100 | 5 | +60.00 | 250.097 | 0.101 | 0.04 |
| 53 | 100 | 5 | -60.00 | 250.106 | 0.101 | 0.08 |
| 53 | 100 | 5 | +84.26 | 50.015 | 0.101 | -0.04 |
| 53 | 100 | 5 | -84.26 | 50.027 | 0.101 | 0.04 |

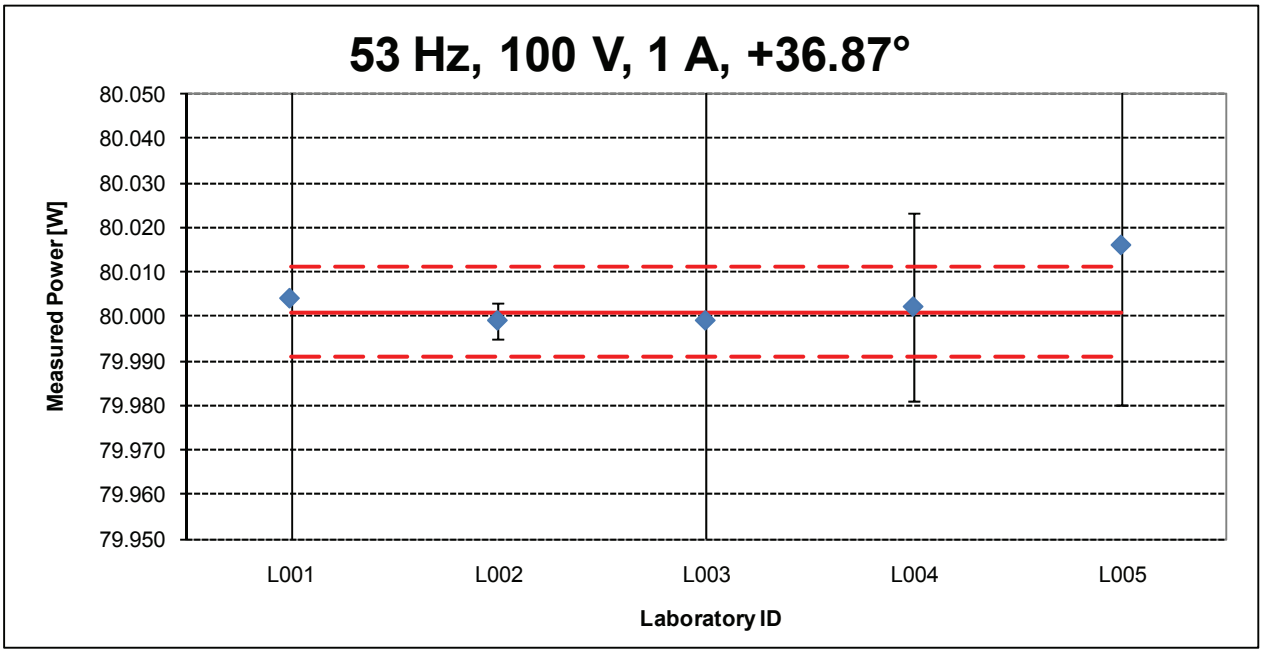
| L005 | | | | | | |
|---|---|---|---|---|---|---|
| Frequency | Voltage | Current | Phase Angle φ | Measured Power | Uncertainty | $E_n$ |
| [Hz] | [V] | [A] | [Degrees °] | [W] | [W] | |
| | | | | | | |
| 53 | 100 | 5 | 0 | 500.269 | 0.101 | 0.76 |
| 53 | 100 | 5 | +36.87 | 400.207 | 0.181 | 0.30 |
| 53 | 100 | 5 | -36.87 | 400.212 | 0.180 | 0.33 |
| 53 | 100 | 5 | +60.00 | 250.128 | 0.113 | 0.31 |
| 53 | 100 | 5 | -60.00 | 250.140 | 0.113 | 0.37 |
| 53 | 100 | 5 | +84.26 | 50.025 | 0.023 | 0.16 |
| 53 | 100 | 5 | -84.26 | 50.036 | 0.023 | 0.34 |

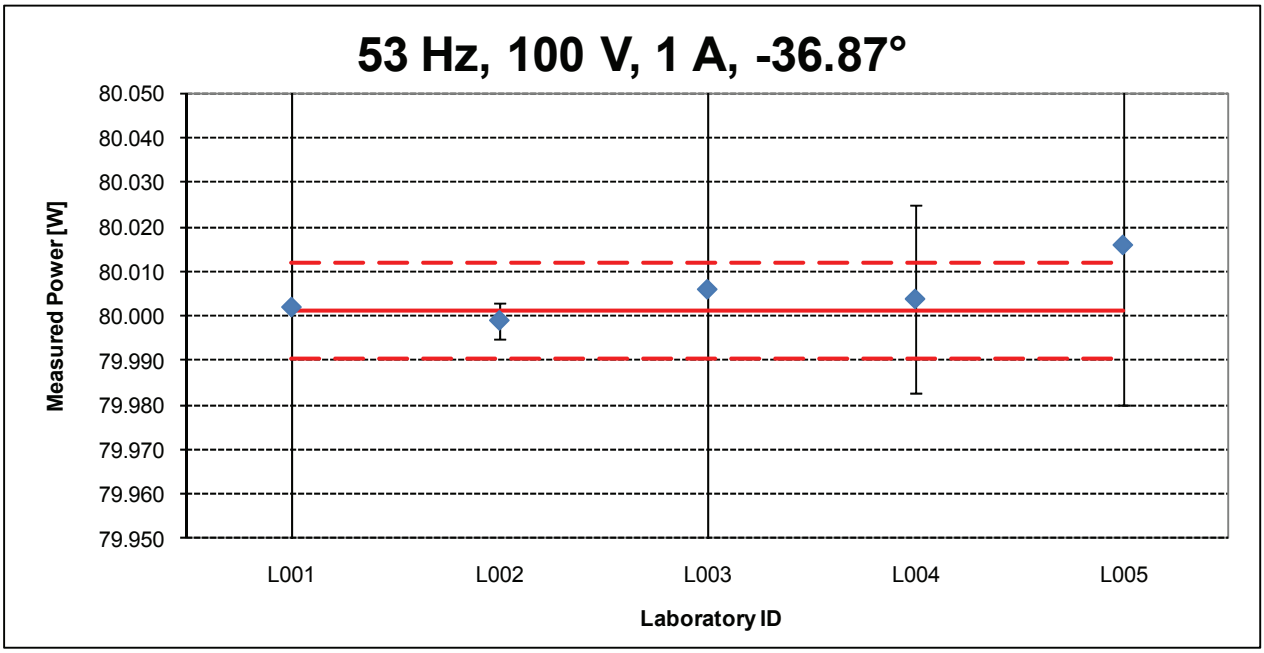
## 4.2 Graphical presentation of the results

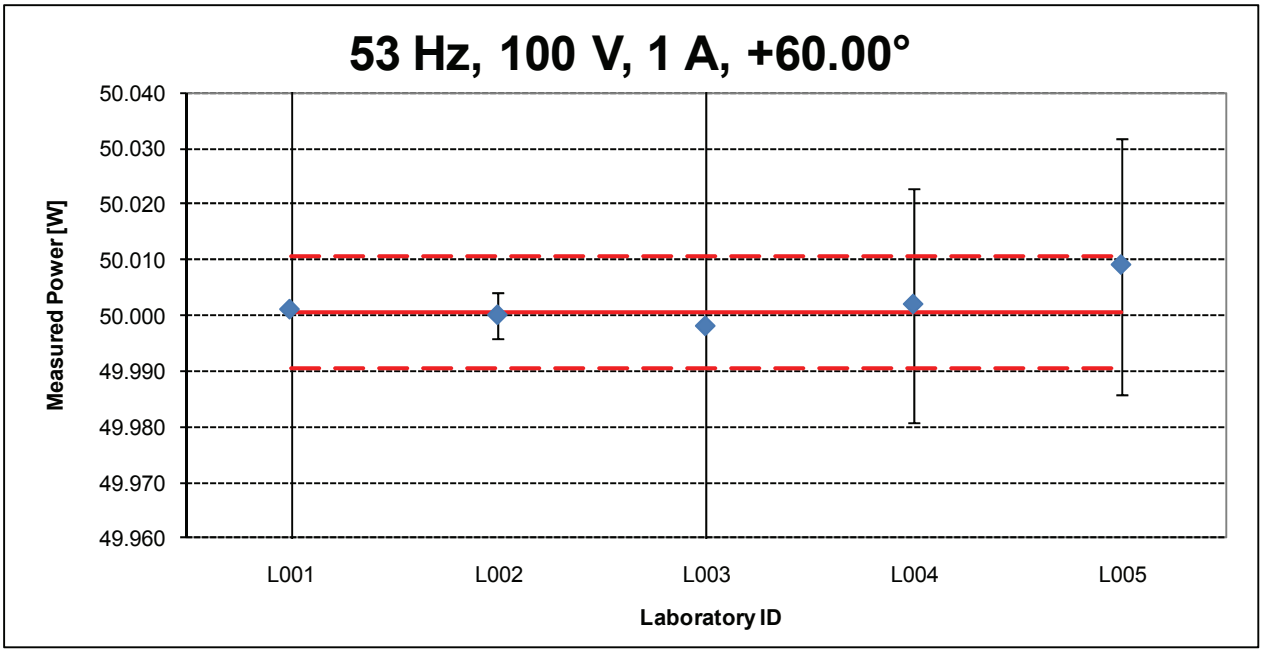
The following graphs provide a quick overview of the results in comparison with the other participants at each measurement point. All uncertainties in the figures are expanded uncertainties at a 95% level of confidence. The reference values in the graphs are presented as the solid red line, and the reference values ± U are presented as the dashed lines.

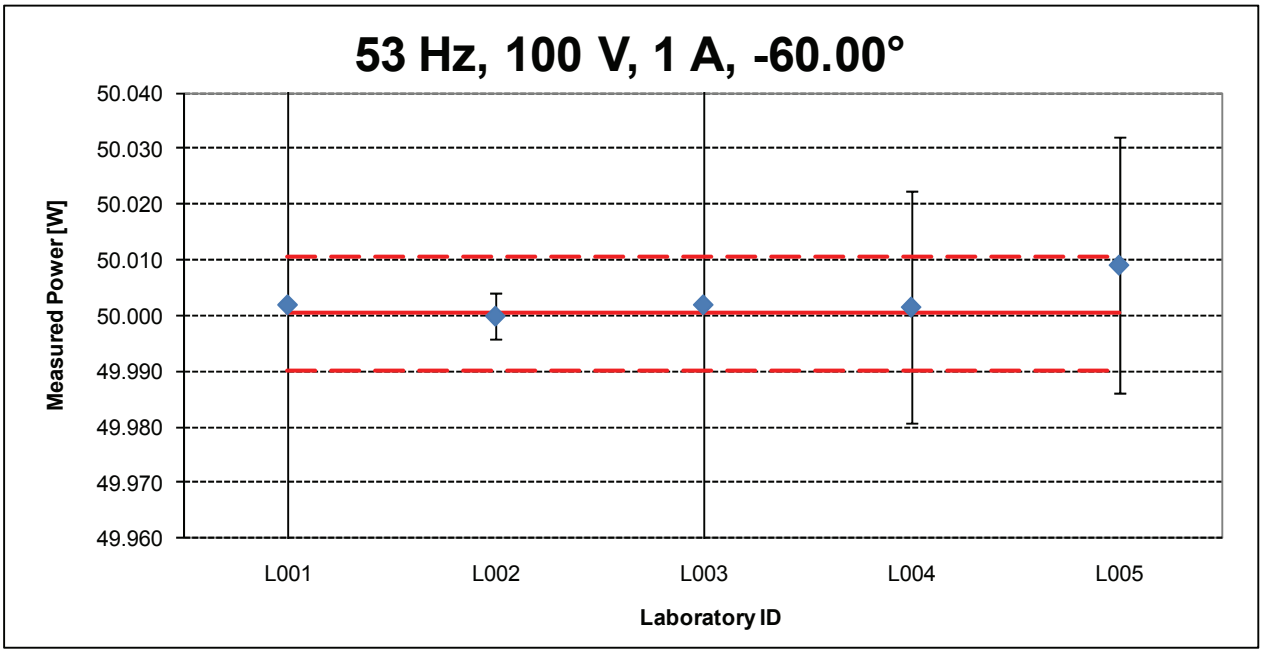
Differences between reported deviations by the participants and the reference value.

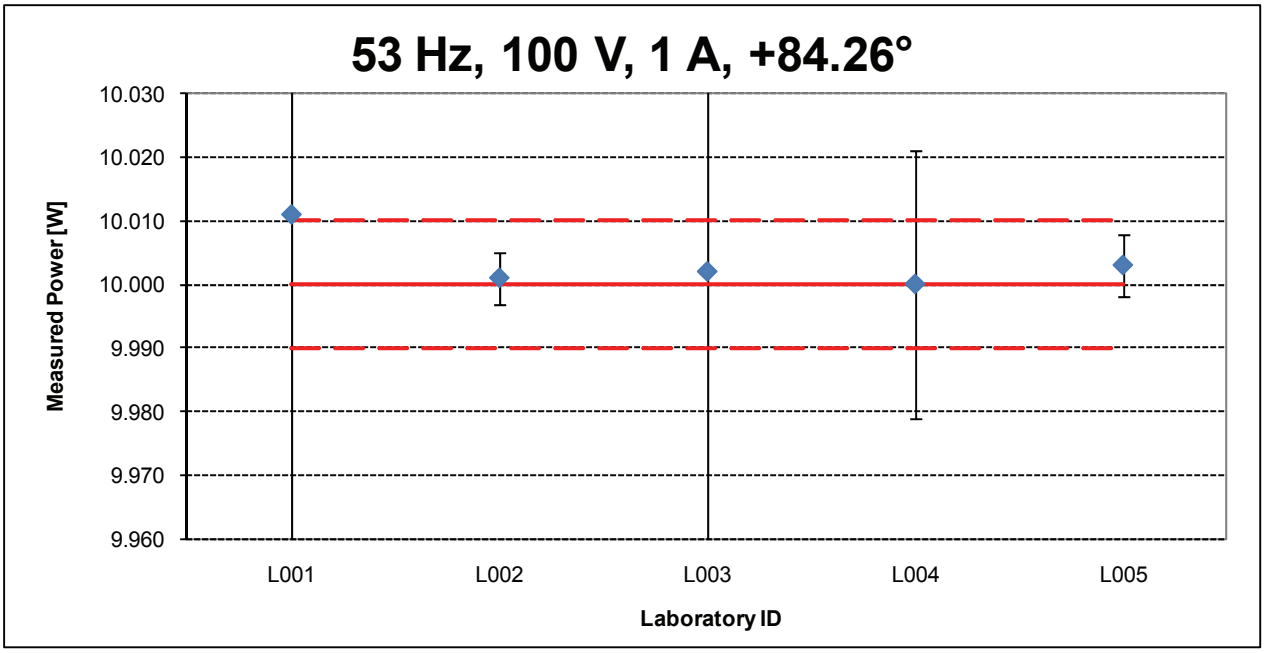


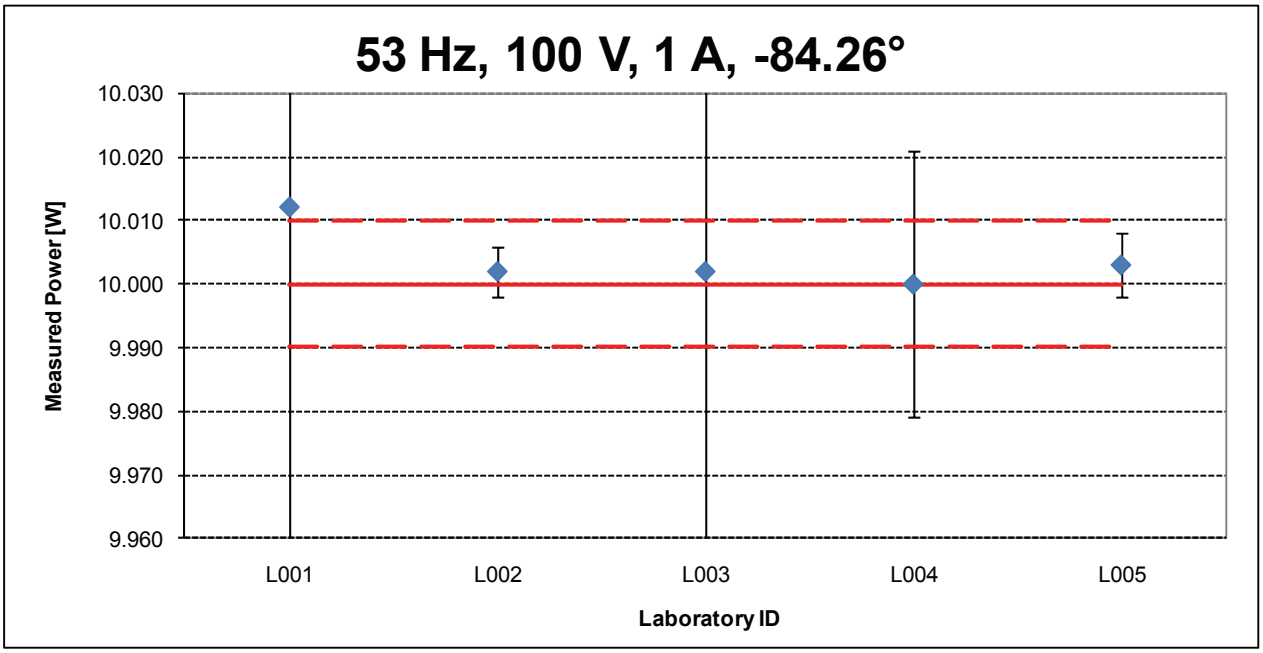



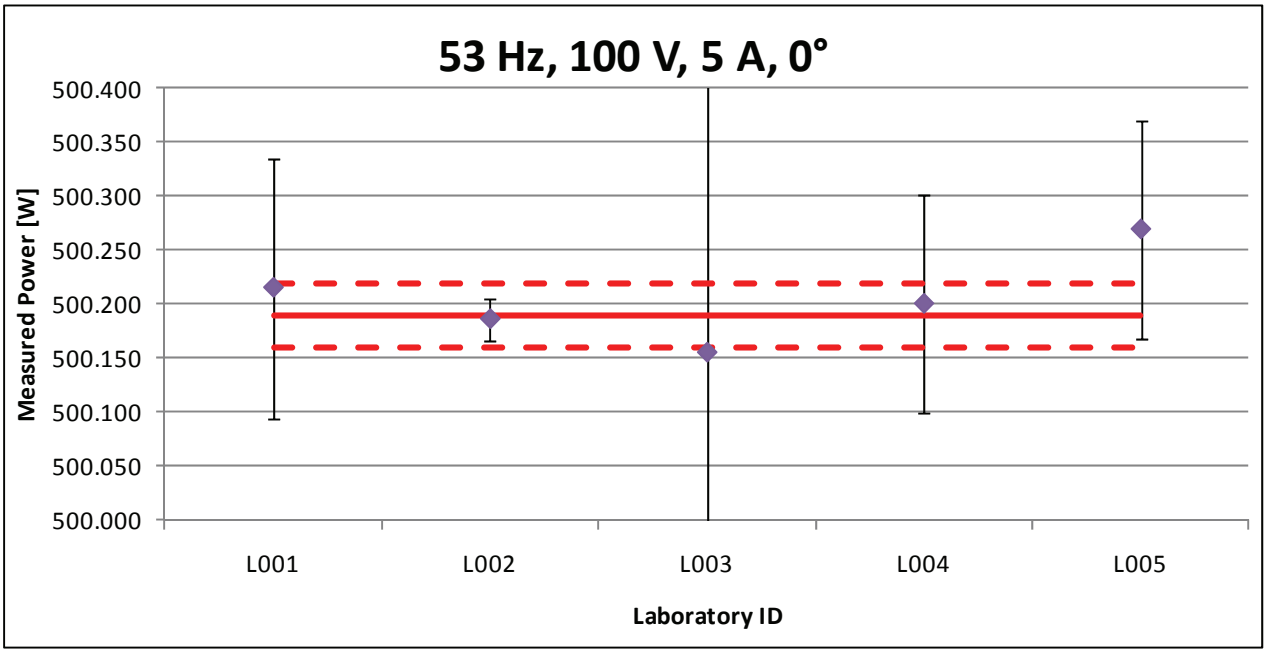

53 Hz, 100 V, 1 A, -36.87°
Measured Power [W]
80.050
80.040
80.030
80.020
80.010
80.000
79.990
79.980
79.970
79.960
79.950
L001
L002
L003
L004
L005
Laboratory ID

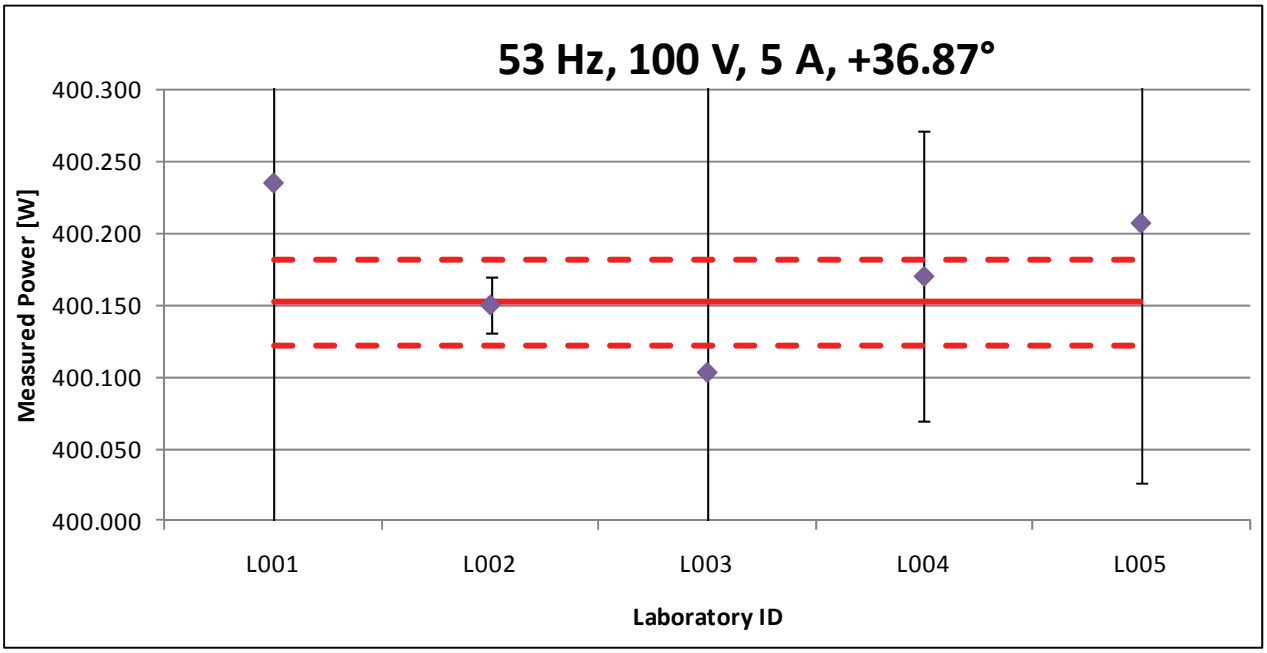

53 Hz, 100 V, 1 A, +60.00°
Measured Power [W]
50.040
50.030
50.020
50.010
50.000
49.990
49.980
49.970
49.960
L001
L002
L003
L004
L005
Laboratory ID

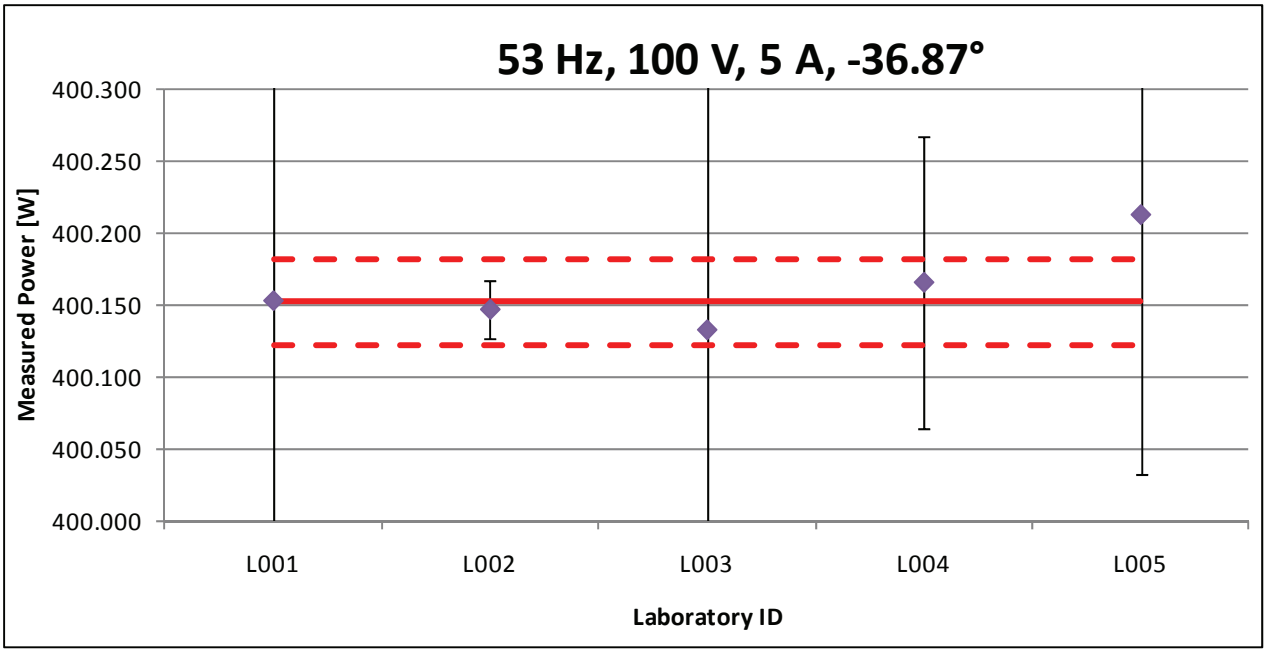

53 Hz, 100 V, 1 A, -60.00°
Measured Power [W]
50.040
50.030
50.020
50.010
50.000
49.990
49.980
49.970
49.960
L001
L002
L003
L004
L005
Laboratory ID

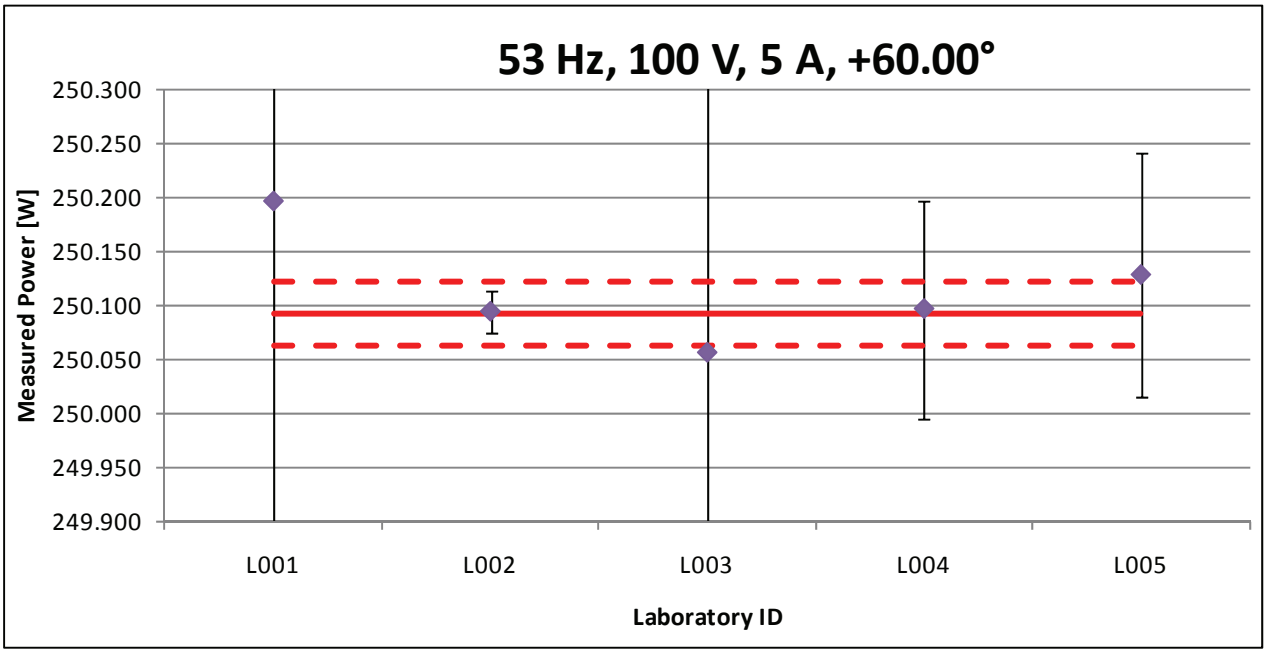

53 Hz, 100 V, 1 A, +84.26°
Measured Power [W]
10.030
10.020
10.010
10.000
9.990
9.980
9.970
9.960
L001
L002
L003
L004
L005
Laboratory ID

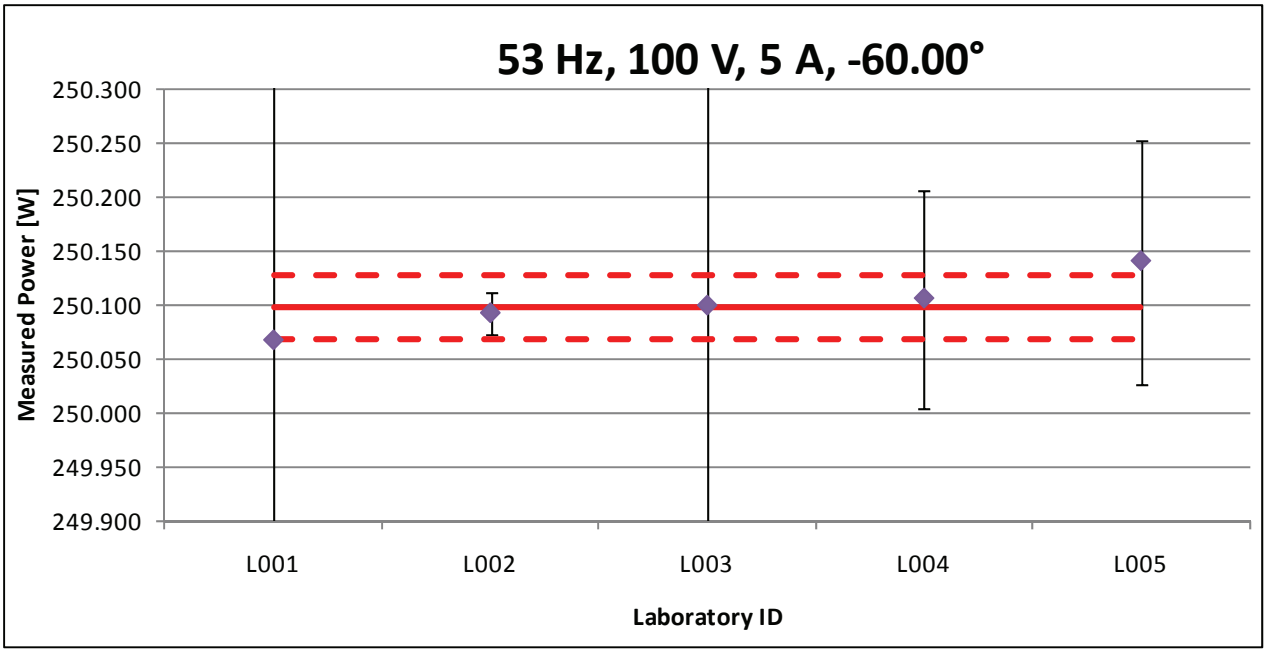

53 Hz, 100 V, 1 A, -84.26°
Measured Power [W]
10.030
10.020
10.010
10.000
9.990
9.980
9.970
9.960
L001
L002
L003
L004
L005
Laboratory ID

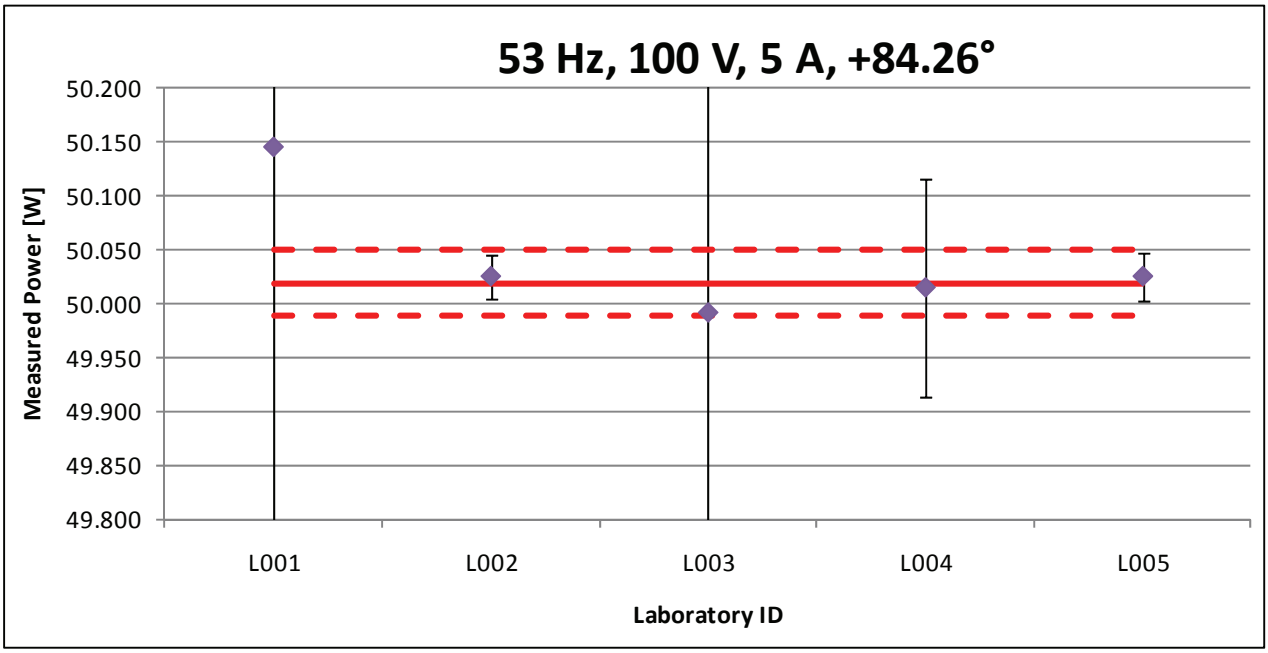

53 Hz, 100 V, 5 A, 0°
Measured Power [W]
500.400
500.350
500.300
500.250
500.200
500.150
500.100
500.050
500.000
L001
L002
L003
L004
L005
Laboratory ID

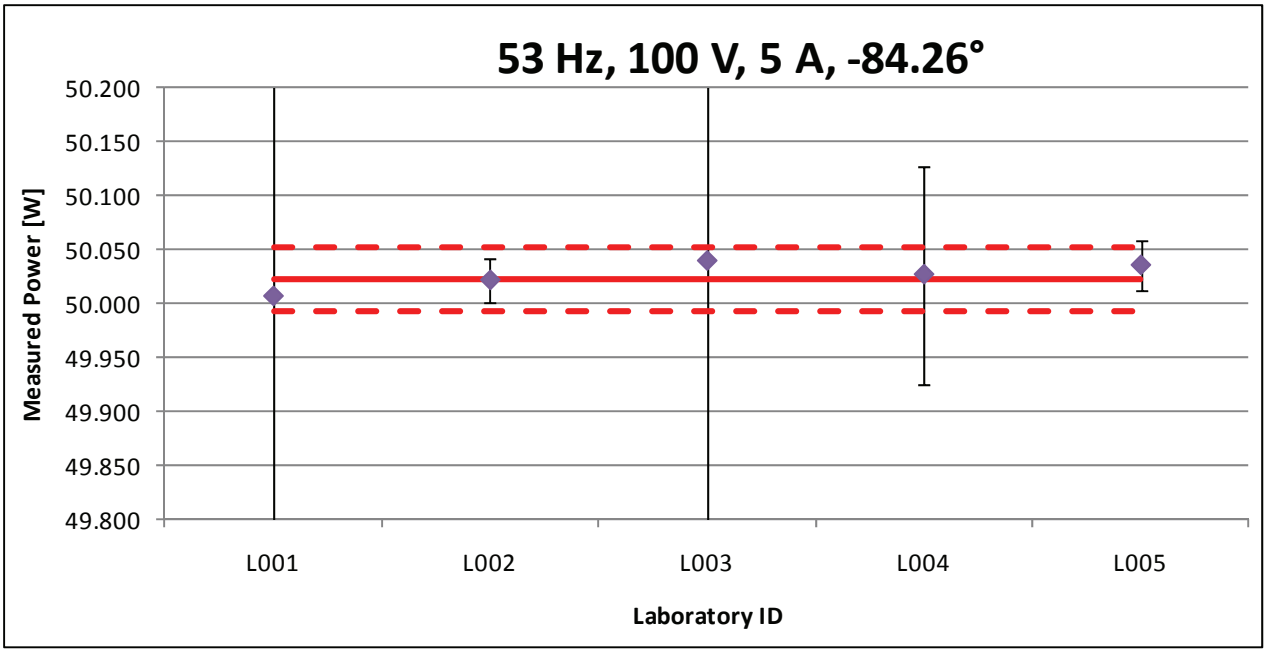

53 Hz, 100 V, 5 A, +36.87°
Measured Power [W]
400.300
400.250
400.200
400.150
400.100
400.050
400.000
L001
L002
L003
L004
L005
Laboratory ID


53 Hz, 100 V, 5 A, -36.87°
Measured Power [W]
400.300
400.250
400.200
400.150
400.100
400.050
400.000
L001
L002
L003
L004
L005
Laboratory ID

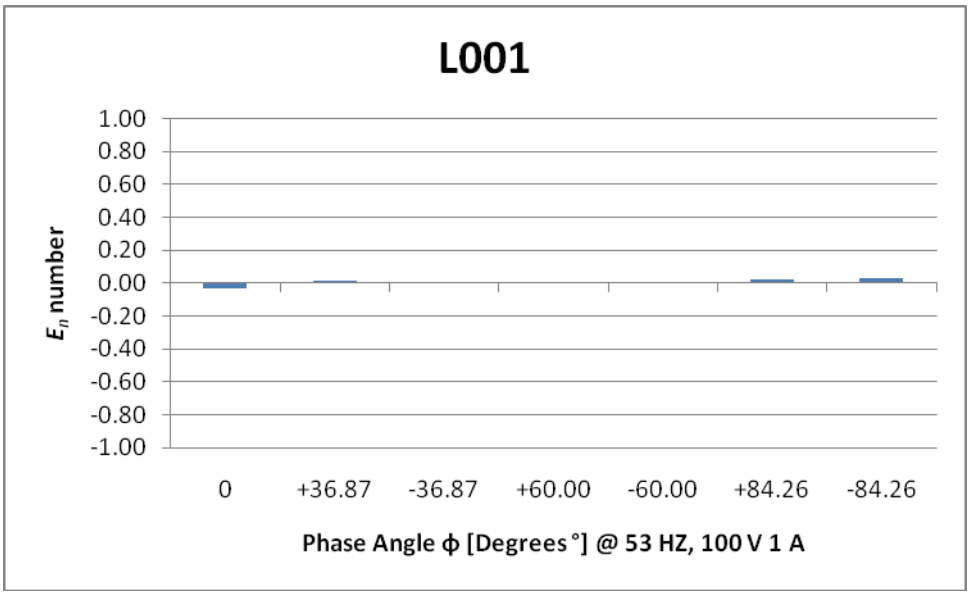

53 Hz, 100 V, 5 A, +60.00°
Measured Power [W]
250.300
250.250
250.200
250.150
250.100
250.050
250.000
249.950
249.900
L001
L002
L003
L004
L005
Laboratory ID

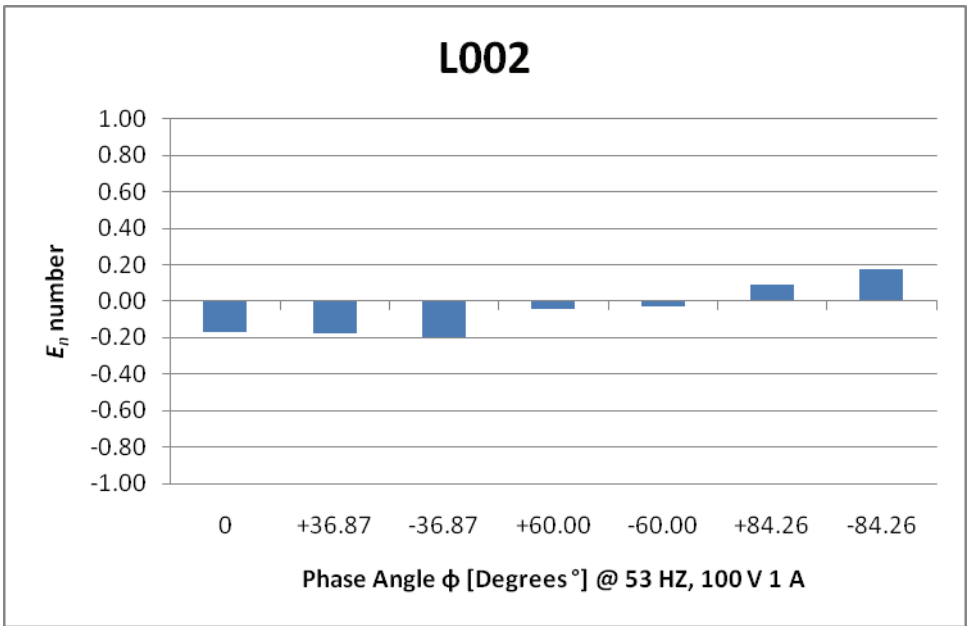

53 Hz, 100 V, 5 A, -60.00°
Measured Power [W]
250.300
250.250
250.200
250.150
250.100
250.050
250.000
249.950
249.900
L001
L002
L003
L004
L005
Laboratory ID

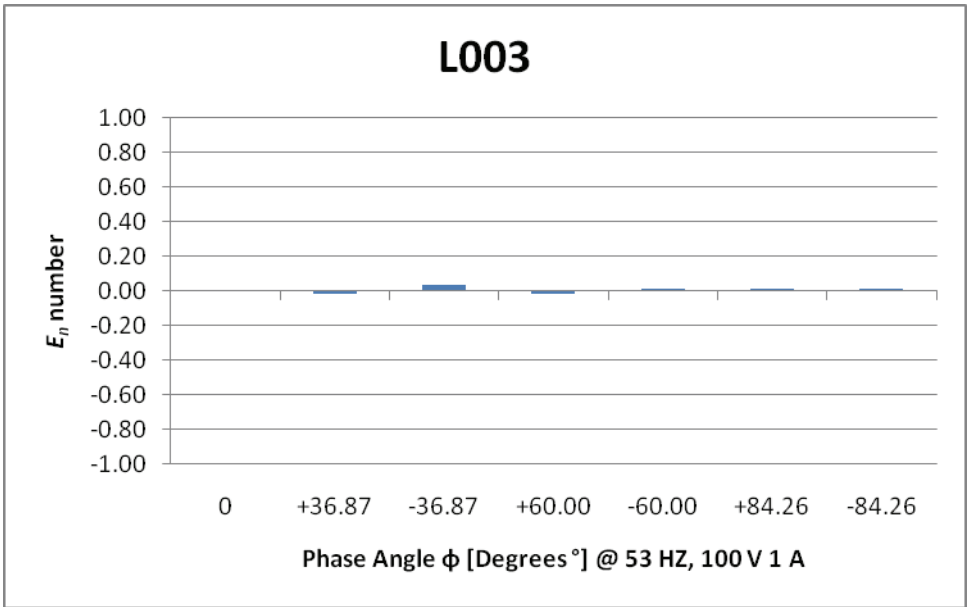

53 Hz, 100 V, 5 A, +84.26°
Measured Power [W]
50.200
50.150
50.100
50.050
50.000
49.950
49.900
49.850
49.800
L001
L002
L003
L004
L005
Laboratory ID

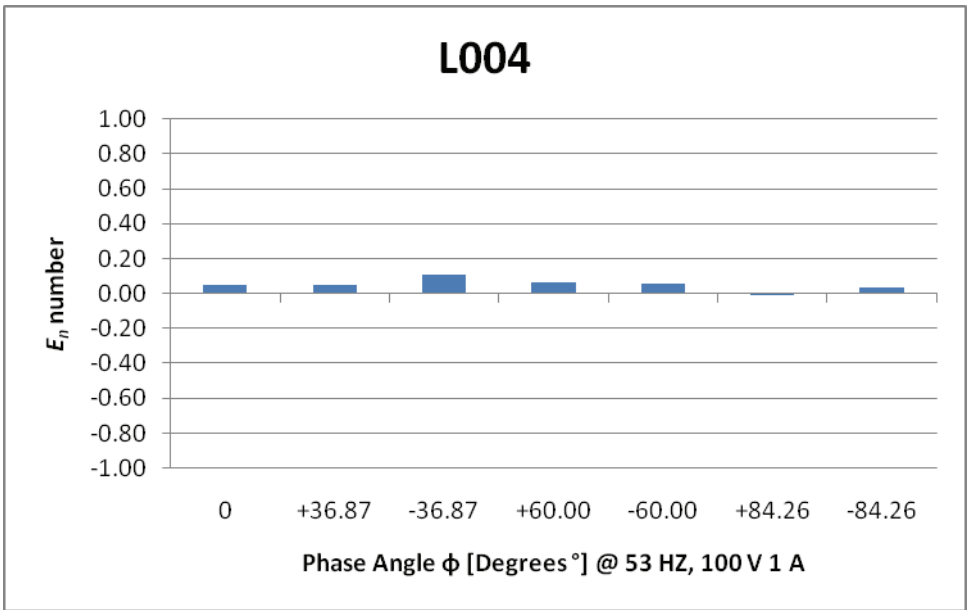

53 Hz, 100 V, 5 A, -84.26°
Measured Power [W]
50.200
50.150
50.100
50.050
50.000
49.950
49.900
49.850
49.800
L001
L002
L003
L004
L005
Laboratory ID

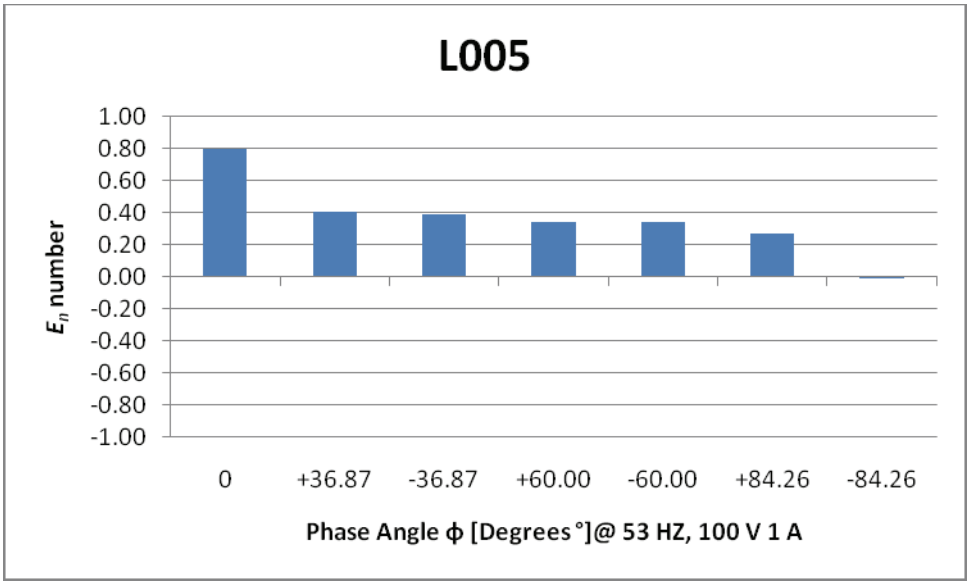
## 4.3 Graphical presentation of the $E_n$ numbers

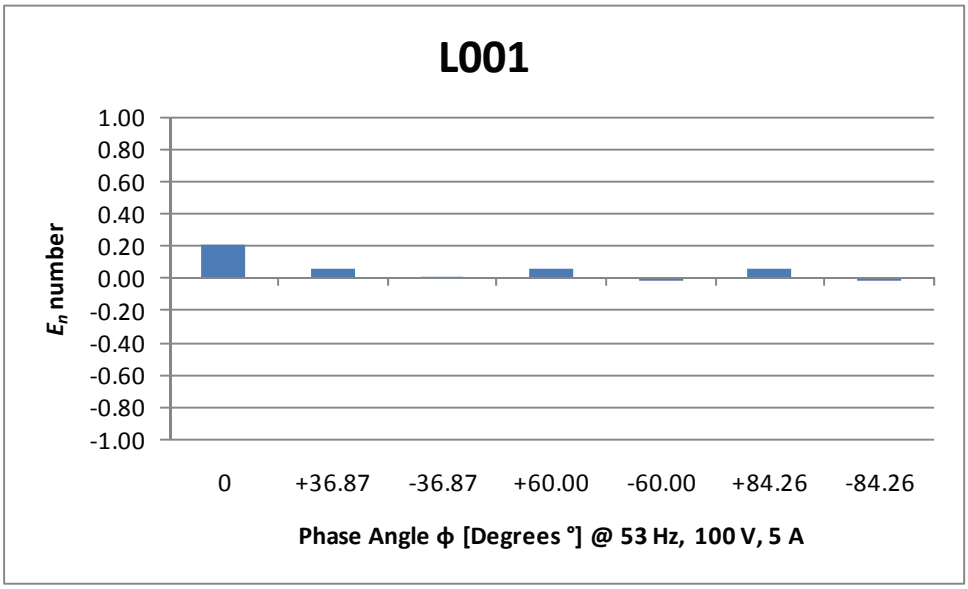


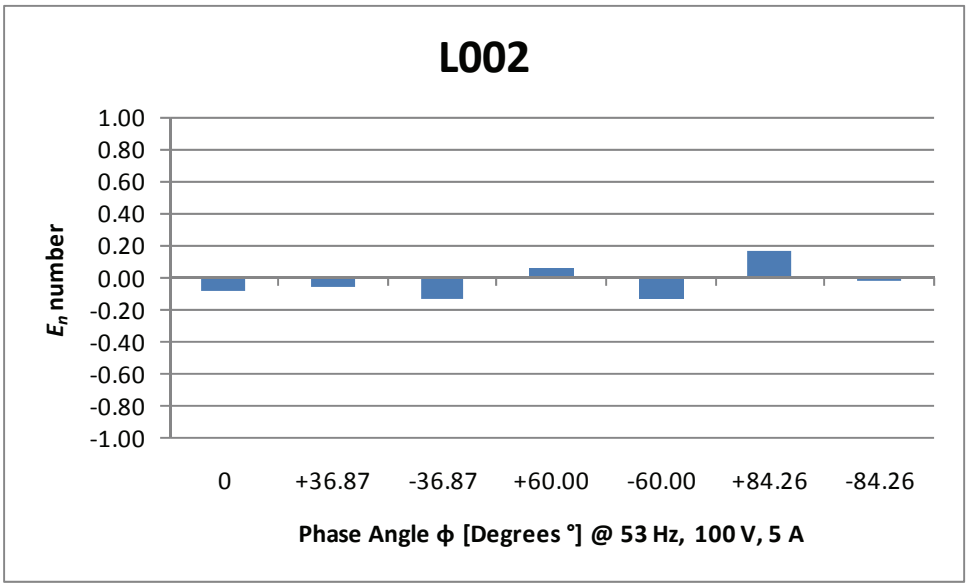



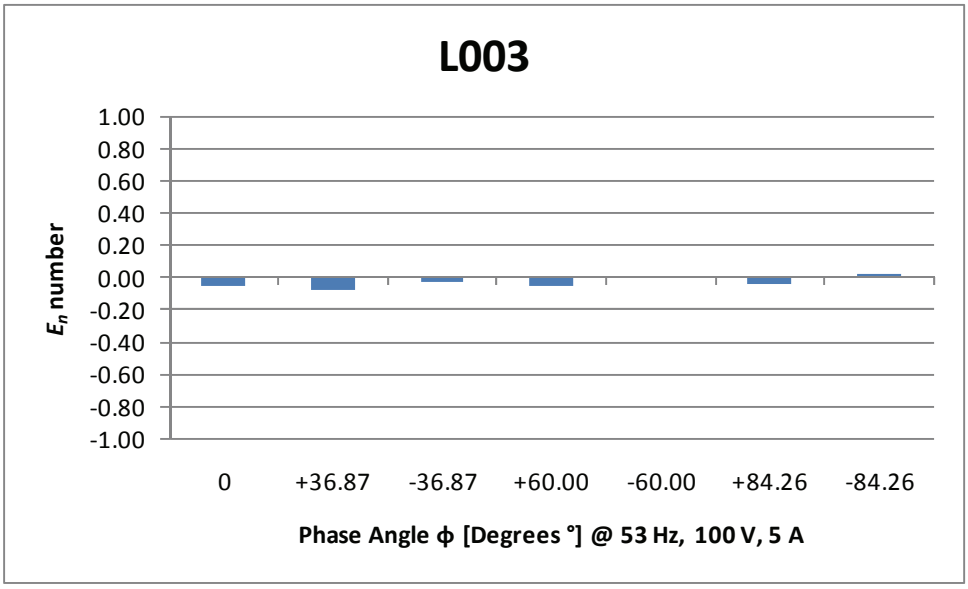

L003
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
$E_n$ number
0
+36.87
-36.87
+60.00
-60.00
+84.26
-84.26
Phase Angle ϕ [Degrees °] @ 53 HZ, 100 V 1 A

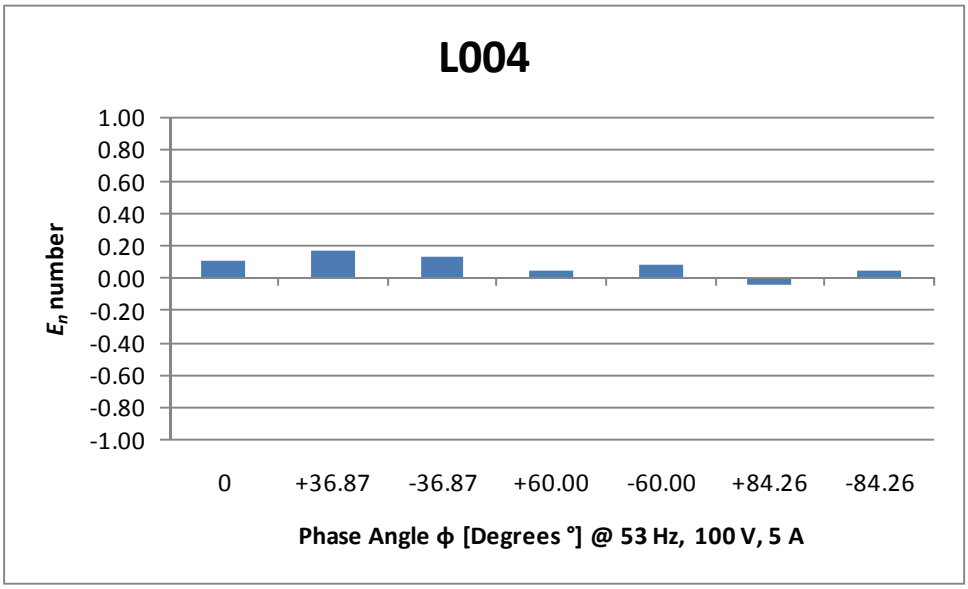

L004
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
$E_n$ number
0
+36.87
-36.87
+60.00
-60.00
+84.26
-84.26
Phase Angle ϕ [Degrees °] @ 53 HZ, 100 V 1 A

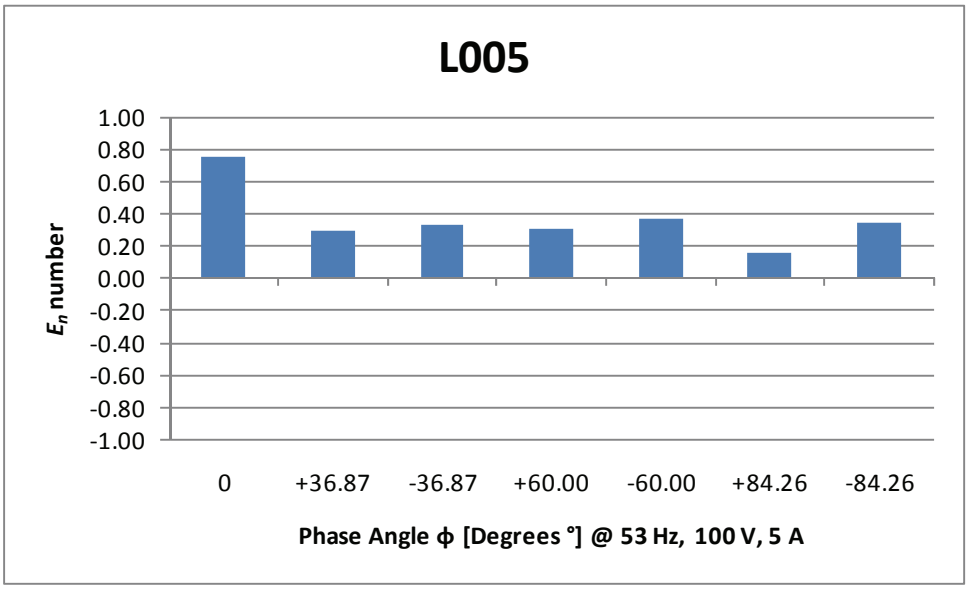

L005
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
$E_n$ number
0
+36.87
-36.87
+60.00
-60.00
+84.26
-84.26
Phase Angle ϕ [Degrees °]@ 53 HZ, 100 V 1 A


L001
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
$E_n$ number
0
+36.87
-36.87
+60.00
-60.00
+84.26
-84.26
Phase Angle ϕ [Degrees °] @ 53 Hz, 100 V, 5 A


L002
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
$E_n$ number
0
+36.87
-36.87
+60.00
-60.00
+84.26
-84.26
Phase Angle ϕ [Degrees °] @ 53 Hz, 100 V, 5 A


L003
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
$E_n$ number
0
+36.87
-36.87
+60.00
-60.00
+84.26
-84.26
Phase Angle ϕ [Degrees °] @ 53 Hz, 100 V, 5 A


L004
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
$E_n$ number
0
+36.87
-36.87
+60.00
-60.00
+84.26
-84.26
Phase Angle ϕ [Degrees °] @ 53 Hz, 100 V, 5 A


L005
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
$E_n$ number
0
+36.87
-36.87
+60.00
-60.00
+84.26
-84.26
Phase Angle ϕ [Degrees °] @ 53 Hz, 100 V, 5 A

# 5 List of participants

To safeguard the anonymity of the participants, a number is used for identification. This number is only known to the pilot and the participating laboratory. Table 3 lists the participant's countries and the number of participants from that country.

*Table 3: List of countries and number of participants*

| Country | Number of participants |
|---|---|
| The Netherlands | 4 |
| Vietnam | 1 |

# 6 Discussion and conclusions

The interlaboratory comparison with SI traceable Interlaboratory Comparison Reference Values enables mutual comparison of the participant's results and a determination of the deviations with respect to the Interlaboratory Comparison Reference Values.

The drift of the instrument has proven to be relatively small over the period of comparison.

All participants have reported the total uncertainty ($k$=2) of their measurements. The performances of the laboratories have been determined based on these uncertainties.

For all of the laboratories, the result of this interlaboratory comparison meets the specified criteria ($E_n \leq 1$) based on the renewed ICRV values and can be considered satisfactory.