Information universal non-contact transducers of control and management systems

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Abstract. In contact and communication devices, power equipment, relay protection and automation terminals, and in the electric power industry of smart cities and houses, microprocessor-based devices for relay protection and automation, distributed generation installations, including renewable energy sources, and energy storage devices, as well as “smart” ones, are beginning to be used automated information-measuring systems. They widely use non-contact transducers of direct and alternating currents of control and management systems. Their disadvantages are a narrow range of controlled currents, large dimensions and weight. Therefore, their elimination is important. The paper considers the general principles of building information non-contact transducers of large direct currents, the basic requirements for them. The paper shows the results of the development of one of the options proposed by us, universal non-contact magnetomodulating transducers of large direct currents with an extended range for various monitoring and control systems in the electric power industry of solar power plants, renewable energy sources, laser and solar installations, in industry, science and technology, in rural and water management, as well as in farming and in everyday life. The developed non-contact transducer can be widely used in industry, in agriculture, as well as in the electric power industry of smart cities.

1. Introduction
In Uzbekistan, as well as around the world, the urgent task of involving autonomous, decentralized energy sources in the energy balance, especially using the energy of the sun, wind, small streams, etc., which also contributes to the replacement of traditional energy sources (oil, coal, gas) and solves environmental and social problems.

One of the ways to solve socio-economic problems related to one degree 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 on the territory of Uzbekistan [1].

The assessment of potential reserves of renewable energy sources in the republic is quite high. It should be noted here that the gross potential of solar radiation, small rivers, wind flows 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 proven hydrocarbon reserves.

It is tedious to say that among renewable energy sources in terms of gross resource or, in other words, theoretical reserves, geothermal energy is the undisputed leader. However, relatively low
temperatures (up to 70-800°C), high salinity and depth 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 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) 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.

Moreover, in all these energy sources and, in particular, in the electric power industry of solar installations, solar power plants, during direct conversion of solar energy into electrical energy using photo and thermoelectric transformations, renewable energy sources, laser systems, in the power supply systems of focusing and rotary electromagnets of elementary accelerators particles, in 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 industrial production and the functioning of technological processes [2]. 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 (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).

Important is the problem of improving 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 [3]. It is shown that the instability of the current control systems, the presence of additional resistance 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 [4]. Moreover, the existing transducer have a narrow range of controlled currents, large dimensions and mass [5-14].

When analyzing the locations of non-destructive non-contact control of the (LDC), the main requirements for (MT) were identified. These include: high accuracy, reliability, sensitivity, low weight, dimensions, material consumption and cost, technological design, the absence of errors from the influence of external magnetic fields, a return bus with current from the center of the integrating circuit, ferromagnetic masses, residual magnetization and the presence of a variable component in controlled direct current, as well as the lack of galvanic connection between the measured direct current and the measuring circuit and the possibility in some cases of being fixed (MT) sensitivity regulation in a wide range of large direct currents converted and flexibility of the integrating circuit, and the implementation of (MT) as a portable or stationary [15].

2. Research Methodology
In this regard, it is very important to develop and study such (MT) that would have increased efficiency (an expanded range of convertible (LDC) with small dimensions and weight and increased accuracy, a simplified and technologically advanced design with low material consumption and cost) and expanded functionality (this is the possibility of conversion both constant and variable high currents).

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 (LDC) of power supply units from 30 A to 30 kA with the help of both
portable and stationary (MT) with an error of 1-3 %, applying in many cases multi-limit, as well as with a flexible integrating circuit (MT) non-destructive quality control. In addition, the calibration of electric meters at the place of their installation is an important necessity.

It has been established that none of the known and considered non-destructive quality control (MT) meets the requirements in full [16 - 37], which only the galvanomagnetic and magnetomodulating non-destructive quality control (MT) meet the above requirements, and that the main role in creating the optimal design of non-destructive (MT) non-destructive quality control belongs to the non-contact ferromagnetic transducer of non-destructive quality control of industrial products and functioning technological processes.

Therefore, the problem of increasing the efficiency and expanding the functionality of non-contact ferromagnetic transducers with distributed magnetic parameters for non-destructive quality control of industrial products and the functioning of technological processes for monitoring and control systems is relevant and promising.

The development of information universal non-contact transducers with advanced functionality UTAF for various monitoring and control systems can help to solve this problem.

We have developed a number of UTAF. Such UTAF allow converting direct and alternating currents in current conductors of any configuration, i.e. possess advanced functionality [38].

The figure (in Figure 1) shows the design of the developed magnetomodulation UTAF with advanced functionality (MUTAF). MUTAF with longitudinal modulation has a detachable closed magnetic circuit assembled from a charged U-shaped 1 and 2 longitudinal ferromagnetic elements. Through the through holes on the transverse rods 3 are wound in series connected modulation windings 4 connected to an AC source. Between the through holes on the transverse rods are measuring windings 5, connected in series in pairs and opposite. The detachable magnetic circuit is located in the insulating casing 6.

Figure 1. MUTAF with longitudinal modulation and transversely distributed magnetic parameters.

The location of the measuring windings 5 on the transverse rods of the U-shaped ferromagnetic elements 1 of the detachable magnetic circuit and their successive pairwise-on switching enable to significantly reduce the error from the influence of external magnetic fields due to the mutual compensation of the opposite directional EMF induced by external magnetic fields in the measuring
circuit, as well as the error from the influence of neighboring busbars with currents, which in general leads to an increase in the accuracy of control of large constant currents without breaking the circuit.

The consistent connection between each of two modulation windings 4 and their location on each transverse rod 3 made it possible to longitudinally modulate the magnetic resistance of the magnetic circuit in the path of the working magnetic flux $\Phi$ created by controlled direct current, and, therefore, have an increased MUTAF sensitivity.

The magnetic system in MUTAF ensures the passage of the working magnetic flux through the ferromagnetic elements and through the longitudinal gaps and allows you to convert large direct currents with a relatively high sensitivity converter and its small mass into the output signal. The implementation of the magnetic circuit in this form allows you to increase the total length of the magnetic flux in steel and thereby expand the current range of MUTAF. When converting large alternating currents, the modulation winding in MUTAF is turned off. The following is a technical description of the developed MUTAF.

MUTAF technical characteristic: range of controlled constant m alternating currents - (0–5000) A; sensitivity - 0.1 mV / A; the magnitude of the reduced error is 1.5%; the diameter of the inner window of the detachable magnetic circuit - 140 mm; weight - 0.45 kg.

To calculate the MUTAF design, a mathematical model of the flow distribution in the MUTAF magnetic system was obtained, which represents the distribution law along the x coordinate of the magnetic flux $\Phi_x$ in the form:

$$\Phi_x = \frac{1}{K_1} I A_1 y^3 \cdot ch \frac{\gamma(2x-x_M)}{2} - \frac{K_2}{K_1} I^3 A_1^3 y^3 \cdot ch \frac{\gamma(2x-x_M)}{2},$$

(1)

Where $A_1$ – design parameter equal to

$$A_1 = \left[ \left( 2n + gX_MZ_{con} \right) \cdot \left( 2r_{mid} th \frac{\gamma X_M}{2} + Z_0 y \right) + Z_{con} y \right] \left( ch \frac{\gamma X_M}{2} \right)^{-1}.$$

(2)

Here

$Z_0$ – magnetic resistance of a longitudinal ferromagnetic rod;

$Z_{con}$ - magnetic resistance of the flow converter to the subsequent signal in the path of the working magnetic flux;

n - the number of air gaps in the corrugated magnetic circuit on one side;

$$K_1 = \frac{4gd}{S_{cm}}, \quad K_1 = \frac{4gq}{S_{cm}},$$

where in turn q and d – approximation coefficients.

In Figure 2 the calculated (solid line) and experimental (dashed line) magnetic flux distribution curves are shown $\Phi_x$ at direct current $I = 1000$ A for a transducer having the following geometric dimensions: $h_1 = 4 \cdot 10^{-3}$ m; $h = 4 \cdot 10^{-3}$ m; $b = 1.5 \cdot 10^{-3}$ m; $X_w = 50.5 \cdot 10^{-3}$ m; $n = 13$; $\rho_{min} = 920$ m / Gn; $\rho_{max} = 4200$ m / Gn; $d = 920$ m / Gn; $q = 2100$ m$^5$ / (Vb·Gn); $g = 1.1 \cdot 10^6$ Gn / m; $Z_{con} = 9.275 \cdot 10^3 l / Gn$.

The material of the magnetic circuit was electrical steel of the ARMCO type.

The error in calculating the magnetic flux of a mathematical model does not exceed 5-6%. This mathematical model can be widely used in the calculation of UTAF and various transducers with transversely distributed magnetic parameters.
3. Discussion
The developed MUTAF has a wide controllable range, low weight and high sensitivity. 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 spaced gaps and transverse gaps along its path and the use of longitudinal modulation along the integration office around the perimeter of the detachable magnetic circuit. Below is the technical description of one of the developed and farms, as well as the electric power industry of "smart" cities and houses, and for checking electricity meters at the place of their installation [39].

The transducer has a simple and technological design at low material consumption and cost and can control large direct currents, as well as alternating currents without contact. The work shows the flow distribution in the transducer, taking into account the magnetization curve and distributed parameters, and gives the main technical characteristics and parameters of one of the developed transducers.

MUTAF technical characteristic: range of controlled constant alternating currents - (0–5000) A; sensitivity - 0.1 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 - 140 mm; weight - 0.45 kg.

The developed MUTAF can be widely implemented in various monitoring and control systems in the electric power industry for solar installations, 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, water and farms, as well as in the electric power industry of smart cities and houses, and for checking electric electricity meters at the place of their installation, located even in remote geographic zones of Uzbekistan.
4. Conclusions
The information universal magnetomodulating non-contact transducers of large direct and alternating currents have been developed for modern monitoring and control systems in solar and laser technology, renewable energy sources, industry, agriculture, as well as for checking electric meters at the installation site, characterized by an extended controlled range of transformed direct and alternating currents with small dimensions and mass, increased accuracy and sensitivity, simplicity and technical the environmental friendliness of the design at its low material consumption and cost and the possibility of noncontact monitoring of currents with an error of 1.5%, as well as for monitoring electricity and checking electricity meters at the place of installation.

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