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CURRENT TRANSFORMERS AND OTHER TYPES OF MAGNETIC CIRCUITS

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Currently, park of measuring current transformers is old. Over time, the magnetic properties of current transformers (CT) have changed, which leads to increase errors and decrease reliability, also required classes of accuracy are not provided. The main problem for replacement of CT is the financial aspect. Therefore, this article presents different design, operating principles, characteristics of different CT.

The CT accuracy depends above all on the properties of a magnetic material used for constructing magnetic cores. The parameters of the magnetic materials applied in CTs up to now do not comply with the designer's requirements any longer because of too high core losses, especially at increased frequencies of transformed signals. The demand for CTs of increased accuracy, higher frequency and large rated power is becoming more and more frequent nowadays. Moreover, the lower costs of production are also essential as far as CTs are concerned. The main purpose of this work was to construct a CT which metrological properties would be better than those of a CT with a core made of standard magnetic materials. It is possible, of course, to construct the core of cheap materials and to increase the accuracy class by appropriate realization of windings (fractional windings) or application of electronic systems. These methods, however, do not allow compensating the transformer phase errors, which results in non-meeting the requirements of the accuracy class. Moreover, additional electronic systems considerably increase the price of a CT. The authors of this paper consider the investigations of the influence of the present-day magnetic material properties on the CT accuracy as well as working out the structure of composite cores which may be used in CTs from the viewpoint of their essential optimal metrological parameters.

Silicon-iron alloy is a magnetic material commonly used for construction of CTs cores. However, because of its large active power losses it is replaced with other magnetic materials in CTs of high accuracy, e.g. amorphous metals and nanocrystalline alloys whose permeability is very high (hundreds of thousands) and core losses are very low (several mW/kg). These materials, however, are much more expensive than silicon-iron steel. Amorphous metals are mainly used for construction of modern power transformers due to their properties (low core losses). Their application in constructing CTs has not been common so far because of less saturation magnetic induction and higher price. The possibilities of the use of composite cores – magnetic circuits composed of cores made with materials of different magnetic properties – for constructing measuring CTs were investigated in the paper. The following composite cores were realized:

a)   core made of silicon-iron steel of the low magnetic permeability, high core losses and high saturation magnetic induction;

b)   composite core composed of silicon-iron steel and an amorphous metal;

c)   composite core composed of silicon-iron steel and a nanocrystalline alloy;

d)   composite core composed of an amorphous metal (Metglas) and a nanocrystalline alloy (Finemet).

The case (a) is the standard construction of a current transformer core. The cases (b) and (c) are the examples of composite cores in which a part of the standard material (silicon-

iron steel) is replaced by materials of better magnetic properties. The case (d) is a composite core made of modern materials only.

The current transformer core made of the standard magnetic material (silicon-iron steel) is shown in Fig. 1a, whereas Fig. 1b presents the hysteresis loop of this core material. The maximum value of the magnetic induction in the core depends on the voltage drop along the shunt branch impedance at the rated load (10 VA) and is equal to about 1 T for this type of transformer construction. The system for determining the current and phase errors of CT was realized. The system is based on a magnetic current comparator enabling very accurate comparison of two currents. It is possible to determine the CT errors from 0,001% to 10%. The characteristics of the current and phase errors of this transformer as a function of the secondary current at 25% and 100% of the rated load (2,5 VA and 10 VA) are shown in Figs. 2a and 2b, respectively.
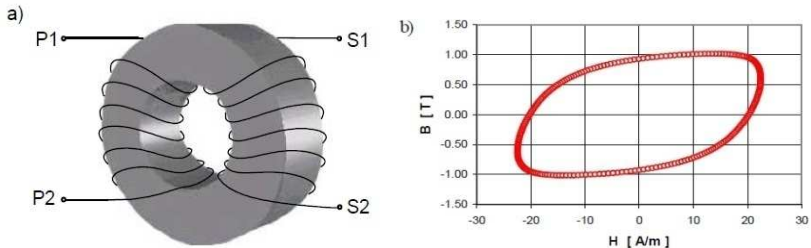

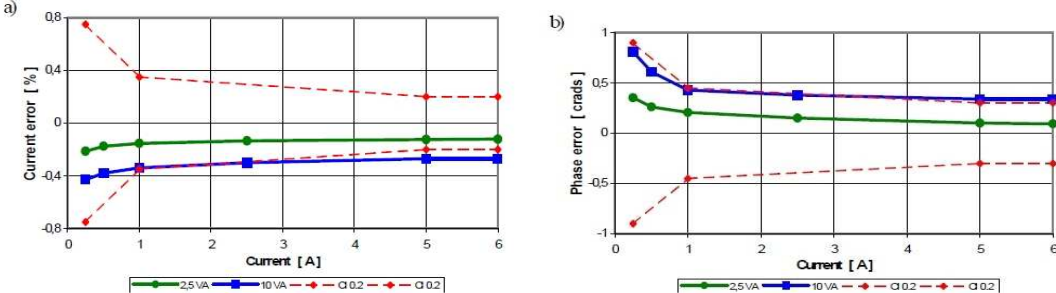Fig. 1. Magnetic core (a) and hysteresis loop (b) of silicon-iron steel

Fig. 2. Current (a) and phase (b) error of CT with silicon-iron steel core

The current and phase errors of this transformer for the rated load(10 VA) are greater than the limit errors specified in the standard for that particular Class 0.2 accuracy.

The cores of the same geometrical dimensions were investigated. The first part of the core was made of silicon-iron steel, whereas the other one – of Metglas or Finemet. The structure of composite cores is presented in Fig. 3a. The resultant hysteresis loops of these cores are shown in Fig. 3b. Such a resultant "magnetic material" has the high initial permeability, the small ratio of the maximum permeability to the initial one and the low hysteresis loss.
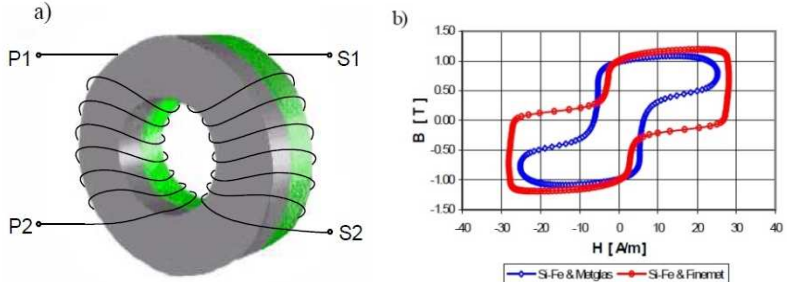

Fig. 3. The structure of composite magnetic cores (a) and their hysteresis loops (b)

The characteristics of the current and phase errors of the CT with the composite core made of silicon-iron steel and Metglas as a function of the secondary current at 25% and 100% of the rated load (2,5 VA and 10 VA) are shown in Figs. 4a and 4b, respectively. The

current and phase errors of this transformer for the rated load (10VA) are smaller than the limit errors specified in the standard for that particular Class 0.1 accuracy.
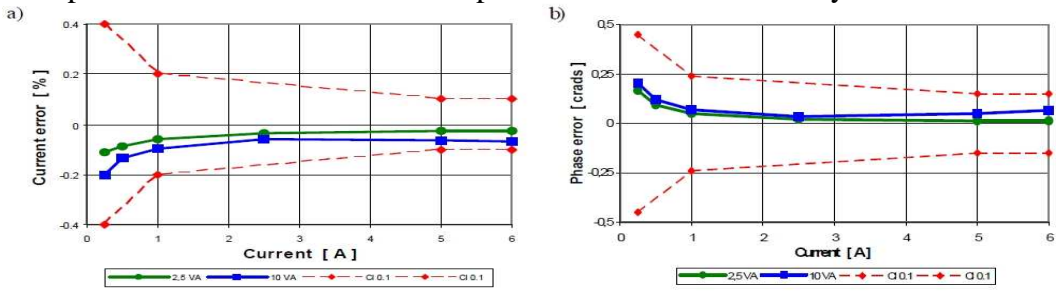

Fig. 4. Current (a) and phase error (b) of CT with silicon-iron steel and Metglas composite core

The errors of the CT with the composite core using Finemet presented in Fig. 5 are smaller than those of the CT with the composite core using Metglas for the current smaller than 40% IN and the low load (2,5 VA). The greater values of the current, the greater these errors. For the rated load they exceed the limit errors for Class 0.1 accuracy for the current greater than 5 A.

The explanation of this fact is that Finemet, in spite of better magnetic properties (higher permeability and lower losses), reaches saturation sooner than Metglas because of the lower saturation magnetic induction. The way to decrease the errors of such a CT at the higher burdens and currents is increase in the rated ampere-turns of the CT by increase in the number of turns.
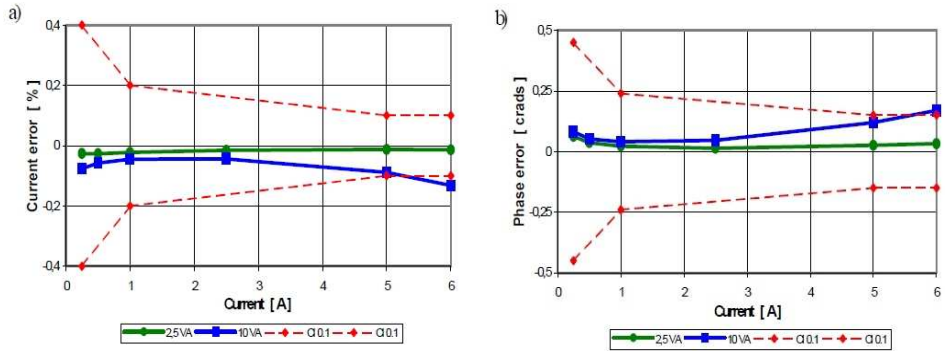

Fig. 5. Current (a) and phase (b) error of CT with silicon-iron steel and Finemet composite core

This way of error minimization was verified experimentally by constructing the composite core using Metglas and Finemet. The rated load was lowered to 5 VA and the rated ampere-turns were increased to 500 A. The hysteresis loop of the core of such construction is shown in Fig. 6.
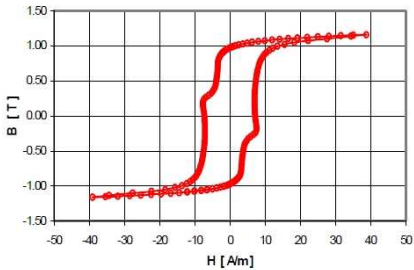
The errors of the CT with the composite core made of Metglas and Finemet are presented in Fig. 7. They do not exceed the limit errors for Class 0.05 accuracy.

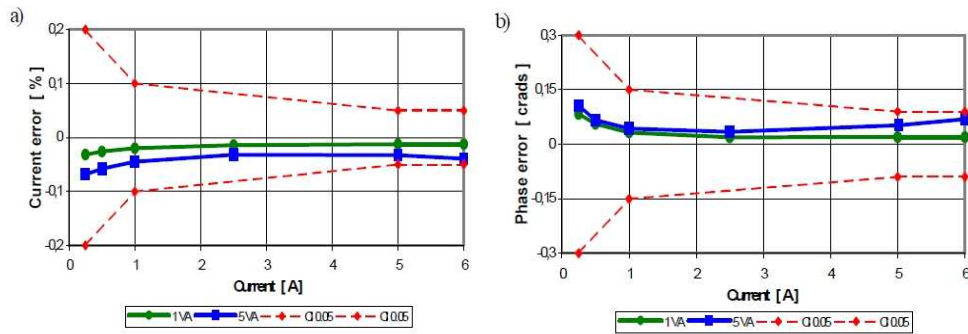Fig. 6. Hysteresis loop of Metglas and Finemet composite core

Fig. 7. Current (a) and phase (b) error of a CT with Metglas and Finemet composite core

The presented results of measurements support the idea of constructing magnetic composite cores and prove its usefulness. Such cores composed of a cheap material of medium magnetic properties and an expensive one of very good parameters ensure the high accuracy of current transformers and relatively low realization costs, which is important in the present market economy. This problem is a live issue since there is a very large demand for measuring transformers of high accuracy class. It is connected with their application to measuring systems of essential economic importance, for instance in the process of calculating costs of electric energy. In these systems measuring transformers are used for supply of very accurate and expensive digital electricity meters.