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Modelling of liner electro drive in the watergate of hydrotechnical constructions

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Abstract. Electromechanized technological equipment of hydrotechnical constructions is a complex of installations and devices designed to extract water, improve its quality, delivery and distribution between water consumers. Among the problems facing the country's agribusiness, an important place is occupied by the integrated electro mechanization and automation of technological processes, increasing the operational reliability, efficiency and productivity of machinery and equipment.

Electromechanized technological equipment of hydrotechnical constructions is a complex of installations and devices designed to extract water, improve its quality, delivery and distribution between water consumers. Water supply of the facilities of the Agro-industrial complex (AIC) has distinctive features - the need to supply water over long distances and to vast territories with unevenly distributed water consumers and with uneven water consumption both during the day and during the year [1]. The supply of benign water to settlements, livestock farms, field camps and pastures contributes to the development of agricultural production, improvement of the cultural and living conditions of rural workers and the gradual approximation of living standards of the urban and rural population. Therefore, measures to improve the water supply of agricultural facilities are of the greatest national economic importance [2].

Among the problems facing the country's agribusiness, an important place is occupied by the integrated electro mechanization and automation of technological processes, increasing the operational reliability, efficiency and productivity of machinery and equipment [3, 4].

The structure of mechanical equipment includes: gates, movable structures for shutting off and regulating expenditures, levels, level differences, water volumes in the downstream of structures; trash cans and other barriers; hoisting-and-transport mechanisms and gripping beams for lifting and transporting watergates, gratings, etc., mounting and dismounting equipment and its transportation; devices and maneuvering systems with watergates and grilles; devices for cleaning grates and litter removal.

A fairly complete classification of the gates of various hydraulic structures is given in [3]. The most used of them in terms of various design, operational and technical and economic indicators are flat gates. They are used as basic, emergency, repair and construction. Flat metal gates cover spans up to 40 m. In reclamation practice, sliding flat gates on sliding supports up to 6 m² in area have become



widespread [3]. Valves are available with manual or electric actuators. Electric gates have a vertically located electric drive shaft. Type of electric drive used is worm gear-motor.

For flat gates, instead of a gear electric drive, it is proposed to use a resource-saving electric drive based on a linear asynchronous motor. It helps to simplify kinematics, reduce electromechanical losses, increase the reliability and speed of the electric drive as a whole.

Structural schemes of the existing gear and gearless linear electric drives are shown in figure 1. In a cylindrical linear induction motor, the gate bar serves as a secondary element.

In water management, various electromagnetic devices are used as technological means, the principle of operation of which is based on the use of the interaction of a traveling magnetic field and various secondary media. These are linear induction motors, induction pumps, trays for pumping liquid media, electromagnetic devices for their mixing, operational monitoring and control of various parameters, and others [5-7].

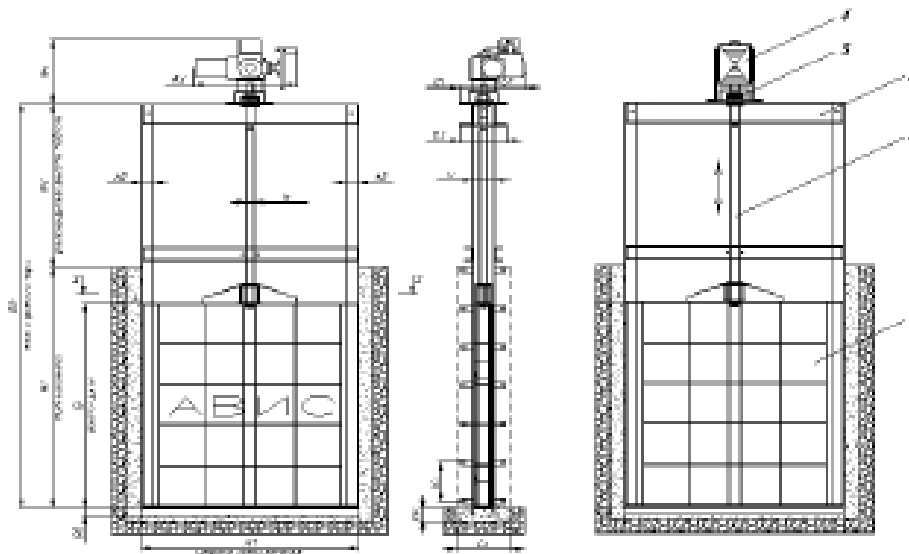


Figure 1. Structural diagrams of the gear and linear electric drive of a flat gate: 1 - watergate; 2 – gate rod; 3 - frame; 4 - inductor of a linear cylindrical induction motor; 5 - fixing mechanism.

The basis is the calculation of electrodynamic forces acting on the secondary body of various geometric shapes, materials and structures. We consider both an infinitely extended body and a body of finite length and width having a different cross-sectional shape.

The calculation is carried out for inductors both closed and of finite length. In this case, it is necessary to take into account the effects caused by the non-sinusoidal wave of the traveling magnetic field, the influence of its spatial and temporal harmonics - associated with the surface features of the inductor and secondary body.

The design of the magnetic circuit, in particular its openness or isolation, fundamentally affects the current and flux distribution, while the physical nature of the electromagnetic processes of the induction converter is the same. Therefore, it seems possible to construct a generalized mathematical model of an induction converter, and design features, including a magnetic circuit, to describe parametrically.

In accordance with the accepted method [8, 9], the induction converter is reduced to a combination of three detailed equivalent circuits: a magnetic circuit, an electric circuit of an inductor, and an electric circuit of a secondary element. For each of them, a matrix algebraic or differential equation of state is prepared that describes the electromagnetic processes in the circuit. To study (simulate) dynamic modes, the resulting system is supplemented by the equation of motion of the induction converter. This model of the induction converter was obtained under the following assumptions: the currents of the inductor and the secondary element are concentrated on each tooth fission at points on

the surface of smooth cores, the gearing of which is taken into account by introducing the Carter coefficient, the electromagnetic values within the tooth fission are unchanged and change stepwise (discrete) when switching to neighboring sections, the magnetic field in the gap is idealized in this way and has only one component of induction. At the input and output of the core, the equivalent circuit of the induction converter with an open magnetic circuit is supplemented by shunt sections, the magnetic properties of which are set in accordance with the exponential law of field decrease with distance from the edge of the inductor [10].

To reduce the number of variables in the analysis, it is advisable to introduce generalized parameters and go to the relative units in the original equations. As a result of such a generalization, we obtain criteria for the electromagnetic similarity of circuits; in addition, the choice of basic quantities (scale) makes it possible to increase the accuracy of computer calculations without additional costs.

For each section of the magnetic circuit, equal to the tooth division, we will draw up an equivalent circuit, which will be an active four-terminal network. Then the equivalent circuit of the magnetic circuit of the machine as a whole is reduced to the cascade inclusion of such four-terminal devices. For a closed magnetic circuit, the equivalent circuit will be closed, and for open - open. Moreover, in the second case, it is not limited by the length of the inductor core, but is supplemented by four-terminal devices with corresponding parameters, i.e. m.s. the stator is zero, and the resistances are calculated in accordance with the recommendations of [11]. Figure 1 shows the calculated models of an induction converter with open (a) and closed (b) magnetic cores, and figure 2 presents equivalent scheme of the magnetic circuit.

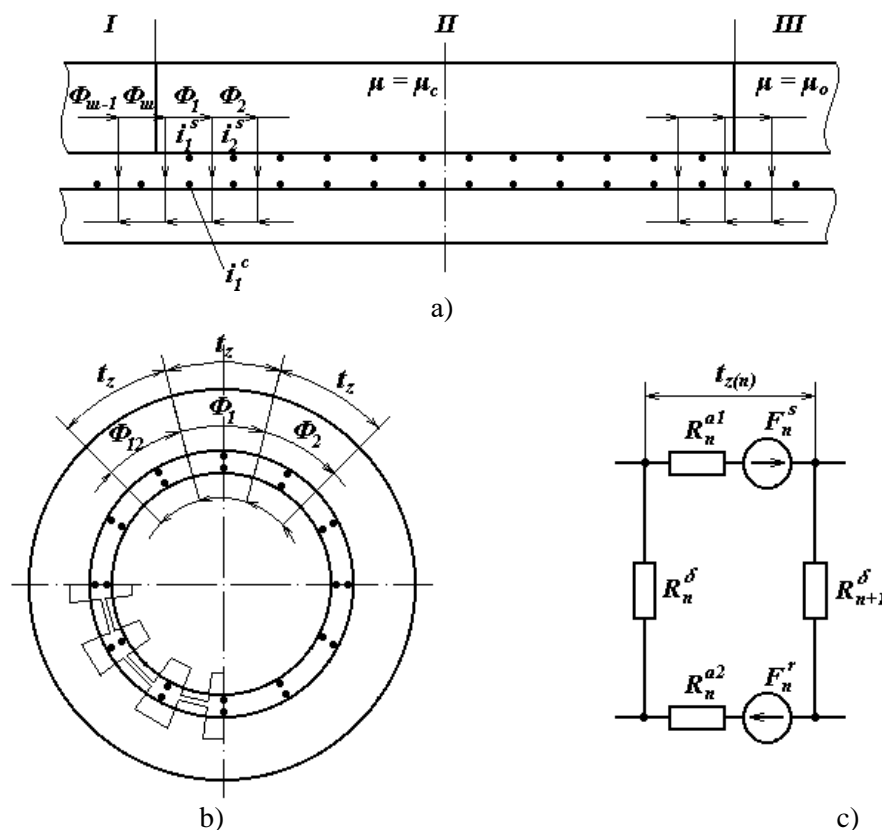


Figure 2. The design model of the magnetic circuit: a - the magnetic circuit is open, (I, III) - shunt zones, II - the core zone of the inductor; b - the magnetic circuit is closed; c is the equivalent circuit of the nth section.

We will select the circuit formed by the neighboring resistances of the nonmagnetic gap and the corresponding resistances of the magnetic cores. We will write for it according to the law of total current:

$$R_n^\delta \cdot \Phi_{n-1} + (R_n^\delta + R_{n+1}^\delta + R_n^{a1} + R_n^{a2}) \cdot \Phi_n - R_{n+1}^\delta \cdot \Phi_{n+1} = i_n^s + i_n^c, \quad (1)$$

where Φ_n – magnetic flux of the n -th yoke section; R_n^δ – magnetic resistance of a non-magnetic gap corresponding to the n -th tooth division; R_n^{a1}, R_n^{a2} – magnetic resistance of the n th portion of the magnetic circuit of the inductor and the secondary element; i_n^s – inductor groove current (current of the n -th inductor groove); i_n^c – reduced current.

The set of equations for the entire magnetic circuit is conveniently written in one matrix:

$$R \cdot \Phi = I^s + I^c, \quad (2)$$

where R – magnetic resistance matrix; Φ – yoke magnetic flux vector; I^s – inductor slot current vector, $I^s = w_k \cdot K_{np} I^\phi$; I^c – vector of independent phase currents; K_{np} – matrix for reducing phase currents to grooves; w_k – number of turns in a coil.

Nonzero matrix elements R :

$$a_{n, n-1} = -R_{n-1}^\delta, \quad a_{n, n} = R_n^\delta + R_{n+1}^\delta + R_n^{a1} + R_n^{a2}, \quad a_{n, n+1} = -R_{n+1}^\delta.$$

It is easy to see that, for an open magnetic circuit, the matrix R is trapezoidal, and for a closed magnetic core, in addition to diagonal, there will also be angular elements: $a_{1, NZ} = -R_1^\delta$ и $a_{NZ, 1} = -R_1^\delta$,

where NZ – the number of cells in the equivalent circuit, which in this case, is equal to the number of grooves.

An example of the formation of K_{np} matrix is shown in figure 3. Figure 2 shows that in the case of an open magnetic circuit, the K_{np} matrix contains the first III1 and the last III2 of zero lines, where III1 and III2 are the number of shunt sections at the input and output of the induction converter.

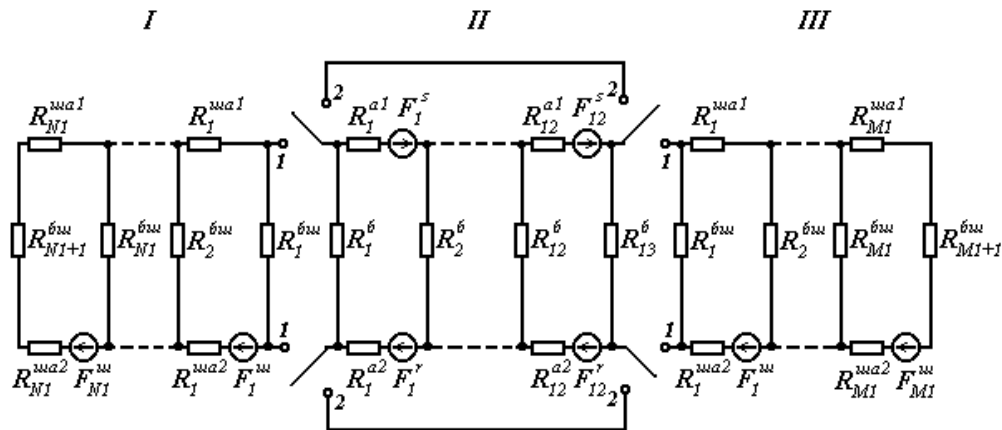


Figure 3. The equivalent circuit of the magnetic circuit of the machine: induction converter with an open magnetic circuit - closed contacts 1; (I, III) - shunt zones, II - inductor core zone; Inductive converter with a closed magnetic circuit - closed contacts 2.

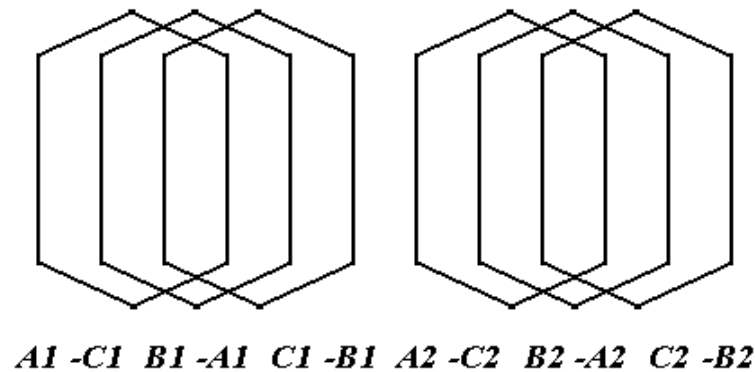


Figure 4. Formation of a matrix for reducing phase currents to grooves.

$$K_{np}^T = \begin{vmatrix} 1 & 1 & 0 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & -1 & 0 & 1 & 1 & 0 & -1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & -1 & -1 \\ 0 & -1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & -1 & 0 \end{vmatrix}$$

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n

$$i_n^s = i_{c1} = i_o - i_{a1} - i_{b1} = (-1) \cdot i_{a1} + (-1) \cdot i_{b1} + 0 \cdot i_{a2} + 0 \cdot i_{b2} + 1 \cdot i_o$$

$$(I^s)^T = (i_1^s, i_2^s, \dots, i_{nZ}^s), \quad NZ = III1 + Z + III2$$

$I^s = K_{np} \cdot I^\phi$ – slot current vector

$$(I^\phi)^T = (i_{a1}, i_{b1}, i_{a2}, i_{b2}, i_o)$$

Z is the number of grooves of the inductor; III1, III2 - the number of shunt sections at the input and output of the induction converter.

It is very remarkable that not the form of equation (2), but the values of the elements of the matrix coefficients depends on the design of the magnetic circuit.

Thus, we can make the following conclusions:

1. Induction converters are effective for operational control and automatic control of water supply parameters.

2. Based on detailed equivalent circuits, a mathematical model of the electromechanical transients of an induction converter is obtained when it is powered from a voltage source of any shape specified analytically or in a table.

3. The presence of nonlinear elements in the electric circuit of the inductor is modelled by the nonlinearity of the parameters of its equivalent circuit, calculated for each moment in time according to a given algorithm. Various power modes are modelled by the corresponding formation of a vector of applied voltages. A method for calculating the static characteristics of a squirrel-cage induction motor based on detailed equivalent circuits using complex amplitudes of sinusoidal values is described.

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