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Multidisciplinary wide-range non-contact converters of control systems

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Multidescription wide-range non-contact converters of control systems

A Plakhtiev^{1*} and G Gaziev²

¹Tashkent institute of irrigation and agricultural mechanization engineers,
Tashkent, Uzbekistan

²Scientific research institute for standardization, certification and technical regulation,
Tashkent, Uzbekistan

aquvvat@mail.ru

Abstract. The paper presents data on the features of the non-contact conversion of large direct currents. It substantiates the need for the development of non-contact monitoring tools. The general principles of the construction of geoinformational non-contact ferromagnetic converters of large direct currents and the basic requirements for them are considered. It also presents the results of the development of one of the variants of the proposed universal multi-profile contactless magnetomodulating converters of large direct currents with an extended range. The converters can be widely used in the control and management systems of renewable energy sources, laser systems, as well as in industry, agriculture, and water management. Their difference is an extended controlled range with small dimensions and weight and increased accuracy and sensitivity. The converters have simple and technologically advanced designs with low material consumption and cost. They can contactless control large both direct and alternating currents. The work provides elements of a theory, a static characteristic, and basic technical data and parameters of one of the developed converters. Moreover, the developed converters can be widely used in any geographical point of Uzbekistan, even in mountainous and desert areas in GIS - technology, and, in particular, in digital coatings and database visualization. They can be used in hydraulic engineering, industry, agriculture, and water management, as well as for checking electricity meters at the place of their installation.

1. Introduction

Purpose – research multidescription wide-range non-contact converters of control systems. Object: an effective geoinformation universal wide-range non-contact ferromagnetic converter of large direct currents with distributed magnetic parameters, for a wide range of different monitoring and control systems, characterized by an extended controlled range with small dimensions and weight, increased accuracy, simplicity, and manufacturability of the design with low material consumption and cost, elements of his theory and basic characteristics.

The task of involving autonomous, decentralized energy sources, especially using the energy of the sun, wind, small streams, etc., is becoming urgent throughout the world and, in particular, in Uzbekistan, which also contributes to the replacement of traditional energy sources (oil, coal, gas) and solves environmental and social problems.

At the same time, when assessing the role of the importance of using renewable energy sources (RES), one should take into account the already realized reality - the finite reserves of organic fuel on the Earth, their ever-increasing rate of consumption and, therefore, the need to find alternative energy sources, as well as a strict fuel economy - energy resources [1]. One of the ways to solve socio-



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economic problems related in one way or another with energy is to more actively develop local energy resources (small reserves of coal, gas, oil in areas with developed infrastructure), as well as the large-scale use of environmentally friendly renewable energy sources available in the territory of Uzbekistan. As the assessment of potential reserves of renewable energy sources shows, they are quite high in the republic.

The gross potential of solar radiation, small rivers, wind streams and other sources of energy annually entering the territory of the republic is several times higher than the annual demand of Uzbekistan for fuel and energy resources, estimated at 55-60 million tons of standard fuel, and many times exceeds the explored reserves of hydrocarbons.

Among renewable energy sources by gross resource or, otherwise, theoretical reserves, geothermal energy is the undisputed leader. However, relatively low temperatures (up to 70-800C), high salinity, and depth of occurrence of artesian waters make it difficult from a technical point of view to use them to generate electricity. Therefore, if we consider technically feasible potentials, then solar energy becomes the leader. The integrated use of solar energy will solve the problem of energy supply to remote consumers of low power in the absolute value of energy consumption, but very efficient in terms of production. This applies, first of all, to settlements and small producers, piedmont regions, distant pastures, etc. In centralized energy supply areas, the use of local autonomous energy sources contributes to the creation of a competitive environment for the energy market. Along with the energy of small and medium-sized watercourses, non-traditional energy sources (wind, solar, biogas energy) can also participate in such competition. According to preliminary calculations, the potential of small and medium-sized watercourses, local and non-traditional energy sources in absolute value is from 1 to 1.5% of the total primary energy consumption. The economic and social effect of its use is immeasurably higher due to the creation of an environment for small and medium-sized businesses, increasing the comfort of living conditions in remote areas of the republic [2].

In all these energy sources and, in particular, in the electric power industry of solar installations, solar power plants, in direct conversions of solar energy into electrical energy using photo and thermoelectric transformations, renewable energy sources, laser systems, in the power supply systems of focusing and rotational electromagnets of particle accelerators, many domestic enterprises, as well as in control and management systems in irrigation and land reclamation, there is a problem of non-destructive quality control of industrial products and the functioning of technological processes [3]. All these processes for the production of industrial products and the functioning of technological processes are characterized by the fact that their main quality control parameter is a large direct current (BP), the value of which is used to judge the quality of industrial products and the functioning of technological processes. Its value is controlled by a number of measuring transducers (IP).

Actual is the problem of increasing the accuracy, reliability, and cost-effectiveness of monitoring these technological processes, which together will improve the quality and quantity of industrial products and the stability of technological processes [4]. It was revealed that the instability of the current control systems, the presence of additional resistances due to oxidation of the contacts lead to a decrease in the productivity of industrial facilities and devices, as well as powerful pumps in agriculture and water management, to their downtime, and large voltage drops on the shunts lead to unjustified losses capacities [5-22]. At the same time, existing converters have a narrow range of controlled currents, large dimensions, and mass.

As a result of the analysis of the studies, an urgent need was found at many facilities and enterprises, as well as in agriculture and water management of the Republic of Uzbekistan, for non-destructive non-contact testing of power supply units from 30 A to 30 kA with the help of both portable and stationary PIs with an error of 1÷3 %, applying in many cases multi-limit, as well as with a flexible integrating circuit IP non-destructive quality control.

As a result of the analysis, it was found that none of the known and considered non-destructive quality control devices satisfies the requirements in full [23-40], which only the galvanomagnetic and magneto modulating non-destructive quality control devices meet the above requirements, and that the main role in creating the optimal design of non-destructive testing devices quality belongs to non-

contact ferromagnetic transducer non-destructive quality control of industrial products and the functioning of technological processes.

Therefore, the problem of increasing the efficiency and expanding the functionality of non-contact geoinformational ferromagnetic converters with distributed magnetic parameters (NFP) for non-destructive quality control of industrial products and the functioning of technological processes for monitoring and control systems is relevant and promising [41].

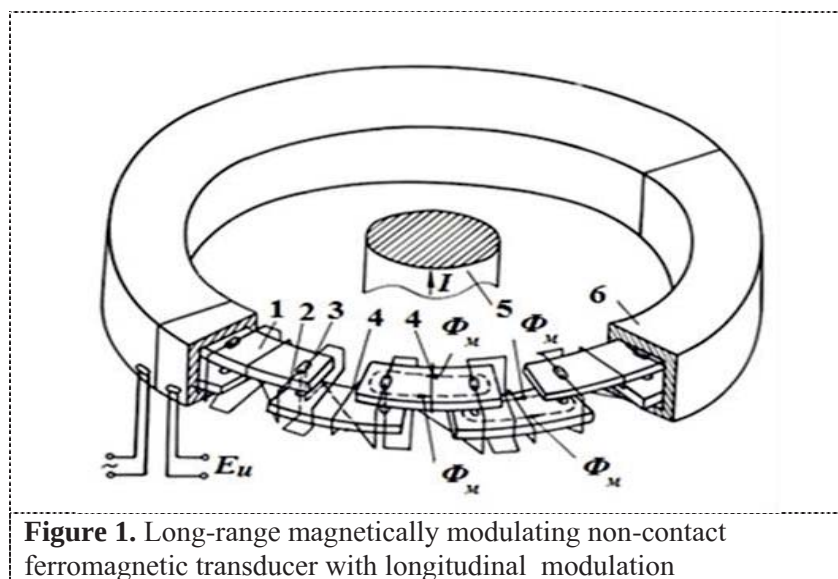
2. Methods

The authors have developed a number of multidisciplinary monitoring systems, including new effective geoinformation universal wide-range non-contact ferromagnetic converters of large direct currents with distributed magnetic parameters for a wide range of different monitoring and control systems that differ from the known extended monitoring range for small dimensions and weight, increased accuracy, simplicity and simplicity manufacturability of the design at its low material consumption and cost, flexible using an integrating circuit and converter multidimensionality, as well as the possibility of contactless monitoring of constant rectified, pulsating and pulsed currents, as well as for monitoring electricity and checking electric meters at the place of installation [18, 41, 42].

Consider the most characteristic design of the developed magneto modulation BFP (MBFP), its features, and its characteristics.

This MBPP design (Fig. 1) has a detachable O-shaped magnetic circuit assembled from identical lined ferromagnetic elements 1 with through holes. After every two combined through holes of parallel located ferromagnetic elements, two are wound in series and according to the connected sections 2 and 3 of the modulation winding (see Fig. 2). The modulation windings themselves are also connected in series and accordance and connected to an AC source. In the gaps between the modulation windings on each ferromagnetic element, there are measuring windings 4 connected in series and accordance. The serial connection between the modulation windings 2 and 3 in the presence of alternating current and the location of the measuring windings 4 in the spaces between the through holes in the ferromagnetic elements 1 made it possible to longitudinally modulate the magnetic resistance of the magnetic circuit in the path of the working flux F created by controlled direct current and direct it into measuring windings 4 EMF, depending on the converted direct current.

The developed MBFP can control alternating current. In this case, in sections 2 and 3 of the modulation winding, the alternating current should be absent.



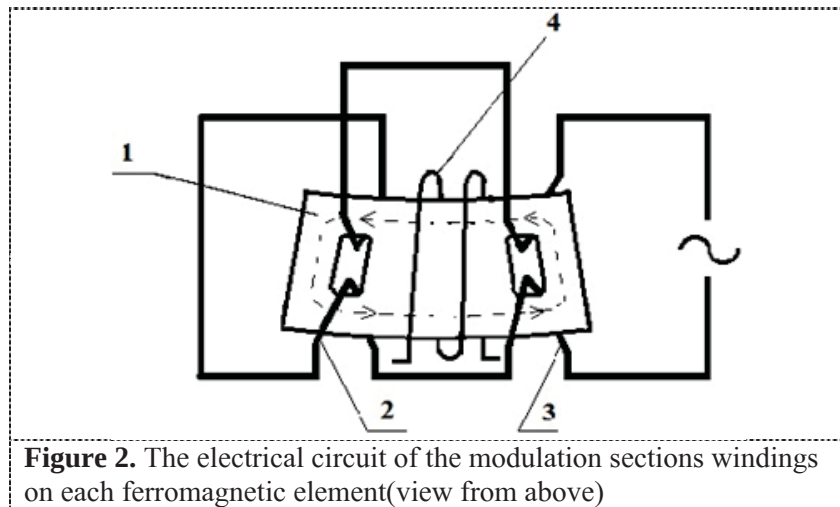


Figure 2. The electrical circuit of the modulation sections windings on each ferromagnetic element (view from above)

We obtained a static characteristic of the developed MBFP in the form

$$e = w_{meas} \cdot S \cdot K_1 \cdot K_2 \cdot \omega \cdot I_m \cdot H_{m\sim} \cdot \cos \omega t \cdot \left[\frac{1}{ch^2 K_2 \cdot (H_{meas} - H_{m\sim} \cdot \sin \omega t)} - \frac{1}{ch^2 K_2 \cdot (H_{meas} + H_{m\sim} \cdot \sin \omega t)} \right] \quad (1)$$

Here: w_{meas} is the number of turns of the measuring winding;
 ω is the angular frequency;
 S is the cross-section of element 1 involved in the induction of the EMF in the measuring winding;
 K_1, K_2, K_3 are the coefficients of approximation of the magnetization curve by the expression

$$B = K_1 \mu_0 K_2 H + K_3 H$$

here in

H is the intensity of the resulting magnetic field in the element 1 MBFP from the converted direct current and the excitation current;

H_{meas} is the magnetic field strength from the measured current I_{meas} ;

$H_{m\sim}$ is the amplitude value of the magnetic field from the excitation current, equal to

$$H_{m\sim} = \frac{I_{m\sim} \cdot w_{\sim}}{l_{mid}}$$

Where: $I_{m\sim}$ is the amplitude value of the magnetic field from the excitation current;

$w_{\sim}$ is the number of turns of the excitation winding MBFP;

- the average length of the line of field intensity in the element 1 MBFP.

We introduce the notation of the measured quantity

$$H_x = K_2 H_{meas} \quad (2)$$

and magnitude of excitation

$$H_{\text{em}} = K_2 H_m \sim \quad (3)$$

which are dimensionless, since the coefficient K_2 has the dimension inverse to the magnetic field strength.

Then expression (1) can be rewritten as

$$e = w_{\text{meas}} \omega SK_1 \cdot H_{\text{em}} \cdot \left[\frac{1}{\text{ch}^2(H_x - H_{\text{em}} \sin \omega t)} - \frac{1}{\text{ch}^2(H_x + H_{\text{em}} \sin \omega t)} \right] \cdot \cos \omega t. \quad (4)$$

The resulting expression is a periodic non-sinusoidal function, so the average value of the output EMF is

$$E_{\text{mid}} = \frac{2}{T} \int_0^{\frac{T}{2}} e dt = \frac{2w_{\text{meas}} SK_1 H_{\text{em}}}{T} \cdot \int_0^{\frac{T}{2}} \left[\frac{1}{\text{ch}^2(H_x - H_{\text{em}} \sin \omega t)} - \frac{1}{\text{ch}^2(H_x + H_{\text{em}} \sin \omega t)} \right] \cdot \omega \cos \omega t dt. \quad (5)$$

We denote $\sin \omega t = Z$, then $\omega \cdot \cos \omega t = dZ$, accordingly, the integration limits at $t_1 = 0$ will be $Z_1 = 0$, and at $t_2 = \frac{T}{2}$ there will be $Z_2 = \sin \frac{\omega t}{2}$. Substituting the accepted notation and integration limits in (5) and integrating, we obtain

$$E_{\text{mid}} = - \frac{2w_{\text{meas}} SK_1}{T} \left[\text{th}(H_x - H_{\text{em}}) + \text{th}(H_x + H_{\text{em}}) - 2\text{th} H_x \right]. \quad (6)$$

After simple transformations we get

$$E_{\text{mid}} = \frac{2E_b \text{sh} 2H_x}{\pi} \cdot \left[\frac{1}{\text{ch}^2 H_x} - \frac{1}{\text{ch}(H_x + H_{\text{em}}) \text{ch}(H_x - H_{\text{em}})} \right]. \quad (7)$$

Here E_b is the base value of the output EMF equal to

$$E_b = w_{\text{meas}} SK_1 \omega \quad (8)$$

The output EMF of the converter in fractional values is equal to

$$E^f = \frac{E_{\text{mid}}}{E_b} = \frac{2}{\pi} \left[\frac{1}{\text{ch}^2 H_x} - \frac{1}{\text{ch}(H_x + H_{\text{em}}) \text{ch}(H_x - H_{\text{em}})} \right] \cdot \text{sh} 2H_x. \quad (9)$$

The resulting expression is a static characteristic of MBFP, showing the dependence $E^d = f(H_x, H_{vm})$. The use of the intermediate variable H_x as a converted value is justified by the fact that the output EMF is a unique function of H_x for a given value of H_{vm} , and on the other hand, H_x carries complete information about the value of the converted current I_i , the steel grade used in the magnetic circuit.

Using computer technology, expression (9) calculates the family of MBFP static characteristics. The results of machine processing for various H_{vm} and H_x are shown in Figure 3. The value of the

excitation H_{vm} corresponds to a certain maximum value of the measured value H_{xm} . In this case, the H_{xm} maxima, increasing in magnitude with an increase in H_{vm} , shift towards an increase in H_x . The error in calculating the static characteristics of the developed MBFP according to (9) does not exceed 6 %. The static characteristic is important for determining the sensitivity, degree of nonlinearity, error, as well as for determining the optimal ratio of the sizes of the magnetic circuit and for calculating MBPF.

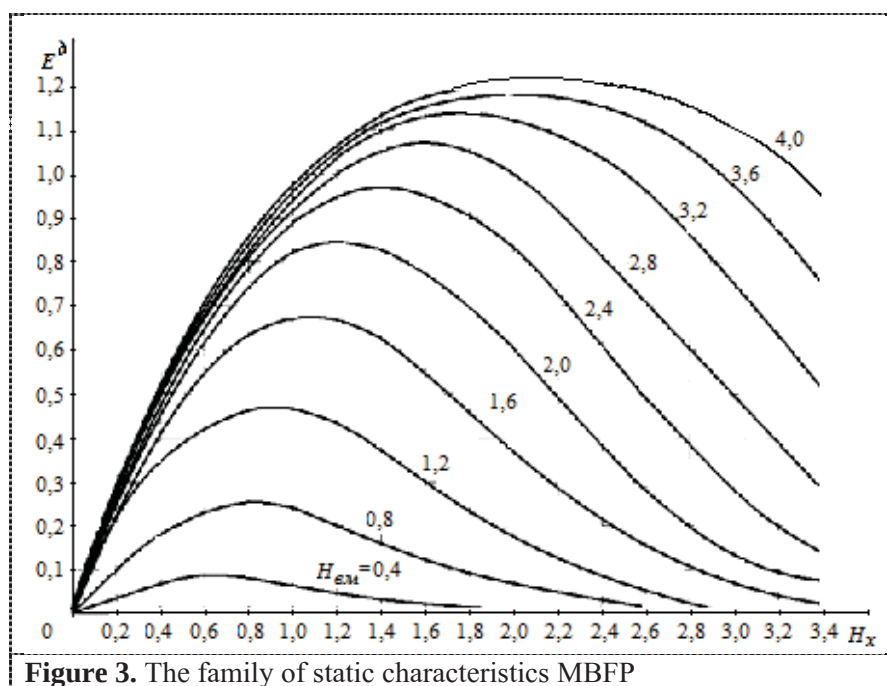


Figure 3. The family of static characteristics MBFP

3. Results and discussion

The developed MBFP has a wide controlled range and low weight. This is ensured by a significant increase in magnetic resistance due to an increase in the length of the working magnetic flux over steel and the inclusion of longitudinally distributed gaps and transverse gaps in its path. Also, the converter has increased accuracy, which is due to the continuity of the modulation flow along the integration office due to mutually overlapping ferroelements and the uniform distribution of a measuring winding along the perimeter of the detachable magnetic circuit, as well as the presence of ferroelements inside the winding throughout the entire length. The following is a technical description of one of the developed MBFPs.

Technical characteristics of MBFP: a range of controlled direct and alternating currents - 0–10000 A; sensitivity - 0.5 mV/A; the magnitude of the reduced error is 1.5%; insulation voltage - 2 kV; the diameter of the inner window of the detachable magnetic circuit - 200 mm; weight - 0.8 kg.

The developed MBFP can be widely implemented in GIS technologies, in particular, in digital coatings and database visualization, in various monitoring and control systems in the electric power industry of solar plants, solar power plants, renewable energy sources, with direct conversion of solar energy into electrical energy using photo - and thermoelectric transformations, renewable energy sources, laser systems, in industry, as well as in control and automation systems in agriculture and water management, dressing even in hard-to-reach geographical areas of Uzbekistan, as well as for checking electric meters at the installation site.

4. Conclusions

Geoinformation universal multidisciplinary wide-range magnetomodulating non-contact converters of large direct and alternating currents for modern monitoring and control systems in solar and laser

technology, renewable energy sources, industry, agriculture, in GIS technology, and in particular in digital coatings and database visualizations, as well as for checking electric meters at the installation site, characterized by an extended controlled range are convertible x constant currents with small dimensions and weight, increased accuracy and sensitivity, simplicity and manufacturability of the structure with low material consumption and cost and the possibility of non-contact control of constant and alternating currents with an error of 1.5%, as well as for monitoring electricity and checking electricity meters in place their installation.

Acknowledgments

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