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ONE APPROACH TO QUASI-OPTIMAL CONTROL OF DIRECT CURRENT MOTOR

Optimum real-time control of dynamic objects based on the Pontryagin maximum principle implies multiple solutions of a system of transcendental equations, which is practically impossible for software and logic controllers used in automation systems at the lower level of control and leads to complication of control structures. Obtaining simple functional dependences of the optimal control variables on the specified control quality indicators will allow overcoming this problem.

Optimal speed control of micromotor in real time based on the Pontryagin maximum principle implies preliminary calculations and the formation of a predicate model or, in the case of a quasi-optimal control, obtaining the regression dependence of the first control interval on the maximum allowable value of the output value in the transient [1,2].

The spread of this approach to the control of dynamic objects of a different physical nature would make it possible to simplify the software and technical implementation of automatic control systems, which are inherently heterogeneous.

Nowadays, DC systems with independent excitation [3,4] are widely used in automation systems and educational laboratory benches. The transfer function of the motors of this class on the control channel "supply voltage - circular frequency of rotation of the motor shaft" has the following form [3]:

$$W(p)=\frac{\bar{\omega}}{\bar{U}}=\frac{1/K_E}{T_E\cdot T_M\cdot p^2+T_M\cdot p+1} \tag{1}$$

Moreover, the values in (1) are calculated by the following formulas:

$$K_E=\frac{U_{annom}-R_{an}\cdot I_{annom}}{\omega_{nom}}, \tag{2}$$

$$\omega_{nom}=\frac{\pi\cdot n_{nom}}{30}, \tag{3}$$

$$T_E=\frac{L_{an}}{R_{an}}, \tag{4}$$

$$T_M=\frac{R_{an}\cdot J}{K_M\cdot K_E}, \tag{5}$$

$$K_M=\frac{P_{nom}}{\omega_{nom}\cdot I_{annom}}. \tag{6}$$

where $\bar{\omega}$ – the image of the circular frequency of rotation of the motor shaft; $\bar{U}$ – image of the micromotor supply voltage; K_E – electromotive force’s coefficient of motor; T_E – electromagnetic time constant; T_M – mechanical time constant; U_{annom} – motor rated voltage; R_{an} – resistance of the anchor circuit; I_{annom} – rated armature current; ω_{nom} – nominal circular frequency of rotation of the motor; n_{nom} – nominal frequency of rotation of the motor; L_{an} – inductance of the motor armature circuit; J – moment of inertia; K_M – motor torque coefficient; P_{nom} – motor rated power.

Table 1 shows the parameters of a DC micromotor DPM-30-H1-0.2.

TABLE I. MOTOR PARAMETER DPM-30-H1-0.2

Motor parameter	Parameter point	Note
U_{an}	27 V	Nameplate data
I_{an}	0.3 A	
n_{nom}	2600 r\min	
P_{nom}	2.67 W	
R_{an}	45 Ohm	Research results [5]
L_{an}	2.83 H	
J	$0.42 \cdot 10^{-4}$ kg·m^2	

According to the Table I taking into account formulas (2)-(6) we get $1/K_E = 20$; $T_E = 0.063$; $T_M = 1.26$. Thus, the dynamic model of a micromotor of constant DPM-30-N1-0.2 through the control channel “supply voltage - circular rotation frequency of the motor shaft” is a second-order link with the transfer function $W(p) = 20/(0.079p^2 + 1.26p + 1)$. The roots of the characteristic equation are respectively: $\alpha_1 = -15.11$ and $\alpha_2 = -0.84$.

In the general case, the problem of optimal in speed control using the Pontryagin maximum principle under steady-state processes is formulated as follows. The control object must be transferred from the initial state y_{in} when $t = 0$ to the final state y_{fin} in the minimum time, using the relay control law with the maximum and minimum values of control actions $U_{\max}$ and $U_{\min}$, respectively.

Since a mikromotor is described by a second-order dynamic equation, to control it, according to the n-interval theorem, two control intervals are enough (one control switching). Moreover, when controlling a micromotor without changing the polarity $U_{\min} = 0$.

Figures 1a and 1b show the changes in the output value y_{out} and control action U, respectively, for the case when $y_{fin} > y_{in}$, and in Fig. 2a and 2b - for the case when $y_{fin} < y_{in}$. Let us write the laws of the change in the output quantity y_{out} and its derivative $\dot{y}_{out}$ at times $t = 0$, $t = t_1$ and $t = t_2$.

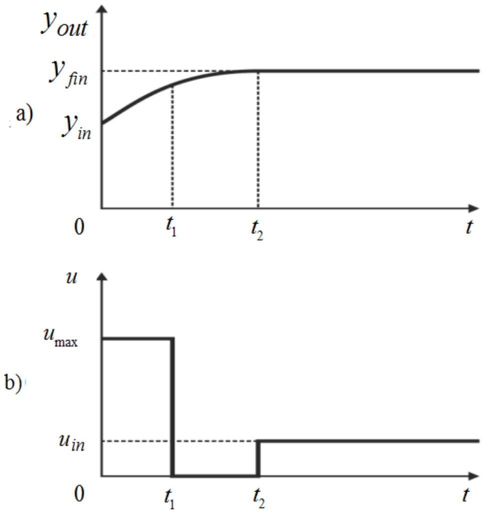

Fig. 1. Control of object if $y_{fin} > y_{in}$: a) change of output value; b) change of controlling action.

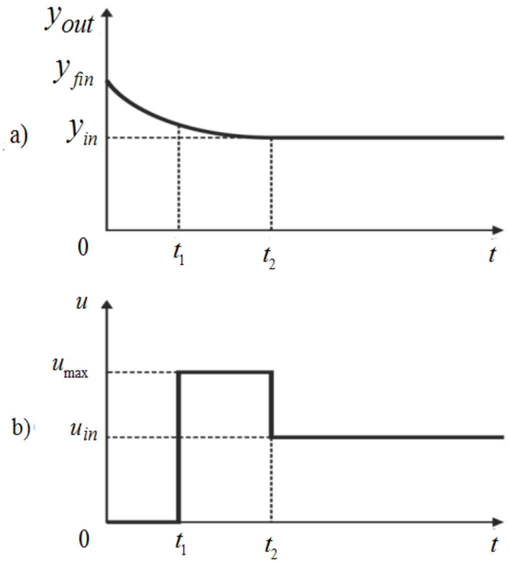

Fig. 2. Control of object if $y_{fin} < y_{in}$: a) change of output value; b) change of controlling action

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