BIPM Capacity Building & Knowledge Transfer Programme

2022 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Calibration of power and energy measuring devices
Description	Studying new methods for calibrating power and energy measuring devices and development of standards
Author, NMI	Kamoliddin Makhamatov, Uzbek national institute of metrology (UzNIM), Uzbekistan
Mentor at TÜBİTAK UME	Burak AYHAN, Hüseyin ÇAYCI, Power and Energy Laboratory, TÜBİTAK UME, Turkey
Date	05.09.2022 – 30.09.2022

Motivation & Introduction

Everyone knows that now all devices work with electricity. But few people think or know about the losses in electricity supply or the order in which they are measured. In order to prevent such losses, accurate measurements are of great importance.

Therefore, the possibilities of measuring and calibrating electrical power have expanded, and the demand for providing such services to metrology institutes, as well as new areas of study and research, has increased.

As an example of these, we can cite the production of non-conventional current and voltage transformers, combined current and voltage transformers, standard power measuring devices with an accuracy of 0.01 and higher. The possibility of calibrating such devices in the old way is certainly limited, if not completely absent.

The main goal of my research and planned project at TÜBİTAK UME is to study the problems in electricity measurement and at the same time to find solutions through the available opportunities in my NMI. Also, using the acquired knowledge, create new and more accurate standards of power and energy measuring devices.

Research

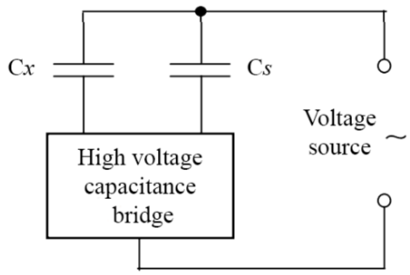
I focused my research on thoroughly studying of calibrating high-voltage reference transformers (VT) based on high-voltage capacitive bridges (HVCB) and studying the performance of an AC power measurement standard - digital sampling wattmeter (DSWM). Below, I will provide a brief explanation of each.

<u>Calibration of conventional VT based on HVCB:</u> The calibration of the reference voltage transformer is performed in two steps by using HVCB based on the current comparator and 2 standard capacitors.

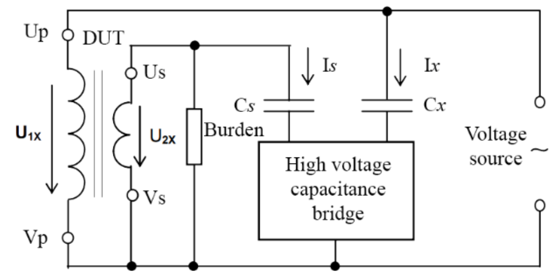
In the first step, the capacitance ratio and the dissipation factor of two low-loss standard capacitors are measured by applying the same voltage to the capacitors.

In the second step, these capacitors are connected in parallel with the primary and secondary windings of the voltage transformer and the rated voltage is applied to the primary winding of the voltage transformer. The currents passing through the capacitors are compared and a capacitance ratio and a dissipation factor are measured again by the HVCB. The ration errors and phase displacements of the voltage transformer are calculated by using the capacitance ratio and dissipation factor values obtained in the first and second steps.

$$\underline{\text{Step 1:}} \quad \frac{V \cdot 2 \cdot \pi \cdot f \cdot C_X \cdot N_X}{N_D} = \frac{V \cdot 2 \cdot \pi \cdot f \cdot C_S \cdot N_S}{N_D} \quad \Rightarrow \quad C_X = \frac{N_X}{N_S} \cdot C_S$$



Step 1



Step 2

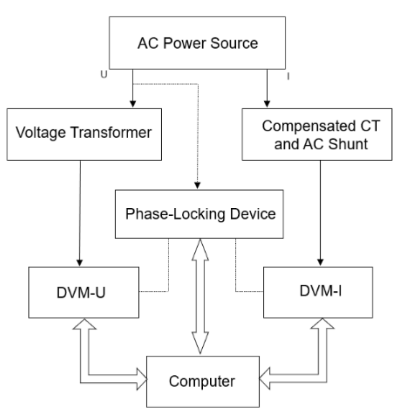
$$\underline{\text{Step 2:}} \quad \frac{V_P \cdot 2 \cdot \pi \cdot f \cdot C_P \cdot N_X}{N_D} = \frac{V_S \cdot 2 \cdot \pi \cdot f \cdot C_S \cdot N_S}{N_D} \quad \Rightarrow \quad \frac{V_P}{V_S} = \frac{N_S \cdot C_S}{N_X \cdot C_X}$$

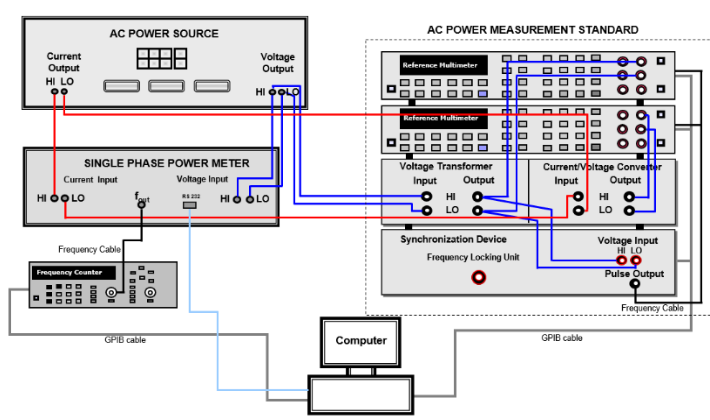
$$\varepsilon_x(ppm) = \frac{Nominal\ ratio - (R_1 \cdot R_2)}{(R_1 \cdot R_2)} \cdot 10^{-6}$$

$$\delta_x(\mu rad) = (DF_1 - DF_2) \cdot 10^{-6}$$

The importance of this calibration method is that the above method can allow us to achieve an uncertainty of about 20 ppm, while the commercial test sets/measuring bridges-based method commonly used to calibrate VTs allows us to calibrate with an uncertainty of about 50 ppm.

<u>AC Power Measurement Standard (DSWM):</u> The core of this set-up is formed by two sampling voltmeters (DMM) that simultaneously sample the voltage and current signal. From these data a computer subsequently calculates the power. An overview of the set-up is schematically depicted in below:





The set-up essentially consists of two parts: one for generation and one for the measurement of the power, where the latter is the core of the system. The incorporation in the system of the power source is needed to feed the standard and the Device Under Test (DUT) was crucial for avoiding problems with synchronization of the DMMs.

Fluke 6105A is used in my example as an AC power source. The output voltage and current signals are first sent to the DUT and then through a resistive voltage divider and an AC shunt to DC 1 V range (more precisely 0.8 V) and converted to DMM sent to The sampling of the voltage and current signal is performed by two Agilent 3458A digital voltmeters in their 1 V ranges. Each measurement consists of taking 64 samples per period during 50 periods before the data is transported to the computer over the communication bus for further calculations. The system is completely computer controlled using software. The data from the meters are saved in arrays and with the standard formulas of the software all necessary parameters are calculated. The results of international research and comparisons show that it is possible to achieve an uncertainty value of about 20-25 ppm and even smaller, through this type of DSWM system.

Conclusions and Future Work

During the course of my research, I was convinced by experience that through new methods and research we would be able to improve our calibration and measurement capabilities and increase the range and accuracy of our standards.

That's what motivated me to come here and learn, to support the methods with experiments and see for myself the results that the standards show in those methods.

Based on these experiences, I aim to establish a new method of calibration and calculation of uncertainty of current burdens, calibrating current comparators and analyzers, and establishing a calibration system for voltage transformers and a reference system for calibrating wattmeters.

Acknowledgements

I would like to thank everyone who helped me with this project. I would like to express my gratitude to Chingis Kuanbayev and all other employees who ensured my participation in the project by BIPM, to the management of TUBITAK UME who provided us with comfortable conditions for living and moving, and to Mrs. Müge Atam, who always communicated with us and gave all her help.

And of course, my greatest gratitude goes to the researchers of the Power and Energy Laboratory. I am extremely grateful to Ms. Özlem Yilmaz, who created the necessary conditions for our research and study, Mr. Burak Ayhan and Mr. Hüseyin Çayci, who taught us from the smallest details and shared their experience, and who always helped us.