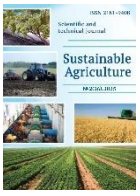
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Wideband Continuous High-Current Converters

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a r t i c l e i n f o

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a b s t r a c t

The article provides information on the necessity of applying continuous monitoring of large alternating currents in land reclamation, irrigation, farming enterprises, power plants, substations, railway transport, and industry using measuring inductive continuous ferromagnetic converters. It also presents the results of developing such converters, as well as a mathematical model of the distribution of the working magnetic flux in a closed magnetic circuit of the continuous converter, which passes through the turns of the measuring winding of our proposed continuous ferromagnetic converter, for the purpose of studying its main characteristics.

1. INTRODUCTION

At present, the need to convert large alternating currents in the electric power sector of the agro-industrial sphere, at many industrial enterprises, and in railway transport arises in connection with monitoring and controlling the operating modes of high-power electric motors, substations, and various energy-intensive consumers [1, 2].

In such cases, significant power losses in current transformers, the undesirability or impossibility of breaking the circuit due to technological process requirements, as well as the necessity to break the current circuit for temporary connection of electrical measuring instruments, have led to the development of continuous conversion and measurement of alternating current in circuits without breaking them, i.e., without damaging the integrity of the current-carrying busbar [3, 4].

In practice, when considering the conversion of large alternating currents (LAC) in high-power facilities and installations, it has been found that their relatively low efficiency is often caused by the poor technical performance of their control and monitoring systems, particularly the measuring ferromagnetic converters of large alternating currents (MFC) used in them [5, 6]. It has been established that these MFCs must have an adjustable conversion range, improved dynamic characteristics in transient operating modes of power systems and installations, and stable performance under the influence of external factors [7].

Practical experience has also made it possible to formulate the main requirements for MFCs. These include: high accuracy, reliability, and sensitivity; low weight, compact dimensions, material consumption, and cost; as well as the absence of errors caused by the influence of external magnetic fields, reverse current busbars, displacement of the current-carrying busbar from the center of the integrating circuit, and ferromagnetic masses, along with the absence of galvanic connection between the converted alternating current and the measuring circuit [8].

Therefore, it is necessary to develop and study such MFCs (measuring ferromagnetic converters) that would feature increased efficiency—namely, an extended range of converted large alternating currents (LAC) with small dimensions and weight, higher accuracy, and a simplified, technologically efficient design with low material consumption and cost. It should be noted that the main tasks in designing passive inductive converters are primarily to extend the upper limit of the current range for converted and measured AC quantities, improve accuracy and sensitivity, and reduce the weight and dimensions of MFCs [6, 8].

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At present, many different designs of active and passive inductive ferromagnetic LAC converters are known [9–26]. However, existing continuous current converters and meters for large alternating currents tend to have significant weight and size parameters while offering only a modest upper limit of the converted current range. Practically free from these shortcomings are the continuous ferromagnetic converters of large alternating currents developed by us. In these devices, to increase the upper limit of the converted current range, extend the linearity range of the static characteristic, and reduce the sensitivity threshold by improving the signal-to-noise ratio in the input circuit, the length of the closed magnetic core and the cross-sectional area of the MFC are increased to the maximum permissible dimensions [8].

It should be emphasized that the problem of improving the efficiency of non-destructive, non-contact ferromagnetic converters with distributed magnetic parameters for control and monitoring systems is both relevant and promising. A contribution to solving this problem can be made by developing measuring inductive wideband continuous ferromagnetic converters of high currents (WCC) for control and monitoring systems in the power sector.

In this context, the main tasks to be addressed when designing passive WCCs, in line with modern trends in the development of AC measurement and conversion devices, are primarily the expansion of the amplitude range of measurable and convertible AC quantities, the extension of their frequency range, and the reduction of WCC weight and dimensions.

These objectives often need to be achieved simultaneously for a single WCC, requiring the selection of circuit designs and structures that can meet the combined requirements of a wide linearity range, low sensitivity threshold, and broad frequency range while maintaining compact dimensions and low weight. Therefore, it is important to devote special attention to approaches and methods that allow these objectives to be achieved while ensuring the specified metrological and operational characteristics of the WCC.

2. MATERIALS AND METHODS

We have developed a series of wideband continuous high-current converters (WCCs) in which the stated objectives are achieved by incorporating into the inductive converters special designs of split closed magnetic cores with transversely and longitudinally distributed magnetic parameters, as well as an increased length of the working magnetic flux path through the steel [8].

One of the proposed WCC designs is shown in Figure 1. It was developed on the basis of [27] and includes a closed O-shaped corrugated magnetic core (1). Such a closed magnetic core can be manufactured either by stamping it from a ferromagnetic material or by cutting transverse slots in a solid closed magnetic core. This design increases the total magnetic reluctance along the path of the working magnetic flux and thereby expands the measurable current range.

On the closed corrugated magnetic core, a measuring winding (2) is wound over its surface.

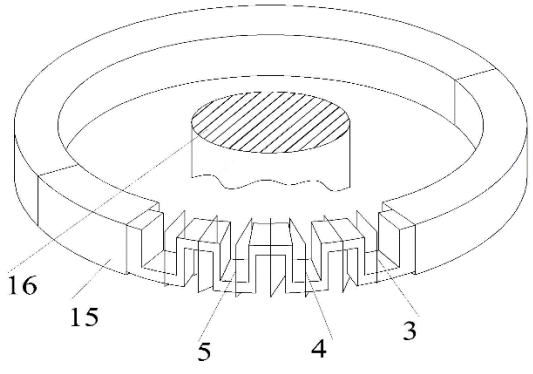


Fig. 1. Wideband Continuous Ferromagnetic Converter for High Currents

The closed corrugated magnetic core, designed to freely encompass the busbar (4) carrying the monitored current, is made split. The closed corrugated magnetic core, together with the measuring winding, is housed in a casing (3) made of heat-resistant insulating material.

The operating principle of the wideband continuous high-current converter is as follows. After the split magnetic core is clamped around the busbar carrying the monitored alternating current, the current generates an alternating magnetic flux. This flux, traveling through the closed magnetic core, links with the turns of the measuring winding and induces in it an EMF proportional to the converted alternating current.

To obtain and study the main characteristics of the continuous ferromagnetic high-current converter, a mathematical model was derived for the distribution of the working magnetic flux Φ_Σ in its closed magnetic core, where the flux links with the turns of the measuring winding, in the following form:

$$\Phi_{\Sigma} = \left(\mathrm{K}_1^{-1}\gamma^3 ch\frac{\beta}{2} + \frac{2d}{S_{bar}} glsh\frac{\beta}{2}\right) AI -$$

$$\left[\frac{K_2}{K_1}\gamma^3 ch^3\frac{\beta}{2} - \frac{2qgl}{S_{bar}^3}\gamma^2\left(1+\frac{1}{3}sh^2\frac{\beta}{2}\right) sh\frac{\beta}{2}\right] A^3 I^3,$$

where A is a structural parameter equal to

$$A = \left\{ch\frac{\beta}{2}\left[2r_{\mu avg}(2n + glZ_{conv})th\frac{\beta}{2} + Z_{conv}\gamma\right]\right\}^{-1}.$$

Here

$\boldsymbol{K_1, K_2}$ - constant coefficients;

$\boldsymbol{\gamma}$ - magnetic flux propagation coefficient in the circuit;

$\boldsymbol{n}$ - number of air gaps in the corrugated magnetic core on one of its sides;

$\boldsymbol{Z_{conv}}$ - magnetic reluctance of the converter for transforming the flux into a subsequent signal along the path of the working magnetic flux in the corrugated magnetic core;

$\boldsymbol{g}$ - specific magnetic conductance of the gaps between the transverse bars of the corrugated magnetic core;

$r_{\mu avg\ v}$ - average specific magnetic reluctance of the transverse bars, equal to

$$r_{\mu avg} = \frac{\rho_{\text{тср}}}{S_{bar}},$$

where S_{bar} is the cross-sectional area of the longitudinal and transverse ferromagnetic bars of the WCC, which in turn is determined from the expression

$$S_{bar} = b \cdot h_1,$$

where b and h_1 are, respectively, the thickness and width of the longitudinal and transverse ferromagnetic bars of the WCC;

ρ_{mavg} is the average value of the specific magnetic reluctance, determined as

$$\rho_{mavg} = \rho_{mmin} + \frac{\rho_{mmax} - \rho_{mmin}}{2},$$

where ρ_{mmin} and ρ_{mmax} are the minimum and maximum values, respectively, of the specific magnetic reluctance corresponding to the lower and upper limits of the working magnetic induction in the longitudinal and transverse ferromagnetic bars of the WCC.

The error in determining the distribution of the working magnetic flux in the closed magnetic core according to equation (1) does not exceed 6%.

3. CONCLUSION:

An efficient wideband continuous ferromagnetic high-current converter has been developed.

The proposed wideband continuous converter features an extended range of converted alternating currents, compact dimensions, low weight, and improved accuracy.

In the developed continuous converter, measurement errors caused by displacement of the current-carrying busbar from the center of the split closed magnetic core, the influence of the reverse current busbar, and external magnetic fields have been reduced. This improvement is due to the continuous presence of ferromagnetic material inside the measuring winding and its uniform winding along the perimeter of the split magnetic core.

Technical specifications of the proposed wideband continuous ferromagnetic high-current converter:

- Measurement range of alternating currents: 0 – 10,000 A
- Sensitivity: 2 mV/A
- Basic reduced error: 1%
- Insulation voltage: 2 kV
- Inner window diameter of the split magnetic core: 180 mm
- Weight: 1.2 kg

REFERENCES

[1] Baratov RJ, Djalilov AU, Chulliyev YE 2019 Low power smart system development for water flow measurement and level controls in open canals. International Journal of Advanced Research in Science, Engineering and Technology ISSN: 2350-0328 6 (12) 12240 - 12246

[2] Mukhamedkhanov UT 2008 Concepts and methods of constructing quality control systems for technological environments of industrial manufacture, Abstract of Doctor of technical science dissertation.

[3] Bolotin O, Portnoy G, Razumovsky K 2012 Primary sensors for energy enterprises. Energy security and energy saving 5 28 - 32.

[4] Danilov A 2004 Modern industrial current sensors, Modern electronics 10 38 - 43.

[5] Bolotin O, Portnoy G, Razumovskiy K 2016 Modern sensors for measuring current and voltage, ISUP 1 (61) 18 - 25.

[6] Plakhtiev AM 2017 Effective informational noncontact transducers for modern monitoring and control systems in the agro-industrial complex, International Scientific and Practical Conference Agrarian science - to agriculture Collection of scientific articles, 37-39.

[7] Gurtovtsev AL 2010 Optical transformers and current transducers. Principles of operation, device, characteristics Electrical Engineering News 5 48 -52.

[8] Plakhtiev A.M., Gaziev G.A., “Multidiscription wide-range non-contact converters of control systems” / IOP Conf. Series: Materials Science and Engineering 883 (2020). doi:10.1088/1757-899X/883/1/0121.

[9] Bolotin O, Portnoy G., Razumovsky K 2016 Modern sensors for measuring current and voltage. ISUP 1 (61) 18 - 25.

[10] Yuki TN 2016 Electromagnetic noncontact measuring apparatus US Patent N234844 IIK G01R 27/04 NKI 324 58.

[11] Bardahl Nils 2016 Einrichtung zur Erfassung des Belastungsstromes in Hochstromanlagen Germany Patent N 3148654 IIK 21E36 / 01.

[12] Eadie EM 2015 Complete specification improvements in multi-range hook-on electrical indication instrument, UK Patent N3966443 IIK G1U.

[13] Standard Telefones & Cables LTD 2016 Current monitoring circuits including hall effect devices UK Patent N 4575111 IIK G01R 19/165 NKI GIU N 4773.

[14] Tokyo Shibaura 2017 Transducers UK Patent N 3036984 IIK G01R 19/22 NKI GIU N4968.

[15] Meierovich EA, Andreevskaya LI 2017 Dispositif paur la mesurede I'intesite du courant. France Patent N 4347944 IIK G01R N2.

[16] Bernard Georges Alhadef 2000 Transducteur electrique comportani un moyen de codage dunparameter du transducteur France Patent N3955731 IIK G01D 18/00 3/04 G01F 25/00 N1.

[17] Reich Ernö 2018 Elektricky měřici přistroj Czech Republic Patent N 2145015 IIK 21E3601.

[18] Zoltàn Lànczi 2015 Aramlökést mérö müszer, Hungary Patent N2146340, IIK 21E 29-36.

[19] Hitachi Ltd Chiyoda-ku Tokyo 100 (JP) 2017 Magnetoelectrical transducer. Japan Patent N3257766 IIC G01D 5/16 N33.

[20] Brodovsky VN, Korzhanov BM 2017 Current transformer USSR Patent N3592239 IIK 21E3601 Bulletin N4.

[21] Yoshihiro Konno, Masaru Sasaki 2009 Electric current measure apparatus Japan Patent IIC G01R CN204154795U.

[22] Chjan Li 2015 Stripping electrical measuring one meter China Patent IIK G01R CN204154795U.

[23] Michel Lynn, John Shie 2019 Power amplifier saturation detection Korean Patent IIK G01R US10224917B2.

[24] Horst Knoedgen, Frank Kronmueller 2019 Highly accurate current measurement European patent office IIC G01R EP2821799A1.

[25] Rudolf Gati, Markus Abplanalp 2008 Configuration of magnetoriesistire sensors for current measurement Spain Patent IIC G01R 07ES2591283T3.

[26] Woifgang Grieshaber, Jean-Pierre Dupraz 2011 Method of opening a bypass switch of a high voltage direct current network Canadian Patent IIC G01R CA284893OC.

[27] Plakhtiev, A., Gaziev, G. (2022). Device for on-site verification of electricity meters. Patent for Utility Model, Republic of Uzbekistan, No. FAP 02106. Rasmiy Axborotnoma, No. 10(258).