

## Wideband resistive voltage dividers. Progress report.

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**Abstract:** In this work, we describe the progress of the design of resistive voltage dividers for use in a standard wattmeter. It covers the frequency range from 50 Hz to 100 kHz and voltages from 4 V to 1024 V.

**Keywords:** power meter, distortion, power quality, high voltage.

### 1. INTRODUCTION

Nonlinear loads in power networks have been increasing during the last decades. These include switched-mode power supplies used in many appliances that can produce harmonics beyond 1 MHz [1], [2]. This leads to distortion in currents and voltages which can disturb communication and control systems, as well as other electronic devices connected to the network. To calibrate voltage, current and power at high frequencies, it is necessary a standard meter. We are running a project [3], [4] for designing and constructing a reference system that can measure voltage, current and power up to 100 kHz and 1000 V. This project is being jointly developed by the National Metrology Institutes of Brazil, Argentina and Uruguay (Instituto Nacional de Metrologia, Qualidade e Tecnologia (Inmetro) in Brazil, Instituto Nacional de Tecnología Industrial (INTI) in Argentina, and Administración Nacional de Usinas y Transmisiones Eléctricas (UTE) in Uruguay). The objective is the construction of three

measuring systems, one for each institute. This project will contribute to provide calibration services in measuring ranges still not covered by these institutes.

The wattmeter uses nine voltage dividers at its input to scale the input voltages from 4 V to 1024 V, to the voltage value required by the analogue-to-digital converter (0.8 V) [5], [6]. In this paper the progress of the development of a set of resistive dividers is described.

This divider design has two arms, an input one whose value depends on the nominal voltage of the divider, and an output arm that has a fixed value, 200  $\Omega$ , for all dividers. The nominal current is the same for all of them, 4 mA, so that the nominal output voltage is 0.8 V. Each arm is enclosed in separate cases, to allow the calibration together as a divider, or as single resistors.

It is not easy to design such dividers with very low error at high frequencies. There are parasitic

capacitances and inductances that produce changes in the voltage ratio in amplitude and phase, which have also been studied in other electrical fields [7], [8]. Among these, the resistors and isolating materials used in the divider have nonlinear losses, which lead to nonlinear behaviors that cannot be compensated for under working distorted waveforms. To test the dividers, many methods have been proposed. One of them is the step-up calibration [9] and other is the ac-dc transfer test. In the latter, it is necessary to split both arms, disconnecting them, and calibrating each one separately.

At the moment, all designs have been concluded and a set of prototypes were manufactured. Preliminary results are in accordance with the specifications. The following sections show the progress in the development of these dividers.

## 2. ERROR SOURCES

In previous papers [5], the influence of stray capacitances and nonlinearity were analysed. A shielding technique was used for nulling radial electric fields. Two symmetric cone-shaped electrostatic-shields were installed at each end of the resistor to get null radial electric field at the whole surface of the resistor, shown in figure 1. The shape of the shield was designed using an electric-field simulation software.



Fig. 1. Electrostatic shield made by two metallic cones.

Regarding non-linear behaviour, the principal cause is dielectric losses in the printed circuit board (PCB) and in the isolation covers of the resistors. This non-linear behaviour changes the resistance when varying the frequency. Note that this change cannot be compensated under distorted waveforms. To reduce this error factor, we use special “naked Z-foil” non-cover resistors without encapsulation, Vishay, mounted on PTFE PCB.

Another error source comes from thermal effects. The higher nominal voltage of the divider set is 1024 V, with 4 W of dissipated power. Although the thermal coefficient of these resistors is low, it is necessary to take into account this error source because the temperature rise can be high.

## 3. COOLING DESIGN

The power dissipated in the input arm of the dividers increases the temperature, changing their values. The output arm has a fixed value of 200  $\Omega$ , so its temperature rise due to power can be neglected. The thermal coefficients of this type of resistor is lower than 1 ( $\mu\Omega/\Omega$ )/K, but the temperature rise for the 1024-V input arm can reach 60 K. This value causes resistance variations over the maximum project tolerance. To reduce the heating, a cooling mechanism was added for dividers from 256 V to 1024 V. It has a small fan installed at the output side of the external cylinder. The air flux is conducted to the resistor through small holes in both cones, as shown in figure 2. Experimental results show that the resistance variation was reduced from more than 60  $\mu\Omega/\Omega$  to 35  $\mu\Omega/\Omega$  in the 1024-V divider. The resistance variation of the input arm, applying step voltages of 250 V (blue), 500 V (red) and 1000 V (green) is shown in figure 3. Each step was applied immediately after the previous one. The temperature rise was reduced

with this cooling system. The thermal constant is around 10 min, so that with 15 min of preheating, the difference with the asymptotic value is under  $2 \mu\Omega/\Omega$ .

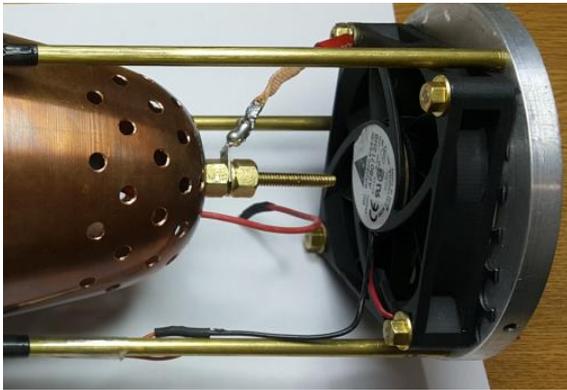


Fig. 2. Cooling system for the input arm of dividers from 256 V to 1024 V.

However, the size and position of the holes was empirically determined. So, a better hole design would improve the thermal behavior. For that, a simulation software is being developed to determine the best number and position of the holes, to get lower temperature rises.

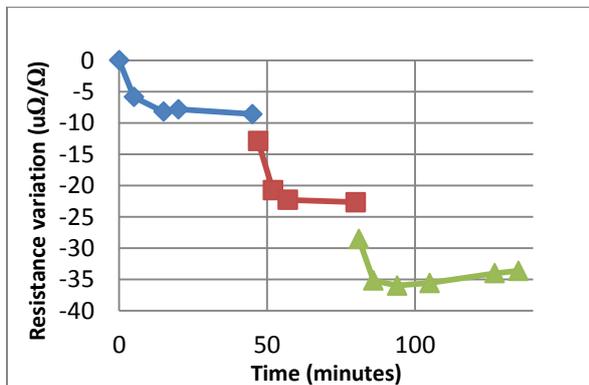


Fig. 3. Resistance variation of the 1024-V input arm, applying 250 V (blue), 500 V (red) and 1000 V (green).

As the size of the holes increases, the electric field moves away from its ideal shape, so it is necessary to balance the temperature rise with the distortion in the electric field.

#### 4. CONCLUSIONS

At the moment, in this project all designs have been concluded and a set of prototypes were manufactured. Preliminary results are in accordance with the specifications, although better results are expected using a computer-assisted design for the cooling system of the dividers with highest voltages.

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