BIPM CAPACITY BUILDING AND KNOWLEDGE TRANSFER PROGRAMME

Future Needs for Metrology Summer School and METAS Project Placement Report.

Project Name: Enhancing Electrical Power Calibration and Digitalization Capacity at EMI through METAS Placement

Project Description: This project aims to address Ethiopia's metrology needs in electrical power calibration and digital transformation by leveraging expertise at METAS. The placement supports EMI's objectives under the CABUREK DCC initiative and enhances national preparedness for CIPM MRA participation in electrical power.

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1. Motivation & Introduction

This project was motivated by the urgent need to support Ethiopia's rapidly growing smart grid and electrical vehicle (EV) infrastructure through robust, internationally traceable calibration service. As the head of the electrical calibration laboratory and national DCC coordinator under the PTB CABUREK initiative, I identified critical capability gaps in AC/DC power calibration harmonic analysis, and uncertainty evaluation.

The primary objectives of this project were:

- To build competence in electrical power calibration, including harmonics and waveform-dependent
- To develop validated uncertainty budget for power measurements.
- To support EMI's DCC roadmap with practical insights and methodologies.
- To incorporate learning from the Varenna Summer School (Modules II and III) into EMI's strategy.

2. Research

2.1. Method and Activities

2.1.1. Summer School Participations International School of Physics "Enrico Fermi" SIF Course (1 Week)

I attended technical lecture on **"future needs for metrology: climate science, quantum technologies and the digital transformation" Module II "Fundamentals of Metrology and the digital transformation of measurement'' and Module III "Physical and quantum metrology"** at Villa Monastero, Varenna, Italy from 12 to 18 July 2025.These sessions provided a theoretical foundation and exposed me to future oriented trends in Metrology.

2.1.2. Placement at METAS (2 Weeks)

The core of my project took place at METAS where I was integrated into the Electrical Power Metrology Team Activities included:

- Familiarization with calibration setups using high accuracy power analyzers and EVSE (Electric Vehicle Supply Equipment)
- Practical work with harmonic analyzers and waveform distortion simulations
- Development of measurement models based on GUM principles and IEC guide 98-3 standards
- Study and contribution to METAS Automated calibration processes

2.1.2.1. Power Calibration at 50 Hz and 5 A

Measurement setup

- Standard
  - ➢ Current and Voltage source from ZERA FG 301 with MTE ICT current transformer for direct connected meter
  - ➢ Fluke 6105A Electrical Power Standard

- Reference Power meter ZERA COM 5023
  - Magnetic coil
- Device under Test
  - SEL Power quality and Revenue meter
- Model Equation

P=V*I*cos(ϕ) where V=Voltage, I=current and (ϕ)=phase angle

- **Uncertainty Budget of Power Calibration at 50 Hz and 5 A**

Source of Uncertainty	Type	Distribution	Divisor	Std. Uncertainty	Sensitivity Coeff.	Contribution
Reference Voltage Source	B	Rectangular	√3	0.01 V	5 A	0.05 W
Reference Current Source	B	Rectangular	√3	0.001 A	230 V	0.23 W
Phase Angle Error (φ)	B	Rectangular	√3	0.002°	1150 W	2.3 W
Resolution of device under test	B	Rectangular	√3	0.1 W	1	0.5 W
Repeatability	A	Normal	1	0.3 W	1	0.3 W
Combined Standard Uncertainty (Uc) $\sqrt{(0.05)^2 + (0.23)^2 + (2.3)^2 + (0.5) + (0.3) + (0.2)^2}$						-2.39 W
Expanded Uncertainty (U) k = 2						-4.78 W
Relative Expanded Uncertainty $\frac{4.78}{1150} * 100$						0.42

2.1.2.2. Power Calibration with Harmonics (3rd and 5th Harmonics)

Measurement setup

- Standard
  - Current and Voltage source from ZERA FG 301 with MTE ICT current transformer for direct connected meter and current shunt resistor
  - Fluke 6105A Electrical Power Standard
  - Reference Power meter ZERA COM 5023
  - Magnetic coil
- Device under Test
  - SEL Power quality and Revenue meter
- Model Equation

  When harmonics are present, power is expressed as:

$$P = \sum_{n=1}^{N} Vn * In \ \cos(\phi n)$$

Where:

  - n is the **harmonic order**
  - Vn and In are the **RMS voltages and currents** of the n^{th} harmonic,
  - (ϕn) is the **phase angle** between Vn and In,
  - $\cos(\phi n)$ is the **power factor** for that harmonic.
- Let's assume the contribution P_1= 900 W, P_3=150 W, P_5= 100 W Total = 1150 W
- **Uncertainty Budget of Power Calibration with Harmonics (3rd and 5th Harmonics)**

Source of Uncertainty	Type	Distribution	Divisor	Std. Uncertainty	Sensitivity Coeff.	Contribution
Voltage harmonic	B	Rectangular	√3	0.02 V	5 A	0.1 W
Current harmonic	B	Rectangular	√3	0.002 A	$P = \sum_{n=1}^{N} Vn * In \ \cos(\phi n)$	0.2 W
Phase angle error	B	Rectangular	√3	0.005	$P = \sum_{n=1}^{N} Vn\sqrt{2} \sin(nwt + \phi n)$	0.75 W (total)
Spectral Purity / Harmonic Isolation	B	Rectangular	√3	0.5% of P_n	1	0.9 W

Repeatability	A	Normal	1	0.3 W	1	0.3 W
Resolution	B	Rectangular	√3	0.1 W	1	0.5 W
Combined Standard Uncertainty (Uc) $\sqrt{(0.1)^2+(0.2)^2+(0.75)^2+(0.9)+(0.3)+(0.5)^2}$						1.33 W
Expanded Uncertainty (U) k = 2						2.65 W
Relative Expanded Uncertainty $\frac{2.65}{1150} * 100$						0.23 %

3. **Key Findings and Conclusions**
   - Existing EMI practices in electrical power calibration can be significantly improved by adopting the traceability architecture and calibration workflow modeled at METAS.
   - Uncertainty budgets were drafted for power calibration at 50 Hz and cross selected harmonic conditions with application scenarios tailored to the Ethiopian energy grid and EV sector.
   - Integration of digital tools and AI assisted analysis offers potential time savings and traceability consistency, but requires infrastructure upgrades at EMI.
4. **Challenges and Mitigation**
   - Limited access to real world smart grid equipment in Ethiopia meant that part of the methodology relied on simulated signals and model instruments

5. **Conclusions and Future Work**

The placement successfully met its objectives. I gained advanced practical experiences in electrical power calibration, drafted uncertainty budgets, and explored cutting edge developments in DCC and digital metrology. These outcomes align with Ethiopia's national needs and EMI's strategic plan.

Future plans include:

- Establishing formal procedures for AC/DC power calibration
- Launching a pilot project at EMI using EVSE tester and digital energy meters.
- Hosting internal training sessions to transfer knowledge from METAS and Varenna
- Initiating collaborations with regional NMIs and utilities to expand metrology services to support clean energy and smart grid rollouts.

6. **Acknowledgements**

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This training has been a remarkable milestone in my career, and I am truly honored to have participated in this impactful initiative.