State Enterprise “All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer” (SE “Ukrmeterteststandard”)

Final Report on
GULFMET Supplementary Comparison of High Current Transformer Measuring Systems (GULFMET.EM-S7)

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1 Introduction

The GULFMET Supplementary Comparison (SC) of High Current Transformer Measuring Systems (comparison identifier – GULFMET.EM-S7) was conducted from December 2020 to December 2021.

This project for comparing of High Current Transformer Measuring Systems was conducted between countries which are member laboratories of regional metrology organizations GULFMET, COOMET and EURAMET. In this comparison three national metrology institutes (NMI) take part: SE "Ukrmetrteststandard" (UMTS, Ukraine), SASO-NMCC (Saudi Arabia) and UME (Turkey).

The State Enterprise "All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer" (SE "Ukrmetr-teststandard"), Ukraine was selected as the pilot laboratory. Dr. Oleh Velychko was the comparison coordinator. The pilot laboratory is responsible for providing the travelling standard, coordinating the schedule, collecting and analyzing the comparison data, preparing the draft of report, etc.

2 Participants

List of participating NMIs, countries of origin is show in Table 1.

Table 1 List of participating NMIs, countries of origin and regional organizations

NMI	Country	Regional organization
UMTS – State Enterprise "All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer" (SE "Ukrmetrteststandard") – **pilot**	Ukraine	COOMET
SASO-NMCC – Saudi Standards, Metrology and Quality Organization of The Kingdom of Saudi – National Measurements and Calibration Center	Saudi Arabia	GULFMET
UME – TÜBITAK Ulusal Metroloji Enstitüsü	Turkey	EURAMET

List of participants contact information is show in Table 2.

Table 2 List of participants contact information

NMI address	Contact name, e-mail, tel. and fax number
State Enterprise "All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer" (SE "Ukrmetrteststandard" – **UMTS**), 4, Metrologichna Str., 03143, Kyiv-143, **Ukraine**	Oleh Velychko Velychko@ukrcsm.kiev.ua Tel./fax: +38 044 526 0335

NMI address	Contact name, e-mail, tel. and fax number
Saudi Standards, Metrology and Quality Organization of The Kingdom of Saudi – National Measurements and Calibration Center (**SASO-NMCC**), Front king Saud Univer-sity Riyadh 11471, P.O. Box 3437, **Kingdom of Saudi Arabia**	Saad Bin Qoud s.qoud@saso.gov.sa Tel: +966 56 902 7551
TÜBITAK Ulusal Metroloji Enstitüsü (**UME**), TÜBİTAK Gebze Yerleskesi Baris Mah., Dr. Zeki Acar Cad. No. 1 41470, Gebze Kocaeli, **Turkey**	Huseyin Cayci huseyin.cayci@tubitak.gov.tr Tel.: +90 262 679 5000

3 Travelling standards and measurement instructions

3.1 Description of travelling standard

The selected travelling standard is standard current transformer CA535/2 (“Трансформатор тока эталонный СА535/2”).

Figure 1 The photo of the travelling standard CA535/2

Main characteristics of the travelling standard:

- primary rated current from 0,5 A to 5000 A;
- secondary rated current 5 A;
- burden not more than 0,05 Ω.

3.2 Measurements

Measurements must be performed under the following conditions:

- temperature: 23 °C ± 3 °C;

- relative humidity: from 30 % to 70 %;

- supply frequencies: 50 Hz ± 0.5 Hz and 60 Hz ± 0.6 Hz with a sinusoidal waveform.

The participants should inform the pilot laboratory if the above conditions cannot be met.

The data to be recorded at each measurement:

- date of measurement;

- air temperature and relative humidity environment;

- burden value (in VA or in Ω) and its PF.

If measurements are carried out within a few days, then measured value together with the measurement date shall be given for each measurement day.

Comparison of national standards is provided by means of measuring of the travelling standard metrological characteristics (ratio error ε_i and phase displacement δ_i). Measurements are performed at the values of primary current 5, 20, 100 and 120 % of each primary nominal current (I_N) according table at the subchapter 6.2 on a frequencies of 50 Hz and 60 Hz and at load fixed for the travelling standard.

Each NMI participant provides up to ten observations at each operation current. Each NMI participant presents arithmetical mean of ten observations and uncertainty in measurements as a result of measurement.

4 Uncertainty of measurement

Uncertainty of the measurements should be calculated according to the GUM [1] and EA-4/02 [2]. With the results of measurements should be given a model that describes how the measurement result was obtained considering all influencing quantities.

For each of the influencing quantities should be given the description of the source of uncertainty and an assessment of this uncertainty. All influencing quantities, their uncertainties, influencing coefficients, degrees of freedom and levels of confidence should be given in the budget of the uncertainty.

The budget of the uncertainty (Table 3) should include such number of influencing quantities and their uncertainties, which ensures the high-level measurements for the laboratory.

Table 3 Uncertainty budget

i	Quantity (unit)	Distribution	x_i	$u(x_i)$	v_i	c_i	$u_i(y)$
1							
…							
y	Std uncertainty of measurement						
		Confidential level = %				k =	
		Expanded uncertainty =					

The components of the uncertainty budget should be expressed as standard uncertainties. The main components of the uncertainty budget are:

- standard uncertainty obtained as a result of an experiment from N independent measurements;

- uncertainty of the standard of the NMI laboratory, by means of which the value of the travelling standard is determined;

- uncertainty caused by the corrections.

Participants in the comparisons may include additional sources of uncertainty.

5 Traceability to the SI

The traceability to the SI standards was provided to pilot NMI. UMTS and UME made high current measurements of 50 Hz and 60 Hz. SASO-NMCC made high current measurements of 60 Hz only. UMTS measurements are traceable to UMTS. UME and SASO-NMCC measurements are traceable to UME.

Traceability route for each participating NMIs given in Table 4.

Table 4 Traceability route for each participating NMI

NMI	Country	Traceability Route
UMTS	Ukraine	UMTS
SASO-NMCC	Saudi Arabia	UME
UME	Turkey	UME

6 Behaviour of the travelling standards

The UMTS as pilot laboratory has performed repeated measurements on the TS CA535/2 during the course of this comparison. TS CA535/2 provides extreme linearity coupled with extreme stability.

The first day of starting GULFMET.EM-S7 comparison was 1 December 2020 and finished 17 December 2021. UMTS has performed repeated measurements on TS for 12 months and 16 days. During the course of comparison, the drift effect was calculated.

The average values x_{av} and standard deviation σ for ratio error ε_I and phase displacement δ_I are given in Table 5 at frequencies 50 Hz and 60 Hz. The drifts were small for all measurement points, so they can be neglected.

Table 5 The average values x_{av} and standard deviation σ for ratio error and phase displacement

Nominal primary current	Percentage of nominal primary current	Average values for ratio error ε_I	Standard deviation for ratio error ε_I	Average values for phase displacement δ_I	Standard deviation for phase displacement δ_I
A	%	%	%	crad	crad
Frequency 50 Hz					
5	5	0.0009	0.0002	-0.0023	0.0004
	20	0.0005	0.0001	-0.0017	0.0002
	100	0.0004	0.0001	-0.0017	0.0002
	120	0.0004	0.0001	-0.0017	0.0002
50	5	0.0008	0.0001	-0.0026	0.0002
	20	0.0003	0.0001	-0.0026	0.0002
	100	0.0004	0.0001	-0.0020	0.0001
	120	0.0004	0.0001	-0.0017	0.0002
200	40	0.0011	0.0001	-0.0011	0.0001
	80	0.0020	0.0001	-0.0016	0.0001
	100	0.0021	0.0001	-0.0012	0.0002
	120	0.0021	0.0001	-0.0010	0.0001
400	5	0.0017	0.0001	-0.0013	0.0001
	20	0.0020	0.0001	-0.0016	0.0001
	100	0.0012	0.0001	-0.0013	0.0001
	120	0.0010	0.0001	-0.0009	0.0001
800	5	0.0005	0.0001	-0.0005	0.0001
	20	0.0004	0.0001	-0.0002	0.0002
	100	0.0002	0.0001	-0.0001	0.0002
	120	0.0006	0.0001	-0.0002	0.0002
1500	5	0.0008	0.0001	-0.0009	0.0001
	20	0.0003	0.0001	-0.0012	0.0007
	100	-0.0001	0.0002	-0.0009	0.0003
	120	-0.0005	0.0001	-0.0001	0.0011
2000	5	0.0006	0.0001	-0.0010	0.0002
	20	0.0006	0.0001	-0.0003	0.0000
	100	0.0009	0.0001	-0.0001	0.0002
	120	0.0009	0.0001	-0.0001	0.0002
4000	5	-0.0001	0.0001	-0.0027	0.0002
	20	-0.0005	0.0001	-0.0011	0.0001
	100	-0.0004	0.0001	-0.0005	0.0002
	120	-0.0002	0.0001	-0.0010	0.0002

Nominal primary current	Percentage of nominal primary current	Average values for ratio error ε_I	Standard deviation for ratio error ε_I	Average values for phase displacement δ_I	Standard deviation for phase displacement δ_I
A	%	%	%	crad	crad
Frequency 60 Hz					
5	5	0.0009	0.0001	-0.0023	0.0004
	20	0.0006	0.0001	-0.0016	0.0002
	100	0.0004	0.0001	-0.0016	0.0002
	120	0.0004	0.0001	-0.0016	0.0002
50	5	0.0009	0.0001	-0.0025	0.0002
	20	0.0004	0.0001	-0.0025	0.0002
	100	0.0005	0.0001	-0.0020	0.0001
	120	0.0005	0.0001	-0.0017	0.0002
200	40	0.0010	0.0001	-0.0011	0.0000
	80	0.0016	0.0001	-0.0015	0.0001
	100	0.0019	0.0001	-0.0012	0.0002
	120	0.0018	0.0001	-0.0010	0.0001
400	5	0.0017	0.0001	-0.0012	0.0002
	20	0.0020	0.0001	-0.0016	0.0001
	100	0.0012	0.0001	-0.0012	0.0002
	120	0.0010	0.0001	-0.0008	0.0001
800	5	0.0005	0.0001	-0.0005	0.0001
	20	0.0004	0.0001	-0.0002	0.0002
	100	0.0003	0.0001	-0.0001	0.0002
	120	0.0004	0.0001	0.0000	0.0005
1500	5	0.0009	0.0001	-0.0009	0.0001
	20	0.0003	0.0001	-0.0012	0.0007
	100	0.0001	0.0001	-0.0009	0.0003
	120	0.0001	0.0001	-0.0001	0.0011
2000	5	0.0009	0.0001	-0.0008	0.0005
	20	0.0008	0.0001	-0.0004	0.0002
	100	0.0008	0.0002	0.0000	0.0003
	120	0.0008	0.0002	0.0000	0.0003
4000	5				
	20				
	100				
	120				

7 Reported results

7.1 General information and data

A full measurement report containing all relevant data and uncertainty estimates was forwarded to the coordinator within six weeks of completing measurement of the energy. The report included a description of the measurement method (facilities and methodology), the traceability to the SI, and the results, associated uncertainty and number of degrees of freedom.

All measurement results and expended uncertainties, and additional parameters for measurement were identified with the serial number of measures high AC ratio error and phase displacement and nominal value (Appendix 1).

List of measurement dates of the NMI participants is show in Table 6.

Table 6 List of measurement dates of the NMI participants

NMI	Measurement dates
UMTS1, Ukraine	01–03.12.2020
SASO-NMCC, Saudi Arabia	17–31.05.2021
UMTS2, Ukraine	10–17.08.2021
UME, Turkey	01–25.10.2021
UMTS3, Ukraine	12–20.12.2021

The additional parameters for measurement of the NMI participants are show in Table 7.

Table 7 The additional parameters for measurement of the NMI participants

Parameter	Value	Absolute expanded uncertainty
UMTS, Ukraine		
Frequency, Hz	50 and 60	0.005
Temperature, °C	21.0…23.0	0.3
Relative humidity, %	45…55	2.0
SASO-NMCC, Saudi Arabia		
Frequency, Hz	60	0.005
Temperature, °C	22.5…23.6	0.5
Relative humidity, %	40…55	3.5
UME, Turkey		
Frequency, Hz	50 and 60	0.005
Temperature, °C	23.5…24.5	0.5
Relative humidity, %	40…50	3.5

The ratio error ε_I and phase displacement δ_I, and its standard uncertainties reported by the participants are given in Appendix 1 for frequencies 50/60 Hz. The value for UMTS is measurement result calculated as simple average value. Detailed uncertainty budgets from all participants are given in Appendix 2.

7.2 Calculation of the reference values and its uncertainties

The key comparison reference values (RV) x_{ref} are calculated as the mean of participant results with GULFMET.EM-S7 data are given by

$$x_{ref} = \sum_{i=1}^{N} \frac{x_i}{u_c^2(x_i)} \Big/ \sum_{i=1}^{N} \frac{1}{u_c^2(x_i)} \tag{1}$$

with combine standard uncertainties

$$u_c^2(x_{ref}) = 1 \Big/ \sum_{i=1}^{N} \frac{1}{u_c^2(x_i)} . \tag{2}$$

Reference values and expanded uncertainties for frequencies 50/60 Hz for all measurements are given in Tables 8.

Table 8 Reference values and expanded uncertainties for 50/60 Hz for all measurements

Nominal primary current	Percentage of nominal primary current	RV for ratio error ε_I	Expanded uncertainty for RV of ratio error $u(\varepsilon_I)$	RV for phase displacement δ_I	Expanded uncertainty for RV of phase displacement $u(\delta_I)$
A	%	%	%	crad	crad
Frequency 50 Hz					
5	5	0.0000	0.0005	-0.0003	0.0005
	20	-0.0002	0.0005	-0.0003	0.0005
	100	-0.0001	0.0005	-0.0003	0.0005
	120	-0.0001	0.0005	-0.0003	0.0005
50	5	0.0006	0.0014	-0.0006	0.0018
	20	0.0004	0.0014	-0.0007	0.0018
	100	0.0004	0.0014	-0.0005	0.0018
	120	0.0004	0.0014	-0.0004	0.0018
200	5	0.0009	0.0014	-0.0003	0.0018
	20	0.0016	0.0014	-0.0008	0.0018
	100	0.0017	0.0014	-0.0006	0.0018
	120	0.0017	0.0014	-0.0006	0.0018
400	5	0.0013	0.0014	-0.0004	0.0018
	20	0.0017	0.0014	-0.0008	0.0018
	100	0.0010	0.0014	-0.0001	0.0018
	120	0.0008	0.0014	0.0001	0.0018
800	5	0.0010	0.0014	-0.0004	0.0018
	20	0.0007	0.0014	-0.0003	0.0018
	100	0.0004	0.0014	-0.0001	0.0018
	120	0.0006	0.0014	-0.0001	0.0018

Nominal primary current	Percentage of nominal primary current	RV for ratio error ε_I	Expanded uncertainty for RV of ratio error $u(\varepsilon_I)$	RV for phase displacement δ_I	Expanded uncertainty for RV of phase displacement $u(\delta_I)$
A	%	%	%	crad	crad
1500	5	0.0009	0.0014	-0.0005	0.0018
	20	0.0005	0.0014	-0.0005	0.0018
	100	0.0001	0.0014	-0.0003	0.0018
	120	-0.0002	0.0014	-0.0002	0.0018
2000	5	0.0010	0.0014	-0.0008	0.0018
	20	0.0007	0.0014	-0.0004	0.0018
	100	0.0006	0.0014	-0.0003	0.0018
	120	0.0006	0.0014	-0.0003	0.0018
4000	5	0.0006	0.0014	-0.0009	0.0018
	20	0.0000	0.0014	-0.0005	0.0018
	100	-0.0002	0.0014	-0.0004	0.0018
	120	-0.0001	0.0014	-0.0005	0.0018
Frequency 60 Hz					
5	5	0.0000	0.0005	-0.0005	0.0005
	20	-0.0002	0.0005	-0.0005	0.0005
	100	-0.0002	0.0005	-0.0005	0.0005
	120	-0.0002	0.0005	-0.0005	0.0005
50	5	0.0006	0.0014	-0.0006	0.0018
	20	0.0004	0.0014	-0.0007	0.0018
	100	0.0005	0.0014	-0.0005	0.0018
	120	0.0004	0.0014	-0.0005	0.0018
200	5	0.0008	0.0014	-0.0004	0.0018
	20	0.0013	0.0014	-0.0009	0.0018
	100	0.0015	0.0014	-0.0008	0.0018
	120	0.0015	0.0014	-0.0007	0.0018
400	5	0.0012	0.0014	-0.0004	0.0018
	20	0.0016	0.0014	-0.0008	0.0018
	100	0.0010	0.0014	-0.0002	0.0018
	120	0.0008	0.0014	0.0001	0.0018
800	5	0.0010	0.0014	-0.0003	0.0018
	20	0.0006	0.0014	-0.0001	0.0018
	100	0.0003	0.0014	0.0001	0.0018
	120	0.0004	0.0014	0.0001	0.0018

Nominal primary current	Percentage of nominal primary current	RV for ratio error ε_I	Expanded uncertainty for RV of ratio error $u(\varepsilon_I)$	RV for phase displacement δ_I	Expanded uncertainty for RV of phase displacement $u(\delta_I)$
A	%	%	%	crad	crad
1500	5	0.0010	0.0014	-0.0005	0.0018
	20	0.0005	0.0014	-0.0005	0.0018
	100	0.0001	0.0014	-0.0003	0.0018
	120	0.0002	0.0014	-0.0002	0.0018
2000	5	0.0011	0.0014	-0.0006	0.0018
	20	0.0007	0.0014	-0.0003	0.0018
	100	0.0005	0.0014	-0.0002	0.0018
	120	0.0005	0.0014	-0.0002	0.0018
4000	5	0.0013	0.0020	-0.0005	0.0020
	20	0.0005	0.0020	-0.0003	0.0020
	100	0.0001	0.0020	-0.0005	0.0020
	120	0.0001	0.0020	-0.0005	0.0020

7.3 Degrees of equivalence

Only one value is reported for NMI participants. Degrees of equivalence (DoE) of the NMI participants are reported with respect to the measurements at 50/60 Hz.

The DoE of *i*-th NMI and its combined standard uncertainties with respect to the RV is estimated as [3]

$$D_i = x_i - x_{ref\ j}\,, \tag{3}$$

$$u_c^2(D_i) = u_c^2(x_i) + u_c^2(x_{ref\ j})\,. \tag{4}$$

Additionally, the performance indicator E_n is calculated as:

$$E_{ni} = \frac{|D_i|}{2u_c(D_i)} \le 1.0 \tag{5}$$

All DoE and DoE and its uncertainties are given in Table 9 for ratio error ε_I and Table 10 for phase displacement δ_I.

E_n values of the NMI participants for ratio error ε_I and for phase displacement δ_I are given in Table 11. E_n number for all NMIs for all measurement points satisfy equation (5) and take values from 0.00 to 0.50.

Table 9 DoE and its uncertainties of the NMI participants for ratio error ε_I

Nominal primary current	Percentage of nominal primary current	DoE			Expanded uncertainty		
		UMTS	SASO-NMCC	UME	UMTS	SASO-NMCC	UME
A	%	%	%	%	%	%	%
Frequency 50 Hz							
5	5	0.0009		-0.0001	0.0021		0.0007
	20	0.0007		0.0000	0.0021		0.0007
	100	0.0005		0.0000	0.0021		0.0007
	120	0.0005		0.0000	0.0021		0.0007
50	5	0.0002		-0.0003	0.0024		0.0024
	20	-0.0001		0.0000	0.0024		0.0024
	100	0.0000		0.0000	0.0024		0.0024
	120	0.0001		-0.0001	0.0024		0.0024
200	5	0.0002		-0.0002	0.0024		0.0024
	20	0.0004		-0.0005	0.0024		0.0024
	100	0.0004		-0.0005	0.0024		0.0024
	120	0.0004		-0.0005	0.0024		0.0024
400	5	0.0004		-0.0004	0.0024		0.0024
	20	0.0003		-0.0004	0.0024		0.0024
	100	0.0002		-0.0003	0.0024		0.0024
	120	0.0002		-0.0003	0.0024		0.0024
800	5	-0.0005		0.0004	0.0024		0.0024
	20	-0.0003		0.0003	0.0024		0.0024
	100	-0.0002		0.0001	0.0024		0.0024
	120	0.0000		-0.0001	0.0024		0.0024
1500	5	-0.0001		0.0001	0.0024		0.0024
	20	-0.0002		0.0001	0.0024		0.0024
	100	-0.0002		0.0001	0.0024		0.0024
	120	-0.0003		0.0004	0.0024		0.0024
2000	5	-0.0004		0.0003	0.0024		0.0024
	20	-0.0001		0.0000	0.0024		0.0024
	100	0.0003		-0.0003	0.0024		0.0024
	120	0.0003		-0.0003	0.0024		0.0024

Nominal primary current	Percentage of nominal primary current	DoE			Expanded uncertainty		
		UMTS	SASO-NMCC	UME	UMTS	SASO-NMCC	UME
A	%	%	%	%	%	%	%
4000	5	-0.0007		0.0006	0.0024		0.0024
	20	-0.0005		0.0005	0.0024		0.0024
	100	-0.0002		0.0003	0.0024		0.0024
	120	-0.0002		0.0002	0.0024		0.0024
Frequency 60 Hz							
5	5	0.0009	-0.0004	-0.0001	0.0021	0.0112	0.0007
	20	0.0008	0.0000	0.0000	0.0021	0.0112	0.0007
	100	0.0006	0.0000	0.0000	0.0021	0.0112	0.0007
	120	0.0006	0.0009	0.0000	0.0021	0.0112	0.0007
50	5	0.0003	-0.0006	-0.0003	0.0024	0.0113	0.0024
	20	0.0000	0.0002	0.0000	0.0024	0.0113	0.0024
	100	0.0000	0.0001	-0.0001	0.0024	0.0113	0.0024
	120	0.0001	0.0012	-0.0001	0.0024	0.0113	0.0024
200	5	0.0002	-0.0017	-0.0001	0.0024	0.0113	0.0024
	20	0.0003	-0.0005	-0.0003	0.0024	0.0113	0.0024
	100	0.0004	-0.0003	-0.0003	0.0024	0.0113	0.0024
	120	0.0003	0.0008	-0.0003	0.0024	0.0113	0.0024
400	5	0.0005	-0.0004	-0.0004	0.0024	0.0113	0.0024
	20	0.0004	-0.0001	-0.0004	0.0024	0.0113	0.0024
	100	0.0002	0.0002	-0.0003	0.0024	0.0113	0.0024
	120	0.0002	0.0012	-0.0003	0.0024	0.0113	0.0024
800	5	-0.0005	-0.0012	0.0005	0.0024	0.0113	0.0024
	20	-0.0002	-0.0010	0.0003	0.0024	0.0113	0.0024
	100	0.0000	-0.0014	0.0001	0.0024	0.0113	0.0024
	120	0.0000	-0.0009	0.0000	0.0024	0.0113	0.0024
1500	5	-0.0001	-0.0009	0.0002	0.0024	0.0113	0.0024
	20	-0.0002	-0.0004	0.0002	0.0024	0.0113	0.0024
	100	0.0000	-0.0002	0.0001	0.0024	0.0113	0.0024
	120	-0.0001	0.0008	0.0000	0.0024	0.0113	0.0024
2000	5	-0.0002	-0.0014	0.0002	0.0024	0.0113	0.0024
	20	0.0001	-0.0008	-0.0001	0.0024	0.0113	0.0024
	100	0.0003	-0.0008	-0.0003	0.0024	0.0113	0.0024
	120	0.0003	0.0003	-0.0003	0.0024	0.0113	0.0024

Nominal primary current	Percentage of nominal primary current	DoE			Expanded uncertainty		
		UMTS	SASO-NMCC	UME	UMTS	SASO-NMCC	UME
A	%	%	%	%	%	%	%
4000	5		-0.0011	0.0000		0.0114	0.0028
	20		-0.0003	0.0000		0.0114	0.0028
	100		-0.0002	0.0000		0.0114	0.0028
	120		0.0007	0.0000		0.0114	0.0028

Table 10 DoE and its uncertainties of the NMI participants for phase displacement δ_I

Nominal primary current	Percentage of nominal primary current	DoE			Expanded uncertainty		
		UMTS	SASO-NMCC	UME	UMTS	SASO-NMCC	UME
A	%	crad	crad	crad	crad	crad	crad
Frequency 50 Hz							
5	5	-0.0020		0.0000	0.0040		0.0007
	20	-0.0014		0.0000	0.0040		0.0007
	100	-0.0014		0.0000	0.0040		0.0007
	120	-0.0014		0.0000	0.0040		0.0007
50	5	-0.0020		0.0005	0.0044		0.0027
	20	-0.0019		0.0005	0.0044		0.0027
	100	-0.0015		0.0004	0.0044		0.0027
	120	-0.0013		0.0003	0.0044		0.0027
200	5	-0.0008		0.0002	0.0044		0.0027
	20	-0.0008		0.0002	0.0044		0.0027
	100	-0.0006		0.0001	0.0044		0.0027
	120	-0.0004		0.0001	0.0044		0.0027
400	5	-0.0009		0.0002	0.0044		0.0027
	20	-0.0008		0.0002	0.0044		0.0027
	100	-0.0012		0.0003	0.0044		0.0027
	120	-0.0010		0.0003	0.0044		0.0027
800	5	-0.0001		0.0000	0.0044		0.0027
	20	0.0001		0.0000	0.0044		0.0027
	100	0.0000		0.0000	0.0044		0.0027
	120	-0.0001		0.0000	0.0044		0.0027

Nominal primary current	Percentage of nominal primary current	DoE			Expanded uncertainty		
		UMTS	SASO-NMCC	UME	UMTS	SASO-NMCC	UME
A	%	crad	crad	crad	crad	crad	crad
1500	5	-0.0004		0.0001	0.0044		0.0027
	20	-0.0007		0.0002	0.0044		0.0027
	100	-0.0006		0.0001	0.0044		0.0027
	120	0.0001		0.0000	0.0044		0.0027
2000	5	-0.0002		0.0001	0.0044		0.0027
	20	0.0001		0.0000	0.0044		0.0027
	100	0.0002		-0.0001	0.0044		0.0027
	120	0.0002		-0.0001	0.0044		0.0027
4000	5	-0.0018		0.0004	0.0044		0.0027
	20	-0.0006		0.0002	0.0044		0.0027
	100	-0.0001		0.0000	0.0044		0.0027
	120	-0.0005		0.0001	0.0044		0.0027
Frequency 60 Hz							
5	5	-0.0018	0.0006	0.0000	0.0040	0.0112	0.0007
	20	-0.0011	0.0011	0.0000	0.0040	0.0112	0.0007
	100	-0.0011	0.0017	0.0000	0.0040	0.0112	0.0007
	120	-0.0011	0.0017	0.0000	0.0040	0.0112	0.0007
50	5	-0.0019	-0.0003	0.0005	0.0044	0.0113	0.0027
	20	-0.0018	0.0001	0.0004	0.0044	0.0113	0.0027
	100	-0.0015	0.0005	0.0003	0.0044	0.0113	0.0027
	120	-0.0012	0.0004	0.0003	0.0044	0.0113	0.0027
200	5	-0.0007	-0.0024	0.0002	0.0044	0.0113	0.0027
	20	-0.0006	-0.0003	0.0002	0.0044	0.0113	0.0027
	100	-0.0004	0.0007	0.0001	0.0044	0.0113	0.0027
	120	-0.0003	0.0008	0.0001	0.0044	0.0113	0.0027
400	5	-0.0008	-0.0012	0.0002	0.0044	0.0113	0.0027
	20	-0.0008	-0.0003	0.0002	0.0044	0.0113	0.0027
	100	-0.0010	0.0003	0.0003	0.0044	0.0113	0.0027
	120	-0.0009	0.0002	0.0002	0.0044	0.0113	0.0027
800	5	-0.0002	-0.0004	0.0001	0.0044	0.0113	0.0027
	20	-0.0001	0.0000	0.0000	0.0044	0.0113	0.0027
	100	-0.0002	0.0007	0.0000	0.0044	0.0113	0.0027
	120	-0.0001	0.0007	0.0000	0.0044	0.0113	0.0027

Nominal primary current	Percentage of nominal primary current	DoE			Expanded uncertainty		
		UMTS	SASO-NMCC	UME	UMTS	SASO-NMCC	UME
A	%	crad	crad	crad	crad	Crad	crad
1500	5	-0.0004	0.0004	0.0001	0.0044	0.0113	0.0027
	20	-0.0007	0.0004	0.0002	0.0044	0.0113	0.0027
	100	-0.0006	0.0007	0.0001	0.0044	0.0113	0.0027
	120	0.0001	0.0007	0.0000	0.0044	0.0113	0.0027
2000	5	-0.0002	-0.0004	0.0001	0.0044	0.0113	0.0027
	20	-0.0001	0.0003	0.0000	0.0044	0.0113	0.0027
	100	0.0002	0.0007	-0.0001	0.0044	0.0113	0.0027
	120	0.0002	0.0007	-0.0001	0.0044	0.0113	0.0027
4000	5		0.0000	0.0000		0.0114	0.0028
	20		0.0003	0.0000		0.0114	0.0028
	100		0.0006	0.0000		0.0114	0.0028
	120		0.0004	0.0000		0.0114	0.0028

Table 11 E_n values of the NMI participants for ratio error ε_I and for phase displacement δ_I

Nominal primary current	Percentage of nominal primary current	E_n values for ratio error ε_I			E_n values for phase displacement δ_I		
		UMTS	SASO-NMCC	UME	UMTS	SASO-NMCC	UME
A	%	1	1	1	1	1	1
Frequency 50 Hz							
5	5	0.43		0.14	0.50		0.00
	20	0.33		0.00	0.35		0.00
	100	0.24		0.00	0.35		0.00
	120	0.24		0.00	0.35		0.00
50	5	0.08		0.13	0.45		0.19
	20	0.04		0.00	0.43		0.19
	100	0.00		0.00	0.34		0.15
	120	0.00		0.04	0.30		0.11
200	5	0.08		0.08	0.18		0.07
	20	0.17		0.21	0.18		0.07
	100	0.17		0.21	0.14		0.04
	120	0.17		0.21	0.09		0.04

Nominal primary current	Percentage of nominal primary current	E_n values for ratio error ε_I			E_n values for phase displacement δ_I		
		UMTS	SASO-NMCC	UME	UMTS	SASO-NMCC	UME
A	%	1	1	1	1	1	1
400	5	0.17		0.17	0.20		0.07
	20	0.13		0.17	0.18		0.07
	100	0.08		0.13	0.27		0.11
	120	0.08		0.13	0.23		0.11
800	5	0.21		0.17	0.02		0.00
	20	0.13		0.13	0.02		0.00
	100	0.08		0.04	0.00		0.00
	120	0.00		0.04	0.02		0.00
1500	5	0.04		0.04	0.09		0.04
	20	0.08		0.04	0.16		0.07
	100	0.08		0.04	0.14		0.04
	120	0.13		0.17	0.02		0.00
2000	5	0.17		0.13	0.05		0.04
	20	0.04		0.00	0.02		0.00
	100	0.13		0.13	0.05		0.04
	120	0.13		0.13	0.05		0.04
4000	5	0.29		0.25	0.41		0.15
	20	0.21		0.21	0.14		0.07
	100	0.08		0.13	0.02		0.00
	120	0.04		0.08	0.11		0.04
Frequency 60 Hz							
5	5	0.43	0.04	0.14	0.45	0.05	0.00
	20	0.38	0.00	0.00	0.28	0.10	0.00
	100	0.29	0.00	0.00	0.28	0.15	0.00
	120	0.29	0.08	0.00	0.28	0.15	0.00
50	5	0.13	0.05	0.13	0.43	0.03	0.19
	20	0.00	0.02	0.00	0.41	0.01	0.15
	100	0.00	0.01	0.04	0.34	0.04	0.11
	120	0.04	0.11	0.04	0.27	0.04	0.11
200	5	0.08	0.15	0.04	0.16	0.21	0.07
	20	0.13	0.04	0.13	0.14	0.03	0.07
	100	0.17	0.03	0.13	0.09	0.06	0.04
	120	0.13	0.07	0.13	0.07	0.07	0.04

Nominal primary current	Percentage of nominal primary current	E_n values for ratio error ε_I			E_n values for phase displacement δ_I		
		UMTS	SASO-NMCC	UME	UMTS	SASO-NMCC	UME
A	%	1	1	1	1	1	1
400	5	0.21	0.04	0.17	0.18	0.11	0.07
	20	0.17	0.01	0.17	0.18	0.03	0.07
	100	0.08	0.02	0.13	0.23	0.03	0.11
	120	0.08	0.11	0.13	0.20	0.02	0.07
800	5	0.21	0.11	0.21	0.05	0.04	0.04
	20	0.08	0.09	0.13	0.02	0.00	0.00
	100	0.00	0.12	0.04	0.05	0.06	0.00
	120	0.00	0.08	0.00	0.02	0.06	0.00
1500	5	0.04	0.08	0.08	0.09	0.04	0.04
	20	0.08	0.04	0.08	0.16	0.04	0.07
	100	0.00	0.02	0.04	0.14	0.06	0.04
	120	0.04	0.07	0.00	0.02	0.06	0.00
2000	5	0.08	0.12	0.08	0.05	0.04	0.04
	20	0.04	0.07	0.04	0.02	0.03	0.00
	100	0.13	0.07	0.13	0.05	0.06	0.04
	120	0.13	0.03	0.13	0.05	0.06	0.04
4000	5		0.10	0.00		0.00	0.00
	20		0.03	0.00		0.03	0.00
	100		0.02	0.00		0.05	0.00
	120		0.06	0.00		0.04	0.00

8 Summary

A supplementary comparison of High Current Transformer Measuring Systems been conducted between participating NMIs from three regional metrological organizations (GULFMET and COOMET, EURAMET). In general, there is good agreement between NMI participants for this quantity.

It is expected that this comparison will be able to provide support for participants' entries in Appendix C of the Mutual Recognition Arrangement. In this comparison, the NMI participants report about three NMIs for realization the traceability of the unit of high current.

References

[1] JCGM 100:2008 Evaluation of measurement data. – Guide to the expression of uncertainty in measurement.

[2] EA-4/02M:2022 Evaluation of the Uncertainty of Measurement in calibration.

[3] COOMET R/GM/19:2016 Guidelines on COOMET supplementary comparison evaluation.

Appendix 1

Reported measurement results for each NMI laboratory

SASO-NMCC (Saudi Arabia)

Measurement results for current transformers given in the Table A1.1.

Table A1.1 Measurement results for current transformers

Frequency	Nominal primary current	Percentage of nominal primary current	Ratio error ε_I	Combined uncertainty for ratio error $u(\varepsilon_I)$	Phase displace-ment δ_I	Combined uncertainty for phase displacement $u(\delta_I)$
Hz	A	%	%	%	crad	crad
60	5	5	-0.0004	0.0056	0.0001	0.0056
		20	-0.0002	0.0056	0.0006	0.0056
		100	-0.0002	0.0056	0.0012	0.0056
		120	0.0007	0.0056	0.0012	0.0056
	50	5	0.0000	0.0056	-0.0009	0.0056
		20	0.0006	0.0056	-0.0006	0.0056
		100	0.0006	0.0056	0.0000	0.0056
		120	0.0016	0.0056	-0.0001	0.0056
	200	40	-0.0009	0.0056	-0.0028	0.0056
		80	0.0008	0.0056-	-0.0012	0.0056
		100	0.0012	0.0056	-0.0001	0.0056
		120	0.0023	0.0056	0.0001	0.0056
	400	5	0.0008	0.0056	-0.0016	0.0056
		20	0.0015	0.0056	-0.0011	0.0056
		100	0.0012	0.0056	0.0001	0.0056
		120	0.0020	0.0056	0.0003	0.0056
	800	5	-0.0002	0.0056	-0.0007	0.0056
		20	-0.0004	0.0056	-0.0001	0.0056
		100	-0.0011	0.0056	0.0008	0.0056
		120	-0.0005	0.0056	0.0008	0.0056
	1500	5	0.0001	0.0056	-0.0001	0.0056
		20	0.0001	0.0056	-0.0001	0.0056
		100	-0.0001	0.0056	0.0004	0.0056
		120	0.0010	0.0056	0.0005	0.0056

Frequency	Nominal primary current	Percentage of nominal primary current	Ratio error ε_I	Combined uncertainty for ratio error $u(\varepsilon_I)$	Phase displace-ment δ_I	Combined uncertainty for phase displacement $u(\delta_I)$
Hz	A	%	%	%	crad	crad
60	2000	5	-0.0003	0.0056	-0.0010	0.0056
		20	-0.0001	0.0056	0.0000	0.0056
		100	-0.0003	0.0056	0.0005	0.0056
		120	0.0008	0.0056	0.0005	0.0056
	4000	5	0.0002	0.0056	-0.0005	0.0056
		20	0.0002	0.0056	0.0000	0.0056
		100	-0.0001	0.0056	0.0001	0.0056
		120	0.0008	0.0056	-0.0001	0.0056

The appropriate primary current values are applied to the current transformer under test and the compensated current comparator using a current source at 60 Hz. The ratio error and phase displacement values between secondary currents of the transformers are measured with most precision microprocessor based Current Transformer Bridge. Figure A1.1 shows the measurement setup of SASO NMCC.

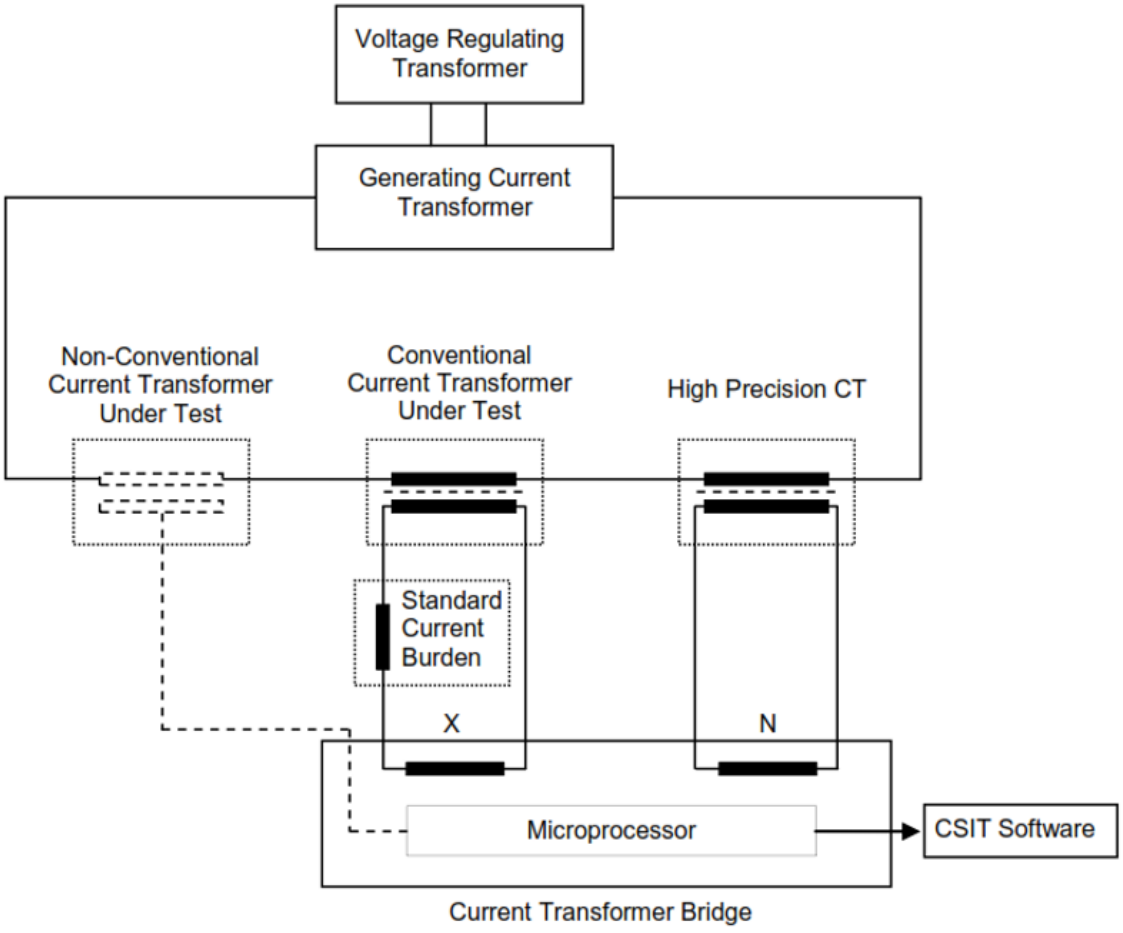

Figure A1.1 Measurement setup of SASO NMCC

The symbols and definitions stated are in accordance with IEC 61869-2.

Current error εx: The error which a transformer introduces into the measurement of a current and which arises from the fact that the actual transformation ratio is not equal to the rated transformation ratio. The current error expressed in per cent is given by the formula:

$$\varepsilon_X(\%) = \frac{K_u I_S - I_p}{I_p} 100,$$

where

K_n is rated transformation ratio;

I_p is actual primary current;

I_s is actual secondary current when I_p is applied under the conditions of measurement.

***Z_B* Burden**: The impedance of the secondary circuit in ohms and power-factor. The burden is usually expressed as the apparent power in volt-amperes absorbed at a specified power-factor and at the rated secondary current.

Phase displacement *δ_X*: The difference (radian) in phase between the primary current and the secondary current vectors, the direction of vectors being so chosen that the angle is zero for a perfect transformer. The phase displacement is said to be positive when the secondary current vector leads the primary current vector

δ Symbol, in order not to cause confusion, is used with the italic format (δ).

Saad BinQoud, Rashed Alroumie, Mohammed Almutairi.

UMTS (Ukraine)

Measurement results for current transformers given in the Table A1.2.

Table A1.2 Measurement results for current transformers

Frequency	Nominal primary current	Percentage of nominal primary current	Ratio error ε_I	Combined uncertainty for ratio error $u(\varepsilon_I)$	Phase displace-ment δ_I	Combined uncertainty for phase displacement $u(\delta_I)$
Hz	A	%	%	%	crad	crad
50	5	5	0.0009	0.0010	-0.0023	0.0020
		20	0.0005	0.0010	-0.0017	0.0020
		100	0.0004	0.0010	-0.0017	0.0020
		120	0.0004	0.0010	-0.0017	0.0020
	50	5	0.0008	0.0010	-0.0026	0.0020
		20	0.0003	0.0010	-0.0026	0.0020
		100	0.0004	0.0010	-0.0020	0.0020
		120	0.0004	0.0010	-0.0017	0.0020
	200	40	0.0011	0.0010	-0.0011	0.0020
		80	0.0020	0.0010	-0.0016	0.0020
		100	0.0021	0.0010	-0.0012	0.0020
		120	0.0021	0.0010	-0.0010	0.0020
	400	5	0.0017	0.0010	-0.0013	0.0020
		20	0.0020	0.0010	-0.0016	0.0020
		100	0.0012	0.0010	-0.0013	0.0020
		120	0.0010	0.0010	-0.0009	0.0020
	800	5	0.0005	0.0010	-0.0005	0.0020
		20	0.0004	0.0010	-0.0002	0.0020
		100	0.0002	0.0010	-0.0001	0.0020
		120	0.0006	0.0010	-0.0002	0.0020
	1500	5	0.0008	0.0010	-0.0009	0.0020
		20	0.0003	0.0010	-0.0012	0.0020
		100	-0.0001	0.0010	-0.0009	0.0020
		120	-0.0005	0.0010	-0.0001	0.0020
	2000	5	0.0006	0.0010	-0.0010	0.0020
		20	0.0006	0.0010	-0.0003	0.0020
		100	0.0009	0.0010	-0.0001	0.0020
		120	0.0009	0.0010	-0.0001	0.0020

Frequency	Nominal primary current	Percentage of nominal primary current	Ratio error ε_I	Combined uncertainty for ratio error $u(\varepsilon_I)$	Phase displace-ment δ_I	Combined uncertainty for phase displacement $u(\delta_I)$
Hz	A	%	%	%	crad	crad
50	4000	5	-0.0001	0.0010	-0.0027	0.0020
		20	-0.0005	0.0010	-0.0011	0.0020
		100	-0.0004	0.0010	-0.0005	0.0020
		120	-0.0002	0.0010	-0.0010	0.0020
60	5	5	0.0009	0.0010	-0.0023	0.0020
		20	0.0006	0.0010	-0.0016	0.0020
		100	0.0004	0.0010	-0.0016	0.0020
		120	0.0004	0.0010	-0.0016	0.0020
	50	5	0.0009	0.0010	-0.0025	0.0020
		20	0.0004	0.0010	-0.0025	0.0020
		100	0.0005	0.0010	-0.0020	0.0020
		120	0.0005	0.0010	-0.0017	0.0020
	200	40	0.0010	0.0010	-0.0011	0.0020
		80	0.0016	0.0010	-0.0015	0.0020
		100	0.0019	0.0010	-0.0012	0.0020
		120	0.0018	0.0010	-0.0010	0.0020
	400	5	0.0017	0.0010	-0.0012	0.0020
		20	0.0020	0.0010	-0.0016	0.0020
		100	0.0012	0.0010	-0.0012	0.0020
		120	0.0010	0.0010	-0.0008	0.0020
	800	5	0.0005	0.0010	-0.0005	0.0020
		20	0.0004	0.0010	-0.0002	0.0020
		100	0.0003	0.0010	-0.0001	0.0020
		120	0.0004	0.0010	0.0000	0.0020
	1500	5	0.0009	0.0010	-0.0009	0.0020
		20	0.0003	0.0010	-0.0012	0.0020
		100	0.0001	0.0010	-0.0009	0.0020
		120	0.0001	0.0010	-0.0001	0.0020
	2000	5	0.0009	0.0010	-0.0008	0.0020
		20	0.0008	0.0010	-0.0004	0.0020
		100	0.0008	0.0010	0.0000	0.0020
		120	0.0008	0.0010	0.0000	0.0020

Reference standard: State primary standard of the unit of the transformation scale coefficient of the alternating current. It is a precision home-made multi-range current comparator. The design of the reference standard allows its self-calibration using the primary reference calibration procedure. Due to this, SE “Ukrmeterteststandard” has its own AC current ratio error and phase displacement unit’s playback system.

Current Comparator Bridge: Two secondary currents of the travelling standard and the reference standard are compared by the current comparator bridge. It is a precision home-made digital device with automatic balancing of input currents and measurement of ratio error and phase displacement values. Calibration of current comparison bridge is performed by applying known ratio error and phase displacement values to the bridge under calibration.

Measurements has been performed through traditional method – comparison of the travelling standard with the reference standard by means of current comparator bridge, by applying appropriate primary currents to the travelling standard and the reference standard, and by measuring the ratio error and phase displacement values of the travelling standard with the current comparator bridge. Ratio error and phase displacement measurements of the travelling standard are read directly from the digital display of the current comparator bridge. A set of measurements consists of measuring each percentage values at least 10 times by adjusting the current from minimum up to highest test point, and then continue by measuring the points in descending order.

UME (Turkey)

Measurement results for current transformers given in the Table A1.3.

Table A1.3 Measurement results for current transformers

Frequency	Nominal primary current	Percentage of nominal primary current	Ratio error ε_I	Combined uncertainty for ratio error $u(\varepsilon_I)$	Phase displace-ment δ_I	Combined uncertainty for phase displacement $u(\delta_I)$
Hz	A	%	%	%	crad	crad
50	5	5	-0.0001	0.00025	-0.0003	0.00025
		20	-0.0002	0.00025	-0.0003	0.00025
		100	-0.0001	0.00025	-0.0003	0.00025
		120	-0.0001	0.00025	-0.0003	0.00025
	50	5	0.0003	0.0010	-0.0001	0.0010
		20	0.0004	0.0010	-0.0002	0.0010
		100	0.0004	0.0010	-0.0001	0.0010
		120	0.0003	0.0010	-0.0001	0.0010
	200	40	0.0007	0.0010	-0.0001	0.0010
		80	0.0011	0.0010	-0.0006	0.0010
		100	0.0012	0.0010	-0.0005	0.0010
		120	0.0012	0.0010	-0.0005	0.0010
	400	5	0.0009	0.0010	-0.0002	0.0010
		20	0.0013	0.0010	-0.0006	0.0010
		100	0.0007	0.0010	0.0002	0.0010
		120	0.0005	0.0010	0.0004	0.0010
	800	5	0.0014	0.0010	-0.0004	0.0010
		20	0.0010	0.0010	-0.0003	0.0010
		100	0.0005	0.0010	-0.0001	0.0010
		120	0.0005	0.0010	-0.0001	0.0010
	1500	5	0.0010	0.0010	-0.0004	0.0010
		20	0.0006	0.0010	-0.0003	0.0010
		100	0.0002	0.0010	-0.0002	0.0010
		120	0.0002	0.0010	-0.0002	0.0010
	2000	5	0.0013	0.0010	-0.0007	0.0010
		20	0.0007	0.0010	-0.0004	0.0010
		100	0.0003	0.0010	-0.0004	0.0010
		120	0.0003	0.0010	-0.0004	0.0010

Frequency	Nominal primary current	Percentage of nominal primary current	Ratio error ε_I	Combined uncertainty for ratio error $u(\varepsilon_I)$	Phase displace-ment δ_I	Combined uncertainty for phase displacement $u(\delta_I)$
Hz	A	%	%	%	crad	crad
50	4000	5	0.0012	0.0010	-0.0005	0.0010
		20	0.0005	0.0010	-0.0003	0.0010
		100	0.0001	0.0010	-0.0004	0.0010
		120	0.0001	0.0010	-0.0004	0.0010
60	5	5	-0.0001	0.00025	-0.0005	0.00025
		20	-0.0002	0.00025	-0.0005	0.00025
		100	-0.0002	0.00025	-0.0005	0.00025
		120	-0.0002	0.00025	-0.0005	0.00025
	50	5	0.0003	0.0010	-0.0001	0.0010
		20	0.0004	0.0010	-0.0003	0.0010
		100	0.0004	0.0010	-0.0002	0.0010
		120	0.0003	0.0010	-0.0002	0.0010
	200	40	0.0007	0.0010	-0.0002	0.0010
		80	0.0010	0.0010	-0.0007	0.0010
		100	0.0012	0.0010	-0.0007	0.0010
		120	0.0012	0.0010	-0.0006	0.0010
	400	5	0.0008	0.0010	-0.0002	0.0010
		20	0.0012	0.0010	-0.0006	0.0010
		100	0.0007	0.0010	0.0001	0.0010
		120	0.0005	0.0010	0.0003	0.0010
	800	5	0.0015	0.0010	-0.0002	0.0010
		20	0.0009	0.0010	-0.0001	0.0010
		100	0.0004	0.0010	0.0001	0.0010
		120	0.0004	0.0010	0.0001	0.0010
	1500	5	0.0012	0.0010	-0.0004	0.0010
		20	0.0007	0.0010	-0.0003	0.0010
		100	0.0002	0.0010	-0.0002	0.0010
		120	0.0002	0.0010	-0.0002	0.0010
	2000	5	0.0013	0.0010	-0.0005	0.0010
		20	0.0006	0.0010	-0.0003	0.0010
		100	0.0002	0.0010	-0.0003	0.0010
		120	0.0002	0.0010	-0.0003	0.0010

Frequency	Nominal primary current	Percentage of nominal primary current	Ratio error ε_I	Combined uncertainty for ratio error $u(\varepsilon_I)$	Phase displace-ment δ_I	Combined uncertainty for phase displacement $u(\delta_I)$
Hz	A	%	%	%	crad	crad
	4000	5	0.0013	0.0010	-0.0005	0.0010
		20	0.0005	0.0010	-0.0003	0.0010
		100	0.0001	0.0010	-0.0005	0.0010
		120	0.0001	0.0010	-0.0005	0.0010

Comparison measurements has been performed according to TLM-05-G1PE-04-05 “Calibration Instruction of Current Transformer” by applying appropriate primary currents to the travelling standard and the reference current transformer, and by measuring the ratio error and phase displacement values of the device with the reference current transformer measuring bridge. The measurement circuit is shown in Figure A1.3.

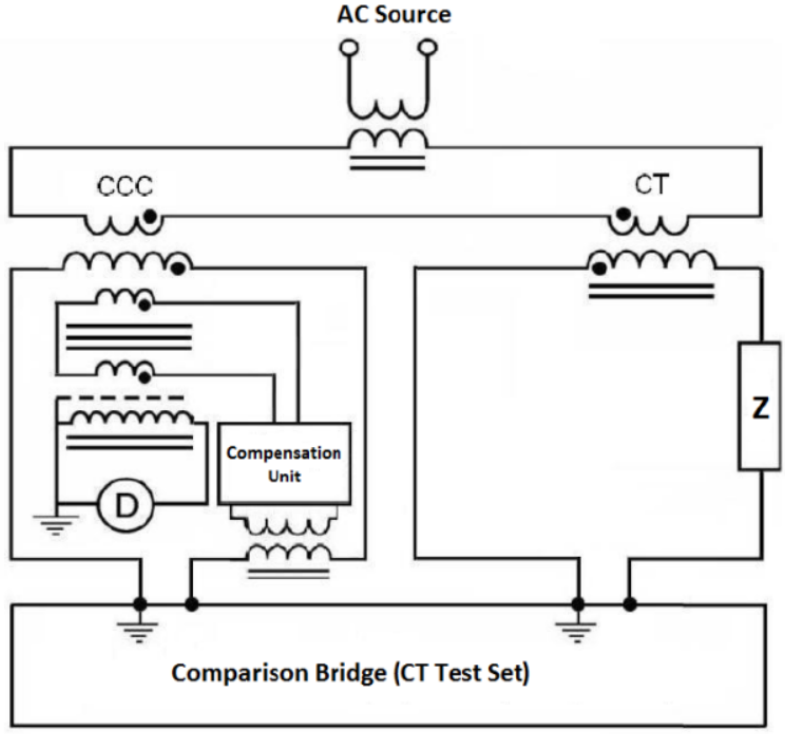

Figure A1.3 Measurement circuit for current transformer

The measurement circuit consists of three parts:

Power Supply: The primary test current has been provided with a semi-automatic current source consisting of fixed AC voltage source of standard frequencies of 50 and 60 Hz, voltage adjustment (variable transformers and amplifiers), and current sourcing transformer.

Reference Current Transformer (Reference CT): The reference CT is a home-made multi-range electronically-compensated current comparator. Construction of a hollow toroid core prevents almost all external unwanted electromagnetic fields to reach its detector core so that the detector can sense the unbalanced currents almost without error. Use of electronic circuitry within the current comparator structure showed that one could design a current transformer with

errors not more than a few ppm. The electronic circuitry is designed as a transconductance amplifier which amplifies the voltage obtained from the detector winding and converts it into a current. It forces this current to the inner and outer compensation windings not only for compensation of the secondary current but also for automatically zeroing the detection voltage. The errors of the current comparator are determined by measuring of the detection voltage with the lock-in amplifier.

Current Transformer (CT) Measuring Bridge: Two secondary currents are compared by the current comparator. An error current adding method is used to balance these currents in the current comparator. Calibration of CT measuring bridge is performed by applying known ratio error and phase displacement values to the bridge under calibration.

Before starting the measurements, initial verifications of the references were carried out by performing Reference CT self-check, CT Measuring Bridge self-check with a resolution of 1 + j1 ppm, and self-check of both devices in 1:1 self-comparison mode with secondary feed of approximately 5A.

The procedure recommended by owner of the travelling standard was considered in the measurements.

Four sets of measurements have been performed for each nominal primary current stated in the technical protocol. A set of measurements consists of measuring each percentage values at least 10 times by adjusting the current from minimum up to highest test point, and then continue by measuring the points in descending order.

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Appendix 2

Reported measurement uncertainty components for each NMI laboratory

SASO-NMCC (Saudi Arabia)

The following sample table shows 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 on ratio and phase displacement form 5 A to 4000A/5 A at I/I_N=120 %, 100 %, 20 %, 5 % at a burden of 0 VA, at a frequency of 60 Hz and an ambient temperature (23 ± 2) °C.

The uncertainty budget given in the Table A2.1 shows the uncertainty contributions associated with the ratio error measurements of current transformers.

Table A2.1 Uncertainty budget for ratio error

Symbol	Description	Unit	Value	Probability distribution	Factor	Sensitivity coefficient	Uncertainty contribution
ε_{Xi}	Repeatability	ppm	0.59	Normal	1.000	1	0.35 $(ppm)^2$
$\delta\varepsilon_{XRcal\ ct}$	Calibration effect (standard current transformer)	ppm	50	Normal	0.500	1	625.00 $(\mu A/A)^2$
$\delta\varepsilon_{XRcal\ ts}$	Calibration effect (for bridge)	ppm	50	Normal	0.500	1	625.00 $(\mu A/A)^2$
$\delta\varepsilon_{XRd\ ct}$	Drift (for standard current transformer)	ppm	50	Rectangular	0.577	1	833.33 $(\mu A/A)^2$
$\delta\varepsilon_{XRd\ ts}$	Drift (for bridge)	ppm	50	Rectangular	0.577	1	833.33 $(\mu A/A)^2$
$\delta\varepsilon_{XRtc}$	Temperature effect	ppm	2	Rectangular	0.577	1	1.33 $(\mu A/A)^2$
$\delta\varepsilon_{XBurden}$	Burden effect	ppm	2	Rectangular	0.577	1	1.33 $(\mu A/A)^2$
$\delta\varepsilon_{XConfig}$	Configuration effect	ppm	20	Rectangular	0.577	1	133.33 $(\mu A/A)^2$
$\delta\varepsilon_{XCurrent}$	Applied voltage effect	ppm	10	Rectangular	0.577	1	33.33 $(\mu A/A)^2$
$\delta\varepsilon_{XFreq}$	Frequency effect	ppm	2	Rectangular	0.577	1	1.33 $(\mu A/A)^2$
						Total variance $u(eX)^2$	3087.68 $(\mu A/A)^2$
						Combined uncertainty $u(eX)$	55.57 µA/A
						Expanded uncertainty (k = 2, 95 %)	111 µA/A

Model function for ratio error measurements:

$$\varepsilon_X = \varepsilon_{Xi} + \delta\varepsilon_{XRcal\ ct} + \delta\varepsilon_{XRcal\ ts} + \delta\varepsilon_{XRd\ ct} + \delta\varepsilon_{XRd\ ts} + \delta\varepsilon_{XRtc} + \delta\varepsilon_{XBurden} + \delta\varepsilon_{XConfig} + \delta\varepsilon_{XCurrent} + \delta\varepsilon_{XFreq}.$$

The uncertainty budget given in the Table A2.2 shows the uncertainty contributions associated with the phase displacement measurements of current transformers.

Table A2.2 Uncertainty budget for phase displacement

Symbol	Description	Unit	Value	Probability distribution	Factor	Sensitivity coefficient	Uncertainty contribution
δ_{Xi}	0.098 (μrad)2	μrad	0.73	Normal	1	1	0.54 $(\mu rad)^2$
$\delta\delta_{XRcal\ ct}$	2500.00 (μrad)2	μrad	50	Normal	0.5	1	625.00 $(\mu rad)^2$
$\delta\delta_{XRcal\ ts}$	625.00 (μrad)2	μrad	50	Normal	0.5	1	625.00 $(\mu rad)^2$
$\delta\delta_{XRd\ ct}$	833.33 (μrad)2	μrad	50	Rectangular	0.577	1	833.33 $(\mu rad)^2$
$\delta\delta_{XRd\ ts}$	833.33 (μrad)2	μrad	50	Rectangular	0.577	1	833.33 $(\mu rad)^2$
$\delta\delta_{XRtc}$	8.33 (μrad)2	μrad	2	Rectangular	0.577	1	1.33 $(\mu rad)^2$
$\delta\delta_{XBurden}$	8.33 (μrad)2	μrad	2	Rectangular	0.577	1	1.33 $(\mu rad)^2$
$\delta\delta_{XConfig}$	100.00 (μrad)2	μrad	20	Rectangular	0.577	1	133.33 $(\mu rad)^2$
$\delta\delta_{XCurrent}$	133.33 (μrad)2	μrad	10	Rectangular	0.577	1	33.33 $(\mu rad)^2$
$\delta\delta_{XFreq}$	133.33 (μrad)2	μrad	2	Rectangular	0.577	1	1.33 $(\mu rad)^2$
						Total variance $u(eX)^2$	3087.87 $(\mu rad)^2$
						Combined uncertainty $u(eX)$	55.6 μrad
						Expanded uncertainty (k = 2, 95 %)	111 μrad

Model function for phase displacement measurements:

$$\delta_X = \delta_{Xi} + \delta\delta_{XRcal\ ct} + \delta\delta_{XRcal\ ts} + \delta\delta_{XRd\ ct} + \delta\delta_{XRd\ ts} + \delta\delta_{XRtc} + \delta\delta_{XBurden} + \delta\delta_{XConfig} + \delta\delta_{XCurrent} + \delta\delta_{XFreq}.$$

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UMTS (Ukraine)

The uncertainty budget given in the Table A2.2 shows the uncertainty contributions associated with the ratio error and in the Table A2.3 shows the uncertainty contributions associated with the phase displacement measurements.

Table A2.2 Uncertainty budget for ratio error

Source of uncertainty	Definition	Type	Probability distribution	Standard uncertainty value, %	Sensitivity coefficient	Contribution to the total standard uncertainty, %
Calibration effect of reference standard	ε_{Ir}	B	Rectangular	0.0013	0.577	0.00072
Calibration effect of current comparator bridge	ε_{Ib}	B	Rectangular	0.0004	0.577	0.00022
Long time drift for reference standard	ε_{Id}	B	Rectangular	0.0004	0.577	0.00022
Standard deviation of measurement results	$S_{I\varepsilon}$	A	Normal	0.0002	1	0.0002
	Combined uncertainty $u_{I\varepsilon}$ = 0.000968 %					
	Confidential level = 95 %			Coverage factor = 2.0		
	Expanded uncertainty $U_{I\varepsilon}$ = 0.0019 %					
	Declared uncertainty $U_{I\varepsilon}$ = 0.002 %					

Measurement equation for ratio error is: $\varepsilon_{\mathrm{X}} = \varepsilon_{\mathrm{Xi}} + S_{I\varepsilon} + \delta\varepsilon_{Ir} + \delta\varepsilon_{Ib} + \delta\varepsilon_{Id}$.

Table A2.3 Uncertainty budget for phase displacement

Source of uncertainty	Definition	Type	Probability distribution	Standard uncertainty value, crad	Sensitivity coefficient	Contribution to the total standard uncertainty, crad
Calibration effect of reference standard	δ_{Ir}	B	Rectangular	0.0029	0.577	0.00168
Calibration effect of current comparator bridge	δ_{Ib}	B	Rectangular	0.0012	0.577	0.00067
Long time drift for reference standard	δ_{Id}	B	Rectangular	0.00067	0.577	0.00022
Standard deviation of measurement results	$S_{I\delta}$	A	Normal	0.0002	1	0.0002
	Combined uncertainty $u_{I\delta}$ = 0.00193 crad					
	Confidential level = 95 %			Coverage factor = 2		
	Expanded uncertainty $U_{I\delta}$ = 0.00386 crad					
	Declared uncertainty $U_{I\delta}$ = 0.004 crad					

Measurement equation for phase displacement is: $\delta_{\mathrm{X}} = \delta_{\mathrm{Xi}} + S_{I\delta} + \delta\delta_{Ir} + \delta\delta_{Ib} + \delta\delta_{Id}$

UME (Turkey)

The uncertainty budget given in the Tables A2.4 and A2.5 (for 5 A/5 A) and Tables A2.6 and A2.7 (from 50 A/5 A to 4000 A/5 A) shows the uncertainty contributions associated with the ratio error and phase displacement measurements of current transformers.

Table A2.4 Uncertainty budget for ratio error for 5 A/5 A

Quantity	Standard uncertainty (%)	Type	Probability distribution	Sensitivity coefficient	Uncertainty contribution (%)
Calibration effect of CT Measuring Bridge	0.0004	B	normal	1	0.0002
Drift for CT Measuring Bridge	0.0001	B	rectangular	1	0.000058
Resolution	0.00005	B	rectangular	1	0.000029
Circuit configuration	0.0001	B	normal	1	0.00005
Repeatability	0.0001	A	normal	1	0.0001
				Combined uncertainty	0.00024
				Expanded uncertainty (U) (k = 2)	0.000048
				Declared uncertainty (U) (k = 2)	0.00050

Table A2.5 Uncertainty budget for phase displacement for 5 A/5 A

Quantity	Standard uncertainty (crad)	Type	Probability distribution	Sensitivity coefficient	Uncertainty contribution (crad)
Calibration effect of CT Measuring Bridge	0.0004	B	normal	1	0.0002
Drift for CT Measuring Bridge	0.0001	B	rectangular	1	0.000058
Resolution	0.00005	B	rectangular	1	0.000029
Circuit configuration	0.0001	B	normal	1	0.00005
Repeatability	0.0001	A	normal	1	0.0001
				Combined uncertainty	0.00024
				Expanded uncertainty (U) (k = 2)	0.000048
				Declared uncertainty (U) (k = 2)	0.00050

Table A2.6 Uncertainty budget for ratio error and phase displacement from 50 A/5 A to 4000 A/5 A

Quantity	Standard uncertainty (%)	Type	Probability distribution	Sensitivity coefficient	Uncertainty contribution (%)
Calibration effect of Reference CT	0.0010	B	normal	1	0.0005
Drift for Reference CT	0.0002	B	rectangular	1	0.000115
Calibration effect of CT Measuring Bridge	0.0004	B	normal	1	0.0002
Drift for CT Measuring Bridge	0.0001	B	rectangular	1	0.000058
Resolution	0.00005	B	rectangular	1	0.000029
Circuit configuration	0.0010	B	normal	1	0.0005
Repeatability	0.0002	A	normal	1	0.0002
				Combined uncertainty	0.00077
				Expanded uncertainty (U) (k = 2)	0.00154
				Declared uncertainty (U) (k = 2)	0.00200

Table A2.7 Uncertainty budget for ratio error and phase displacement from 50 A/5 A to 4000 A/5 A

Quantity	Standard uncertainty (crad)	Type	Probability distribution	Sensitivity coefficient	Uncertainty contribution (crad)
Calibration effect of Reference CT	0.0010	B	normal	1	0.0005
Drift for Reference CT	0.0002	B	rectangular	1	0.000115
Calibration effect of CT Measuring Bridge	0.0004	B	rectangular	1	0.0002
Drift for CT Measuring Bridge	0.0001	B	rectangular	1	0.000058
Resolution	0.00005	B	rectangular	1	0.000029
Circuit configuration	0.0010	B	normal	1	0.0005
Repeatability	0.0002	A	normal	1	0.0002
				Combined uncertainty	0.00077
				Expanded uncertainty (U) (k = 2)	0.00154
				Declared uncertainty (U) (k = 2)	0.00200

The contributions for the “Calibration effects of the CT Comparison Bridge and Reference CT” take into account any error of the CT Comparison Bridge and Reference CT used in calibration of the transfer standard.

The value for repeatability is the standard deviation of the mean for each individual set of measurements.

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approximately 95%. The standard uncertainty of measurement has been determined in accordance with GUM and EA-4/02.

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Appendix 3
Technical Protocol of Comparison

State Enterprise “All-Ukrainian state research and production center of standardization, metrology, certification consumers’ right protection”
(SE “Ukrmetertеststandard”)

TECHNICAL PROTOCOL
on Supplementary Comparison of
High Current Transformer Measuring Systems
(GULFMET.EM-S7)

Oleh Velychko, Valeriy Kikalo

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Coordinator of comparison: Oleh Velychko

January 2020
Kyiv, Ukraine

Table of Content

1 Introduction

The GULFMET Supplementary Comparison (SC) of high current transformer measuring systems (comparison identifier – GULFMET.EM-S7) will be in the framework of GULFMET project from January to June, 2020.

This project for comparing of national current ratio standards will be between countries which are member laboratories of GULFMET, EURAMET and COOMET regional metrology organizations. In this comparison take part three national metrology institutes (NMI): SE "Ukrmetrteststandard" (UMTS, Ukraine); SASO-NMCC (Saudi Arabia); UME (Turkey).

The State Enterprise "All-Ukrainian State Scientific and Production Center of Standardization, Metrology, Certification and Protection of Consumer" (SE "Ukrmetrteststandard"), Ukraine was selected as the pilot laboratory. Dr. Oleh Velychko will be the comparison coordinator. The pilot laboratory is responsible for providing the travelling standards, coordinating the schedule, collecting and analyzing the comparison data, preparing the draft report, etc.

2 Participants and time schedule of the comparison

Each participant is given 2 weeks to perform the measurements of the travelling standard and 1 week to transfer standards to the pilot laboratory. The NMI participants and the time schedule of the comparison are given in Table 1 and Table 2. There are three NMI participants in this comparison. Participants should have the traveling standard delivered to the address of the participant scheduled to perform measurements after themselves according to the schedule.

Table 1 List of NMI participants of the comparison

№	NMI	Abbreviation of NMI	Address	Contact person	e-mail, phone, fax
1	State Enterprise "All-Ukrainian state research and production center of standardization, metrology, certification consumers' right protecttion" (SE "Ukrmetrtest-standard") – **pilot**	**UMTS**	4, Metrologichna Str., 03143, Kyiv, Ukraine	Oleh Velychko	velychko@ukrcsm.kiev.ua Tel./Fax: +38 044 526 0335
2	Saudi Standards, Metrology and Quality Organization of The Kingdom of Saudi – National Measurements and Calibration Center	**SASO-NMCC**	Front king Saud Univer-sity Riyadh 11471, P.O. Box 3437 Kingdom of Saudi Arabia	Saad Bin Qoud	s.qoud@saso.gov.sa Tel: +966 56 902 7551

№	NMI	Abbreviation of NMI	Address	Contact person	e-mail, phone, fax
3	TÜBITAK Ulusal Metroloji Enstitüsü	**UME**	TÜBİTAK Gebze Yerleskesi Baris Mah., Dr. Zeki Acar Cad. No. 1 41470, Gebze Kocaeli, Turkey	Huseyin Çayci	huseyin.cayci@tubitak.gov.tr Tel.: +90 262 679 5000

Table 2 List of dates of measurements

Abbreviation of NMI	Dates of measurements	Dates of delivery
UMTS	02–27.03.2020	30.03.2020
UME	06–17.04.2020	20.04.2020
UMTS	27.04–29.05.2020	01.06.2020
SASO-NMCC	07–18.06.2020	21.06.2020
UMTS	29.06–10.07.2020	-

3. Financial aspects and insurance

Each NMI participant of comparison should be at their own expense to perform all the measurements and send travelling standards back to the pilot laboratory (including transportation costs, insurance costs and customs).

In addition, each NMI participant of comparison should be at their own expense to cover all costs from the moment of arrival the travelling standard in the country, up to the moment of sending back to the pilot laboratory.

Expenses may include (but are not limited to): charges at check travelling standard (customs fees, brokerage services, transportation within the country) and the costs of returning the standard to the pilot laboratory.

4. The travelling standard and measurement instruction

4.1. Description of the travelling standard

The selected travelling standard is standard current transformer CA535/2 (“Трансформатор тока эталонный CA535/2”).

Figure 1 The photo of the travelling standard CA535/2

Main characteristics of the travelling standard:

- primary rated current from 0,5 A to 5000 A;
- secondary rated current 5 A;
- burden not more than 0,05 Ω.

4.2 Handling of travelling standards

The travelling standard will be transported in two transport boxes which are designed for safe transportation. Upon arrival the participants must check transport boxes to make sure that all the parts are present according to the list. The travelling standard will be neatly stacked in a transport box (Figures 3 and 4).

Linear dimensions of the transport box according to Figure 2 are: 580x570x200 mm. Weight of this transport box (together with the content) is about 17 kg.

Linear dimensions of transport box according to Figure 3 are: 480x540x400 mm. Weight of this transport box (together with the content) is about 12 kg.

Figure 2 Transport box #1

Figure 3 Transport box #2

If the damage of any transport box is found the travelling standard must be packed in new transport box which will provide the necessary protection during transporting.

Travelling standard must be carefully removed from the transport box. Opening the corpus of travelling standards is strictly prohibited. If noticed any malfunction of travelling standards, the NMI participants should immediately notify the pilot laboratory by fax or email. If travelling standards are needed to be repaired the NMI participant must send travelling standards to the pilot laboratory.

NMI participants must inform the pilot laboratory by fax or e-mail about the arrival of travelling standards by using the form shown on Figure 4.

Confirmation notes for receipt		
Date of arrival		
NMI		
Name of responsible person		
The travel standard	□ Damaged	□ Not Damaged
Additional notes:		

Figure 4 Sample form for the information of arrival of travelling standards

The NMI participants should inform the pilot laboratory about departure of the travelling standard by using the form shown on Figure 5.

Confirmation notes for dispatch	
Date of shipment	
NMI	
Name of responsible person	
Shipment information (company name etc.)	
Additional notes:	

Figure 5 Sample form for the information of departure of the travelling standard

After the measurements, NMI participant of comparison must send the travelling standard to the pilot laboratory. NMI participants in the comparison are responsible for arranging shipment of the travelling standard to the pilot laboratory.

5. Description of the method of measurement

5.1 Operations before measurements

After power up of the travelling standard in NMI participant it will be stabilizing for 2 days.

To connect the travelling standard NMI participants can use any adapters but participants should take into account all relevant adjustments. Before the measurements, it is necessary to familiarize design features and work principles of the travelling standard by using technical description.

5.2 Measurements

Measurements must be performed under the following conditions:

- temperature: 23 °C ± 3 °C;

- relative humidity: from 30 % to 70 %;

- supply frequencies: 50 Hz ± 0.5 Hz and 60 Hz ± 0.6 Hz with a sinusoidal waveform.

The participants should inform the pilot laboratory if the above conditions cannot be met.

The data to be recorded at each measurement:

- date of measurement;

- air temperature and relative humidity environment;

- burden value (in VA or in Ω) and its PF.

If measurements are carried out within a few days, then measured value together with the measurement date shall be given for each measurement day.

Comparison of national standards is provided by means of measuring of the travelling standard metrological characteristics (ratio error ε_i and phase displacement δ_i). Measurements are performed at the values of primary current 5, 20, 100 and 120 % of each primary nominal current (I_N) according table at the subchapter 6.2 on a frequencies of 50 Hz and 60 Hz and at load fixed for the travelling standard.

Each NMI participant provides up to ten observations at each operation current. Each NMI participant presents arithmetical mean of ten observations and uncertainty in measurements as a result of measurement.

5.3 Measurement uncertainties

Uncertainty of the measurements should be calculated according to the GUM – Guide to the expression of uncertainty in measurement JCGM 100:2008 [1] (GUM 1995 with minor corrections). With the results of measurements should be given a model that describes how the measurement result was obtained considering all influencing quantities.

For each of the influencing quantities should be given the description of the source of uncertainty and an assessment of this uncertainty. All influencing quantities, their uncertainties, influencing coefficients, degrees of freedom and levels of confidence should be given in the budget of the uncertainty.

The budget of the uncertainty (Table 3) should include such number of influencing quantities and their uncertainties, which ensures the highest-level measurements for the laboratory.

Table 3 Uncertainty budget

i	Quantity (unit)	Distribution	x_i	$u(x_i)$	v_i	c_i	$u_i(y)$
1							
…							
y	Std uncertainty of measurement						
		Confidential level = %				*k* =	
		Expanded uncertainty =					

The components of the uncertainty budget should be expressed as standard uncertainties. The main components of the uncertainty budget are:

- standard uncertainty obtained as a result of an experiment from N independent measurements;

- uncertainty of the standard of the NMI laboratory, by means of which the value of the travelling standard is determined;

- uncertainty caused by the corrections.

Participants in the comparisons may include additional sources of uncertainty.

6. The measurement report

6.1 General information

Each NMI participant of the comparisons shall provide a report within six weeks from the date of departure travelling standards to the pilot laboratory. For quick detection of possible problems with the travelling standards a brief report shall be sent immediately after the measurements.

The report shall be sent to the coordinator of comparison by e-mail: velychko@ukrcsm.kiev.ua

The report shall include:

- description of measurement method(s);

- description of the measurement circuit and used the standard possibilities;

- confirmation of the metrological traceability (if NMI participant has its own units playback system, or must provide proof of traceability from another laboratory).

- temperature and humidity in the laboratory during the measurement;

- measurement results;

- values of the respective standard uncertainties;

- detailed budget of uncertainty, which will be included in a report on the comparisons.

If the corrections affecting the measurement result were applied, then they must be described in the report.

If between the measurements of any NMI participant, provided the pilot laboratory and preliminary comparisons reference value is detected a significant difference, it will be reported to the appropriate party. No other information on the measurement results will not be reported.

If any NMI laboratory has difficulties in fulfilling one or more of the requirements listed in this protocol, instead of not taking part in the comparison, this NMI laboratory is recommended to contact the coordinator of the comparisons and find a way out of this situation.

6.2 Measurement results

GULFMET.EM-S7 comparison.

Name of NMI participant: _____

Country: _____

Dates of measurements: from _____ to _____.

Frequency	Nominal primary current	Percentage of nominal primary current	Ratio error ε_I	Total standard uncertainty for ratio error $u(\varepsilon_I)$	Phase displace-ment δ_I	Total standard uncertainty for phase displacement $u(\delta_I)$
Hz	A	%	%	%	crad	crad
50	5	5				
		20				
		100				
		120				
	50	5				
		20				
		100				
		120				
	200	5				
		20				
		100				
		120				
	400	5				
		20				
		100				
		120				
	800	5				
		20				
		100				
		120				
	1500	5				
		20				
		100				
		120				
	2000	5				
		20				
		100				
		120				
	4000	5				
		20				
		100				
		120				

Frequency	Nominal primary current	Percentage of nominal primary current	Ratio error ε_I	Total standard uncertainty for ratio error $u(\varepsilon_I)$	Phase displace-ment δ_I	Total standard uncertainty for phase displacement $u(\delta_I)$
Hz	A	%	%	%	crad	crad
60	5	5				
		20				
		100				
		120				
	50	5				
		20				
		100				
		120				
	200	40				
		80				
		100				
		120				
	400	5				
		20				
		100				
		120				
	800	5				
		20				
		100				
		120				
	1500	5				
		20				
		100				
		120				
	2000	5				
		20				
		100				
		120				
	4000	5				
		20				
		100				
		120				

7. The report on comparison

Preliminary and final reports on the results of comparison will be prepared by the pilot laboratory. The report will be prepared by the pilot laboratory within 1 month after the end of the measurement, and sent to the NMI participants. The report is only for the NMI participants of comparisons and is confidential.

Notes. The report should be directed to the pilot laboratory for 1 month from the date of distribution of the Draft A. Comments will be considered in the Draft B. Draft B will be completed within 1 month after the end of the measurement. The final report will be prepared within 1 month from the receipt of the comments on the Draft B.

References

[1] JCGM 100:2008 Evaluation of measurement data – Guide to the expression of uncertainty in measurement.