INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

IEC TC38/WG55 “Uncertainty evaluation in the calibration of Instrument Transformers”

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IEC TC38/WG55 “Uncertainty evaluation in the calibration of Instrument Transformers”

Convenor Lorenzo Peretto

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Mrs Mihaela Marilena Albu	RO
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Mr Fahd Banakhr	IEEE
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TC 38 Instrument transformers

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Title & Task

JWG 55

Uncertainty evaluation in the calibration of Instrument Transformers

To write a publication that stands as a common viewpoint of the evaluation of uncertainty in calibration and its application in testing procedures for ITs.

IEC TC38/WG55 “Uncertainty evaluation in the calibration of Instrument Transformers”

Scope of the IEC 61869-105

- IEC 61869-105 establishes a common viewpoint of the evaluation of uncertainty in calibration and its application in testing of Instrument Transformers (IT) used for a.c (in the frequency range 15Hz – 3kHz) covering Low Voltage (LV) as well as High Voltage (HV)
- This part of IEC 61869 covers the uncertainty evaluation in calibration of IT independently of the technology used (either inductive or non-inductive IT) with both analogue and digital output format
- This part of IEC 61869 also provides a guideline for on-site calibration of IT

IEC TC38/WG55 "Uncertainty evaluation in the calibration of Instrument Transformers"

Scope of the IEC 61869-105

- The document reports how to take into account the sources of uncertainty of the calibration set-up and how to combine their effects in order to evaluate the uncertainty in the calibration results
- Furthermore, the document will present also the test procedures to be used for assessing the accuracy of IT

Note: this publication has a dual-logo IEC/IEEE

STANDARDS RELATED TO UNCERTAINTY

ILAC G17: INTRODUCING THE CONCEPT OF UNCERTAINTY OF MEASUREMENT IN TESTING IN ASSOCIATION WITH APPLICATION OF THE STANDARD ISO/IEC 17025

VDI/VDE/DGQ/DKD 2622-2: CALIBRATION OF MEASURING EQUIPMENT FOR ELECTRICAL QUANTITIES - METHODS FOR THE DETERMINATION OF THE UNCERTAINTY OF MEASUREMENT (last version 2015)

IEC 61557-12:2007
ELECTRICAL SAFETY IN LOW VOLTAGE DISTRIBUTION SYSTEMS UP TO 1 000 V A.C. AND 1 500 V D.C. - EQUIPMENT FOR TESTING, MEASURING OR MONITORING OF PROTECTIVE MEASURES - PART 12: PERFORMANCE MEASURING AND MONITORING DEVICES (PMD)

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STANDARDS RELATED TO UNCERTAINTY

ISO IEC Guide 115: APPLICATION OF UNCERTAINTY OF MEASUREMENT TO CONFORMITY ASSESSMENT ACTIVITIES IN THE ELECTROTECHNICAL SECTOR

IEC 60060-1/2/3: HIGH VOLTAGE TEST TECHIQUES (IEC TC42)

IEC 62475: HIGH CURRENT TEST TECHNIQUES: DEFINITION AND REQUIREMENTS FOR TEST CURRENTS AND MEASURING SYSTEMS (IEC TC42)

ISO/IEC Guide 98-3:2008 - Uncertainty of measurement -- Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)

ISO/IEC Guide 99 - International vocabulary of metrology -- Basic and general concepts and associated terms (VIM)

Uncertainty

Error & Uncertainty – *Terms and Definitions* according to VIM-GUM & comparison with those given in IEC IEV (Electropedia) & VIM

A survey regarding the definitions on this topic has been necessary as there are inconsistencies on the same terms.

For instance, the definition of *Uncertainty*

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Example of nonconsistency

IEC 61000-4-30: “… measurement uncertainty affecting a measurement result is the **maximum expected deviation of a measured value from its actual value**”

ISO/IEC Guide 98-3: distinguishes between **"uncertainty"** and **"error.“**

“… measurement uncertainty is the **standard deviation of a random variable** associated with the measurement results”

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Example of nonconsistency …

This probabilistic approach is not considered in the IEC 61000-4-30 **(DETERMINISTIC APPROACH)**

In ISO/IEC Guide 98-3 the uncertainty expresses an interval around a central value in which the measurand value can fall within a given probability **(PROBABILISTIC APPROACH)**

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Example of nonconsistency …

Example: if a rectangular distribution is assumed for the random variable representing the measurement result, the difference between the values of uncertainty according to the two definitions above is equal to the **sqrt(3).**

The IEC 61000-4-30 uncertainty is 70 percent larger!

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Influence quantities in the IT calibration process

They can influence both the IT’s errors quantities and the uncertainty affecting their measurements

1. Burden dependency
2. Secondary connection effect (in case of the transmitting cable is part of the IT)
3. Return primary connection effect
4. Residual magnetization of the magnetic circuit
5. Temperature (stratification,…)
6. External fields effects
7. Proximity effect
8. Linearity
9. Other sources for digital output ITs (DC reference, timing...)
10. Grounding

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1. Sources of uncertainty in calibration system

1. Metrological characteristics of the reference device (transducer, divider, …)
   a. Ratio error, phase error, bandwidth, …
2. Metrological characteristics of the bridge (comparator)
   a. Commercial bridge (error on reading & on range, random effects)
   b. DAQ-based bridge (i.e. resolution, # of effective bits, time-skew between input channels)
3. Metrological characteristics of the Burden (i.e. stability)

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4. Power Source
    a. Frequency stability
    b. Amplitude stability
    c. Noise & Distortion

5. System effects: ground effects, interference effects, effect of wiring

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6. **Processing**
   a. Method for extracting the phasor (amplitude and phase)
   b. Observation interval (Spectral Leakage effect: it depends on the measuring system and on mathematical expression used; frequency resolution)
   c. Aliasing (noise, mainly in Rogowski coil calibration, can have a bandwidth outside the calibration system one)
   d. # of measurements (we have to refer to the DoF, see 60060-2, Section A.8)
   e. Windowing effect

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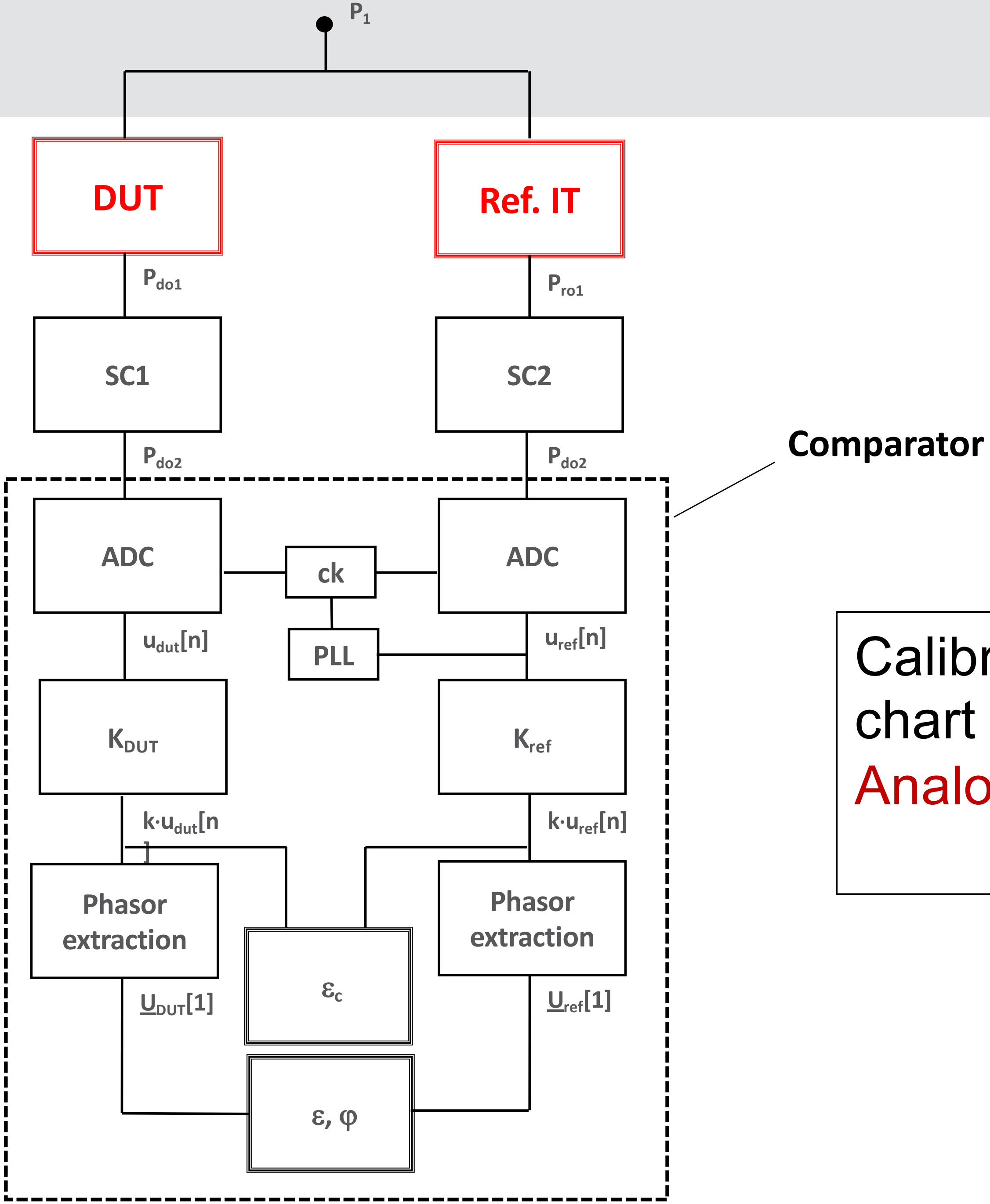
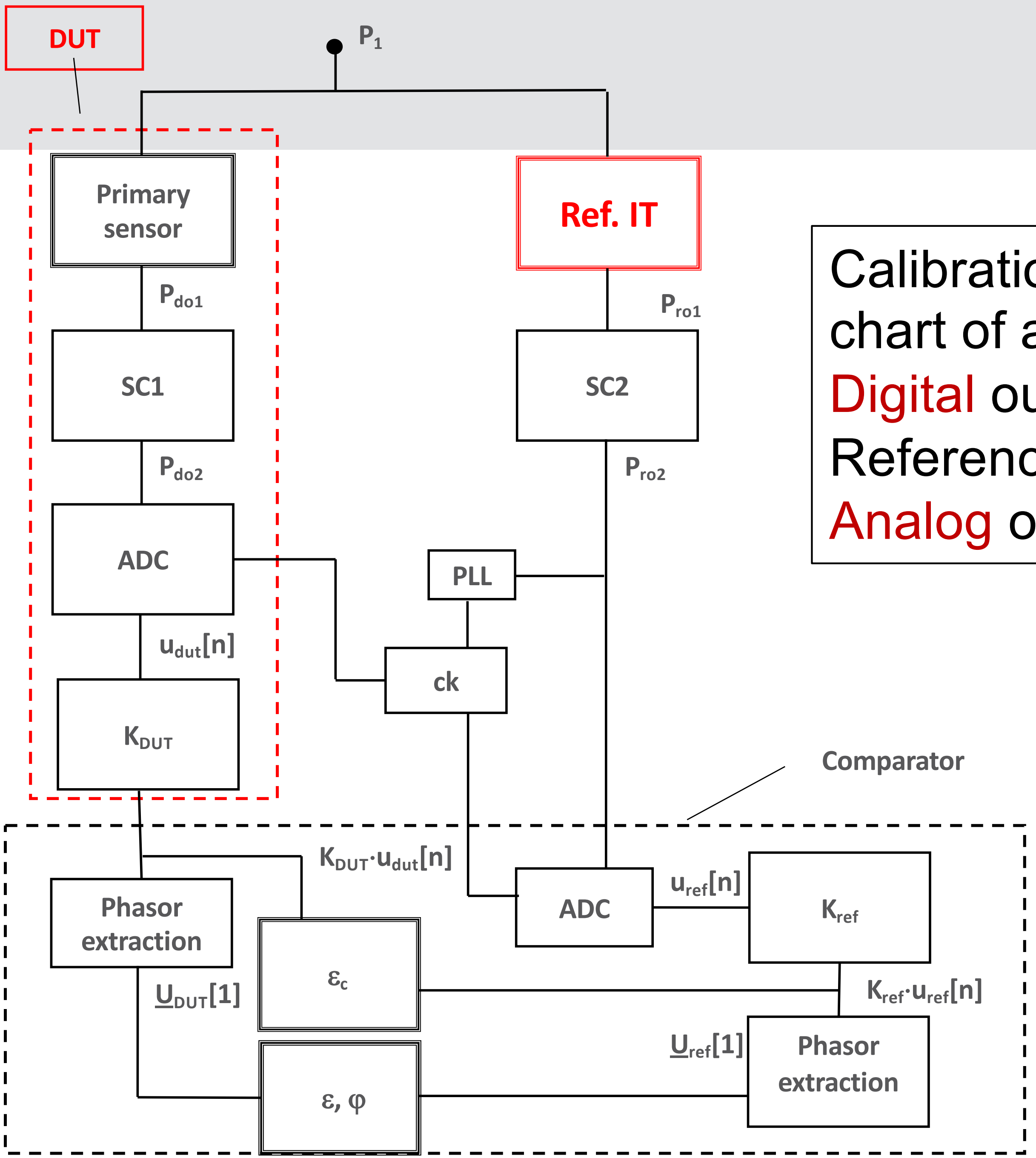
2. Calibration set-up and <u>methods</u> for calibrating IT

Single-phase / three-phase; on-site calibration; reference transformers; bridge (comparator) characteristics; calibration of the software; interval between calibrations; errors indexes (terms) provided for the calibration instrument (how to manage them according to the GUM)

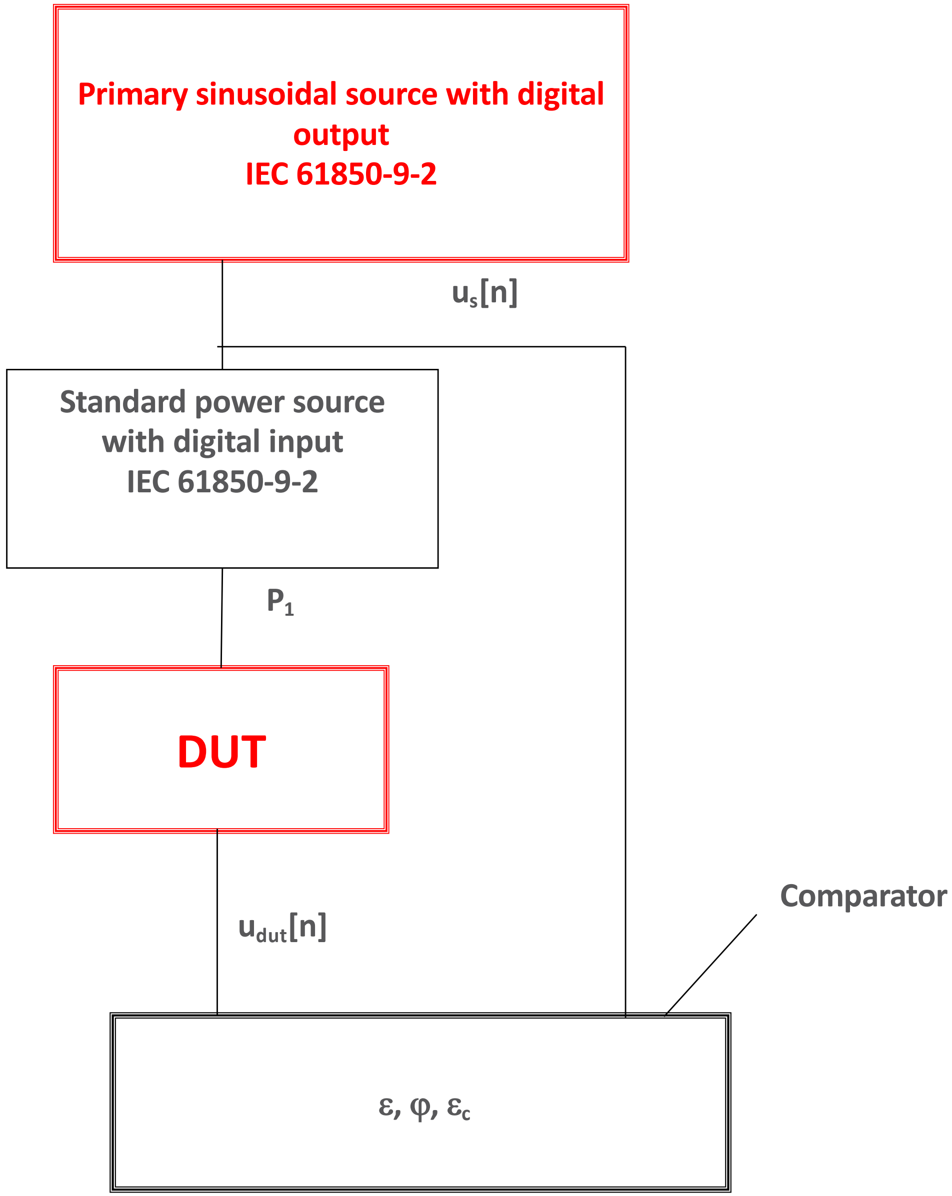
3. Methods for evaluating the uncertainty affecting errors of ITs (GUM)



Calibration flow chart of an Analog IT



Calibration flow chart of a DUT with Digital output and Reference IT with Analog output.



Example of calibration flow chart of a DUT and Reference IT with Digital output

Reference document for evaluating uncertainty -GUM-

Type A method

Central Limit Theorem: # measurements (mean value evaluated as an estimate of the Expected Value of the measurand); Normal Distribution of the estimate of the mean value (estimate of the Expected Value of the measurand);

Type B method

Dependent on the information available. Usually MEP (Maximum Entropy Principle) is applied (Uniform Distribution is considered)

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Uncertainty expressions

Expanded Uncertainty on Ratio Error

$$U(\varepsilon_{\mathbf{X1}}) = \sqrt{U^2(\varepsilon_{\mathbf{Int1}}) + U^2(\varepsilon_{\mathbf{Int2}}) + U^2(\varepsilon_{\mathbf{Int3}})}$$

Expanded Uncertainty on phase displacement

$$U(\delta_{\mathbf{X1}}) = \sqrt{U^2(\delta_{\mathbf{Int1}}) + U^2(\delta_{\mathbf{Int2}}) + U^2(\delta_{\mathbf{Int3}})}$$

Int1 = transformers contributions (both Ref and DUT)

Int2 = set-up contributions (cabling, burden, cross-talk, EMI, frequency, temperature,…)

Int3 = comparator (fluctuations, stability,…)

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Thank you for your attention

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