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Some remarks on metrological properties and production technology of current transformers made of nanocrystalline cores

Wojciech A. Pluta [a,*], Cezary Swieboda [b], Jacek S. Leszczynski [c], Marian Soinski [b]

[a] Czestochowa University of Technology, Electrical Engineering Faculty, Al. Armii Krajowej 17, 42-200 Czestochowa, Poland
[b] Magnetic Research Centre, Magneto Ltd., Czestochowa, Poland
[c] Department of Hydrogen Energy, AGH University of Science and Technology, Krakow, Poland

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ABSTRACT

Instrument current and voltage transformers remain the basic apparatuses used in energy measurements in electrical grid. The increasing importance of distributed energy sources necessitates more accurate measurements of consumed as well as generated electrical energy. Both types occur in low voltage network where the main focus is on current transformers (CTs) for electronic-type electrical energy meters. These current transformers should fulfil many requirements for precise electrical energy measurements. This paper presents a modern measurement system for various metrological research of CTs offered as 1 and 3-phase current transformers modules (CTMs).

1. Introduction

Together with the development of electricity use, there appeared a necessity to perform more and more accurate electrical energy measurements. This is because for example the European Commission has recently introduced directives concerning improvements of effectiveness of electrical energy use and efficient communication between producer and consumers of electrical energy is becoming more and more important. Due to all facts, modern electrical devices are more effective but at the same time the consumed energy is more distorted from sinusoidal waveform. That is, the consumed electrical current contains higher harmonics. An assumption of Directive EED (Energy Efficiency Directive) is to reach 20% energy saving up to the year 2020. The directive also stipulates that inductive watt-hours meters should be replaced by electronic watt-hour meters (the so called Smart Meters). This will make it possible to create intelligent Smart Grid, giving the possibility of two-way communication between the seller's computer system and the consumer's watt-hour meter.

In practice measurement of electrical energy is performed as a time product of distorted waveforms of voltage and current. Next, the current waveform is most often obtained by transformation from primary current to voltage obtained by the use of current transformer (CT) and shunt resistance [1,2]. What confirms the importance of paper subject.

An ideal CT is characterized over a wide range linear relationship between its primary and secondary currents and is capable to reproduce a high-current waveform as a low-current one. Accuracy of such transformation depends strongly on magnetic properties of the material used for magnetic cores of the CT as well as on shunt resistance [1–5]. Such cores of CTs can be made of different very soft magnetic materials and should have very high quality level. Nowadays nanocrystalline strips are more often used for CT cores production instead of Co-based amorphous strips [2,5,6]. It is also well known that due to induced anisotropy, nanocrystalline tapes have a wide range of magnetic properties like steep or flat but always slim hysteresis loop and are quite easy available to be obtained in the production process. Nanocrystalline cores for current transformers are characterized by a very good linearity of magnetic flux density versus magnetic field strength [2,7]. This enables accurate current transformation in CT made of such a cores and hence, accurate measurement of electrical energy by electronic watt-hour meters. Usually one or three single phase CTs only with secondary windings [2] are placed into meter housing. Because of this disadvantage, the module structure with primary copper bars (consisting for example of three CTs covered by one casing - Fig. 2 and name as CTM) is described in the paper and is recommended for the industrial use for smart electrical energy meters' construction.

* Corresponding author.
E-mail address: w.pluta@gmail.com (W.A. Pluta).

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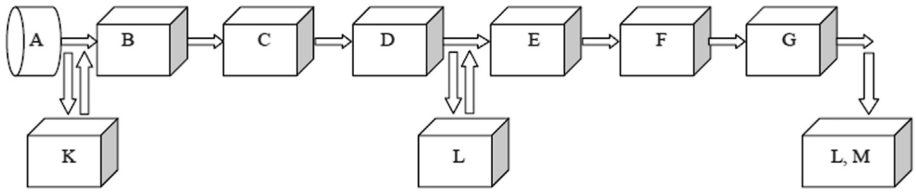

Fig. 1. Schematic diagram of current transformers modules (CTMs) production line. A - cores winder; B - workplace for magnetic cores annealing (Fig. 5); C – workplace for cores with protective cups; D - electrical coil winder; E - bender line for copper bars of high current; F - priming system for modules; G - device for the production of magnetic shield, K – system for the study of the properties in magnetic cores; L - system for measurement of amplitude and phase errors - quality control (Fig. 7); M – high-voltage attempts.

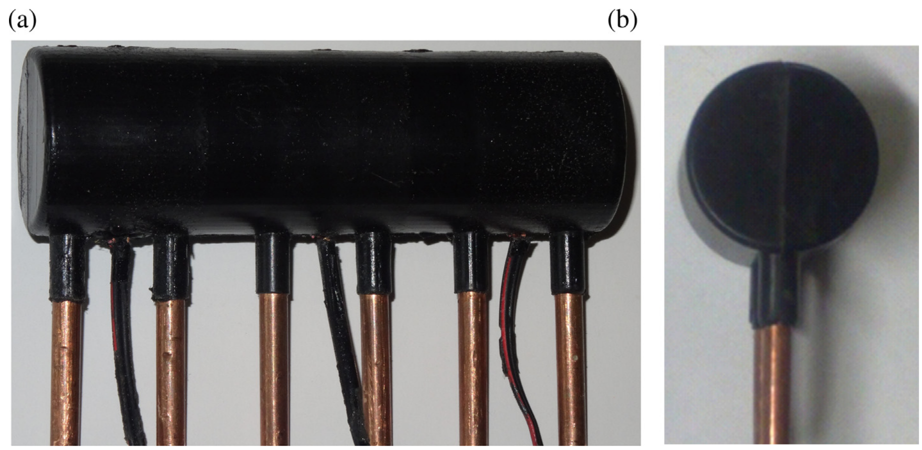

Fig. 2. Photographs of oval type three-phase and single phase current transformer modules, respectively: (a) three CT units in one casing and (b) one CT unit module.

Industrial production process of CTMs is arranged on the logic way and divided into stages, as presented in Fig. 1.

The paper is based on metrological research of CTMs and describes the key steps of modules production (Fig. 1) in which magnetic cores are made of nanocrystalline strips.

2. Observables

The production results of single-phase and three-phase CT modules that met the requirements specified in the European Union Directive 2006/32/W are presented the paper. This solution is highly innovative, offers compact and resistant to magnetisation processes (are DC tolerant, i.e. are resistance to incidental magnetisation by the constant component of the measured current) CTMs with accuracy class of 0.1 or better. This is because magnetic cores are wound of nanocrystalline strips with proper heat treatment [5,6]. The most desirable magnetic properties of the cores are not only very low losses and the magnetization linearity but first of all, the very low and stable magnetic permeability (Fig. 4). Cores features depend mainly on the chemical composition and thermomagnetic processing of magnetic strips used for production. Low magnetic permeability is obtained by appropriate parameters selected during the process of inducing anisotropy in magnetic cores by applying a strong transverse magnetic field during heat treatment (Fig. 5) [8].

The size of the electronic electrical energy meter can be reduced due to the compact construction of the 3 phase CT modules. Fig. 2 presents photographs of CTMs solution in standard version, i.e. without magnetic shield against external stationary field (an example of shield and shielded module is presented in Fig. 9).

The construction presented in Fig. 2(a) is equipped with wire connections but can fit the standard for pin connections of electrical energy meters as well. This possibility is afforded by the use of high-quality dielectrics insulating the neighbouring current windings from different phases. In similar way, the shape of the module can be adapted to the requirements of a specific meter type. The module design makes geometrical dimensions reduction of electronic watt-hour meters, facilities modules assembly, simplifies production and lowers the final cost of energy meters.

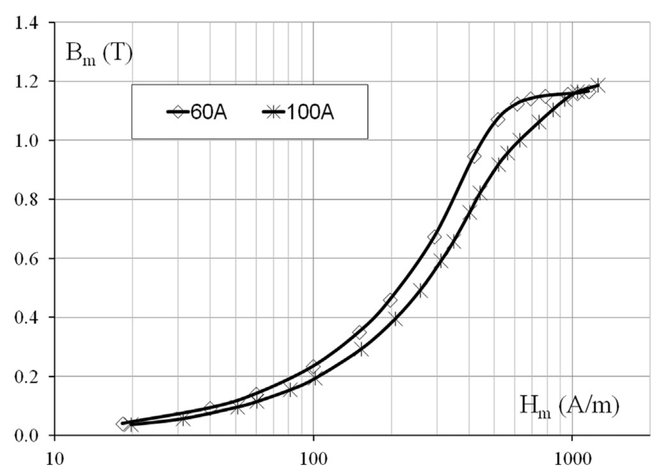

Fig. 3. Magnetization curves $B_m = f(H_m)$ of magnetic cores for current transformers 60 A or 100 A and resistant to the incidental magnetisation by the constant component of the measured current.

3. Experimental setup

The production process of the CTMs starts with winding the toroid cores out of nanocrystalline strips by means of a precise winding machine (A - Fig. 1). Selected cores are tested for magnetic