12th IMEKO TC4 International Symposium
Electrical Measurements and Instrumentation
September 25–27, 2002, Zagreb, Croatia

IRON LOSSES MEASUREMENT USING SAMPLE AUTO-RANGING DATA ACQUISITION TECHNIQUES

Marinel Temneanu, Cristian Zet, Mihai Cretu, Cristian Fosalau

Faculty of Electrical Engineering, Technical University “Gh. Asachi” of Iasi, Romania

Abstract − Being one of the most important quality parameters of magnetic materials, iron losses, and consequently iron losses measurement, are extensively treated in scientific papers. There are many experimental set-up arrangements and also data processing algorithms proposed in order to improve the accuracy of measurement results. A sample auto-ranging data acquisition technique, implemented using National Instrument support, is presented in this paper. The experimental results obtained with three different A/D converters (12, 10 and 8 bits) are presented and compared with the results obtained by using the classic acquisition and processing algorithm.

Keywords: Iron losses, sample auto-ranging acquisition.

1. INTRODUCTION

The accurate measurement of the total amount of iron losses becomes more and more important since the magnetic materials used in our day’s equipments are subject to various magnetization regimes, both in frequency, amplitude and waveform of the magnetic induction. In low and medium intensity fields, with a sinusoidal waveform of induction, it seems that the well known integral method, which computes the iron losses from magnetizing currents and induced voltage, gives fairly good results. It is not the case of the high magnetic fields where the magnetizing current is strongly distorted. The reported relative errors are increasing once the saturation limit is exceeded. To better understand this, in Fig.1 is presented the typical experimental set-up used in magnetic measurements.

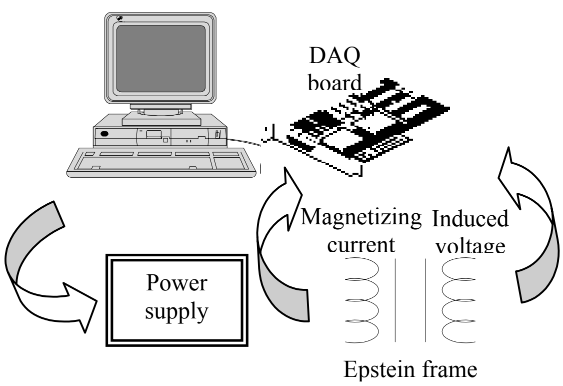

Fig.1 Information flow in magnetic measurement set-up

The material being tested is usually forming a closed magnetic circuit (toroidal or a squared). A programmable power supply, with current or voltage feedback, is used to prescribe the desired magnetizing regime. Using a shunt resistor and resistive voltage divider samples of the excitation current i(t) and induced voltage u(t) are acquired and digitally processed in order to determine magnetic quantities H(t) and B(t) with the well-known formulas:

$$\begin{cases} H(t) = \dfrac{N_1 i(t)}{l_m} \\ B(t) = B_0 - \dfrac{1}{N_2 A}\displaystyle\int_{to}^{t} u(t)dt \end{cases} \qquad (1)$$

where N_1, N_2, l_m, A and B_0 are the number of turns of the excitation and measurement windings, magnetic path length, cross section area and initial value ($t=t_0$) of magnetic field density respectively. If the excitation winding is supplied with an alternate symmetrical voltage the hysteresis loop is symmetrical too and the value of B_0 can be easily determined averaging the magnetic field density waveform over a period. The accuracy of the computed magnetic quantities is determined by the acquisition process of the electric ones. When experimental data are acquired using a DAQ system the analogic gain is usually determined by the peak value of the input signal. For all the samples the quantization error is less than 1/2 LSB. However, for those samples with small value, the relative error due to quantization is very high. With most of the commercially available systems, builded around a 12 bit A/D converter, this error can be neglected for a large number of signal waveforms. Unfortunately this is not the case in magnetic measurement. There are a lot of samples with small values in the waveform of the exciting current and, as we are approaching the saturation point, this number is increasing. Moreover these samples are multiply by the corresponding voltage values resulting in great relative errors in the iron losses evaluation. In order to reduce them, some authors have proposed a hardware method for sample self-scaling [1], [2]. On a classic data acquisition system, a sample and hold circuit before the programmable gain amplifier and a fast scaling device determine a 3 bit sample value which is used to modify the gain, is added. Other similar systems have been presented in literature [3], [4]. This paper makes use of a different approach, which requires no additional hardware, and it is easy to implement by software.

2. PROPOSED PROCEDURE

When acquiring a waveform with DAQ board, whatever programming utility is used (LabView, HPVEE, TestPoint, DAQ routines), the acquisition parameters cannot be modified "on the fly". We are referring here mostly at PGA's gain, sampling rate and number of samples. For example, once an acquisition is started in LabView, in order to reconfigure the input limits one should use again the AI Config.VI which means that the acquisition must first be stopped. The whole process being time consuming, only extremely low levels in sampling rate are addressing this technique (it depends on hardware support, but they are usually lower than 10 Hz). A different technique was proposed in order to replace the dynamic adjustment of the PGA's gain. Instead of changing the gain from one sample to another each signal is acquired with more than one gain (different channels) and then the original waveform is rebuild starting with the samples from the channel with highest gain. Each sample on this channel is first tested in order to verify if the channel is saturated (a maximum condition is imposed). If it is the case the second channel is taken into consideration and so on. For an extended presentation of the algorithm please refer to [5]

The method has some drawbacks the most important being:

- A smaller number of signals that can be acquired simultaneously (number of input channels on the DAQ board rated by number of gains used for each input signal);
- A lower sampling frequency (DAQ board maximum sampling frequency rated by number of gains used for each input signal).

If measurements have to be done in low frequency this algorithm is a very powerful tool in accurate evaluation. The purpose of our study is to determine the relative error made in iron losses measurements with two different data acquisition systems (8 bits and 10 bits A/D converters). The reference term is the result obtained by using a 12 bits A/D converter.

Experiments have been conducted using a standard (IEC 404-10) Epstein frame (grain oriented FeSi alloy), and three data acquisition boards with 12, 10 and 8 bits A/D converters respectively. An external signal was used to trigger the whole acquisition process.

For the data acquisition card equipped with an 8 bits A/D converter the following steps have been completed:

- The two input signals (magnetizing current and induced voltage) have been applied, each of them, to two input channels;
- Two different gains were programmed for these channels (1 and 2);
- Scaled data have been processed in order to avoid the phase shift due to the interchannel delay;
- The translated signals have been processed and the original signal rebuild.

In Fig. 2. are shown the results of these processes.

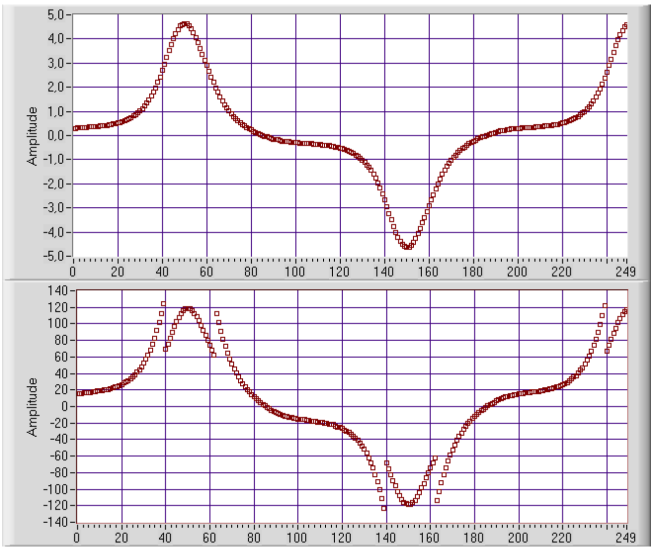

Fig.2 8 bits ADC. Data acquisition result (lower graph) and reconstructed waveform of magnetizing current (upper graph)

For the graphical presentation the acquired data have been decimated (1/4) in order to allow the observation of the differences between samples. Note that in the lower graph the sorted unscalled results are presented. It is clearly revealed that a large number of samples have been acquired with a gain value of 2 even if the peak value of the signal is approaching 5V (input limit of the channel). Only two gains (1 and 2) were used for each input signal because the board has 4 input channels.

For the DAQ board equipped with a 10 bits A/D converter three gains (1, 2 and 5) have been used for each input signal the same steps have been completed as for the previous presented board. The only differences consist in the number of channels used for each input signal and the number of programmed gains (three for each signal). The rest of the algorithm remains unchanged.

The results obtained are presented in Fig.3.

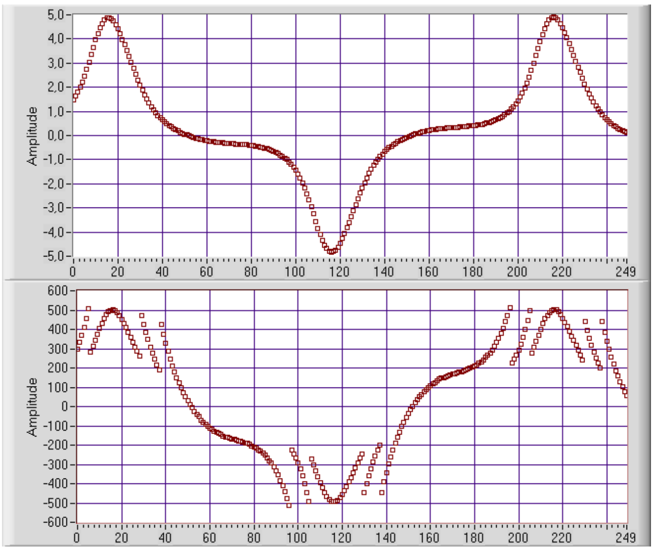

Fig.3 10 bits ADC. Data acquisition result (lower graph) and reconstructed waveform of magnetizing current (upper graph)

From the lower graph in Fig.3. (uncalled results) one may observe that most of the samples have been acquired with high resolution (channel with gain =5). Due to the specific shape of the magnetizing current waveform only few samples are selected from the second channel (gain=2) the rest of them being selected from the channel with gain=1.
In order to estimate the iron losses waveform of induced voltage was acquired, the results obtained with 10 bits ADC being presented in Fig. 4.

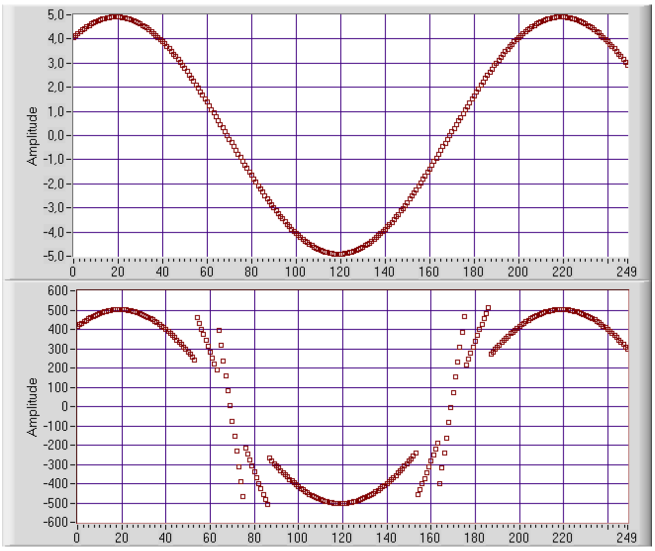

Fig.4 10 bits ADC. Data acquisition result (lower graph) and reconstructed waveform of induced voltage (upper graph)

It can be observed that, for the sinusoidally shaped induced voltage, only 24 samples from 250 have been acquired with high resolution.

3. EXPERIMENTAL RESULTS

In Fig.5 are represented the relative errors in iron losses estimation versus peak value of induced voltage. Two different curves are shown:

- the "one gain" 8 bits ADC relative errors curve;
- the "two gains" (1 and 2) 8 bits ADC relative errors one.

The values obtained by using the information provided by the 12 bits AD converter have been considered as the reference values.

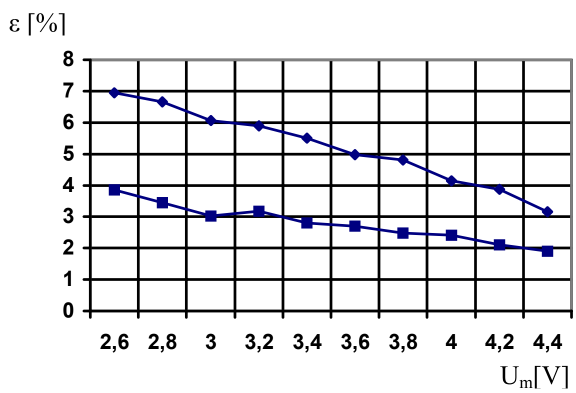

Fig.5 8 bits ADC. Relative errors in iron losses evaluation versus peak induced voltage. ♦ - 1 gain errors, ■ – 2 gain errors

As expected the relative error in iron losses measurement is decreasing when using a 2 gains acquisition techniques. A similar result, presented in Fig.6. was obtained for the 10 bits AD converter.

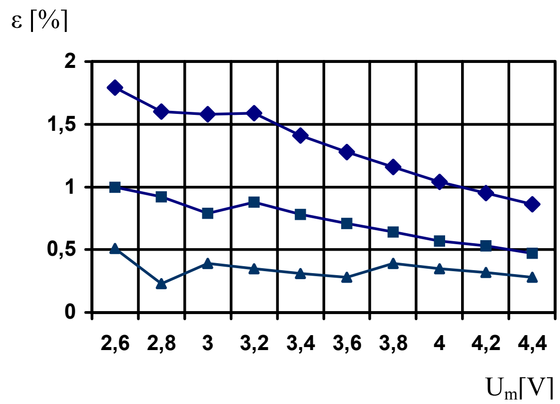

Fig.6 10 bits ADC. Relative errors in iron losses evaluation versus peakvalue of induced voltage.
♦ - 1 gain errors, ■ – 2 gain errors, ▲ – 3 gains

Three different curves are represented, relative errors versus peak value of induced voltage (adjusted to fit the DAQ input limits) for 1, 2 and 3 gains acquisition techniques (gain values – 1, 2 and 5). Once again the values obtained by using a 12 bits ADC have been considered as being the reference values.

4. CONCLUSIONS

It was emphasis in this paper that a more accurate evaluation of the iron losses can be done using a software sample auto scaling system. This technique is suited to analyze some intense magnetizing fields where classic data processing yields high relative errors.

5. FURTHER DEVELOPMENTS

As pointed before, one of the major drawbacks of the multi gain algorithm consists in the limitation of the number of input signals. Therefore it is necessary to develop some acquisition techniques allowing gain adjustments to be done "on the fly". This can be done by changing the values of the PGA command lines between two scans. Only a low level registry-programming algorithm can be used in order to provide this facility. There are two possible solutions:

- to acquire one sample with gain=1, to evaluate the value and then to adjust the gain for the next reading;
- to compute the time derivative of the signal in each point, to predict the next value of the input and then to adjust the gain for the next sample.

The main advantage consists in the fact that there is no limitation on the number of gain used for each input signal.

ACKNOWLEDGMENT

This work was financed and developed in the framework of the LEONARDO DA VINCI pilot project with the contract number: RO/98/83550/PI

REFERENCES

[1] C. Zet, E. Vremera, "Hardware Method to Increase Speed and Accuracy in Multichannel Plug-In Data Acquisition Systems", *Proceedings of the 9th IMEKO-TC4 Symposium*, Glasgow, pp. 69-72, September, 1997.

[2] C. Zet, E. Vremera, "Improving Power Measurements Using Data Acquisition System with Hardware Self-Scaling", *Proceedings of the 10th IMEKO-TC4 Symposium*, Napoli, pp. 245-248, September, 1998.

[3] L.Grisoni, A. Heubi, P. Balsiger, F. Pelladini, "Implementation of a Micopower 15 bit Floating Point A/D Converter", *IEEE Transaction On Solid State Circuits*

[4] Francis Chen, C.S. Chen, "A High Speed High Resolution Floating Point Data Acquisition System", *IEEE Transaction on Industrial Application*, pp. 740-742, 1991

[5] Zet C., Temneanu M., Fosalau C., Cretu M., "Sample auto-ranging acquisition using National Instruments support" *IMEKO TC4 ADC Modelling and Testing Workshop*, Lisabona, pp. 177-150, 2001.

Authors:

Marinel Temneanu, Lecturer PhD, Electrical Measurement Dept., Faculty of Electrical Engineering, Bdul Mangeron, 53, Iasi, Romania, Phone: 4032278683/1240, Fax: 4032237627, E-mail: mtemnean@ee.tuiasi.ro

Cristian Zet, Lecturer PhD, Electrical Measurement Dept., Faculty of Electrical Engineering, Bdul Mangeron, 53, Iasi, Romania, Phone: 4032278683/1125, Fax: 4032237627, E-mail: czet@ee.tuiasi.ro

Mihai Cretu, Professor PhD, Electrical Measurements Dept., Faculty of Electrical Engineering, Bdul Mangeron, 53, Iasi, Romania, Phone: 4032278683/1122, Fax: 4032237627, E-mail: mcretu@ee.tuiasi.ro

Cristian Fosalau, Assoc. Professor PhD, Electrical Measurements Dept., Faculty of Electrical Engineering, Bdul Mangeron, 53, Iasi, Romania, Phone: 4032278683/1125, Fax: 4032237627, E-mail: cfosalau@ee.tuiasi.ro