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AC-DC current shunts: assembling and preliminary characterization at Inmetro

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Abstract: In this paper we discuss the assembling and characterization of cage-type current shunts for applications in ac-dc current transfer and, in a near future, electric power measurements. We started by measuring the shunts associated with planar multijunction thermal converters (PMJTCs). Measurements in dc resistance will also be addressed. Modelling, frequency dependence and simulations to evaluate the shunts' characteristics are also under research.

Keywords: current shunts, ac-dc transfer, thermal converters

1. INTRODUCTION

The increasing importance of developing new methods led Inmetro towards the research and construction of several devices and instruments in all its working areas.

In order to advance the electrical calibration and measurement capability of three countries in South America, the Instituto Nacional de Metrologia, Qualidade e Tecnologia (Inmetro) is coordinating a project involving the Instituto Nacional de Tecnología Industrial (INTI), from Argentina, and the Administración Nacional de Usinas e Transmisiones Eléctricas (UTE), from Uruguay [1].

Some resources from this project have been allocated to the construction of current shunts to be used in the dissemination of ac-dc current transfer at Inmetro.

Currently, Inmetro covers the current range in this field from 1 mA to 100 A, with frequencies ranging from 10 Hz to 100 kHz. The primary standard is described in [2].

The investigation on different construction types is fundamental for further improvement in the high frequency behavior of current shunts.

2. CURRENT SHUNT CONSTRUCTION

Two sets of 12 shunts each are under construction at Inmetro. Their nominal values are 20 mA, 50 mA, 100 mA, 200 mA, 500 mA, 1 A, 2 A, 5 A, 10 A, 20 A, 50 A, and 100 A. Additional sets are being constructed by INTI (see [3] for details).

The importance of maintaining two sets built exactly the same way is to compare their behavior, determine their drift over time, and assess the reliability of the results. This comparison can be also used to better define the level dependence of the shunts in ac-dc transfer measurements.

The design is based on the cage-type construction (Figs. 1 and 2), which minimizes the external magnetic field generated and also reduces undesirable thermal effects (see [4] for details).

By suppressing the intermediate printed circuit board (PCB) which most cage-type current shunts present, the design adopted reduces the inductance of its output voltage circuit path. This design also promotes a well distributed current flow through its parallel crossbars [4].

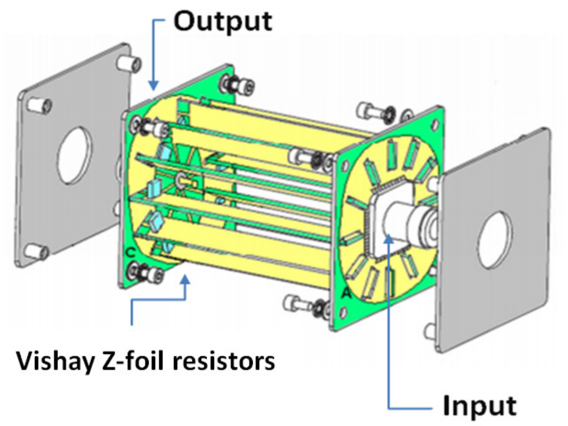

Fig. 1. Schematic overview of the shunt.

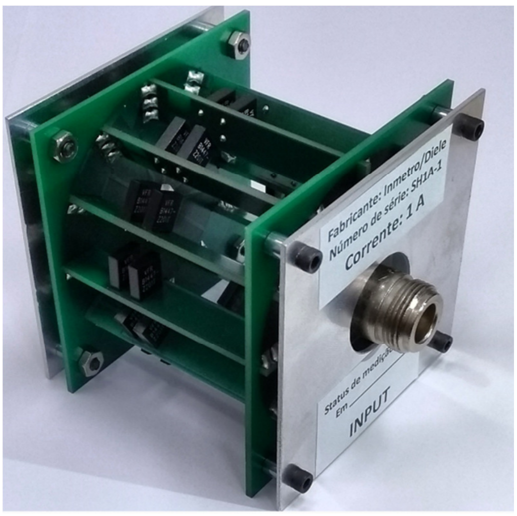

Fig. 2. 1 A shunt assembled at Inmetro.

3. AC-DC TRANSFER MEASUREMENTS

Inmetro has built two sets of 5 (five) current shunts up to now: 1 A, 2 A, 5 A, 10 A, and 20 A. Their labels are listed in Table 1. Column "I(A)" refers to the shunts' nominal values, in which the measurements were performed, as seen in section 3.1.

Table 1. Shunts' labels.

I (A)	Set 1	Set 2
1 A	Sh1A-1	Sh1A-2
2 A	Sh2A-1	Sh2A-2
5 A	Sh5A-1	Sh5A-2
10 A	Sh10A-1	Sh10A-2
20 A	Sh20A-1	Sh20A-2

The arrangement of the setup components for the ac-dc current transfer measurements is given in figure 3. The measuring setup is composed by two calibrators (one of them in dc mode and the other in ac mode to avoid switching transients), a switching unit, a transconductance amplifier and two nanovoltmeters for acquisition of the readings at the planar multijunction thermal converter (PMJTC) outputs. The system employs potential-driven guards. The standard is positioned at higher potential.

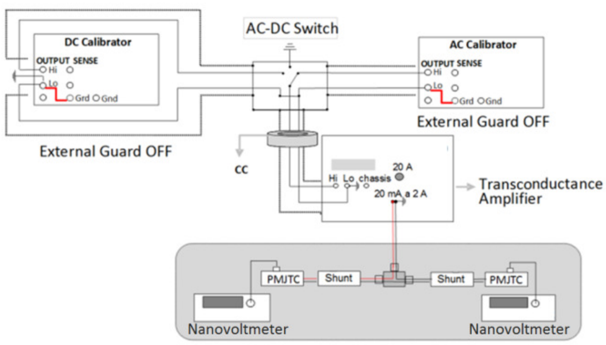

Fig. 3. Measurement circuit (adapted from [2]).

The ac-dc transfer measurements presented adequate agreement between the two sets of shunts. In the near future, a step-up procedure for each set will be evaluated. The PMJTCs were used in this system coupled with the shunts.

The basic setup for the ac-dc current transfer measurements is shown in figure 4.

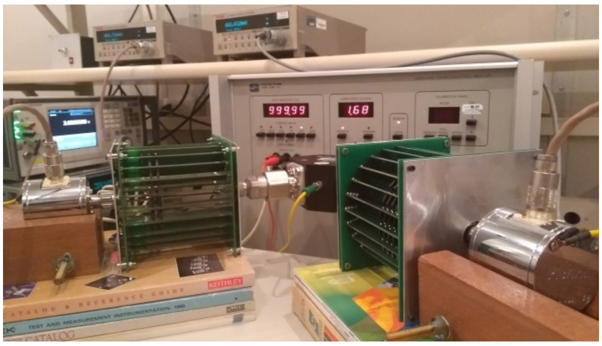

Fig. 4. Measurement setup.

A commercial series-type tee connector was used for measurements above 5 A.

3.1. Preliminary results – comparison with the primary standard

The following graphs depict the results obtained by comparing the two sets of shunts with Inmetro's primary standard, which is based on PMJTCs cascaded to Fluke's current shunts, model A40B [3].

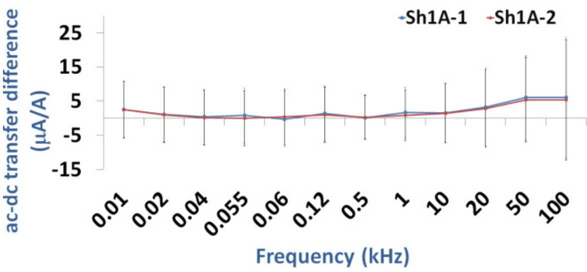

Fig. 5. ac-dc transfer difference for the 1 A shunt.

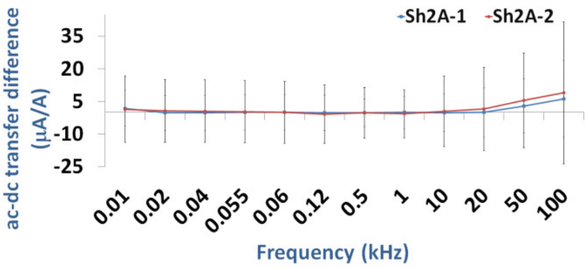

Fig. 6. ac-dc transfer difference for the 2 A shunt.

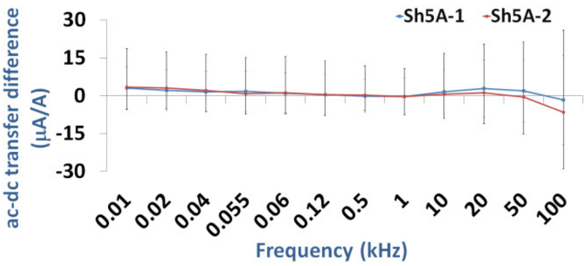

Fig. 7. ac-dc transfer difference for the 5 A shunt.

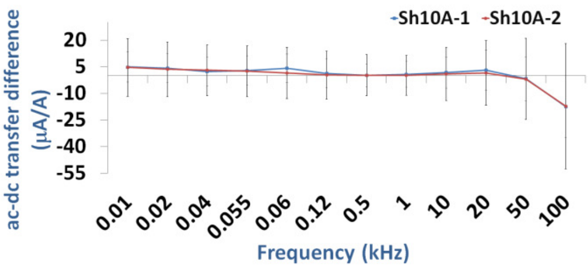

Fig. 8. ac-dc transfer difference for the 10 A shunt.

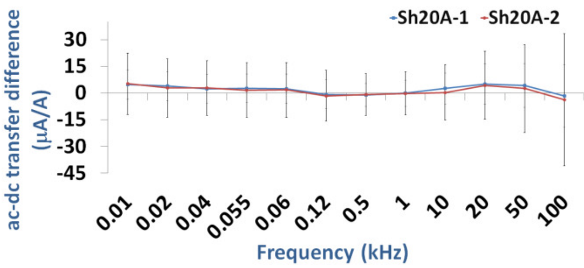

Fig. 9. ac-dc transfer difference for the 10 A shunt.

To improve the investigation on the behavior of the new shunts, measurements considering only the shunts' ac-dc current transfer difference will be performed. The tests will be also carried out using 90 Ω PMJTCs.

Note that the results presented here include the contribution of the PMJTCs to the ac-dc transfer difference. Their contribution will be studied as described in [5] in the near future.

4. UNCERTAINTY CALCULATION

The ac-dc transfer difference of the current shunt and thermal converter combination is determined as

$$\delta = \delta_{Ref} + \delta_C + \delta_{ST} + \delta_{Lev} + \delta_{Con} \quad (1)$$

where,

- δ_{Ref}: transfer difference of the standard
- δ_C: Contribution of the set-up
- δ_{ST}: Contribution of the mean of the readings
- δ_{Lev}: Contribution due to level dependence of the shunts
- δ_{Con}: Contribution of the connectors

The square of the standard uncertainty is given by

$$u^2(\delta) = u^2(\delta_{Ref}) + u^2(\delta_C) + u^2(\delta_{ST}) + u^2(\delta_{Lev}) + u^2(\delta_{Con}) \quad (2)$$

5. CONCLUSIONS

In this paper, preliminary results of the shunts built at Inmetro were presented. The standard deviations of the ac-dc transfer measurements were mostly within 1 µA/A. The shunts corresponding to the nominal values of 20 mA, 50 mA, 100 mA, 200 mA, 500 mA, 50 A and 100 A will be assembled by the end of 2017.

At the end of this project, all the current shunts designed will have been finished. They will be fully characterized and functional, not only for ac-dc transfer , but also for other electrical metrology fields, like multifunction instruments calibration, electric power measurements and other ones which require precision current measurements up to 100 A.

6. REFERENCES

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