ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 3 , March 2020

Synthesis of a current control loop with proportional-integrating-differentiating regulators according to control and disturbing influences

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ABSTRACT: this article discusses the synthesis of a current control loop with proportional-integrating-differentiating regulators according to control and disturbing influences

KEYWORDS: thyristor electric drive, current regulation, dynamic surge current, boost coefficient, PID controller

I. INTRODUCTION

The proportional-integral-differentiating (PID) controller is a device in the control loop with feedback. It is used in automatic control systems to generate a control signal in order to obtain the necessary accuracy and quality of the transition process. The PID controller generates a control signal, which is the sum of three terms, the first of which is proportional to the difference between the input signal and the feedback signal (mismatch signal), the second is the integral of the mismatch signal, and the third is the derivative of the mismatch signal.
When designing a subordinate control system for variable thyristor electric drives of the main mechanisms of bucket excavators, one of the main tasks is to ensure the aperiodic nature of the change in the motor current at any speed of the optimized current control loop.

II. METHODOLOGY

Studies have established [3,4] that the use of proportional-integrating-differentiating regulators with both sequential MCA and mixed corrections does not provide a solution to this problem, since the maximum speed of the motor current control loop, the anchor circuit of which is written from a thyristor converter (TP) with an inertial system pulse-phase control (SPFU), is limited by the permissible amount of current overshoot.
The delivered circuit is most easily achieved using a real proportional-integrating-differentiating current regulator (CR), the transfer function of which is described by the expression [4].

$$W_{CR}(P) = \frac{U_y(P)}{U_{3T}} = \frac{(PT_{я}+1)(PT_{д}+1)}{PT_{PT}(PT_{фт}+1)} \quad (1)$$

Transfer function according to the control $U_{зт}$ action of a closed current control loop, the structural diagram of which is shown in fig. 1a, has the form.

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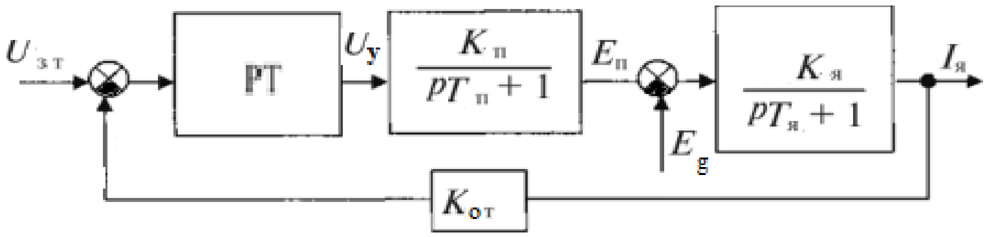

Fig. 1 a: Structural diagram of the current loop.

$$W_{TY}(P) = \frac{I_я(P)}{U_{3T}} = \frac{K_T}{PT_T(PT_{\phi m}+1)+1} \qquad (2)$$

where $K_п$, $T_п$ - respectively, the gain and equivalent time;
$K_я$, $T_я$ - respectively, the current transfer coefficient and the time constant of the anchor circuit of the thyristor converter system to the TP-D motor;
$K_т$, $T_т$– respectively, transmission coefficient and equivalent time constant of the optimized current control loop;
T_{PT}, $T_{ΦT}$–, respectively, the integration time and the filter constant of the regulator.

An analysis of expression (2) shows that to ensure the aperiodic nature of the current change at any speed of the current circuit, it is sufficient to fulfill the condition $T_{ΦT} \le 0{,}25T_T$. In this case, the law of the voltage change of the thyristor converter, when the jump U_{3T} is characterized by the transfer function

$$W_{ПУ}(P) = \frac{E_П(P)}{U_{3T}(P)} = \frac{K_T(PT_я+1)}{K_я[PT_T(PT_{\phi m})+1]} = \frac{K_T(PT_я+1)}{K_я(PT_1+1)(PT_2+1)} \qquad (3)$$

Here, the dummy time constants T_1 and T_2 ($T_1 \geq T_2$) are determined

$$T_1 = \frac{2T_T T_{ΦT}}{T_T - \sqrt{T_T^2 - 4T_T T_{ΦT}}},\ T_1 = \frac{2T_T T_{ΦT}}{T_T + \sqrt{T_T^2 - 4T_T T_{ΦT}}} \qquad (4)$$

Using the method of decomposing complex transfer functions into transfer functions of elementary links, expression (3) can be represented as follows.

$$W_{ПУ}(P) = \frac{K_т}{K_я}\left[\frac{T_я - T_2}{(T_1 - T_2)(pT_2+1)} - \frac{T_я - T_1}{(T_1 - T_2)(pT_2+1)}\right] \qquad (5)$$

Then the change in time of the voltage TP is described by the equation

$$E_{ПУ} = E_K\left[\frac{T_я - T_2}{T_1 - T_2}\left(1 - e^{-\frac{t}{T_2}}\right) - \frac{T_я - T_1}{T_1 - T_2}\left(1 - e^{-\frac{t}{T_1}}\right)\right] \qquad (6)$$

Where $E_K = \frac{K_T U_{3T}}{K_я}$ voltage drop in the anchor circuit of the GP-D generator converter system with a fixed armature and a given motor current.
Having determined the derivative of expression (6) $(T_1 > T_2)$ and equating it to zero, we determine the time $t_{МП}$ (in relative units) when the voltage GP reaches its maximum value

$$t_П^* = \frac{t_{МП}}{T_Т} = \frac{A}{\sqrt{1-4A}} ln \frac{mn-1}{m-1} \qquad (7)$$

where $A = \frac{T_{ΦТ}}{T_Т}$, $n = \frac{\beta(1-\sqrt{1-4A})}{2A}$, $m = \frac{1+\sqrt{1-4A}}{1-\sqrt{1-4A}}$ - constant coefficients;

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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$\beta = \frac{T_я}{T_т}$ - generalized current loop parameter.

Substituting the value of $t_{mп}$ from (7) into (6), we find an expression for determining the value of the necessary coefficient of boosting the K_{Φ} voltage TP voltage in an optimized current control loop

$$K_f = \frac{E_{лmax}}{E_K} = 1 + (m-1)\left(\frac{m-1}{mn-1}\right)^{\frac{1}{n-1}} \qquad (8)$$

The dependence $t_п^* = f(\beta)$ and $K_f = f(\beta)$ for A = 0.15 are shown in fig. 1 b (curves I).

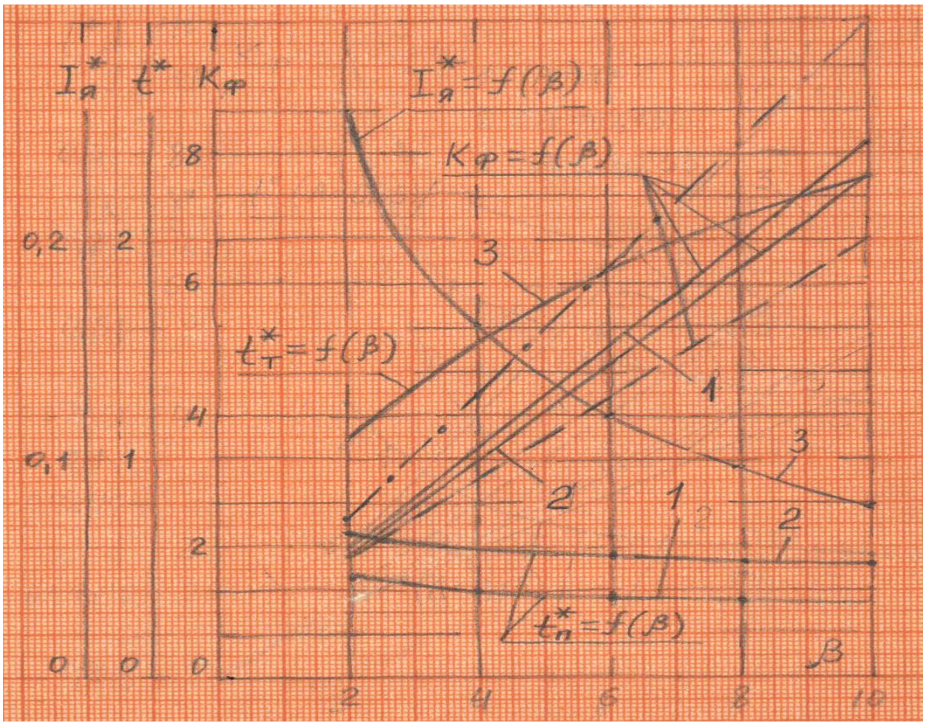

Fig. 1 b: Dependencies $K_f = f(\beta)$ for classic current loop settings.

The above expressions (7) and (8) are valid if ($T_1 > T_2$).
When $T_1 = T_2$, the time for the voltage TP to reach its maximum value is found from the equation

$$t_П^* = \frac{t_{МП}}{T_Т} = \frac{\beta}{2\beta - 1} \qquad (9)$$

A boost voltage coefficient TP

$$К_f = 1 + (2\beta - 1)e^{-\frac{2\beta}{2\beta - 1}} \qquad (10)$$

The dependences $t_п^* = f(\beta)$ and $К_\Phi = f(\beta)$ for A = 0.15 are shown in fig. 1 b (curves 2).

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ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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III. EXPERIMENTAL RESULTS

To assess the technical feasibility of applying a control structure with a PID controller in terms of acceptable voltage boosts, we compare it with the known ones. Dependences $K_F = f(\beta)$ for the classical settings of the current loop [2] are shown in fig. 1 b by dashed (modular optimum) and dashed-dashed (symmetric optimum) lines. From this drawing, it follows that the required voltage margin of the TP in the current control loop with the PID controller, ceteris paribus, is greater than when the current loop is set to a modular optimum and less to a symmetrical one.
The disturbing effect for the current control loop is the electromotive force (EMF) *Eg* of the motor (fig. 1 a). The study of the law of variation of the motor current when changing its EMF is of great practical importance, since the mode of operation of the electric wires of the pressure and lifting mechanisms of single-bucket excavators is characterized by the presence of a variable load on the motor shaft, the maximum value of which in most cases is comparable with the stop load of the mechanism. In this case, the drive control system should provide a reliable limitation of the dynamic surges of the armature current when the motor suddenly stops.

According to fig. 1 a, the law of measuring current at a jump *Eg* characterized by a transfer function

$$W_{TB}(p) = \frac{I_я(p)}{E_g(p)} = \frac{K_я p T_T (p T_{ФT}+1)}{(p T_{ФT}+1)[p T_T (p T_{ФT}+1)+1]} \quad (11)$$

Which, for the convenience of analysis, can be represented without a large error, as follows ($A \leq 0{,}25$)

$$W_{TB}(p) = \frac{K_я p T_T (p A T_T+1)}{(p T_я+1)(p T_T+1)} \quad (12)$$

An analysis similar to the above allows one to determine the time $t_{mп}$ (in relative units) when the current reaches its extremum

$$t_T^* = \frac{t_{MT}}{T_T} = \frac{\beta}{\beta-1} ln \frac{\beta^2(1-A)}{\beta-A} \quad (13)$$

And the maximum magnitude of the motor current when it is instantly locked

$$I_я = \frac{I_{яв}}{I_{кз}} = \frac{\beta-A}{\beta^2}\left[\frac{\beta-A}{\beta^2(1-A)}\right]^{\frac{1}{\beta-1}}$$

where $I_{кз} = \frac{E_g}{R_я}$ short-circuit current of the motor for a given value of Eg = Ep.

The dependences $t_T^* = f(\beta)$ and $I_я = f(\beta)$ for A = 0.25 are shown in Fig. 1 b (curves 3).

IV. CONCLUSION

The following conclusions can be drawn that this setting of the current loop allows you to implement the calculated transfer function of the subsequent speed control loop, maximize the use of the motor in terms of overload capacity, reduce the dynamic surge of the motor current and reduce shock loads during gap selection.
Thus, the possibility of adjusting the current loop with a quick action exceeding this indicator with the PID controller allows you to reduce the dynamic surge of the motor current when it suddenly stops.

REFERENCES

[1]. Klyuchev V.I. Limitation of dynamic loads of the electric drive. M .: Energy, 1971, 320 p.
[2]. Garnov V.K., Rabinovich VB, Vishnevetsky L.M. Unified automatic control systems for electric drives in metallurgy. M.: Metallurgy, 1971, 216 p.
[3]. Control of DC valve electric drives (E.D. Lebedev, V.E. Neymark, M.Ya. Pistrak, O.V. Sledzhanovsky). M .: Energy, 1970, 200 p.
[4]. Sozaev A.M. Sequential correction of the dynamic links of the object of regulation of the PID controller. The manuscript is deposited in the series "Opencast coal mining" TsNIIEIugol, 1980, No. 7-8.

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 7, Issue 3 , March 2020

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ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 7, Issue 3 , March 2020

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