

# A HIGH CURRENT SELF-CALIBRATING STANDARD-TRANSFORMER

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**Abstract:** This paper presents the development of a self-calibrating transformer for using as a primary standard in the Uruguayan National Metrology Institute. Nominal ratios go from 5 A/ 5 A to 2000 A/ 5 A. The ratio of the transformer can be changed using the same primary windings, so that there is no appreciable effect on the errors for different ratios.

**Key words:** current transformer, self-calibration, measurement, calibration, power.

## 1. INTRODUCTION

High precision current measurements are necessary in electrical networks, mainly for energy measurements. As the uncertainty in these measurements is decreasing, it forces all devices in the power measurement chain to achieve better accuracy. Current transformers are one of the devices needed for power and energy measurements, so high accuracy references are required. These transformers perform ratio measurements, so that, from a theoretical point of view, it is not necessary a standard. As a dimensionless quantity, current ratio can be measured using methods that do not require external standards. One of these methods is based on a transformer that has many primary windings, one of them of the same turn number of the secondary winding. In this ratio (1:1), the errors can be measured, comparing the primary current against the secondary one, directly, without any other transformer. In this way, the device is self-calibrating, at least in the 1:1 ratio. For other ratios, the primary winding is divided in sections of equal turns, so that different series-parallel configurations can be got, with different ratios. The idea is that the same turns are used for all configurations, with the same currents, so that the errors remain the same.

## 2. GENERAL DESIGN

The goal is to get a standard transformer with uncertainties in the order of few  $\mu\text{A}/\text{A}$  and  $\mu\text{rad}$ . In this kind of transformers, the main error source is the magnetizing currents, and many methods to reduce its influence have been proposed. Most of them are electronic based [1, 2] or multi-stage based [3], but for this work, a two-transformer method was used [4]. One transformer generates all the power required by the external load and the internal losses, while the other one works at zero flux. In this way, this last transformer has very low errors. Fig. 1 shows a schematic diagram of the method.

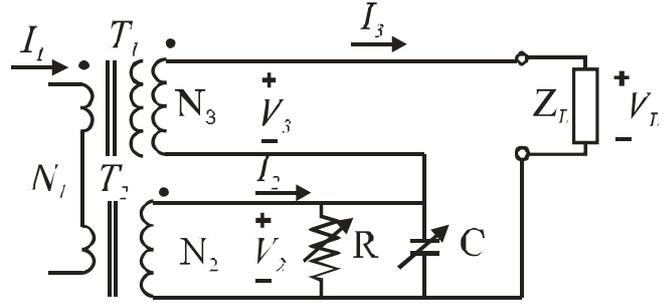


Fig. 1. Diagram of the proposed transformer

$T_1$  is the measuring transformer, while  $T_2$  is the auxiliary one. Both share the same primary winding ( $N_1$ ). The resistor  $R$  and the capacitor  $C$  are adjusting elements of total impedance  $Z$ , and  $Z_L$  is the external load.

The purpose of this method is to null  $V_3$ , which can be done according to the following equations.

$$V_3 = I_3(Z_L + Z) - I_2Z \quad (1)$$

$$N_2I_2 \cong N_3I_3 \quad (2)$$

Then, to null  $V_3$  it is necessary to fix the following relation.

$$N_2 = N_3 \frac{1}{1 + \frac{Z_L}{Z}} \quad (3)$$

Equation (3) shows that  $N_2$  must be lower than  $N_3$ . In the prototype, it was fixed 0,25% lower. Additionally, the angle of  $Z_L$  must be the same than the angle of  $Z$ . This last one is small inductive, and  $Z_L$  has also an inductive behavior due to the magnetizing impedance of  $T_2$  (not shown in Fig. 1). This justifies the addition of  $C$  for compensation of this last inductive impedance.

This method requires a manual adjust of  $R$  and  $C$ . This would be inconvenient for general use; but, as the main purpose of this standard is to use only in very high accuracy calibrations, the time required by the adjust is not a problem.

To know what close is the R-C adjust from the ideal point (null flux) a third winding exists in  $T_1$ . This is used to measure the voltage on it. The fundamental component of this voltage can be easily related to the magnetic flux. The adjust is made until this voltage is below a defined level.

A second order source of errors is parasitic capacitances. For the proposed transformer, it affects the secondary and

the primary windings as well. To analyze its effect, all stray capacitances were measured and the errors produced by them were estimated. A resume of the uncertainties added by this source will be presented at the meeting.

### 3. CONSTRUCTION

The cores are of mumetal for the measuring transformer and silicon iron for the auxiliary one. They have 30 cm of diameter. The measuring transformer secondary winding has 400 turns. The primary winding consists of 10 groups of 40 turns each, plus 10 groups of 4 turns each. So that, using the first set it can be arranged from 40 turns (all groups in parallel) to 400 turns (all groups in series), corresponding to nominal currents from 5 A to 50 A. Other currents are 10 A and 25 A using series-parallel connections. This first set permits the autocalibration procedure in the 5/5 A/A connection. Higher primary currents use the same turns with the same currents through each turn so that the errors must remain constant. For going to higher currents, a second set of primary windings exists. It has 10 groups of 4 turns each, so that it reaches from 50 A to 500 A. As the ratio 50/5 A/A can be got with both sets, it is possible to relate the errors determined by autocalibration at 5/5 A/A to these higher primary current ratios. A similar step-up is possible using a third group formed by 4 single bars. It goes from 500 A to 2000 A.

Detailed errors and uncertainties at each ratio will be given at the meeting.

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### Biography



**Daniel Slomovitz** was born in Montevideo, Uruguay, in 1952. He received the Electric-Engineer and the Dr. Eng. degrees from the Universidad de la República del Uruguay, Montevideo.

He is currently a Professor at the same university. In 1977, he joined the Laboratory of the National Electrical Power Utility (UTE), Uruguay as Engineering Assistant. Nowadays,

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**Alejandro Santos** was born in Montevideo, Uruguay, in 1959. He received the title of Perito in Electrical Engineering from the University of the Republic, Uruguay, in 1983 and the degree of Electrical Engineer from the same University in 2003. He works in the laboratory of UTE as an engineer, and is currently in charge of the Low Voltage Section. It has carried out research in the field of measuring transformers.