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RELIABILITY OF ELECTROMAGNETIC CONVERTER

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Abstract:
Classic single-phase current transformers, Methods for calculating the reliability of elements, Probability of no-failure operation of an electromagnetic converter

Keywords: single-phase current transformers, magnetic fluxes, reliability, calculation of the reliability of elements, linearity of the output characteristics.

At present, the use of electromagnetic converters for control systems of electrical quantities with high accuracy, linearity of output characteristics, unified output quantities, expansion of the range of converted electrical quantities is limited due to insufficient formation of the principles of construction, methods of calculation and design of distributed magnetic systems of converters. The applied classical methods for studying magnetic circuits and conversion systems do not provide the necessary accuracy, especially with the asymmetry of the three-phase primary current of the electrical network, do not have sufficient generality, covering only the magnitudes and parameters of circuits of electrical and magnetic nature. Magnetic conversion systems with nonlinear and inhomogeneous parameters are considered in calculations as objects with lumped parameters [1-3].

Classic single-phase current transformers have a complex converting part, large weight and size indicators, are laborious in design and operation in control systems, and do not provide unification of the output value when working together with modern information processing technology. They do not take into account the mutual influence of magnetic fluxes and fields created by the currents of a three-phase electrical network [3].

The low accuracy of the analyzed devices is due to a number of shortcomings of existing current conversion systems, since measuring complexes were created earlier, and are also being created at the present time according to standard designs developed back in the 20th century, which did not provide solutions for ensuring high accuracy by current converters and unification of the output signal primary measuring transducers [2].

A comprehensive analysis of the elements and systems for controlling sources of electricity and power and their modes, the principles of their construction indicates insufficient knowledge of the problem in the field of electromagnetic conversion of three-phase currents of the control system for sources of electricity and power [2-4].

The purpose of this work is to study the reliable operation of nodes and a complex of devices for electromagnetic converters of a three-phase primary current of an electrical network used in power management systems.

Methods for calculating the reliability of elements and a complex of devices of electromagnetic primary current converters are in a state of continuous development. According to the fundamental principles, the reliability calculations of the elements and the complex of devices of electromagnetic primary current converters are divided into elemental (hardware) and functional (parametric) ones [4].

Consider an electromagnetic primary current converter as an element conditionally consisting of two series-connected elements, in one of which sudden failures can occur, and in the other - gradual failures. Sudden failures appear due to a sharp, sudden change in the converted currents under the influence of one or more random environmental factors or due to errors in the operation of parts of the primary electromagnetic converter. With gradual failures, a smooth, gradual change in the parameter of the primary electromagnetic transducer is observed as a result of wear of individual parts or the entire primary electromagnetic transducer as a whole.

The probability of failure-free operation of the primary electromagnetic converter can be represented as a product of probabilities [3].

$$P_{тр}(t)=P_{в}(t)\ P_{п}(t), \qquad (1)$$

where: Pв(t) and Pп(t) - respectively, the probability of failure-free operation of the primary current electromagnetic converter, corresponding to a sudden and gradual failure due to wear.

The probabilities of operable states of the main components of the primary current electromagnetic converter are presented in Table 1.

Analyzing the principle of converting EMPTC with FEC, a table of possible operable states of the elements is compiled (Table 1.), which allow determining the elemental reliability of each node of the primary current electromagnetic converter.

As can be seen from Table 1., there are seven possible operable states of the nodes of the primary current electromagnetic converter. Summing up the probabilities of all possible operable states of the nodes, we obtain the probability of operability of the electromagnetic converter of the primary current:

$$P = p_1+p_2+p_3+p_1p_2p_3-p_1p_2-p_2p_3-p_1p_3 \qquad (2)$$

The probability of operability of the main elements (primary winding, magnetic circuit, FEC) of the primary current electromagnetic converter units, respectively, is equal to:

$$p_1= =0{,}97;\ p_2 =0{,}99\ ;\ p_3=0{,}97.$$

Table 1 Probabilities of operational states of the main nodes electromagnetic converter of primary current

№	State	Probability	Operable components of the primary current electromagnetic converter
1	C_1	P_1 P_2 P_3	1-Primary winding, 2-magnetic core, 3-PIO
2	C_2	$P_1P_2(1-P_3)$	1;2
3	C_3	$P_1P_3(1-P_2)$	1;3
4	C_4	$P_2P_3\ (1-P_1)$	2;3
5	C_5	$P_1(1-P_2)(1-P_3)$	1
6	C_6	$P_2(1-P_1)(1-P_3)$	2
7	C_7	$P_3(1-P_1)(1-P_2)$	3

Then the probability of operability of the nodes of the electromagnetic converter of the primary current:

$$P = 0{,}97+0{,}99+ 0{,}97+0{,}97\cdot0{,}99\cdot0{,}97-0{,}97\cdot0{,}99-0{,}99\cdot0{,}97-0{,}97\cdot0{,}97=0{,}98.$$

The calculation of the functional reliability of the nodes of the primary current electromagnetic converter is based on the analysis of the conversion of the currents of a three-phase electrical network - the input current Ievkh to Uev - the output voltage performed in the nodes of the primary current electromagnetic converter. The functional reliability of the components of the primary current electromagnetic converter is calculated in the following sequence:

- the form of the function Uev is formed, i.e. the conversion equation Ievkh to Uevkh is written, which establishes the relationship between the quantities used in the designs of the primary current electromagnetic converter [10]:

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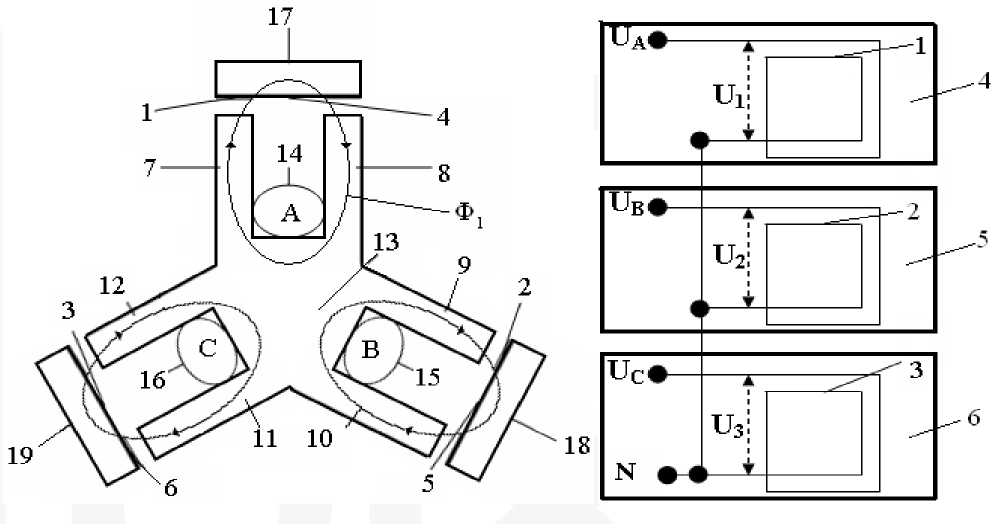
$$U_{эвых} = К_{μэ} T_{μ} Π_{μ} К_{эμ} T_{эвх} Π_{эвх} I_{эвх} \quad (3)$$

- based on the analysis of the conversion equation Ieq to Ueq, a block diagram is drawn up for calculating the reliability of the nodes of the electromagnetic converter of the primary current and the reliability due to complete failures of the elements of the nodes of the electromagnetic converter of the primary current (p1) is calculated.

For the nodes of the electromagnetic converter of the primary current, the analysis of equation (3) made it possible to establish that the breakage of the primary winding - the excitation winding TevkhPevkh=0, the failure (breakage) of the magnetic circuit TμΠμ=0, the breakage of the secondary measuring winding TevхΠевх=0, loss of connection between the magnetic current КΦμUe = 0, КIeFμ = 0, leads to a complete failure of the components of the primary current electromagnetic converter. Taking into account catastrophic failures p=0.98, the total reliability of the components of the primary current electromagnetic converter will be:

$$P = P_{кат} P_{пар}=0,98 * 0,98=0,96$$

As can be seen from the performed calculation, the parametric reliability is most affected by the change in M.F.S. F and induction under the influence of ambient temperature and aging of materials.



a) b)

a - a magnetic core of a three-beam star-shaped rod

b - insulating plates with PIO

Fig.1. General view of the MF EMF with FEC

Figure 1 shows the developed MF EMPTS with FEC:

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in Figure 11, a - a general view of the converter, in Figure. 11, b - insulating plates with FEC.

MF EMPTN with PIO contains (Fig. 11) PIO 1,2 and 3, insulating plates 4, 5 and 6, rods 7, 8, 9, 10, 11 and 12, a magnetic circuit with three-beam star-shaped rods with a common base 13, current conductors - primary windings 14 (phase A), 15 (phase B) and 16 (phase C) and additional cores 17, 18 and 19.

The main technical data of the developed MF EMPTN with FEC:

Rated voltage,	kV 0.38
Maximum operating voltage,	kV 0.44
Transformation range,	A 0÷300
Rated secondary voltage,	V 20
Number of turns of the primary winding,	1
Number of turns of the secondary winding (PIO),	4÷8
Rated secondary load, mA	100
Rated AC frequency, Hz	50
Static characteristic linear	
Basic reduced error,	% 0.5
Dimensions, cm	44*44*12
Weight, kg Not more than	0.5

The total reliability of the MF EMPTN with FEC is

P \u003d Pcat Ppar \u003d 0.98 x 0.98 \u003d 0.96,

where: Pcat – catastrophic reliability, Ppar – parametric reliability.

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