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CONTROL OF DIRECT CURRENT ELECTRICAL MACHINE: DESIGN OF A SERVOCONTROLLER

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ABSTRACT

In this paper, a servocontroller electric drive is used for the regulation of executive organposition in functioning machine depending on input signal. The servocontroller should install the executive organ into corresponding position with a given precision. The servocontroller will include a stabilization current loop and its limitator installation, and also a stabilization speed loop. It is also necessary to build a third external loop on position of functioning machine executive organ.

Keywords: *Direct current machine, servocontroller*

I. INTRODUCTION

A servo control system is one of the most important and widely used forms of control system. Any machine or piece of equipment that has rotating parts will contain one or more servo control systems. The job of the control system may include:

- Maintaining the speed of a motor within certain limits, even when the load on the output of the motor might vary. This is called regulation.
- Varying the speed of a motor and load according to an externally set program of values. This is called set point (or reference) tracking.

Our daily lives depend upon servo controllers. Anywhere that there is an electric motor, there will be a servo control system to control it. Servo control is very important. The economy of the world depends upon servo control. Manufacturing industry would cease without servo systems because factory production lines could not be controlled, transportation would halt because electric traction units would fail, computers would cease because disk drives would not work properly and communication networks would fail because networks servers use hard disk drives.
DC servo motors have been widely used for applications such as industrial robot manipulators. These DC servo motors have been changingdynamics caused by parameter variations such as inertia changes due to grasping objects. The changing dynamics and other nonlinear effects can be suppressed by the use of high gear ratios. However, the high gear ratios have the disadvantages of higher friction deflection and backlash. Therefore, the ability to design DC servo motor controllers with fast drive performance and reduced sensibility to parameter variations that do not rely on high gear ratios is desired.

Kenji Tamaki and others in 1985 proposed a control system that consisted of two controllers: a complementary controller used to reduce system sensitivity, and a position controller used to specify the system transfer function. The advantage of this approach is that both system sensitivity and system response can be designed and realized independently [1] – [4].

Much research on adaptive control is being conducted in the area of DC servo-motor control. In particular, model reference adaptive control (MRAC) systems are capable of adjusting to DC servo-motor parameter variations such as inertia change. However, MRAC systems generally require extensive computations, and sometimes have difficulty compensating for large disturbance effects [5],[6].

II. CONSTRUCTION OF POSITION CAPTOR

The structural circuit of servocontroller electric drive is shown on figure 1.

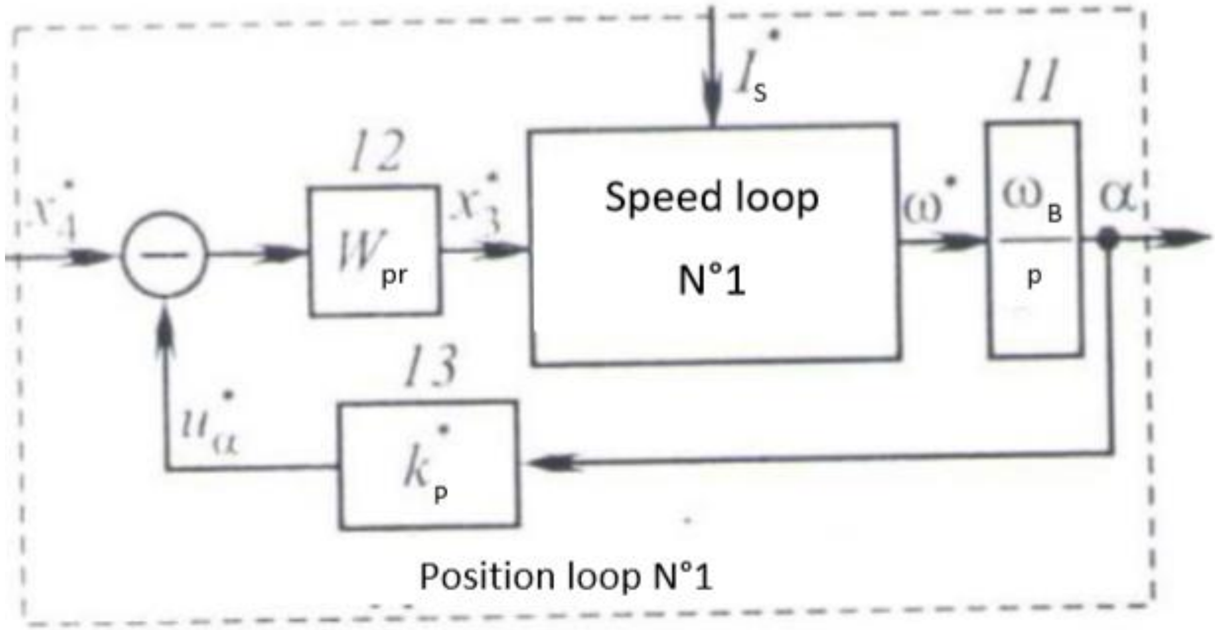

Figure 1 Structural circuit of servocontroller electric drive

11-mechanical transducer; 12-position regulator; 13-position captor

The output signal of mechanical transducer x is applied to the shaft of electromotor by the transformation $x = Z\alpha$, where Z = coefficient of transformation of space coordinate x to generalized position coordinate α (rotor rotation angle)

Between the rotation speed and generalized position coordinate, we have the relation $\omega = p\alpha, p = \frac{d}{dt}$ is the differential operator.
In per units, $\omega^* = p\alpha/\omega_B$

III. DESIGN OF POSITION REGULATOR

The control object of position loop (figure 1) is the mechanical transducer with transfer function ω_B/p and speed loop with transfer function.

$$W_{slc} \approx \frac{1/K_s^*}{4.T_\mu p + 1}$$

Thus, the transfer function of position loop control object is $W_{po} = \frac{\omega_B/K_s^*}{(4.T_\mu\ P+1)\ P}$

The transfer function of series position regulator is chosen to also ensure standard transfer function of position loop.

$$W_h = \frac{1/K_P^*}{2\,T_{\mu_2}^2.P^2 + 2.T_{\mu_2}P + 1}$$

Therefore, for $T_{\mu_2} = 4T_\mu$, the transfer function of position regulator

$$W_{pr} = \frac{1/K_P^*}{W_{po}.2.T_{\mu_2}.P(+T_{\mu_2}P+1)} = \frac{K_s^*}{8\omega_B.K_P^*.T_\mu} \qquad (1)$$

It is a proportional element.
From figure 1, $x_3^* = (x_4^* - K_P^*\alpha)W_{pr}$; $\alpha^* = \omega^*.\omega_B/P$
Considering that $\omega^* = K_{slc}x_3^* - W_{slp}.I_s^*$
$\alpha^* = W_{plc}.x_4^* - W_{plp}.I_s^*$ (2)

Where W_{plc} – transfer function of generalized position coordinate α on control signal x_4^*;
W_{plp} - Transfer function of generalized position coordinate α on perturbation signal I_s^*

We have:
$W_{plc} = \frac{\alpha_{max}}{(8.T_{\mu}2p^2+4.T_\mu p+1)^2}$;

$$W_{plp} = 32 * \frac{(2\,T_{\mu^2}p^2 + 2.T_\mu p + 1).T_{\mu^2}.\omega_B}{(8\,T_\mu^2 p^2 + 4\,T_\mu p + 1)^2.T_{Mech}.K_s^*}$$

If we assume in (2) that p=0, then we have the load characteristic of electric drive with proportional position regulator:

$$\alpha = \alpha_{max}.x_4^* - (T_\mu^2.\omega_B\left(\frac{T_{Mech}}{K_s^*}\right).I_s^*$$

Thus the static error of control system for nominal load is

$$\Delta\alpha = T_\mu^2\omega_B/T_{Mech}$$

IV. DESIGN OF ADAPTIVE POSITION REGULATOR

Proportional position regulator creates static error. If the level of error $\Delta\alpha = T_\mu^2\omega_B/T_{Mech}$ does not satisfy technological process constraints, then it is necessary to create a second position loop. The structural circuit of second position regulator is represented on figure 2.

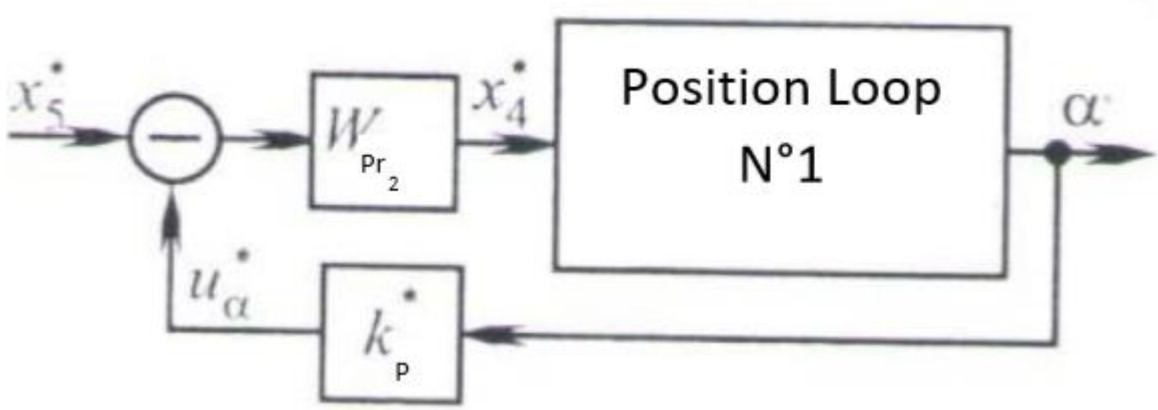

Figure 2 Structural circuit of second position loop

The first position loop in that case is control object of second position loop and has the following transfer functions.

$$W_{plc} = \frac{\alpha_{max}}{(8T_\mu^2 P^2 + 4T_\mu P + 1)^2} \approx \frac{\alpha_{max}}{8T_\mu P + 1}$$

The transfer function of position regulator W_{pr_2} is chosen so as to ensure standard transfer function of second position loop.

The choice of position regulator according to the procedure of construction on technical optimum is as follows:

$$W_{pr_2=1/(16T_\mu P)} \qquad (3)$$

By using the structural circuit of second position loop we have

$$x_4^* = (x_5^* - K_p^*.\alpha)W_{pr_2}$$

We replace that relation in (2) to obtain the representation of generalized coordinate:

$$\alpha = W_{plc_2}.x_5^* - W_{plp_2} I_S^* \qquad (4)$$

Where $W_{plp_2} = 521.T_\mu^3 P.\omega_B (2T_\mu^2 P^2 + 2T_\mu P + 1)/T_{Mech}/K_s^*/Y(P)$

$W_{plc\,2} = \alpha_{max} \,/\, Y(P)$ – Transfer functions or generalized position coordinate α on perturbation I_S^* and control signal x_5^*,
$Y(p) = 16.T_\mu p\ (8T_\mu^2 p^2 + 4\,T_\mu p + 1)^2 + 1$ is characteristic polynom.

By considering (4) p=0, we have the expression for the load characteristic of electric drive with position integral regulator $\alpha = \alpha_{max}\,.x_5^*$

Thus the static error of control system is zero.
The dynamic error of position stabilization is characterized by transient function created by the transfer function $W_{plp\,2}.T_{Mech}.K_S^*/T_\mu^2/\omega_B$. The aspect of the transient function is shown on figure 3.

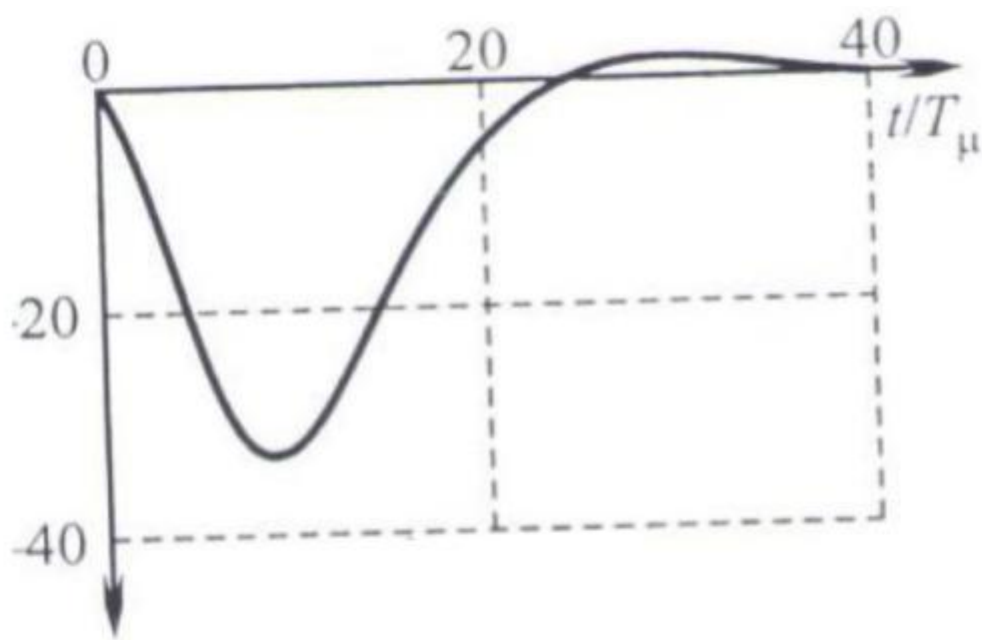

Figure 3 Transient function created by transfer function $W_{plp2}.T_{Mech}.K_S^*/T_\mu^2/\omega_B$.

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The maximal deviation of position generalized coordinate for nominal load is reached with $t = 13{,}4\, Tu$ and is defined as follows:

$$\Delta\alpha = 31\, T_\mu^2 \omega_B / T_{Mec\,h} / K_S^*$$

We can distinguish three functioning regimes of electric drive: current stabilization regime, speed stabilization and position stabilization. Obviously, in speed and current stabilization regime, integral position regulator cannot influence on armature rotation speed of electromotor. That is why its output expression in current stabilization regime can have any value and provoke damping of speed and position coordinates.

To avoid such processes, the position regulator should be adaptive. The structure of adaptive regulator of second position loop is analog to structure of adaptive regulator for second speed loop, and they have the same functioning. In speed and current stabilization regime, the adaptive regulator should be aperiodical element of first order while in position stabilization regime, the second position loop should be an integral element.

V. CONCLUSION

For the construction of etalon dynamic processes in control of position of executive mechanism for direct current electric drive, it is necessary to use control position loop with proportional regulator. The static error of stabilization of position control loop with proportional regulator depends on the load. To obtain a position stabilization with zero static error, the adaptive position regulator is necessary.

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