WP2: Reference Measurement Systems and Simplified Test Methods for Instrument Transformer Calibration

Overview of WP2 project activities

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A. Overview of WP2 (Aim and objectives, Partners, Deliverables, Planned papers and Gannt Chart)

B. Activities status (First 18M)

- By Tasks

C. Achievements so far

- by partners

A. Overview of WP2 (aim; objectives)

Support IEC TC 38 with the traceable calibration of ITs to be employed for PQ measurements in electricity grids

WP2 aims at establishing suitable reference measuring systems for ITs, establishing traceable test procedures for industrial ITs and evaluating the ITs performance using the PQ performance indices

Objectives of IT4PQ:

2. **Reference measuring systems**
   - reference measuring systems for ITs
   - methods for the evaluation of the uncertainty to PQ indices
3. **Traceable test procedures**
   - calibration of ITs for PQ measurements in electricity grids
5. **Contribute to revision of technical report IEC/TR 61869-103 as well as to the standards in the IEC 61869 product family**

A. Overview of WP2 (partners)

No.	Partners
1	PTB
2	CMI
3	INRIM
4	LNE
5	SUN
6	TUBITAK
7	TUD
8	UNIBO
9	VSL

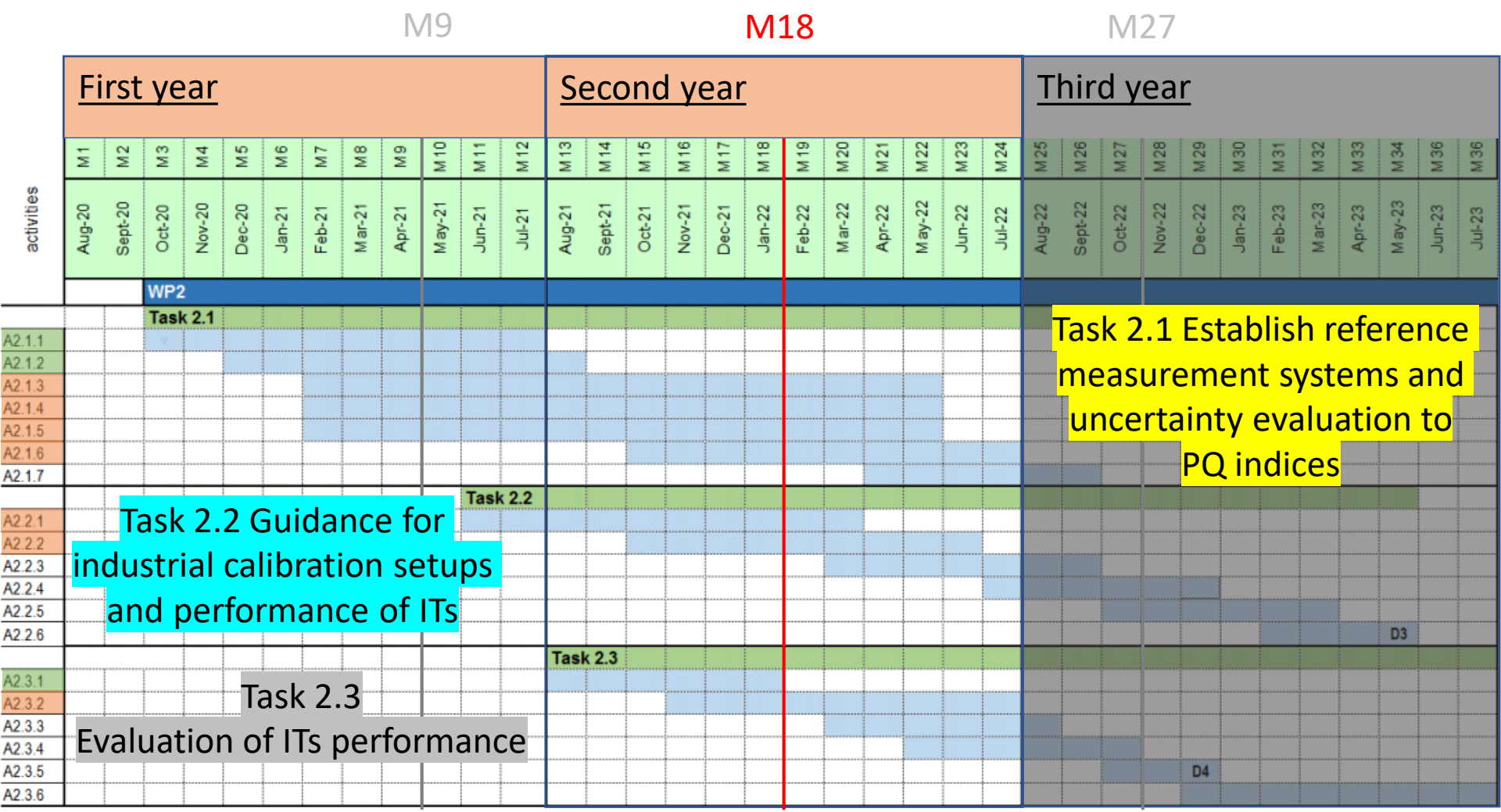
A. Overview of WP2 (deliverables; papers)

Objective	No.	Deliverable description	Type	Partners	Date
Obj. 3 (A2.2.6)	**D3**	**Good practice guide** on the simplified calibration setups and traceable methods to be used for the characterisation of ITs in industrial premises	Guide	**PTB**, INRIM, VSL, LNE, TUBITAK, SASO-NMCC, TUD	May 2023 (M34)
Obj. 2 (A2.3.5)	**D4**	**Report** on reference measurement systems, for ITs and methods for the evaluation of the relevant uncertainty contribution of ITs to PQ indices	Report	**TUD**, INRIM, PTB, TUBITAK, UNIBO	Dec 2022 (M29)

Planned papers (as per Annex 1):

A2.1.7 M26	**Submission of a paper** PTB with support from INRIM, CMI, TUBITAK, SASO-NMCC, UNIBO, and TUD will prepare a paper on the reference measurement systems and their uncertainties for publication in a suitable peer-reviewed conference or journal.	**PTB**, INRIM, CMI, TUBITAK, SASO-NMCC, UNIBO, TUD

A. Overview of WP2 (Gannt Chart)



Ax.x.x : should be done

Ax.x.x : ongoing

A. Overview of WP2 (Aim and objectives, Partners, Deliverables, Planned papers and Gannt Chart)

B. Activities status (First 18M)

- By Tasks

C. Achievements so far

- by partners

Task 2.1

Establish reference measurement systems and uncertainty evaluation to PQ indices

Aims at to establishing suitable reference measuring systems for ITs and methods for the evaluation of the relevant uncertainty contribution of ITs to PQ indices.

Activities:

1. Identify the requirements
2. Test procedure and conditions
3. Reference measurement system for current transformers
4. Reference measurement system for voltage transformers
5. Reference measurement system for combined transformers
6. Evaluation of the uncertainty and validation
7. Submission of a paper

Task 2.2

Guidance for industrial calibration setups and performance of ITs

Aims at studying and implementing architecture for simplified calibration setups and methods for the characterisation of ITs in industrial premises

Activities:

1. Study of simplified industrial calibration methods and setups
2. Implementation and realisation of simplified calibration circuits and methods
3. Ensuring traceability of simplified calibration setup
4. Comparison of simplified procedure results with the references in Task 2.1
5. Good practice guide
6. **D3***: Good practice guide on simplified calibration setups and traceable methods to be used for the characterisation of ITs in industrial premises*

Task 2.3

Evaluation of ITs performance

Aims at selecting and assessing the behaviour of a representative sample of commercial instrument transformer, using the worked-out performance indices from A1.2.3, A1.2.4 and A1.2.5

Activities:

1. Selection of ITs to be tested
2. Tests of commercial ITs using the worked-out performance indices
3. Analysis and classification of results, Survey on IT characterisation data
4. Report on IT performance
5. **D4**: *Report on reference measurement systems, for ITs and methods for the evaluation of the relevant uncertainty contribution of ITs to PQ indices*
6. Report to standardisation IEC TC 38 WG 47 on *evolution of instrument transformer requirements*.

A. Overview of WP2 (Aim and objectives, Partners, Deliverables, Planned papers and Gannt Chart)

B. Activities status (First 18M)

- By Tasks

C. Achievements so far

- by partners

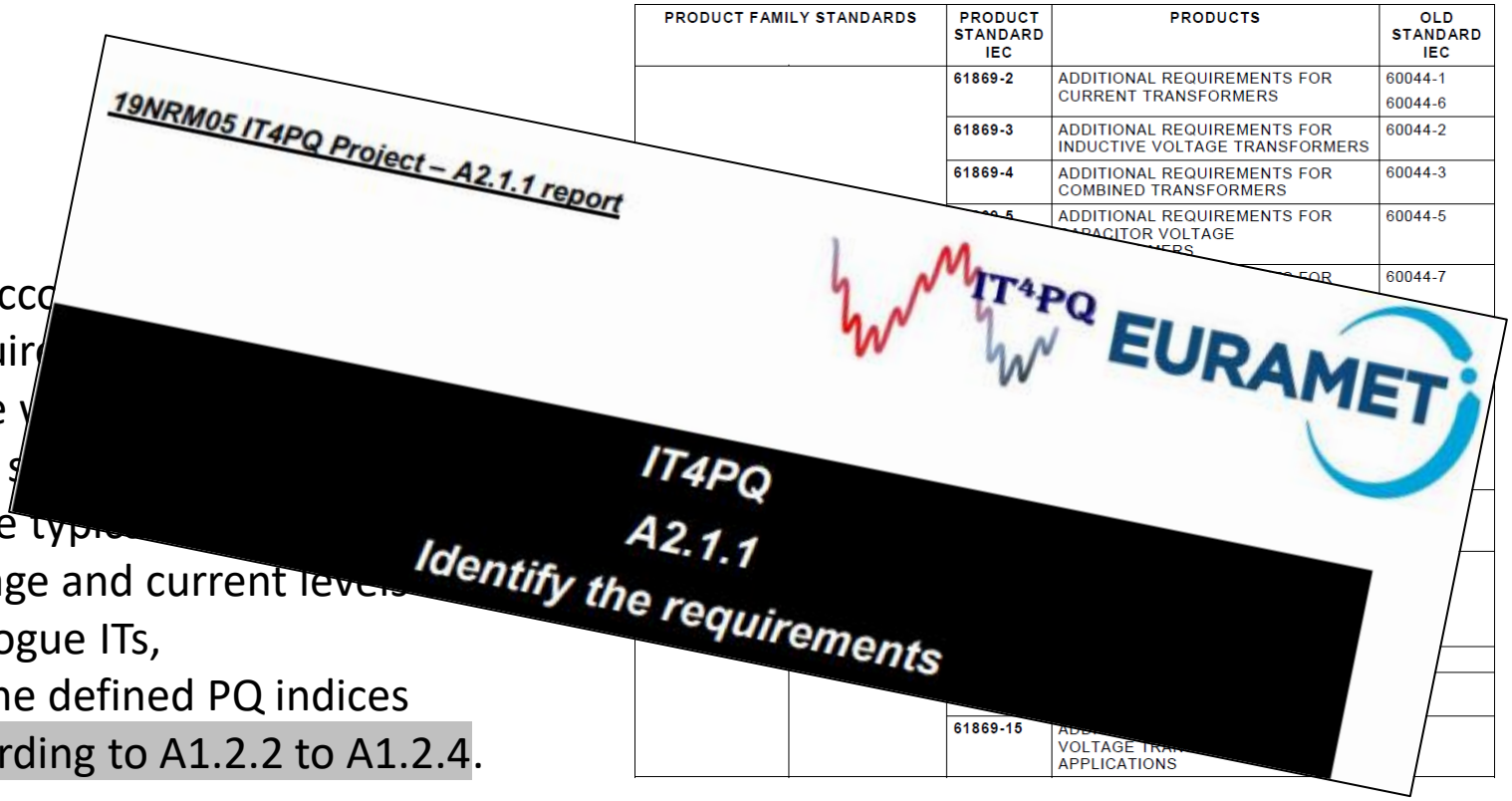
C. Achievements so far (by partners)

No.	Partners	Relevant activities (first 18M)	Contributions (first 18M)
1	**PTB**	✓	✓
2	**CMI**	✓	✓
3	**INRIM**	✓	✓
4	**LNE**	no	no
5	**SUN**	✓	✓
6	**TUBITAK**	✓	
7	**TUD**	✓	✓ no
8	**UNIBO**	✓	✓ no
9	**VSL**	✓	✓ separate presentation

C. Achievements so far (PTB)

Identify the requirements (A2.1.1)

- Requirements for the reference measurement systems (36 kV / 2 kA; 9 kHz) for voltage and current transformers are currently summarized to a **small report** by PTB.



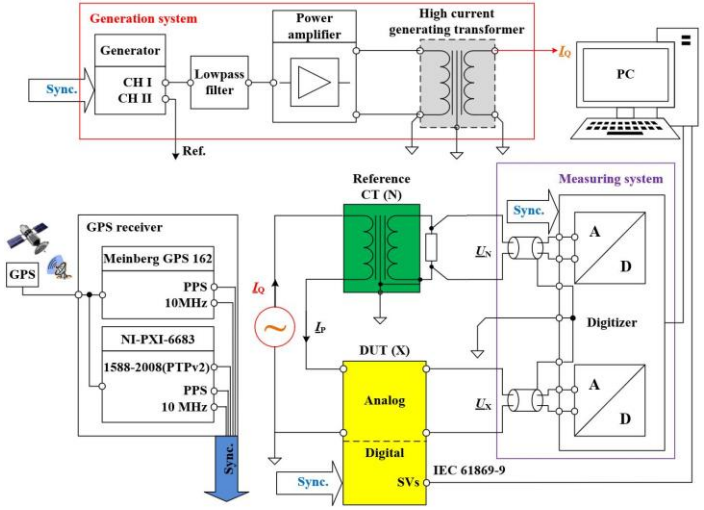
PRODUCT FAMILY STANDARDS	PRODUCT STANDARD IEC	PRODUCTS	OLD STANDARD IEC
	61869-2	ADDITIONAL REQUIREMENTS FOR CURRENT TRANSFORMERS	60044-1 60044-6
	61869-3	ADDITIONAL REQUIREMENTS FOR INDUCTIVE VOLTAGE TRANSFORMERS	60044-2
	61869-4	ADDITIONAL REQUIREMENTS FOR COMBINED TRANSFORMERS	60044-3
		ADDITIONAL REQUIREMENTS FOR	60044-5
			60044-7
	61869-15	APPLICATIONS	

➢ Acc
Requir
i. the
(test
ii. the
voltage and current
analogue ITs,
iii. The defined PQ indices
according to A1.2.2 to A1.2.4.

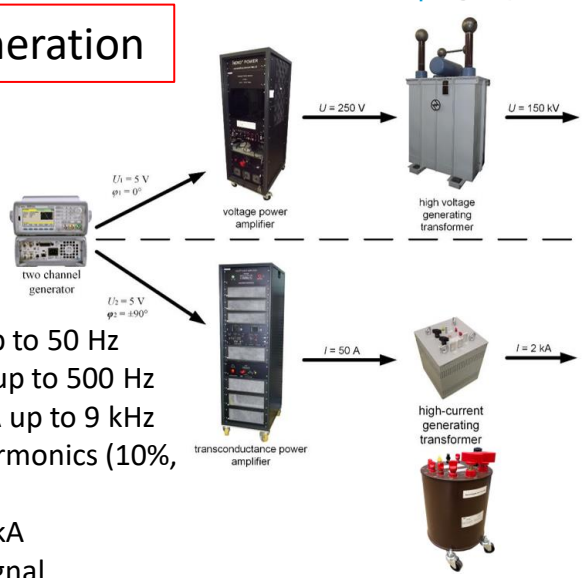
C. Achievements so far (PTB)

Reference Measurement System for Current Transformers (A2.1.3)

Reference system and calibration method



High current generation



- Sinusoidal signals 5 kA up to 50 Hz
- Sinusoidal signals 1 kA up to 500 Hz
- Sinusoidal signals 100 A up to 9 kHz
- Sinusoidal Signal with harmonics (10%, up to 50th) up to 1 kA
- Rectangle Signal up to 1 kA
- Amplitude Modulated Signal

Figure: Setup of the power source

- Papers (reference systems):

- 2 published:

Y. Chen, E. Mohns, M. Seckelmann and S. de Rose, "Traceable calibration system for non-conventional current sensors with analogue or digital output," 2021 IEEE 11th International Workshop on Applied Measurements for Power Systems (AMPS), 2021, pp. 1-6, doi: 10.1109/AMPS50177.2021.9586012.

Y. Chen, G. Crotti, A. Dubowik, P. S. Letizia, E. Mohns, M. Luiso, J. Bruna, "Novel Calibration systems for the dynamic and steady-state testing of digital instrument transformers," 2021 IEEE 11th International Workshop on Applied Measurements for Power Systems (AMPS), 2021, pp. 1-6, doi: 10.1109/AMPS50177.2021.9586040.

- 1 submitted:

Y. Chen, A. Dubowik, E. Mohns, "Reference system for current sensor calibrations at power frequency and for wideband frequencies," 2022 IEEE PES 20th International Conference on Harmonics and Quality of Power (ICHQP), 2022, pp. 1-6.

- Next step: Algorithms for calculating PQ indices (A1.2.5) will be integrated

C. Achievements so far (PTB)

Selection of ITs to be tested (A2.3.1) and Tests of commercial ITs (A2.3.2)

1. Different types of current transformers selected and invested

i. conventional (inductive) current sensors

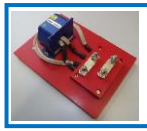
class 0.5 - 500A - 1A – 2.5VA (ext.120% FS5)

class 0.2S - 400A - 1A – 5VA

- A CT from customer

class 1 - 5000A - 5A – 5VA

ii. electronic current sensors (LEM)



LEM: 100 A – 0.1A

iii. Rogowski coil (LEM)

class 1 - 1000A – 22.5 mV (50 Hz)

Most of the results are summarised in ICHQP 2022 paper

2. SAMU/MU (VIZIMAX) can be provided

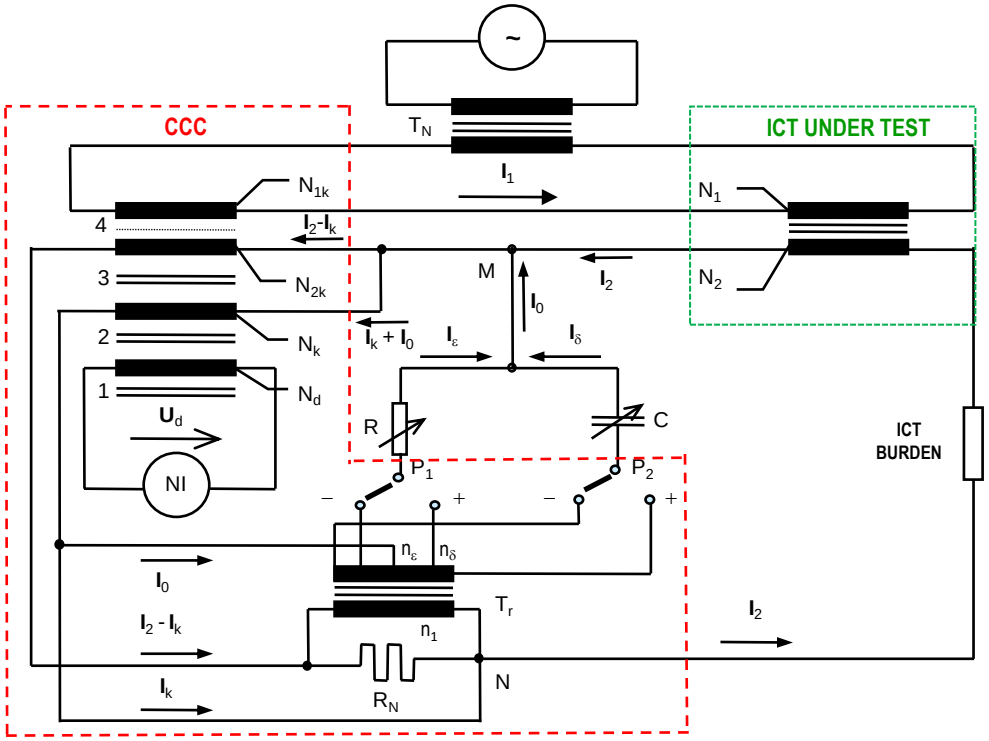
- Initial tests of SAMU/MU have been carried out with sinusoidal waveform (50 Hz).

Task 2.1: Establish reference measurement systems and uncertainty evaluation to PQ indices

USE OF A COMPENSATED CURRENT COMPARATOR FOR ICT CALIBRATION AT WIDER FREQUENCY RANGE

- CMI HAS AVAILABLE A HOME MADE TOROIDAL COMPENSATED CURRENT COMPARATOR (CCC)
- THIS CCC IS USED AS AN AC CURRENT RATIO STANDARD AT 50 HZ FREQUENCY
- **POSSIBILITY OF USE THIS CCC FOR ICT CALIBRATION AT WIDER FREQUENCY RANGE WILL BE VERIFIED**

TRADITIONAL LAYOUT FOR ICT CALIBRATION USING CCC (Difference method)



ICT RATIO ERROR

$$\varepsilon_I = \pm R_N \frac{n_\varepsilon}{n_1} \frac{1}{R} 100 \quad (\%; \Omega; \Omega)$$

ICT PHASE DISPLACEMENT

$$\delta_I = \pm R_N \frac{n_\delta}{n_1} \omega C \qquad (\text{rad}; \Omega; \text{rad}\cdot\text{s}^{-1}; \text{F})$$

$n_\varepsilon / n_1 = p_\varepsilon$; $n_\delta / n_1 = p_\delta$ is transformation ratio of the auxiliary transformer T_r

CCC TECHNICAL PARAMETERS

- RANGE: 34 ratios: (0.5 – 1 200) A/5 A
- OVERLOAD: 120 %I_R continuously, 200 %I_R/1 min
- SENSITIVITY AT 50 Hz: 1/0.73 mV/mA
- INHERENT ERROR AT 50 Hz: ratio error 0.5 ppm
  phase displacement : 0.5 μrad
- INHERENT BURDEN: 2 mΩ

1. DETERMINATION OF CCC SENSITIVITY IN WIDER FREQUENCY RANGE UP TO 9 kHz (done)

2. DETERMINATION OF CCC INHERENT ERROR ε_c

$N_1 = N_2 = 200$;

$I = 5\ A \quad \rightarrow \quad \hat{\varepsilon_c} = \frac{N_1\hat{I_1} - N_2\hat{I_2}}{N_1\hat{I_1}} = \frac{N_1\hat{\Delta I_f}}{N_1\hat{I_1}} = \varepsilon_{Ic} + j\delta_{Ic}$

ΔI_f is fictional current corresponding to CCC inherent error

ε_{Ic} is inherent CCC ratio error

δ_{Ic} is inherent CCC phase displacement

IDEAL CASE: $U_d = 0 \quad \Rightarrow \quad \hat{\varepsilon_c} = 0$

REAL CASE: $U_d \neq 0 \quad \Rightarrow \quad \hat{\varepsilon_c} = \varepsilon_{Ic} + j\delta_{Ic}$

INHERENT CCC ERROR CORRESPONDING TO U_d

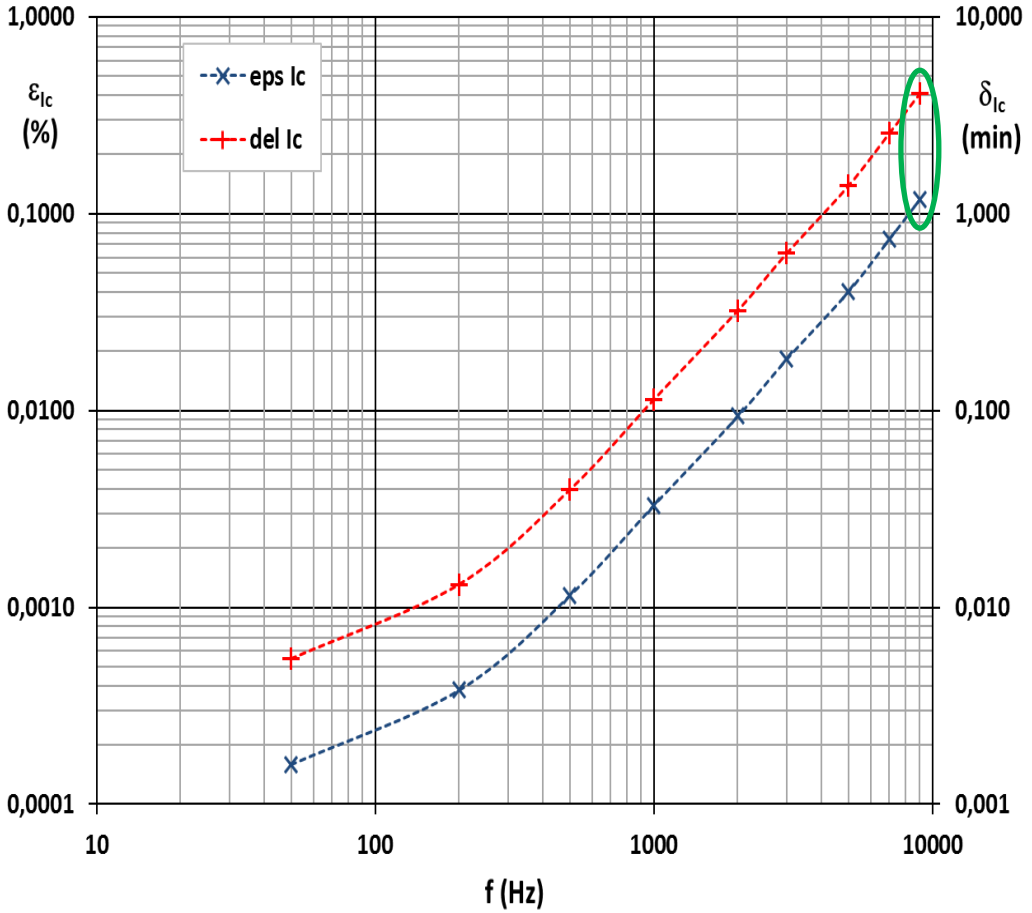
MAXIMUM OF CCC INHERENT ERROR COMPONENTS:

- assuming for given U_d is $\hat{\varepsilon_c} = \varepsilon_{Ic}$ resp. $\hat{\varepsilon_c} = \delta_{Ic}$

$$\varepsilon_{Ic} = \frac{U_d}{S \cdot N_1 I_1} \cdot 100 \quad (\%)$$

$$\delta_{Ic} = \frac{U_d}{S \cdot N_1 I_1} \quad (\mathrm{rad})$$

CCC INHERENT ERROR IN WIDER FREQUENCY RANGE



3. DETERMINATION OF A CT 100 A/5 A (CLASS 0.5) INHERENT ERRORS (done)

WP2 – INRIM and SUN activity and outputs (M10-M18)

- **A2.1.1** '***Identify the requirements***' (**M12**) : **Reference measurement systems for VTs defined according to Fig.1** and A2.1.1 prescriptions.
- **A2.1.2** '***Test procedure and conditions***'(**M13**) :
- Definition of the sequence of tests for evaluating the PQ performance indices of ITs as proposed in A1.2.2, A1.2.3, A1.2.4.

  Submission of a paper dealing with possible test waveforms to evaluate the performance indices (see Fig. 2).
- Identification of optimum laboratory conditions for the calibration of ITs (INRIM best conditions: (23±1) °C; 40% to 60% rel. humidity; 1.5 m proximity).
- **A2.3.1** '***Selection of ITs to be tested***' (**M18**): in progress (3 IVTs from 6/√3 kV to 20/ √3 kV primary voltages (3 manufacturers); passive/actives dividers (R, C, RC), MV VT with digital output.

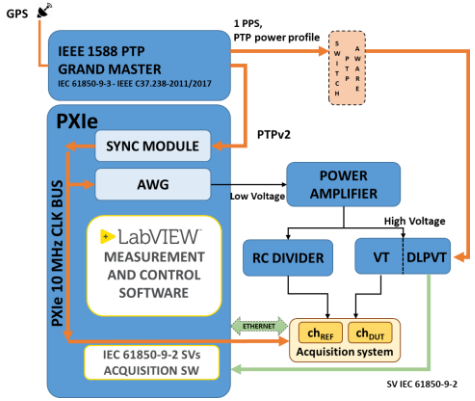


Fig. 1

A2.1.1: *Generation and reference measurement systems for laboratory calibration of VTs.*

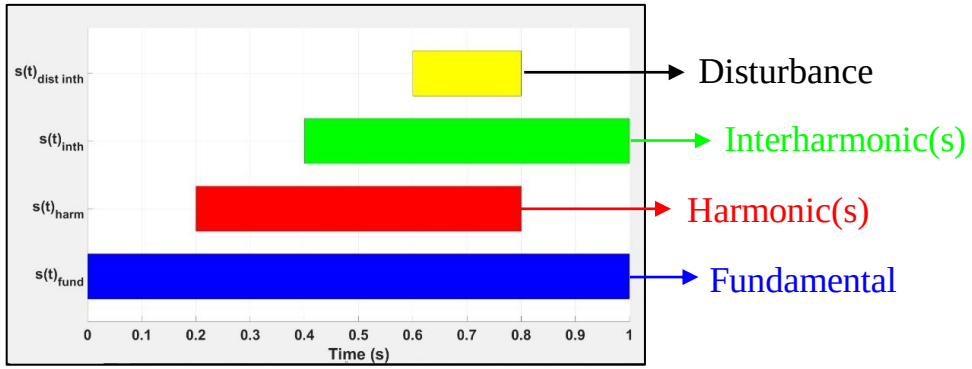


Fig.2

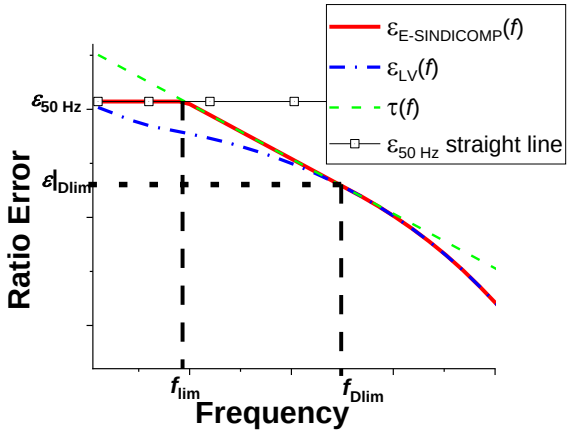
A2.1.2: *Example of a time combined waveform for the evaluation of VT performances in presence of harmonics and interharmonics.*

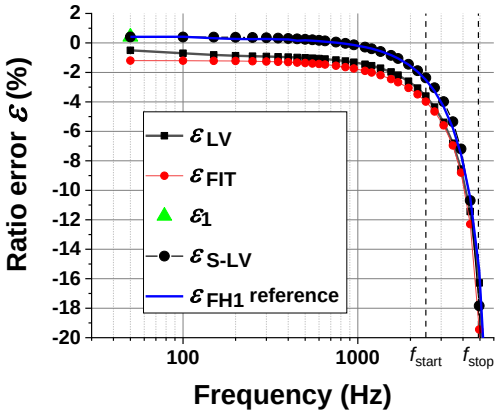
WP2 – INRIM and SUN activity and outputs (M10-M18)

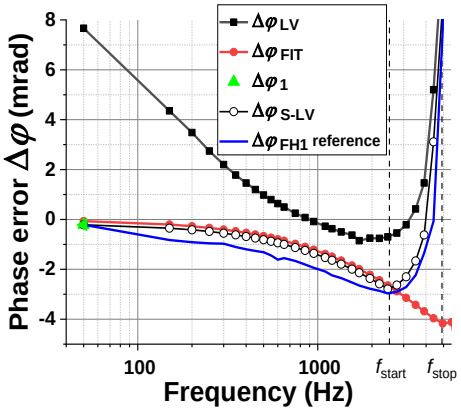
- **A2.2.1** '***Study of simplified industrial calibration methods and setups***'(**M20**):
- **Development of simplified method for the frequency characterisation of inductive VTs.** Currently two methods have been identified:
  - E-SINDICOMP
  - SINDICOMP-LV

Both based on data set obtained from 2 measurement steps:

1. **Step 1** measurement of ratio and phase errors @ power frequency and rated voltage + the measurement of the first 10-15 harmonics.
2. **Step 2** measurement of the frequency response at LV.







VSL

Presentation by Fabio Munoz:

Approach for a wideband comparator based on two synchronised sampling units

Fabio Munoz, Dutch Metrology Institute (VSL), Netherlands.

Thanks for your attention !

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