REEVALUATION OF AC-DC CURRENT TRANSFER SYSTEM BASED ON SINGLE JUNCTION THERMAL CONVERTERS AT INMETRO

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Abstract: As the national metrology institute of Brazil, Inmetro is responsible for the maintenance and support given to clients in Brazil and abroad. In order to implement its services with high quality performance, Inmetro develops systems which will provide the dissemination of the basic magnitudes.

Corroborating to this mission, the Voltage and Current Laboratory (Latce) presents its standard for ac-dc current transfer based on Single Junction Thermal Converters (SJTCs), the behaviour of Latce's standards, and the recent upgrades in the system.

Responsible for the calibration of both voltage and current instruments, such as accurate multifunction calibrators and multimeters for other laboratories or industry, the transfer standards are between the first levels of the traceability pyramid for the dissemination of time-dependent voltage and current magnitudes.

The system for ac-dc current transfer measurement has been improved since BIPM international key comparison of ac-dc current transfer standards – CCEM K12, by changes in the setup and uncertainty budget reevaluation. The aim of this paper is to show how Latce managed to reduce uncertainty magnitude.

Key words: current, ac-dc, uncertainty

1. INTRODUCTION

Thermal current converters (TCC) are an important bridge to the measurement of ac current quantity. With a consistent response and characterization, it is possible to include SJTCs in a system capable of measuring any kind of transfer standard, either electronic or another thermal one.

Today, sets for ac-dc current transfer based on SJTCs worldwide have been replaced specially for Plannar Multijunction Thermal Convertes (PMJTCs).

Inmetro's calibration system consists on a set of SJTCs associated to shunts model A40/A40A, manufactured by Fluke. This set was periodically calibrated by PTB (Physikalisch-Technische Bundesanstalt) over the last decade, but it will soon begin to be calibrated using PMJTCs as standard in Latce.

The ac-dc difference (δ) for a SJTC is influenced by thermoelectric effects, such as Thomson and Peltier [1,2], which are likely to change the temperature distribution along the heater (Fig. 1).

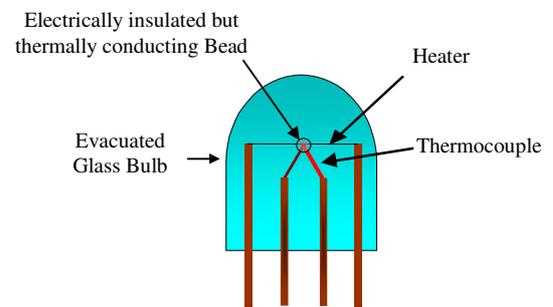A sketch representation of a SJTC is shown below:

Fig. 1: SJTC schematics [3]

2. MEASUREMENT AND CALIBRATION SETUP

The ac-dc current transfer calibration consists in the comparison of two TCs connected in series by using a current tee.

Figure 2 shows an overview of Inmetro's system, presenting its best configuration.

2.1. Parameters of the measurement

Basically, the measurement proceed as follows:

Two voltage sources are used to apply the rated voltage that supplies to the transconductance amplifier.

The linearity coefficients are measured, and also Δ_o, which is the relative deviation of the output voltage with ac input relative to the output voltage with dc input [4], calculated by:

$$\Delta_o = \frac{U_{ac} - U_{dc}}{U_{dc}} \qquad (1)$$

Where:

U_{ac} and U_{dc} are the outputs of both TCs.

If $\Delta_o \leq 50\ \mu V/V$, the sequence *ac, dc$^+$, ac, dc$^-$, ac* is performed at each cycle of the measurement. If not, some iterations are done as long as required to satisfy this condition.
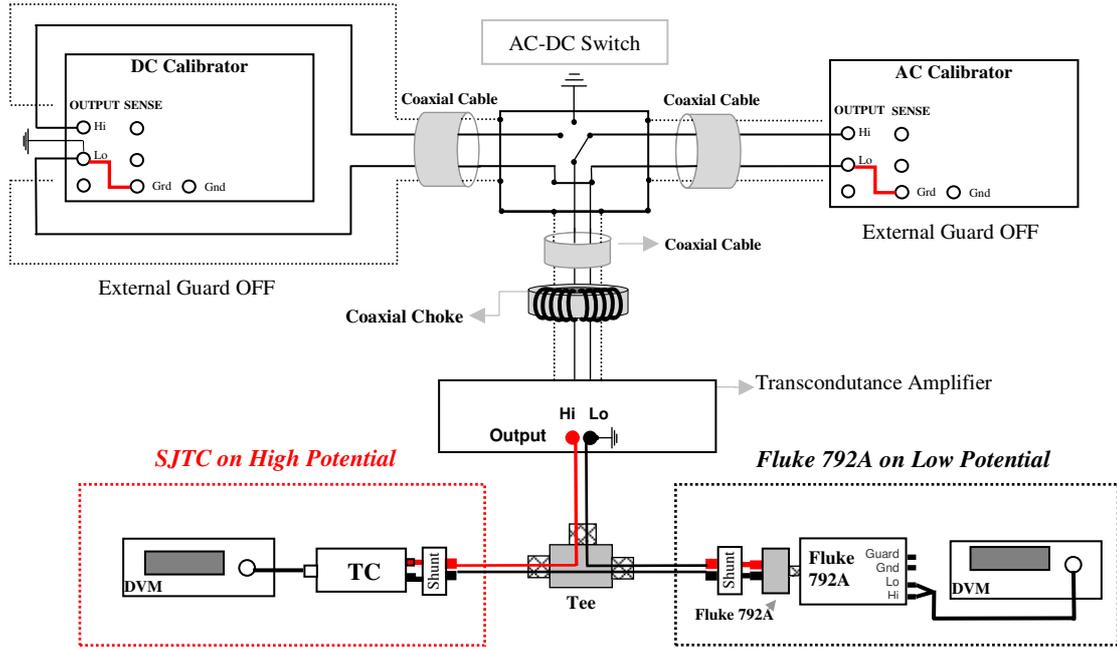
Fig. 2: Calibration setup

Above, the voltage sources are will operate in frequencies from 10 Hz to 100 kHz. The toroidal choke is used to avoid common mode noise.

For this measurement, it is used potential driven guard method, and in the case above, Latce's standard in on high potential. By using this method, it is possible to reduces significantly the uncertainty [5, 6].

2.2 Uncertainty model

The ac-dc transfer difference is defined by:

$$\delta_x = \delta + \delta_s \tag{2}$$

Where δ is the difference of the measurement and δ_s is the difference of the standard.

$$\delta = \delta_A + \delta_C + \delta_{DVM} + \delta_{CON} + \delta_{TC} \tag{3}$$

The variance $u^2 (\delta)$ associated with the transfer difference is:

$$u^2(\delta) = u^2(\delta_A) + u^2(\delta_C) + u^2(\delta_{DVM}) + \\ + u^2(\delta_{CON}) + u^2(\delta_{TC}) \tag{4}$$

Where δ_C is the standard uncertainty of the measured difference [7], defined by:

$$\delta_c = \frac{U_{dc} - U_{ac}}{nU_{dc}} = \frac{1}{n} - \frac{U_{ac}}{nU_{dc}} \tag{5}$$

After computing the results of the partial derivatives of the equation, the variance of δ_C is determined by:

$$u^2(\delta_C) = \left(\frac{U_{dc} - U_{ac}}{n^2 U_{dc}}\right)^2 u^2(n) + \\ + \left(\frac{1}{nU_{dc}^2}\right)^2 \left(\frac{U_{ac}}{U_{dc}} u(U_{dc}) - u(U_{ac})\right)^2 \tag{6}$$

Definitions by order of appearance:

δ_S standard's uncertainty

δ_A type A standard uncertainty

δ_{DVM} Stability of the digital voltmeter standard uncertainty

δ_{CON} Connectors

δ_{TC} Temperature coefficient

U_{dc} is the mean of the output voltage when a *dc* signal is applied to the system

U_{ac} is the mean of the output voltage when an *ac* signal is applied to the system

n is the linearity coefficient of the standard

2.3 Uncertainty results

Below, some results obtained from a real calibration show the improvement in Latce's uncertainty level since CCEM K12 comparison. The mandatory points were 10 mA and 5 A, from 10 Hz to 50 kHz, this last not represented here. The tables correspond to a calibration using a 792A ac-dc transfer, calibrated by Latce's SJTCs standards.

Table I. ac-dc transfer difference - $\delta_{ac\text{-}dc}$ (μA/A)

Current	55 Hz	120 Hz	1 kHz	10 kHz
10 mA	-2	2	0	0
20 mA	0	0	1	0
30 mA	2	-1	0	-14
100 mA	0	1	1	14
200 mA	2	5	4	16
300 mA	1	0	0	2
500 mA	6	6	7	21
1 A	0	-1	-10	-53
2 A	-2	-1	-14	-26
3 A	0	-2	-9	-52
5 A	-1	-1	-17	-44
10 A	-4	-9	-4	-4
20 A	1	0	-9	-51

Table II. Uncertainty - $U_{ac\text{-}dc}$ (μA/A)

Current	55 Hz	120 Hz	1 kHz	10 kHz
10 mA	7	7	7	7
20 mA	7	7	7	7
30 mA	8	8	8	8
100 mA	8	8	8	8
200 mA	8	8	8	8
300 mA	8	8	8	8
500 mA	8	8	8	8
1 A	8	8	8	8
2 A	8	8	8	8
3 A	18	18	18	18
5 A	19	19	19	24
10 A	29	29	29	29
20 A	35	35	35	44

2.4 Stability of the transfer standard

Although the current transfer system works as expected nowadays, it is essential to perform a deep analysis on the SJTC behaviour, and also the Fluke A40/A40A shunts, that cover the range 10 mA to 5 A.

It is never recommended to use a single calibrator to switch from ac to dc during the measurement. Specially in ac-dc systems based on SJTC standards. They are very likely to be damaged in a short period of time by having a not negligible noise caused by the calibrator switching.

In Inmetro's case, an ac-dc transfer switch has been included in the system in order to shorten the time required to keep the junction still warm during the measurement, which provides a more reliable result and retain the SJTC condition.

About the Fluke A40/A40A shunts, its delicate assembly is responsible for the necessity of maintenance over the years. It does not happen with the 10 A and 20 A shunts due to their coaxial design.

3. CONCLUSION

Despite the results from the last international comparison in ac-dc current transfer field, the Voltage and Current laboratory managed to fix its issues regarding the SJTC-based system.

In the near future, Inmetro's SJTCs standards will be replaced by PMJTCs together with coaxial shunts, which will reduce significantly the uncertainty for the ac-dc current transfer system.

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