Static Characteristics of Contactless Converters of Monitoring and Control Systems

Anatoliy Plakhtiev, Gayratjon Gaziev, Yaxyojon Meliboev,
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STATIC CHARACTERISTICS OF CONTACTLESS CONVERTERS OF MONITORING AND CONTROL SYSTEMS

Anatoliy Plakhtiev[1], *Gayratjon* Gaziev[2] , *Yaxyojon* Meliboev[1], *Odil* Donierov[1], *Davron* Norholboyev[1], *Jasur* Ibragimov[1]

[1]Tashkent institute of irrigation and agricultural mechanization engineers, 39, Qori Niyaziy str., 100000, Tashkent, Uzbekistan
[2]Triple Point Engineering LLC, 1, Beshagach str., 100066, Tashkent, Uzbekistan

Abstract: The paper substantiates the need to use non-contact conversion and measurement of large direct currents using magnetic modulation contactless transducers of increased sensitivity for the needs of land reclamation, irrigation, industry, metallurgy and agriculture and water management in general, and the results of their design development are presented. It is shown that the developed converter, in contrast to the known ones, has increased accuracy and sensitivity, a technologically advanced design and low weight and dimensions with low material consumption and cost. Considered statically characteristics of information non-contact magnetic modulation converters... Shown, that the value of the excitation value corresponds to a certain maximum value of the measured value. In this case, the maxima of the measured value, increasing in value with an increase in the excitation value, are shifted towards the increase in the measured value. The discrepancy between the experimentally and theoretically obtained static characteristics of the converter does not exceed 6 percent. The developed converter can be widely used in electrical systems in land reclamation and irrigation, in water supply, industry, railway transport, in science, technology and for checking electric meters at their installation site for contactless control of direct and also alternating currents.

Keywords: magnetically modulating transducer, static characteristic, control and management systems, integrating circuit, contactless, direct and alternating current.

Introduction

In the electric power industry, powerful electrical consumers are widely used, in which large electrical installations are used, in the operation of monitoring and control systems of which large direct currents (LDC) are used, which, in turn, must be controlled [1].

It was revealed that the instability of the current control systems, the presence of additional resistances due to the oxidation of the contacts lead to a decrease in the performance of electrical installations, to downtime, and large voltage drops on the shunts lead to unjustified power losses.

As a result of the analysis of the conducted studies, an urgent need was revealed at many industrial enterprises and in farms in the irrigated agriculture zone of the Republic of Uzbekistan in the non-destructive contactless control of LDC with a value from 100 A to 30 kA using both portable and stationary measuring transducers (MT) with an error of 1 – 3 %, using in a number of cases multi-range, as well as with a flexible integrating circuit of IP non-destructive testing LDC [2].

The ever-increasing requirements for the elements and technical means of monitoring and control systems in the electric power industry, railway transport, as well as agriculture have led to the development of energy-saving contactless magneto-modulation converters of large direct currents with detachable integrating circuits (MNT), which allow to wrap around the device without violating the structural and circuit integrity conductors with convertible LDC [3 - 5].

As a result of the analysis of places, transducers and devices for non-destructive non-contact control of high currents, the main requirements for MNT were identified [6 - 31]. These include: high accuracy, reliability, sensitivity, low weight, dimensions, material consumption and cost, manufacturability of design, absence of errors from the influence of external magnetic fields, return conductor with current, displacement of the conductor with current from the center of the integrating circuit, ferromagnetic masses, no consumption energy from the measured circuit, the ability to work in an aggressive environment, explosion safety, as well as the absence of a galvanic connection between the controlled direct current and the measuring circuit and the presence in some cases of the possibility of fixed regulation of the sensitivity of the MNT in a wide controlled range and the manufacture of the MNT as portable or stationary.

We have developed a number of universal energy-saving non-contact galvanomagnetic converters of large direct currents, allowing without breaking the circuit to convert both direct and alternating large currents in various monitoring and control systems, in which the tasks are solved by using special designs of detachable closed magnetic circuits with transverse and longitudinal distributed magnetic parameters and increased path length of the working magnetic flux over steel [2].

One of the developed IBE is information non-contact magnetomodulation converter of large direct currents, partially shown in Fig. 1 with basic dimensions. This design was developed on the basis of the IP [8] and is an MNT with transversely and longitudinally distributed magnetic parameters... It features increased sensitivity and an extended range of converted currents. IBE contains a detachable closed magnetic circuit 1, consisting of two identical halves 2 and 3, each of which, in turn, consists of separate ferromagnetic elements made in the form of trapezoids with the same gaps between them. Each ferromagnetic element has two through holes, through each of which a modulation winding is wound, consisting of sections 4 and 6. Sections 4 and 6 are connected in series and according to. A measuring winding 5 is wound between the through holes over the modulation winding 5. All measuring windings are connected in series and closed to the measuring device, and the modulation windings are also connected in series and connected to a stable AC source (not shown in Fig. 1). In order to freely grip the bus 7 with controlled current, the closed magnetic circuit 1 is made detachable. The series connection of the modulation windings 4 and 6 with each other in the presence of alternating current in them and the arrangement of the measuring windings 5 in the intervals between the through holes in the ferromagnetic elements allowed to carry out longitudinal modulation of the magnetic resistance of the magnetic circuit on the path of the working flow Φ, created by a controlled direct current, and induce an EMF in the measuring windings 5, depending on the converted direct current. The developed MNT can also control alternating current. In this case, there should be no alternating current in sections 4 and 6 of the modulation winding.

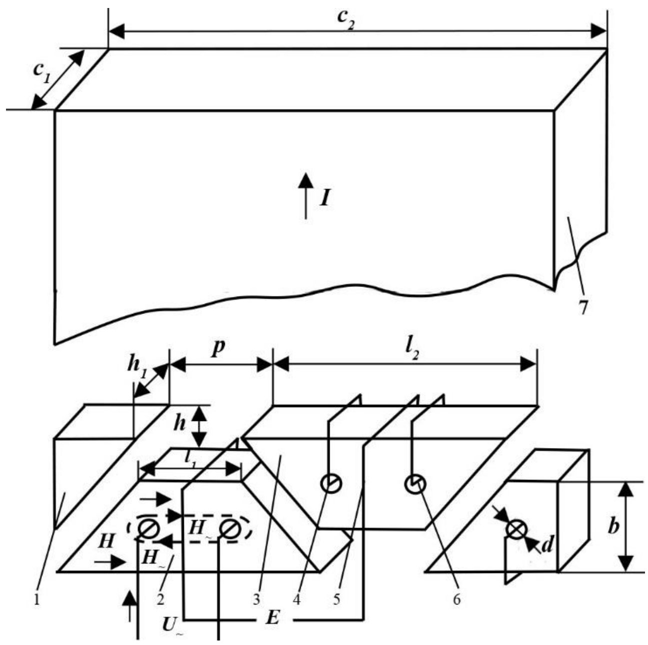

Fig. 1. Part of information non-contact magneto-modulation converter of large direct currents

The expansion of the upper limit of the controlled direct current in the developed design of the MNT is carried out by increasing the length of the working magnetic flux along the steel of the magnetic circuit elements and including transverse and longitudinal air gaps in its path, i.e., the implementation of a split magnetic circuit with transversely and longitudinally distributed magnetic parameters.

To control the LDC, the MNT detachable magnetic circuit covers the bus 7. Due to the modulation ampere turns, the detachable magnetic circuit is in a saturated state during each half-period of the supply voltage. In this case, the permeability of the magnetic circuit for the longitudinal field created by the controlled current decreases sharply. At the moment when the modulation current passes through zero, the magnetic core permeability rises to the initial value. Thus, with the stability of the modulation ampere turns, an EMF of double frequency will be induced in the measuring winding, which depends on the controlled current.

With the mutual movement of halves 2 and 3 of the detachable magnetic circuit of the MBP, the size of the gaps between the trapezoids changes, leading to a change in the whole of the magnetic resistance of the magnetic circuit on the path of the working magnetic flux Φ created by the controlled direct current. This leads to changing the limits of the controlled current, i.e. allows you to make the MBE multi-limit.

To analyze the main characteristics of the MBE and its calculation, it is necessary to express the static characteristics of the MBE. To determine the expression of the static characteristics of the MBFP (Fig. 1), let us single out one of its elements (Fig. 2). Let's divide it into two halves: upper 1 and lower 2. At the moment when the current of the excitation windings $I_\sim$ has the direction shown by the arrow, the magnetic field strength $H_\sim$ created by this current in the upper half of the element coincides with the direction of the magnetic field strength. measured current Ii. In the lower half of the element, on the contrary, the direction $H_{\sim}$ is opposite to the direction of H_u. Therefore, one can write

$$H_1 = H_u + H_{\sim}; \tag{1}$$

$$H_2 = H_u - H_{\sim}. \tag{2}$$

In the next half-period, the direction of the field strength $H_{\sim}$ changes.

Approximating the main magnetization curve by the sum of the trigonometric arctangent and the straight line with the slope

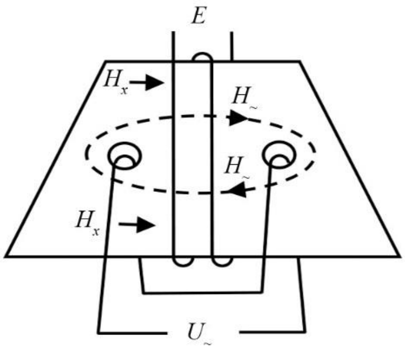

Fig. 2. Element MNT

$$B = a_1 arctg a_2 H + a_3 H \text{ ,} \tag{3}$$

where a_1, a_2, a_3 are the approximation coefficients, and substituting (1) and (2) into (3), we obtain

$$B_1 = a_1 arctg a_2 (H_u + H_{\sim}) + a_3 (H_u + H_{\sim}); \tag{4}$$

$$B_2 = a_1 tg a_2 (H_u - H_{\sim}) + a_3 (H_u - H_{\sim}); \tag{5}$$

Here, the field strength from the excitation current is

$$H_{\sim} = H_{m\sim} \sin \omega t \text{ ...} \tag{6}$$

Wherein

$$H_m \sim = \frac{I_{m\sim} w_{\sim}}{l_{cp}} \text{ ,} \tag{7}$$

where $H_{m\sim}$, $I_{m\sim}$ - amplitude values of field strength and excitation current;

$w_{\sim}$ - the number of turns of the excitation winding IBE;

l_{Wed} - the average length of the line of the field strength of the excitation element of the MBP.

The initial equation for the output EMF of the MNT has the form

$$e = -w_u S \frac{d(B_1 + B_2)}{dt} \cdots \tag{8}$$

The cross-section S of the two halves of the element, participating in the induction of the EMF in the measuring winding, having the total number of turns w_u, is determined from Fig. 1 in the form

$$S = h_1 (в - d), \tag{9}$$

where

h_1 - the thickness of the set of the magnetic circuit element;

$в$ - the width of the magnetic circuit element;

d - the diameter of the hole for the field winding.

Substituting the values of magnetic inductions (4) and (5) into (8) and taking into account (6), we find

$$e = a_1 a_2 \omega w_u S\, H_m\, \cos\omega t\, \left(\frac{1}{1+a_2{}^2(H_u - H_{m\sim}\sin\omega t)^2} - \frac{1}{1+a_2{}^2(H_u + H_{m\sim}\sin\omega t)^2}\right). \qquad (10)$$

Let us introduce the notation of the measured quantity

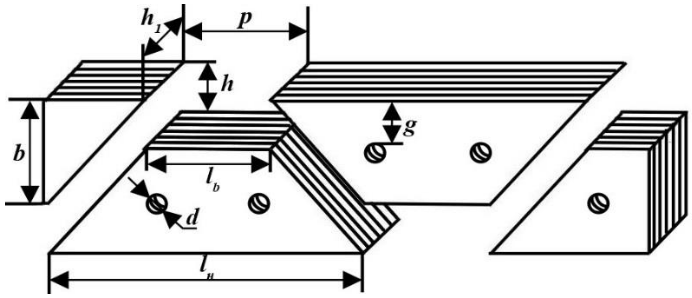

Fig. 3. Geometrical dimensions of the MNT magnetic circuit

$$H_x = a_2 H_u \qquad (11)$$

and excitation values

$$H_M = a_2 H_{m\sim}, \qquad (12)$$

which are dimensionless, since the coefficient a_2 has the inverse dimension of the magnetic field strength.
Then expression (10) can be rewritten as

$$e = a_1 \omega w_u S\, H_{вм} \left(\frac{1}{1+(H_x - H_M\sin\omega t)^2} - \frac{1}{1+(H_x + H_M\sin\omega t)^2}\right)\cos\omega t\,. \qquad (13)$$

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

$$E_{cp} = \frac{2}{T}\int_0^{\frac{T}{2}} e dt = \frac{2 w_u S K_1 H_{вм}}{T}\int_0^{\frac{T}{2}} \left(\frac{1}{1+(H_x - H_M\sin\omega t)^2} - \frac{1}{1+(H_x + H_M\sin\omega t)^2}\right)\omega\cos\omega t dt\,. \qquad (14)$$

We denote sin $\omega_t = Z$, then ωcos ωt $dt = d_Z$, respectively, the limits of integration at $t_1 = 0$ will be $Z_1 = 0$, and at $t_2 = \frac{T}{2}$ will be $Z_2 = \sin\frac{\omega t}{2}$.

Substituting the accepted designations and limits of integration into (14) and integrating, we obtain

$$E_{cp} = \frac{\omega a_1 w_u S}{\pi}\left\lfloor 2arctgH_x - arctg(H_x - H_M) - arctg(H_x + H_м)\right\rfloor \qquad (15)$$

or

$$E_{cp} = \frac{E_б}{\pi}\left\lfloor 2arctgH_x - arctg(H_x - H_M) - arctg(H_x + H_м)\right\rfloor \qquad (16)$$

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

$$E_б = \omega a_1 w_u S\,. \qquad (17)$$

The output EMF of the converter in fractional values is

$$E^{д} = \frac{E_{cp}}{E_б} = \pi^{-1}\left\lfloor 2arctgH_x - arctg(H_x - H_M) - arctg(H_x + H_м)\right\rfloor \qquad (18)$$

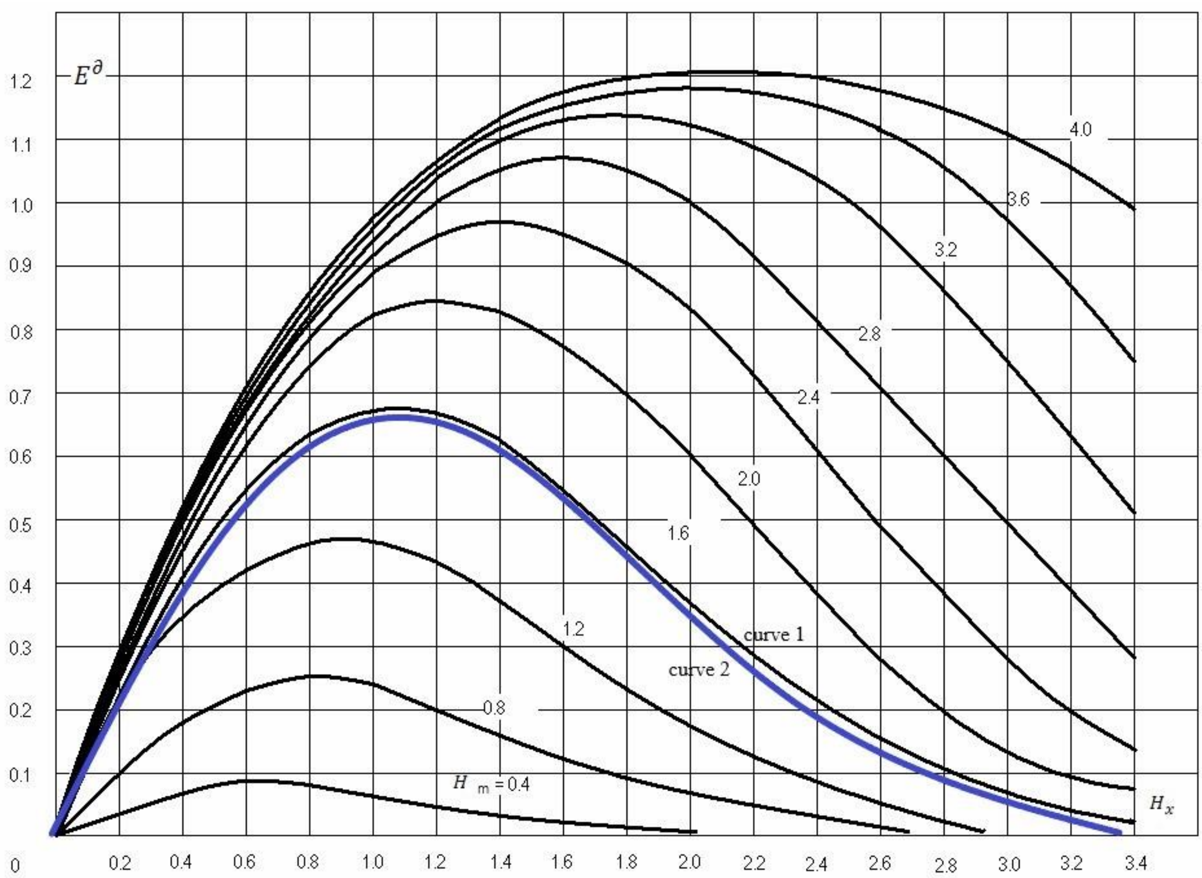

Fig. 4. Family of static characteristics of the MBE

The resulting expression is a static characteristic of the MNT, showing the dependence of E_d = f (H_x, H_M). The use of the intermediate variable H_x as a converted value is justified by the fact that the output EMF is an unambiguous function of H_x at a given value of H_M, and, on the other hand, H_x carries complete information about the value of the converted current I and the steel grade used in the magnetic circuit. With the help of computer technology, using expression (18), a family of static characteristics of the MNT is calculated. The results of machining at various H_M and H_x are shown in Fig. 3. The value of the magnitude of the excitation of the H_M corresponds to a certain maximum value of the measured value H_{xM}. In this case, the maxima of H_{xM}, increasing in value with increasing H_M, are shifted towards increasing H_x. The experiments performed showed that the discrepancy between the experimentally (curve 2) and theoretical (curve 1) obtained static characteristics of the MNT does not exceed 6 percent.

Conclusions

Informational contactless converters have been developed for modern control and management systems in water supply, land reclamation, irrigation, as well as solar and laser technology, renewable energy sources, industry, agro-industrial sphere, characterized by an extended controlled range of converted direct currents with small dimensions and weight, increased accuracy and sensitivity, simplicity and manufacturability of the design with low material consumption and cost and the possibility of contactless control of direct and alternating currents with an error of 1.5%, as well as for control of electricity and verification of electricity meters at their installation site. The static characteristics of information contactless magnetomodulation converters are considered. It is shown that the value of the excitation value corresponds to a certain maximum value of the measured value. In this case, the maxima of the measured value, increasing in value with an increase in the excitation value, are shifted towards the increase in the measured value. The discrepancy between the experimentally and theoretically obtained static characteristics of the converter does not exceed 6 percent.

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