Final Report

Bilateral Comparison of 50/60 Hz Energy

SIM.EM-S14

March 2019

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1. Introduction

Under the auspices of the Consultative Committee of Electromagnetism, CCEM the SIM and AFRIMET carried out a supplementary comparison of energy standard at 50/60 Hz, where the CENAMEP AIP was the pilot laboratory. This supplementary comparison, identified as SIM.EM-S14, aims at evaluates the stated uncertainty and degrees of equivalence between CENAMEP AIP-Panamá and NIS-Egypt.

Measurements in this supplementary comparison were conducted from April to June 2018.

2. Participants laboratories

The data of the participant laboratories are listed in Table 1.

Table 1: List of participating laboratories

Organization	Acronym	Country	Contact Person
Centro Nacional de Metrología de Panamá	CENAMEP AIP	Panamá	Julio González
			Carlos Espinosa
National Institute of Standards	NIS	Egypt	Mamdouh Halawa

3. Reference standard

The standard utilized in the bilateral comparison was a Radian Research RD-23-433 single-phase reference standard aims at providing a worst-case accuracy of ± 0.01 % for all measurements functions.

For the bilateral comparison, CENAMEP AIP supplied the traveling standard with the following characteristics:

RD-23-433	
Manufacturer	Radian Research. Inc.
Input current	0.2 A to 67 A
Input voltage	30 V to 630 V, auto ranging
Frequency	45 Hz to 75 Hz
Phase angle	0° to 360°
Power factor	1 to 0 lead, lag
Energy constant K_h	0.00001 Wh/pulse
Temperature	20 °C to 30 °C
Humidity	0% to 95 % non-condensing
Auxiliary power	120 V- 240 V, 50 Hz – 60 Hz

4. Quantities to be measured

Table 2 shows the testing points for the SIM.EM-S14 which were agreed by the participants.

The expression of measurement results and their associated uncertainty are given in terms of µWh/VAh, for active energy.

Table 2: Test point

Parameter	Active energy
RMS voltage	120 V
RMS current	5 A
Power factor	1.0 and 0.5 lead/lag
Frequencies	50 and 60 Hz

5. Circulation and date of measurements

The travelling standard was measured first at NIS and then at CENAMEP AIP according to the dates of Table 3.

Table 3: Dates of measurement of the travelling standard

Acronym	Date
NIS	April 4 to 19, 2018
CENAMEP AIP	May 22 to June 8, 2018

6. Calibration Methods and Traceability of Results Reported by Participants.

For the calibration of the RD-23-433, both laboratories used their own facilities, instruments and methods. Each laboratory determined the errors and their associated uncertainties for the traveling standard.

Both laboratories used a measurement system, based on the direct comparison of emitted pulses between the device under calibration and those issued by a reference standard. The reference through an internal comparator pulse compares the signals and the difference; represent it as an error of the equipment under calibration.

Table 4 lists the calibration methods and the reference standards used in this bilateral comparison, as well as the source of traceability. The reader may refer to Appendix A for more information.

Table 4: Calibration methods, reference standards and traceability

Acronym	Method	Standard	Traceability
NIS	Direct Comparison	3-Phase Comparator ZERA, Type COM 3003 Serial Number: 98-717-1	UME, Turkish
CENAMEP AIP	Direct Comparison	3-Phase Comparator ZERA, Type COM 3003 Serial Number: 050037106	PTB - Germany

7. Measurement results

For each test point, described in Table 2, the participant laboratories measured the standard RD-23-433, calculated the errors and associated uncertainties.

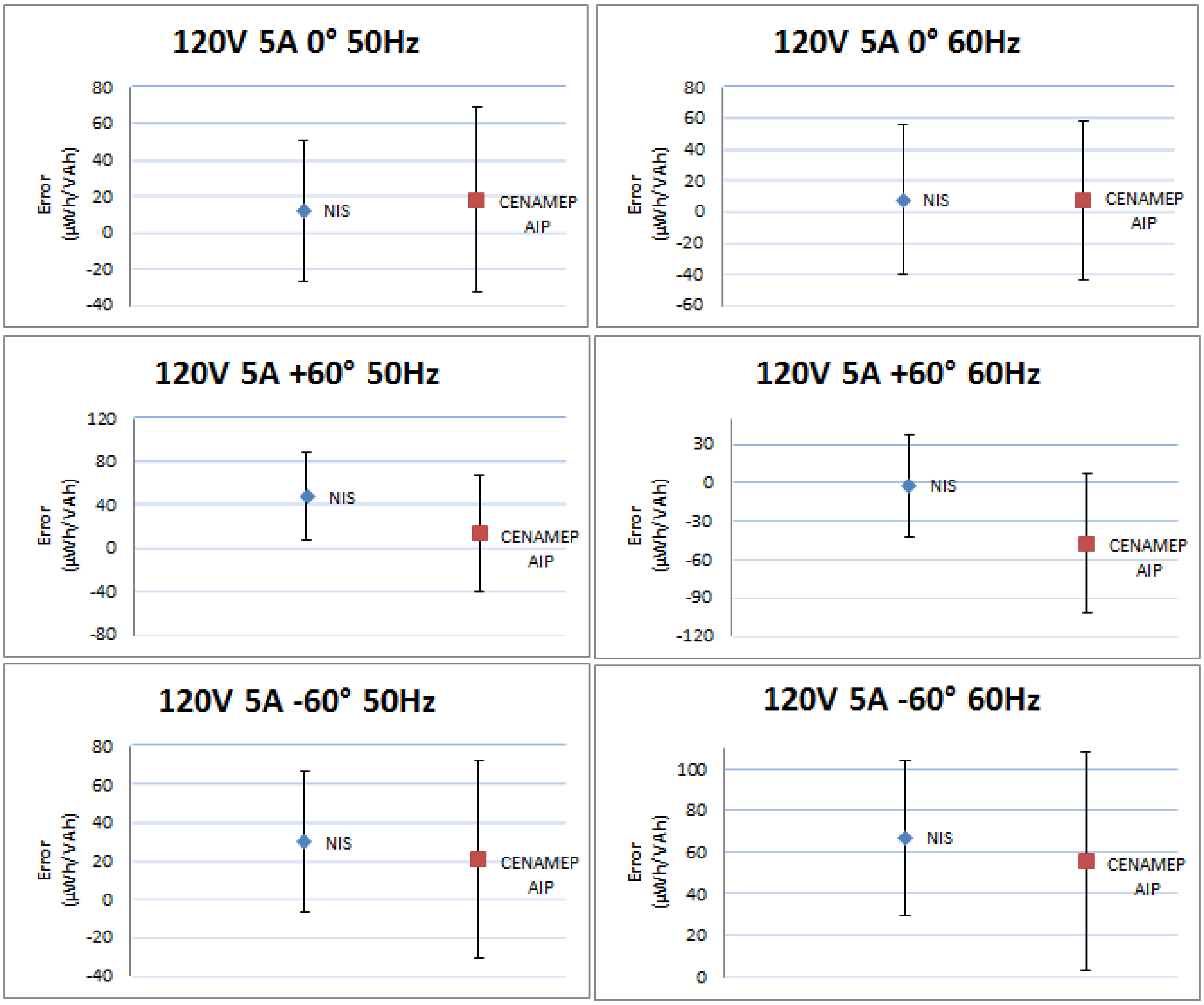
Errors and their associated uncertainties reported by participants are listed in Table 5.

Table 5: Errors and uncertainties reported by laboratories, expressed in (µWh/VAh.)

Active Energy Reference Standard RD-23-433		Error			Uncertainty (k = 2)		
		0°	+60°	-60°	0°	+60°	-60°
50 Hz	NIS	12	48	30	39	41	37
	CENAMEP AIP	18	14	21	51	54	52
60 Hz	NIS	8	-2	67	48	40	37
	CENAMEP AIP	8	-47	56	51	54	52

Note: For the Table 5 and the following graphs, 0° represent a unity power factor; +60° a capacitive power factor and -60° represent an inductive power factor.

The measurement results reported by the participants of this bilateral comparison are viewed in the following graphs.



8. Degree of equivalence between participants

The degree of equivalence among participant laboratories was calculated as the difference between the values reported by participants.

$$D_{CENAMEP-NIS} = X_{CENAMEP} - X_{NIS} \qquad [1]$$

with the expanded uncertainty as follows,

$$U(D_{CENAMEP-NIS}) = \sqrt{U^2(X_{CENAMEP}) + U^2(X_{NIS})} \qquad [2]$$

From this difference and corresponding uncertainty, the normalized errors were calculated for each nominal values as follows:

$$E_n = \frac{|D_{CENAMEP-NIS}|}{U(D_{CENAMEP-NIS})} \qquad [3]$$

In the Table 6 are listed the degrees of equivalence between CENAMEP AIP and NIS for the measurements done in this bilateral comparison.

Table 6: Degree of equivalence between CENAMEP AIP and NIS

Voltage (V)	**Current (A)**	**Angle (°)**	**Frequency (Hz)**	**Difference CENAMEP- NIS** $D_{CENAMEP-NIS}$ **(µWh/VAh)**	**Expanded uncertainty** $U(D_{CENAMEP-NIS})$ **(µWh/VAh)**	**Normalized Error** E_n
120	5	0	50	0	70	**0.0**
		+60		-11	64	**0.2**
		-60		-45	67	**0.7**
		0	60	6	64	**0.1**
		+60		-9	64	**0.1**
		-60		-34	68	**0.5**

Note: For the Table 6, 0° represent a unity power factor; +60° a capacitive power factor and -60° represent an inductive power factor.

9. Conclusions

The main objective of this bilateral comparison was to evaluate the stated uncertainty offered by NIS-Egypt in the calibration of energy standards by direct comparison methods, and evaluate the degree of equivalence between both laboratories.

In order to reach such objectives, one energy standard (Radian Research, RD-23-433) was measured in both laboratories from April to June, 2018. Each laboratory used by measurement their own facilities, procedures and measurement system.

From results reported by participants (see Table 5), there were calculated the normalized errors. In the Table 6, it can be noted that results reported by both participants are consistent within the reported uncertainty, where, the largest normalized error calculated for this comparison was 0.7.

10. References

- T. Nelson, N. F. Zhang and T. Nelson, “SIM International Comparison of 50/60 Hz Energy (2002-2007)”. Metrologia 40. Tech. Sup. 01009.
- SIM.EM-S7 Supplementary Comparison 50/60 Hz Energy Protocol; May 2010.
- Measurement Comparisons in the CIPM MRA; CIPM MRA-D-05; March,2016
- Evaluation of measurement data – Guide to the expression of uncertainty in measurement, BIPM JCGM 100:2008.

11. Appendix

Appendix A. Measurement methods

A.1 Measurement standard at CENAMEP AIP, Panama

CENAMEP AIP measurement system, is based on the direct comparison of emitted pulses between the equipment under calibration and those issued by the reference standard ZERA, type COM 3003.

The reference, through an internal pulse comparator, compares the signals and the difference represent it as an error of the equipment under calibration.

Prior to the bilateral comparison of energy, the reference standard (COM 3003) was calibrated at PTB, Germany (certificate # 20958PTB17).

A.2 Measurement standard at NIS, Egypt

NIS measurement system is based on the direct comparison of emitted pulses between the device under calibration and those issued by the reference standard (COM303, ZERA). The reference, through an internal pulse comparator, compares the signals and the difference represents it as an error of the equipment under calibration.

The traveling standard was measured directly against NIS´s measurement system, which is traceable to SI unit through the calibration certificate # 2017.02056, issued by UME, Turkish in November 2017.

The measured value of the error displayed by the traveling standard was recorded in a PC using the internal software of NIS’s system.

The system setup and operation principle of this measurement, as shown in Figure 1.

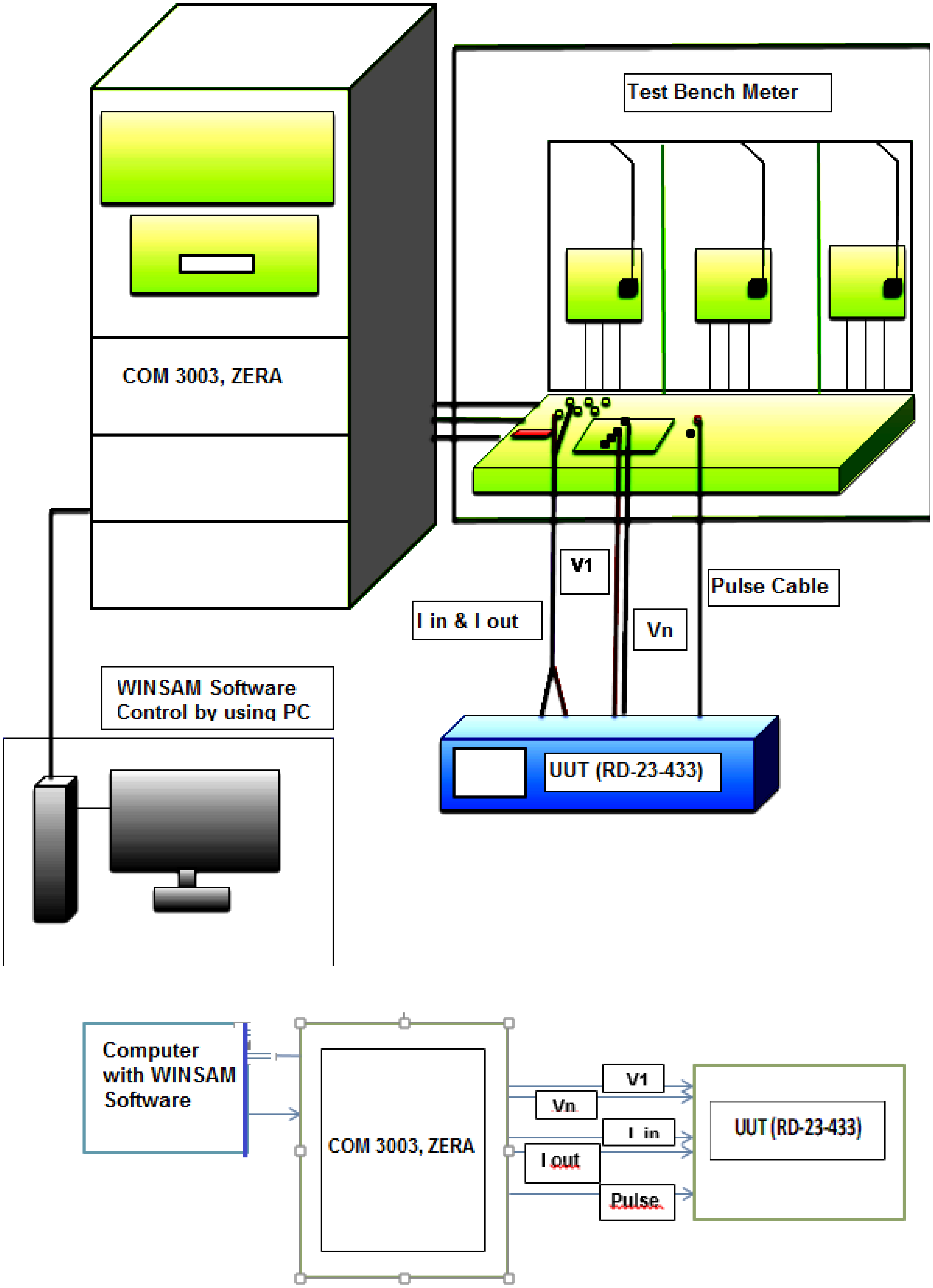


Figure 1: System Setup using COM 3003, ZERA

Appendix B. Uncertainty Budget

B.1 Uncertainty Budget - CENAMEP AIP, Panama

120V 5A Fp=1 60Hz							
Main Uncertainty Components (yi)	**Standard Uncertainty u(yi)**		**Type method A or B of evaluation/probability distribution function**	**Sensitivity coefficient Ci**	**Uncertainty contribution u(Ri)**		**Degrees of freedom ni**
Desviation of the readings of traveling standard	0.2	µWh/VAh	Type A (Normal)	1	0.2	µWh/VAh	224
Standard calibration uncertainty	25.0	µWh/VAh	Type B (Normal)	1	25.0	µWh/VAh	1000
Resolution of Standard	0.6	µWh/VAh	Type B (Rectangular)	1	0.6	µWh/VAh	1000
Drift of Standard	5.8	µWh/VAh	Type B (Rectangular)	1	5.8	µWh/VAh	1000
Standard temperature coefficient	0.0	µWh/VAh	Type B (Rectangular)	1	0.0	µWh/VAh	1000
Root square sum of type A standard uncertainties and effective degrees of freedom					0	µWh/VAh	6
Root square sum of type B standard uncertainties and effective degrees of freedom					26	µWh/VAh	658667
Combined standard uncertainty and effective degrees of freedom					26	µWh/VAh	658602
Expanded uncertainty (95.45% coverage factor)					51	µWh/VAh	2.0

120V 5A Fp=0.5 Ind. 60Hz							
Main Uncertainty Components (yi)	**Standard Uncertainty u(yi)**		**Type method A or B of evaluation/probability distribution function**	**Sensitivity coefficient Ci**	**Uncertainty contribution u(Ri)**		**Degrees of freedom ni**
Desviation of the readings of traveling standard	0.3	µWh/VAh	Type A (Normal)	1	0.3	µWh/VAh	224
Standard calibration uncertainty	25.0	µWh/VAh	Type B (Normal)	1	25.0	µWh/VAh	1000
Resolution of Standard	0.6	µWh/VAh	Type B (Rectangular)	1	0.6	µWh/VAh	1000
Drift of Standard	7.5	µWh/VAh	Type B (Rectangular)	1	7.5	µWh/VAh	1000
Standard temperature coefficient	0.0	µWh/VAh	Type B (Rectangular)	1	0.0	µWh/VAh	1000
Root square sum of type A standard uncertainties and effective degrees of freedom					0	µWh/VAh	19
Root square sum of type B standard uncertainties and effective degrees of freedom					26	µWh/VAh	681667
Combined standard uncertainty and effective degrees of freedom					26	µWh/VAh	681459
Expanded uncertainty (95.45% coverage factor)					52	µWh/VAh	2.0

120V 5A Fp=0.5 60Hz Cap.							
Main Uncertainty Components (yi)	**Standard Uncertainty u(yi)**		**Type method A or B of evaluation/probability distribution function**	**Sensitivity coefficient Ci**	**Uncertainty contribution u(Ri)**		**Degrees of freedom ni**
Desviation of the readings of traveling standard	0.4	µWh/VAh	Type A (Normal)	1	0.4	µWh/VAh	224
Standard calibration uncertainty	25.0	µWh/VAh	Type B (Normal)	1	25.0	µWh/VAh	1000
Resolution of Standard	0.6	µWh/VAh	Type B (Rectangular)	1	0.6	µWh/VAh	1000
Drift of Standard	9.8	µWh/VAh	Type B (Rectangular)	1	9.8	µWh/VAh	1000
Standard temperature coefficient	0.0	µWh/VAh	Type B (Rectangular)	1	0.0	µWh/VAh	1000
Root square sum of type A standard uncertainties and effective degrees of freedom					0	µWh/VAh	45
Root square sum of type B standard uncertainties and effective degrees of freedom					27	µWh/VAh	721667
Combined standard uncertainty and effective degrees of freedom					27	µWh/VAh	721170
Expanded uncertainty (95.45% coverage factor)					54	µWh/VAh	2.0

120V 5A Fp=1 50Hz							
Main Uncertainty Components (yi)	**Standard Uncertainty u(yi)**		**Type method A or B of evaluation/probability distribution function**	**Sensitivity coefficient Ci**	**Uncertainty contribution u(Ri)**		**Degrees of freedom ni**
Desviation of the readings of traveling standard	0.2	µWh/VAh	Type A (Normal)	1	0.2	µWh/VAh	224
Standard calibration uncertainty	25.0	µWh/VAh	Type B (Normal)	1	25.0	µWh/VAh	1000
Resolution of Standard	0.6	µWh/VAh	Type B (Rectangular)	1	0.6	µWh/VAh	1000
Drift of Standard	5.8	µWh/VAh	Type B (Rectangular)	1	5.8	µWh/VAh	1000
Standard temperature coefficient	0.0	µWh/VAh	Type B (Rectangular)	1	0.0	µWh/VAh	1000
Root square sum of type A standard uncertainties and effective degrees of freedom					0	µWh/VAh	7
Root square sum of type B standard uncertainties and effective degrees of freedom					26	µWh/VAh	658667
Combined standard uncertainty and effective degrees of freedom					26	µWh/VAh	658589
Expanded uncertainty (95.45% coverage factor)					51	µWh/Wh	2.0

120V 5A Fp=0.5 Ind. 50Hz							
Main Uncertainty Components (yi)	**Standard Uncertainty u(yi)**		**Type method A or B of evaluation/probability distribution function**	**Sensitivity coefficient Ci**	**Uncertainty contribution u(Ri)**		**Degrees of freedom ni**
Desviation of the readings of traveling standard	0.3	µWh/VAh	Type A (Normal)	1	0.3	µWh/VAh	224
Standard calibration uncertainty	25.0	µWh/VAh	Type B (Normal)	1	25.0	µWh/VAh	1000
Resolution of Standard	0.6	µWh/VAh	Type B (Rectangular)	1	0.6	µWh/VAh	1000
Drift of Standard	7.5	µWh/VAh	Type B (Rectangular)	1	7.5	µWh/VAh	1000
Standard temperature coefficient	0.0	µWh/VAh	Type B (Rectangular)	1	0.0	µWh/VAh	1000
Root square sum of type A standard uncertainties and effective degrees of freedom					0	µWh/VAh	25
Root square sum of type B standard uncertainties and effective degrees of freedom					26	µWh/VAh	681667
Combined standard uncertainty and effective degrees of freedom					26	µWh/VAh	681391
Expanded uncertainty (95.45% coverage factor)					52	µWh/VAh	2.0

120V 5A Fp=0.5 Cap. 50Hz							
Main Uncertainty Components (yi)	**Standard Uncertainty u(yi)**		**Type method A or B of evaluation/probability distribution function**	**Sensitivity coefficient Ci**	**Uncertainty contribution u(Ri)**		**Degrees of freedom ni**
Desviation of the readings of traveling standard	0.6	µWh/VAh	Type A (Normal)	1	0.6	µWh/VAh	224
Standard calibration uncertainty	25.0	µWh/VAh	Type B (Normal)	1	25.0	µWh/VAh	1000
Resolution of Standard	0.6	µWh/VAh	Type B (Rectangular)	1	0.6	µWh/VAh	1000
Drift of Standard	9.8	µWh/VAh	Type B (Rectangular)	1	9.8	µWh/VAh	1000
Standard temperature coefficient	0.0	µWh/VAh	Type B (Rectangular)	1	0.0	µWh/VAh	1000
Root square sum of type A standard uncertainties and effective degrees of freedom					1	µWh/VAh	68
Root square sum of type B standard uncertainties and effective degrees of freedom					27	µWh/VAh	721667
Combined standard uncertainty and effective degrees of freedom					27	µWh/VAh	720922
Expanded uncertainty (95.45% coverage factor)					54	µWh/VAh	2.0

B.2 Uncertainty Budget NIS, Egypt

Uncertainty Budget for PF = 1 @ 50 Hz (for k = 2)

Main uncertainty components (yi)	Standard uncertainty u(yi)		Type method A or B of evaluation/probability distribution function	Sensitivity coefficient Ci	Uncertainty contribution u(Ri)		Degrees of freedom ni
Readings repeatability of traveling standard	0.6	µWh/VAh	TypeA / Normal	1	0.6	µWh/VAh	9
Standard calibration uncertainty of NIS	15	µWh/VAh	TypeB / Normal	1	15	µWh/VAh	∞
Resolution of traveling standard	0.3	µWh/VAh	TypeB / Rectangular	1	0.3	µWh/VAh	∞
Drift of NIS standard since last calibration	0.4	µWh/VAh	TypeB / Rectangular	1	0.4	µWh/VAh	∞
Effect of change in the applied frequency (50 - 53) Hz	7	µWh/VAh	TypeB / Rectangular	1	7		∞
Effect of short term stability of the applied Energy	9.6	µWh/VAh	Type B / Rectangular	1	9.6	µWh/VAh	∞
Temperature coefficient of traveling Standard	Negligible	µWh/VAh	TypeB / Rectangular	-	-	µWh/VAh	NA
Root square sum of type A standard uncertainties and effective degrees of freedom					0.6	µWh/VAh	9
Root square sum of type B standard uncertainties and effective degrees of freedom					19.14	µWh/VAh	∞
Combined standard uncertainty and effective degrees of freedom					19.16	µWh/VAh	5.E+06
Expanded uncertainty (95.45% coverage factor)					**39**	**µWh/VAh**	

Uncertainty Budget for PF = 0.5 (ind.) @ 50 Hz (for k = 2)

Main uncertainty components (yi)	Standard uncertainty u(yi)		Type method A or B of evaluation/probability distribution function	Sensitivity coefficient Ci	Uncertainty contribution u(Ri)		Degrees of freedom ni
Readings repeatability of traveling standard	0.8	µWh/VAh	TypeA / Normal	1	0.8	µWh/VAh	9
Standard calibration uncertainty of NIS	15	µWh/VAh	TypeB / Normal	1	15	µWh/VAh	∞
Resolution of traveling standard	0.3	µWh/VAh	TypeB / Rectangular	1	0.3	µWh/VAh	∞
Drift of NIS standard since last calibration	0.9	µWh/VAh	TypeB / Rectangular	1	0.9	µWh/VAh	∞
Effect of change in the applied frequency (50 - 53) Hz	3	µWh/VAh	TypeB / Rectangular	1	3		∞
Effect of short term stability of the applied Energy	9.6	µWh/VAh	Type B / Rectangular	1	9.6	µWh/VAh	∞
Temperature coefficient of traveling Standard	Negligible	µWh/VAh	TypeB / Rectangular	-	-	µWh/VAh	NA
Root square sum of type A standard uncertainties and effective degrees of freedom					0.8	µWh/VAh	9
Root square sum of type B standard uncertainties and effective degrees of freedom					18.1	µWh/VAh	∞
Combined standard uncertainty and effective degrees of freedom					18.11	µWh/VAh	1.E+06
Expanded uncertainty (95.45% coverage factor)					**37**	**µWh/VAh**	

Uncertainty Budget for PF = 0.5 (cap.) @ 50 Hz (for k = 2)

Main uncertainty components (yi)	Standard uncertainty u(yi)		Type method A or B of evaluation/probability distribution function	Sensitivity coefficient Ci	Uncertainty contribution u(Ri)		Degrees of freedom ni
Readings repeatability of traveling standard	1.4	µWh/VAh	TypeA / Normal	1	1.4	µWh/VAh	9
Standard calibration uncertainty of NIS	15	µWh/VAh	TypeB / Normal	1	15	µWh/VAh	∞
Resolution of traveling standard	0.3	µWh/VAh	TypeB / Rectangular	1	0.3	µWh/VAh	∞
Drift of NIS standard since last calibration	0.2	µWh/VAh	TypeB / Rectangular	1	0.2	µWh/VAh	∞
Effect of change in the applied frequency (50 - 53) Hz	10	µWh/VAh	TypeB / Rectangular	1	10		∞
Effect of short term stability of the applied Energy	9.6	µWh/VAh	Type B / Rectangular	1	9.6	µWh/VAh	∞
Temperature coefficient of traveling Standard	Neg ligib le	µWh/VAh	TypeB / Rectangular	-	-	µWh/VAh	NA
Root square sum of type A standard uncertainties and effective degrees of freedom					1.4	µWh/VAh	9
Root square sum of type B standard uncertainties and effective degrees of freedom					20.4	µWh/VAh	∞
Combined standard uncertainty and effective degrees of freedom					20.5	µWh/VAh	3.E+05
Expanded uncertainty (95.45% coverage factor)					**41**	µWh/VAh	

Uncertainty Budget for PF = 1 @ 60 Hz (for k = 2)

Main uncertainty components (yi)	Standard uncertainty u(yi)		Type method A or B of evaluation/probability distribution function	Sensitivity coefficient Ci	Uncertainty contribution u(Ri)		Degrees of freedom ni
Readings repeatability of traveling standard	0.6	µWh/VAh	TypeA / Normal	1	0.6	µWh/VAh	9
Standard calibration uncertainty of NIS	15	µWh/VAh	TypeB / Normal	1	15	µWh/VAh	∞
Resolution of traveling standard	0.3	µWh/VAh	TypeB / Rectangular	1	0.3	µWh/VAh	∞
Drift of NIS standard since last calibration	0.4	µWh/VAh	TypeB / Rectangular	1	0.4	µWh/VAh	∞
Effect of change in the applied frequency (53 - 60) Hz	15.6	µWh/VAh	TypeB / Rectangular	1	15.6		∞
Effect of short term stability of the applied Energy	9.6	µWh/VAh	Type B / Rectangular	1	9.6	µWh/VAh	∞
Temperature coefficient of traveling Standard	Negli gible	µWh/VAh	TypeB / Rectangular	-	-	µWh/VAh	NA
Root square sum of type A standard uncertainties and effective degrees of freedom					0.6	µWh/VAh	9
Root square sum of type B standard uncertainties and effective degrees of freedom					23.7	µWh/VAh	∞
Combined standard uncertainty and effective degrees of freedom					23.7	µWh/VAh	2.E+07
Expanded uncertainty (95.45% coverage factor)					48	µWh/VAh	

Uncertainty Budget for PF = 0.5 (ind.) @ 60 Hz (for k = 2)

Main uncertainty components (yi)	Standard uncertainty u(yi)		Type method A or B of evaluation/probability distribution function	Sensitivity coefficient Ci	Uncertainty contribution u(Ri)		Degrees of freedom ni
Readings repeatability of traveling standard	1.8	µWh/VAh	TypeA / Normal	1	1.8	µWh/VAh	9
Standard calibration uncertainty of NIS	15	µWh/VAh	TypeB / Normal	1	15	µWh/VAh	∞
Resolution of traveling standard	0.3	µWh/VAh	TypeB / Rectangular	1	0.3	µWh/VAh	∞
Drift of NIS standard since last calibration	0.9	µWh/VAh	TypeB / Rectangular	1	0.9	µWh/VAh	∞
Effect of change in the applied frequency (53 - 60) Hz	2	µWh/VAh	TypeB / Rectangular	1	2		∞
Effect of short term stability of the applied Energy	9.6	µWh/VAh	Type B / Rectangular	1	9.6	µWh/VAh	∞
Temperature coefficient of traveling Standard	Negligible	µWh/VAh	TypeB / Rectangular	-	-	µWh/VAh	NA
Root square sum of type A standard uncertainties and effective degrees of freedom					1.8	µWh/VAh	9
Root square sum of type B standard uncertainties and effective degrees of freedom					18	µWh/VAh	∞
Combined standard uncertainty and effective degrees of freedom					18.1	µWh/VAh	8.E+05
Expanded uncertainty (95.45% coverage factor)					37	µWh/VAh	

Uncertainty Budget for PF = 0.5 (cap.) @ 60 Hz (for k = 2)

Main uncertainty components (yi)	Standard uncertainty u(yi)		Type method A or B of evaluation/probability distribution function	Sensitivity coefficient Ci	Uncertainty contribution u(Ri)		Degrees of freedom ni
Readings repeatability of traveling standard	1	µWh/VAh	TypeA / Normal	1	1	µWh/VAh	9
Standard calibration uncertainty of NIS	15	µWh/VAh	TypeB / Normal	1	15	µWh/VAh	∞
Resolution of traveling standard	0.3	µWh/VAh	TypeB / Rectangular	1	0.3	µWh/VAh	∞
Drift of NIS standard since last calibration	0.2	µWh/VAh	TypeB / Rectangular	1	0.2	µWh/VAh	∞
Effect of change in the applied frequency (53 - 60) Hz	9	µWh/VAh	TypeB / Rectangular	1	9		∞
Effect of short term stability of the applied Energy	9.6	µWh/VAh	Type B / Rectangular	1	9.6	µWh/VAh	∞
Temperature coefficient of traveling Standard	Negligible	µWh/VAh	TypeB / Rectangular	-	-	µWh/VAh	NA
Root square sum of type A standard uncertainties and effective degrees of freedom					1	µWh/VAh	9
Root square sum of type B standard uncertainties and effective degrees of freedom					19.96	µWh/VAh	∞
Combined standard uncertainty and effective degrees of freedom					19.98	µWh/VAh	8.E+05
Expanded uncertainty (95.45% coverage factor)					40	µWh/VAh	