Efeitos do campo magnético externo em minitransformadores de corrente

External stationary magnetic field effects on mini current transformers

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Abstract: Stationary external magnetic fields on the alternating current sensors, used in the measurement of electric power, can influence the reading with disadvantages for the power distributors. Such fields may be purposely applied in order to circumvent the measurement. Measurement frauds are called commercial losses and in Brazil account for 8.4% of all energy supplied by energy distributors. An experimental investigation was carried out with a current minitransformer by subjecting it to external stationary magnetic fields of up to 320 mT, up to 100 A, 60 Hz. The effects on ratio error, phase and measurement error on electronic meters were identified.

Keywords: Metering; Current Transformer; Energy Meter; Error; Magnetic Field.

1 INTRODUCTION

There are concerns about the effects of currents and telluric magnetic fields on electric transformers [4].

If this concern does indeed make any sense to power transformers, then surely it should make more sense to the transformers for measuring instruments. And in this case, most likely, there must indeed be some effect of such magnetic fields on the current minitransformers, here called mCTs, used in electronic power meters. The Indian specifications for static, or electronic, electric power meters indicate serious concern with such effects [6].

This work deals with the measurement of electrical quantities, particularly of sensors and transducers of alternating currents, in the industrial frequency, for electric energy charging, and will show a survey of the effects of stationary magnetic fields on the error of ratio, error of angle and combined error of the current minitransformers used in digital metering, or electronic metering, through experimental research.

The intensity of the external magnetic fields applied to the mCTs, however, was not limited to the telluric levels but extended to the levels found in the current permanent super magnets, as referred in literature [5], [9].

A magnetic shielding in the mCTs, against external magnetic fields, has been tried for the mitigation of the effects on the measurement errors and will also be presented here.

2 SAMPLE SELECTION OF mCT

Four samples of current minitransformers - mCTs were previously evaluated for the choice of one as object of more detailed studies [7]. The results of the preliminary analysis to evaluate the ratio error and the phase angle error are shown in Figure 1.

The sample of current minitransformer mCT, type TCT103-01 from Moldova, made by Oswell Metering, weighing 61 g, with a 33 mm of external diameter and 8 mm of internal diameter, used in Elo electric power metering, also of Moldovan origin, was the best of the samples.

This sample had the lowest ratio error and the smallest error of phase between the primary and secondary currents.

Opening the sample, by disassembly, it was found that the core was made by a very fragile amorphous magnetic material. The core was enclosed in a bakelite toroidal box, to protect it.

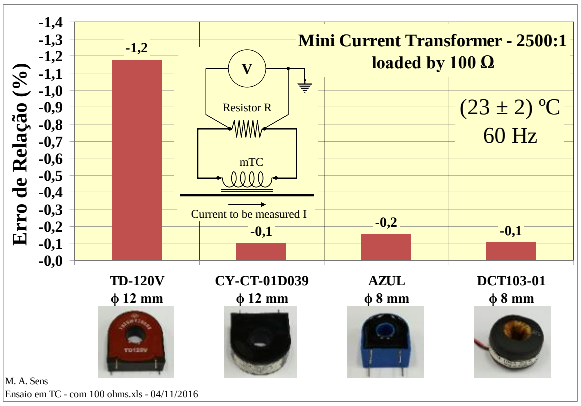

Figure 1 - Preliminary evaluation of mCTs.

The sample picture of selected sample is shown on the far right of Figure 1. Four samples of this model were evaluated for ratio and phase angle errors as shown in Table 1.

Table 1 - Error of ratio and phase of mCTs from Moldova.

Measured Parameter	OSWELL METERING - mCT - 2500:1 - I=100 A; R=12.5 Ω			
	mTC - 01	mTC - 02	mTC - 03	mTC - 04
Ratio	2508	2507	2507	2507
Ratio Correction Factor	1.003	1.003	1.003	1.003
Ratio Error (%)	-0.3	-0.3	-0.3	-0.3
Phase Angle (min)	8	7	6	7

3 METHOD OF MEASUREMENT

To verify the error of the mCTs a Wide Band Power Analyzer, model Lem Norma D6100, of class 0.1% and uncertainty of angles of ± 87 µrad was used. The instrumentation normally available for testing and for the evaluation of current transformers was not suitable for the tests and for the evaluation of current minitransformers since it would certainly cause the destruction of the samples by over current. Initially, a Tek DPO7104 digital oscilloscope was tried, but the sensitivity for the measurement of phase angles was not adequate, resulting in uncertainty of ± 6 mrad [7]. This uncertainty value is above the limits of standardized errors for the sensors intended for the measurement of electric energy for charging purposes [3].

Thus, the Norma D6100 power analyzer showed better results, with sensitivity on angle measurement of ± 6 min[7]. The Norma Lem D6100 was then adopted to evaluate the effects of magnetic fields on mCTs, mainly because it allows direct evaluation of the combined measurement error, since it can operate on the same principle as an electronic energy meter.

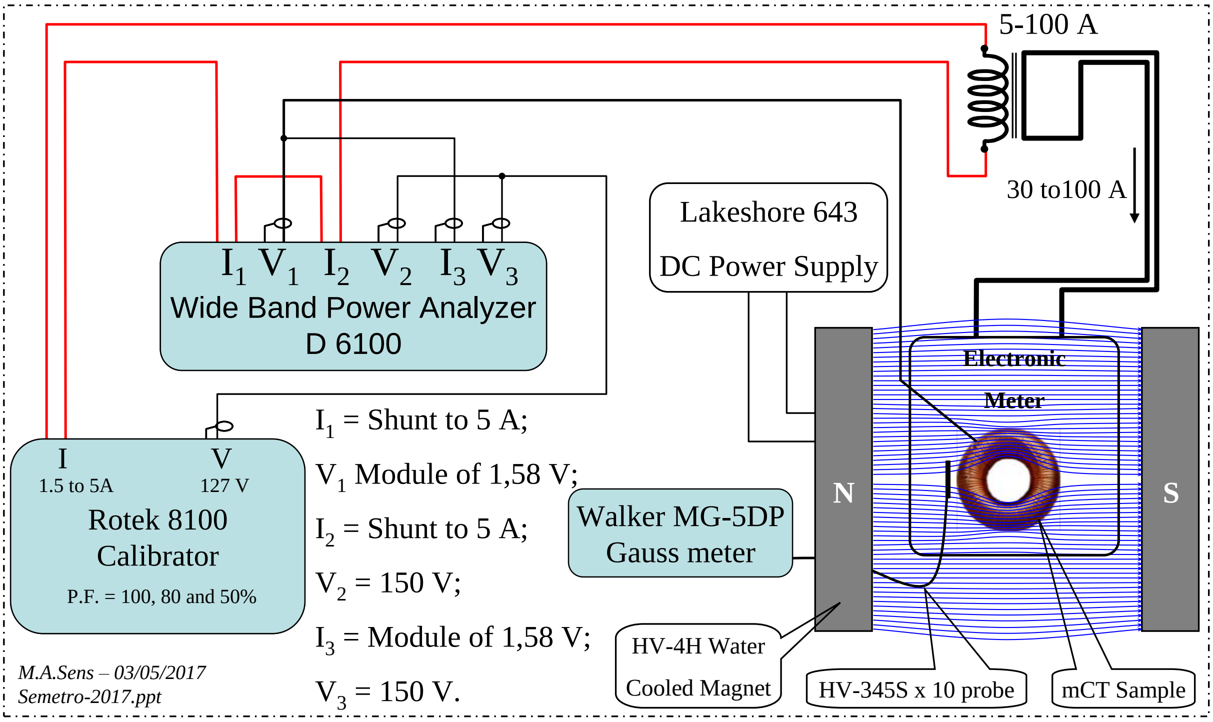

Figure 2 – Circuit of tests for ratio error, phase error and measurement error of mCTs.

The Brazilian standards [1] recommend a maximum error of ± 3 % for single-phase energy meters, such as the selected working sample.

3.1 *Stationary magnetic field*

For the generation of the external stationary magnetic field on the mCT sample, a Walker Scientific electromagnetic system, model HV-4H, was used as shown in Figure 1.

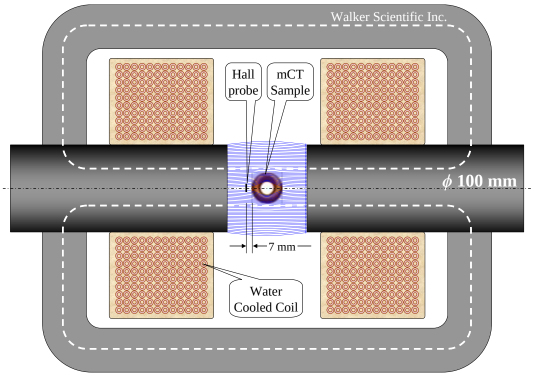

Figure 3 – Stationary magnetic field generator.

A stabilized direct current source, Lakeshore DC Power Supply 643 was used to power the Walker magnet for stationary magnetic field generation.

3.2 *Magnetic flux density measurement*

To measure the magnetic flux density external to the mCT, a Hall-type sensor probe was used, Walker HP-345S, X 10, 7 mm apart from mCT, connected to the digital gauss meter, Walker MG-5DP. The probe and instruments were pre-tested against a standard 300 mT Walker MR-3 (3 kG) reference magnet. This standard magneto was also evaluated through search coil Walker MS-1-100 of NA = 1/100 m².t (100 cm².turns) and digital integration by Tek DPO 7104, according to the equation below, indicating magnetic flux density of (298.33 ± 0.16) mT.

$$B = 100 \bullet \int_{t_1}^{t_2} e \cdot dt \;\; [T]$$

Where e = voltage generated in search coil by withdrawal from the action of the magnetic flux.

4 EXPERIMENTAL RESULTS

4.1 *Minitransformers as used*

The sample of mCT, as used, within an original electronic power meter, together with other electronic and electromechanical components, including three other similar mCTs, was installed inside the magnet shown in Figure 3 and subjected to currents of 30 to 100 A, on 60 Hz, with power factors of 100 %, 80 % and 50 %, under external magnetic flux density of up to 320 mT. The ratio error reached -800 %, as shown in Figure 4, starting effects at 120 mT.

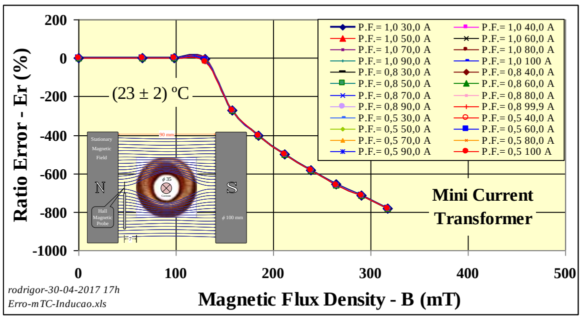

Figure 4 – Ratio error due to magnetic field.

The phase error, due to the external stationary magnetic field to the mCT, resulted in up to 1.5 radians, as shown in Figure 5.

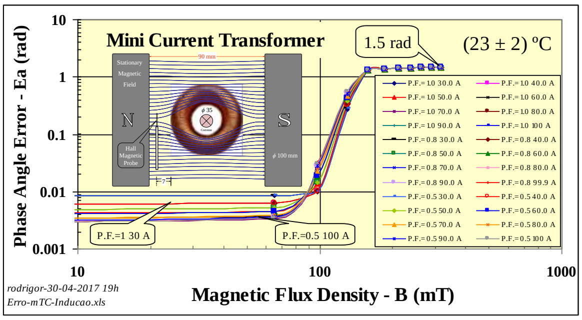

Figure 5 – Phase error due magnetic field.

The combined error in power or electric energy measurement due to the external stationary magnetic field to the mCT was up to -140 % for 50 % power factor and 100 A current as shown in Figure 6, with point of starting effects at 100 mT.

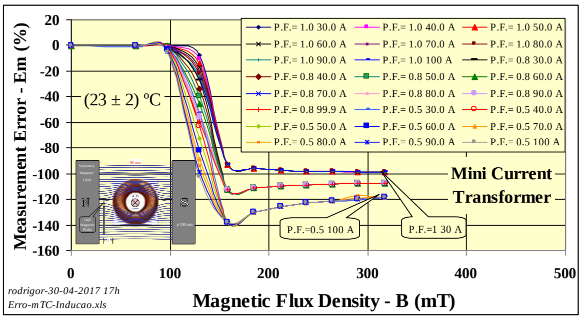

Figure 6 – Combined measurement error due to external stationary magnetic field.

4.2 *Shielded Minitransformer*

The same sample previously evaluated for the effects of the external stationary magnetic fields, in the same configuration, was provided with a granular magnetic shield of angular steel grit G50, according to SAE J444 and the evaluation was repeated. The results, in summary form, are shown in Figure 7.

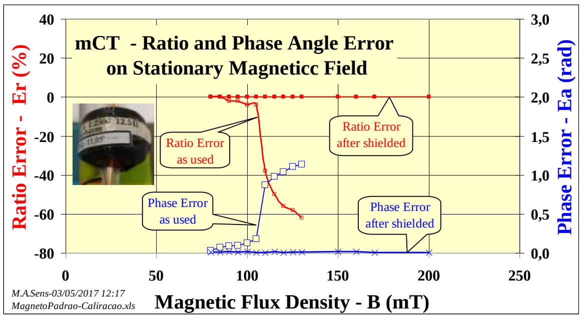

Figure 7 - Shield effects on measurement error.

5 CONCLUSIONS

Fact is that electric energy measurement fraud, called commercial losses, in Brazil accounts for 8.4% of all energy supplied by distributors, as verified from 2000 to 2015 [2]. There is an increasing preference for permanent magnet fraud techniques and the current technical standards clearly address this issue [6]. The standards and specifications of energy metering already establish the immunity criterion for alternating magnetic flux density of up to 0.5 mT and 500 mT for stationary fields applied to electronic meters [6]. Techniques of defrauding the tariff of electric energy, are treated openly in books, showing dozens of possibilities [8].

The results showed that the external application of stationary magnetic fields on the current minitransformers, actually have significant harmful effects on the energy measurements, when under magnetic flux density greater than 100 mT. For fields up to 65 mT the mCT still meet the normative error limits of ± 3% [1].

On the other hand, after the shielding of the same current sensor, the effects were mitigated up to 200 mT, as shown in Figure 7.

Two other mTCs samples, from Asian origin, were evaluated, showing different magnetic flux density from which the effects become drastic. Both results are much lower than Moldovan sample, revealing that this is an intrinsic feature of the magnetic core material.

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