Universal Contactless Converters of Monitoring and Control Systems in Water Power Industry

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Abstract: The paper substantiates the need to use non-contact conversion and measurement of large direct currents using non-destructive magnetomodulation non-contact ferromagnetic transducers of increased sensitivity for the needs of land reclamation, irrigation, industry, metallurgy and, in general, agriculture and water management, 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 small weight and dimensions with low material consumption and cost. The issues of reliability of magnetic modulation contactless converters are considered. The results of their research have been obtained. It is shown that the reliability of wide-range magnetomodulation contactless converters of large direct currents is equal to 0.998, and taking into account catastrophic failures, their total reliability is 0.9969. 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 electrical meters at their installation site

Keywords: direct and alternating current, magnetic modulation converter, monitoring and control systems, land reclamation, contactlessness.

Introduction

In the electric power industry of solar power plants, solar power plants, during direct conversion of solar energy into electrical energy using photo- and thermoelectric conversions, renewable energy sources, laser systems, in power systems for focusing and rotary electromagnets of particle accelerators, at many domestic enterprises, railway transport, in metallurgy , as well as in the 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 [1]. All these processes for obtaining industrial products and the functioning of technological processes are characterized by the fact that their main parameter of quality control is a large direct current (LDC), 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 (MT) [2].

The problem of increasing the accuracy, reliability and efficiency of control of these technological processes is urgent, which together will improve the quality and quantity of industrial products and the stability of technological processes (TP) [3,4].

It was revealed that the instability of the current control systems, the presence of additional resistances due to the oxidation of contacts lead to a decrease in the performance of industrial facilities and devices, as well as powerful pumps in agriculture and water management, and often to their downtime, and large voltage drops on the shunts lead to unjustified power losses [5-9].

As a result of the analysis of the conducted studies, an urgent need was revealed at many objects and enterprises, as well as in the agriculture and water management of the Republic of Uzbekistan, for non-destructive contactless control of BPT with a value from 30 A to 30 kA using both portable and stationary power supplies with an error of 1-3 %, using in some cases multi-limit IP of non-destructive quality control [9].

As a result of the analysis, it was found that none of the known and considered IP of non-destructive quality control satisfies the requirements in full, which to a greater extent satisfies the listed requirements mainly magnet-modulation IP of non-destructive quality control [11-30]. Therefore, the problem of increasing the efficiency and expanding the functionality of non-contact wide-range magnetomodulation ferromagnetic converters of large direct currents with distributed magnetic parameters

(DCBD) for non-destructive quality control of industrial products and the functioning of technological processes for monitoring and control systems is an important necessity.

Research materials and methods

The authors have developed a number of multidisciplinary monitoring systems, including new effective universal creative 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 ones in an extended controlled range with small dimensions and weight, increased accuracy, simplicity and the manufacturability of the design with its low material consumption and cost, the multi-range of the converter, as well as the possibility of contactless control of constant rectified, pulsating and impulse currents, as well as for checking the electric meters at their installation site [9].

Let us consider the most typical design of the developed WNFC - a non-contact wide-range magnetomodulation ferromagnetic converter of large direct currents (MWNFC), its features and reliability.

Figure 1 shows the developed MBShPT of monitoring and control systems. It is developed on the basis of the BSPT [10] and is distinguished by increased sensitivity and an extended range of converted currents. MBShPT contains a split 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 5. Sections 4 and 5 are connected in series and in accordance with. A measuring winding 6 is wound over the modulation winding between the through holes. All measuring windings are connected in series and closed to the measuring device,

fig. 1 not shown). In order to freely wrap around the bus 8 with controlled current, the closed magnetic circuit 1 is made detachable. Series connection between modulation windings 2 and 3 in the presence of alternating current in them and the location of the measuring windings 6 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 6, depending on the converted direct current. The developed MWNFC can also control alternating current. In this case, there should be no alternating current in sections 4 and 5 of the modulation winding.

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

To control the BPT, the detachable magnetic circuit of the MWNFC covers the bus 8. 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 turn in the measuring winding, an EMF will be induced doubled frequency, proportional to the controlled current.

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

For widespread use of MWNFC, it is necessary to determine its reliability.

Reliability is understood as the property of a converter to perform specified functions, while maintaining its performance indicators within specified limits under specified operating conditions and conditions for a required period of time or required operating time [53]. According to the physical nature of manifestations, failures are divided into catastrophic and parametric. In the well-known literature [54 - 56], methods for reducing catastrophic failures of automation elements and devices, which include MWNFC, are well developed.

According to their intended purpose, reliability calculations are distinguished at the design stage (predictive) and at the test and operation stage (ascertaining). According to the fundamental principles, the calculation of reliability MWNFC divided into elemental (hardware) and functional (parametric). By the nature of the considered failures (sudden, gradual) and taking into account the characteristics of the failures (sudden, gradual, complete, partial, short circuit, open circuit, etc.). Real designs MWNFC do not strictly correspond to some one model of reliability calculation [56].

The most famous is the calculation of reliability by the average group failure rates of elements [57]. To carry out the calculation, it is necessary to know: the types of elements, the failure rate of elements of various types λ and the number of elements of each type Ni included in the system. Consideration of operating conditions MWNFC comes down to the choice of the types of elements capable of operating under specified operating conditions.

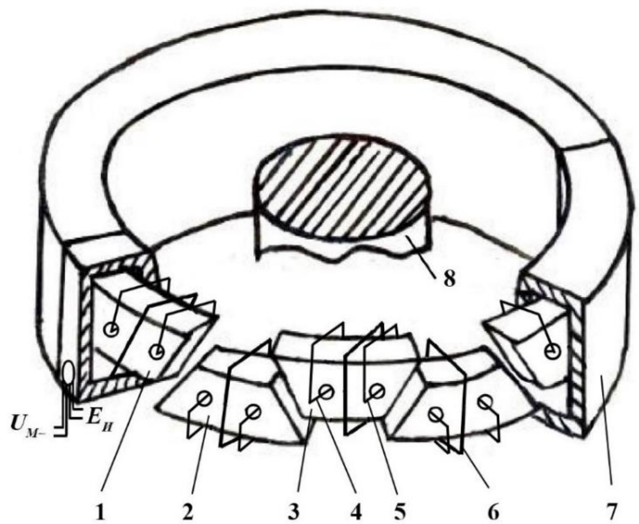

Fig. 1. Magnitomodulation contactless wide-range converter high currents control and management systems

At the design stage, the number of elements included in MWNFC is usually already known. The considered method of calculating the reliability makes it possible to determine the mean time between failures Tav and the probability of failure-free operation P (t) MWNFC [33]. The calculation is performed in the following order:

- all elements MWNFC divide into several groups n with approximately the same failure rate λ_i within the i-th group and calculate the approximate number of elements in each group N_i;

- according to the tables, the average value of the failure rate of the elements of each group is found λi;

- calculate the product $Ni\ \lambda i$;

- calculate the total failure rate of MWNFC for all n groups of elements:

$$\lambda = \sum_{i=1}^{n} N_i \lambda_i ; \tag{1}$$

- determine the MWNFC:

$$T_{cp} = \frac{1}{\sum_{i=1}^{n} N_i \lambda_i} ; \tag{2}$$

- find the probability of failure-free operation of MBShPT in time t:

$$P(t) = e^{-t\sum_{i=1}^{n} N_i \lambda_i} \ldots \tag{3}$$

For small values $(\sum_{i=1}^{n} N_i \lambda_i)^{-1}$ to find P (t), it is convenient to use the approximate formula

$$P(t) \approx 1 - t\sum_{i=1}^{n} N_i \lambda_i \ \ldots \tag{4}$$

The reliability of the developed MWNFC will be determined using the above methodology. Therefore, it is important to find the failure rate k when determining the reliability of MWNFC. The failure rate of the entire MBShPT can be determined according to [9] as the sum of the failure rates of individual elements and nodes. For this purpose, MBShPT is represented in the form of the following elements:

Table

The elements converter	Converter assemblies		
	Winding	Insulation	Solder connection
Modulation system	$0.05\ 10^{-6}$n	$0.5\ 10^{-6}$n	$0.004\ 10^{-6}$ (n-1)
Measuring system	$0.1\ 10^{-6}$n	$0.5\ 10^{-6}$n	$0.004\ 10^{-6}$ (n-1)
Power supply	-	$7.2\ 10^{-6}$	-
Potentiometer	-	$1.4\ 10^{-6}$	-
Resistance	-	$0.04\ 10^{-6}$	-
The total failure rate of converter elements	$\lambda 0 = 0.15n10^{-6}$ [hour^{-1}]	$\lambda i = (8.64n)\ 10^{-6}$ [hour^{-1}]	$\lambda p = 0.008\ (n-1)\ 10^{-6}$ [hour^{-1}]

Failure rates table modulation systems, measurement systems, power supply, potentiometer and resistance. In this case, the MWNFC nodes include: winding, winding insulation and soldering of the windings. For simplicity the manufacture of the transducer has a modulation winding and a measuring winding to be performed for each ferroelement separately. Then carry out the soldering connection of all winding leads. Therefore, when determining the failure rate, it is necessary to take into account the number of ferroelements. The values of the failure rates according to the data of the "Gene" company (USA) [57] are given in the table.

The total failure rate of the converter elements is determined by the expression

$$⌊ = ⌊0 + ⌊ι + ⌊π = (8.632 + 1.158ν)\ 10^{-6},\ [ηουρ^{-1}]. \quad (5)$$

It can be seen from the last expression that the failure rate of MBShPT depends on the number of ferroelements n.

Let's define the reliability of MBShPT according to the formula (3) taking into account (5), taking psr = 20 and t = 103 hours, in the form:

$$P(t) = e^{-t\sum_{i=1}^{n} N_i \lambda_i} = 0{,}998... \quad (6)$$

Taking into account catastrophic failures Pк = 0.9989 [55], the total reliability of MWNFC will be determined

$P = P\Pi \cdot P\kappa$ = 0,9980 0,9989 = 0,9969.

Gradual failures resulting from aging, aggressiveness of the environment, changes in its temperature are characterized by a gradual deterioration of the specified parameters of the MWNFC, which change the parametric reliability of the MWNFC.

Comparing the obtained values of reliability of MWNFC with the values of similar reliability of DC transformers, one can indicate their compliance. It is also possible to note the increased reliability of chemical devices with MWNFC, and, consequently, ACS TP in electrochemistry, in comparison with similar chemical devices and systems using shunts as converters of large direct currents.

Conclusion

Wide-range magnetomodulation non-contact converters of high direct currents have been developed for modern control and management systems in water supply in irrigation, land reclamation, as well as renewable energy sources, industry, railway transport, in the agro-industrial sphere, in GIS technologies, and, in particular, in digital coverage and database visualization, as well as for the verification of electric meters at the place of their installation, characterized by an extended controllable range of convertible 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%. The issues of reliability of magnetic modulation contactless converters are considered. The results of their research have been obtained. It is shown that the reliability of wide-range magnetomodulation non-contact converters of high direct currents is 0.998, and taking into account catastrophic failures, their total reliability is 0.9969.

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