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Two-Zone Control of Direct Current Electric Drive

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Abstract*: The speed regulation from zero to limit value in direct current electric drives is done by means of increasing armature voltage from zero to nominal value. It is called the speed regulation in first zone. The speed regulation above the limit value is called the speed regulation in second zone. It is done by reduction of excitation winding voltage under the nominal value.*

In this paper, we study an algorithm design of common control of rotor rotation speed in first and second zones.

Keywords: *Two-Zone Control; Direct Current; Electric Drive.*

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I. Introduction

DC machines are the keystone of world industry. Simplicity in exploitation and regulating, as well as in control systems building, allows to get high quality properties of response, static precision, durability and reliability of synthesized control systems [1], and also the setup simplicity for most of them. Generally, these machines are considered as linear objects. In order to extend its regulation possibilities, the control in excitement loop is used. In this case, they become nonlinear systems and are treated respectfully. All this transforms DC machines into perfect testing sample for different control systems and control approaches.

Two-zone speed control systems for direct current motors with separate excitation are widely spread in different industrial applications, for example in the field of metal processing machines. The principle of the two-zone control [2] is to change the motor speed below the rated value changing the armature voltage while the excitation current is constant and rated. The speed above the rated value is provided by weakening of the magnetic flux, but the armature voltage or EMF of the motor is constant and rated. For industrial implementation of the two-zone control, leading manufacturers most often apply the cascade two-channel system with P or PI-speed controllers, PI-controllers of armature and excitation currents, as well as I- controller for EMF [3,4].

We shall assume that the control system of rotation speed in first zone is a subordinate control system that includes an internal current loop, an external speed loop and ensures the limitation of armature current. The installation that controls the excitation winding while working in first and second zones changes the aim of the control.

For the functioning in first zone, the installation must stabilize excitation winding current; for functioning in second zone, there is stabilization in e.m.f of armature rotation at the level of nominal voltage.

In that case, the control system of armature winding continues to execute the same functions as in the first zone.

For the rotation speed control in first and second zones, we use two electrical transducers ET_1 and ET_2 that favor the regulation of voltage in excitation winding and armature winding respectively. The electrical circuit of electromotor rotation speed control in first and second zones is shown in figure 1

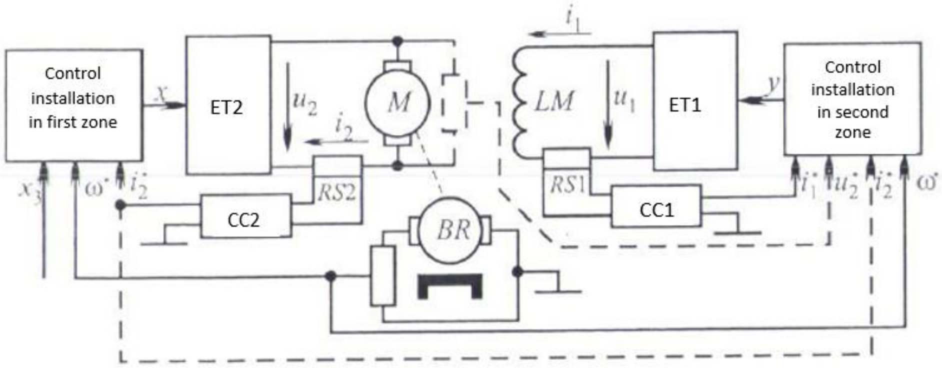

Figure 1: Electrical circuit of electromotor rotation speed control in first and second zones.

For algorithm construction, we shall assume that the armature winding control circuit is reversible, while the excitation winding control circuit is non reversible.

II. Algorithm Of Common Control In First And Second Zones With Excitation Winding Current Loop

The regulation of voltage in separate excitation winding is done by an electrical transducer. Its input control signal y and its output voltage u_1 are linked through the transfer function

$$W_{E_1} = K_{E_1}/(T_{E_1} P + 1)$$

With K_{E_1} – transfer coefficient of electrical transducer on voltage;

T_{E_1} - time constant

We assume that for an input control signal y, equal to basic voltage value of control system U_B, the voltage u_1 is equal to nominal value U_N. In that case, the transfer coefficient of the electrical transducer in per-unit is ${K_{E_1}}^* = 1$.

Considering that $(T_1 p + 1)\Psi^* = u_1^*$,

We have the transfer function of excitation winding in the form:

$$W_1 = \frac{\Psi^*}{u_1^*} = \frac{1}{T_1 p + 1}$$

Where $T_1 = L_{o1}/R_1$ – constant, L_{o1}- inductance, R_1- resistance of excitation winding.

For the control of flux linkage of excitation winding and armatureΨ^*, we construct the current loop of excitation winding (figure 2).

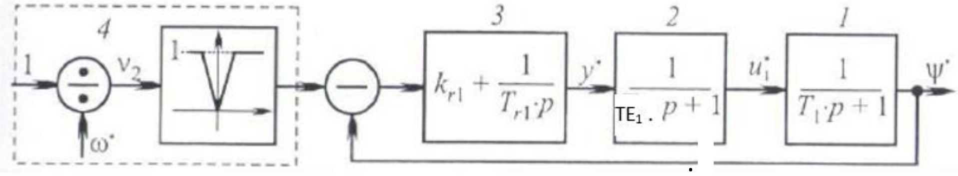

Figure 2: Structural circuit of excitation winding control loop: 1- excitation winding; 2 – electrical transducer; 3 – PI-regulator of control loop; 4- The installation of input signal construction.

Since the flux linkage $\Psi^*$is proportional to excitation winding current i_1^*, thus the excitation current loop is called the flux linkage loop.

Excitation winding and electrical transducer are aperiodical elements in series and they form the control object of flux linkage loop with transfer function:

$$W_{0_{T1}} = \frac{1}{T_1 p + 1} \cdot \frac{1}{T_{E_1} p + 1}$$

The regulator of flux linkage loop is positioned at technical optimum and is proportional-integral:

$$W_{r_1} = \frac{T_1}{2T_{E_1}} + \frac{1}{2T_{E_1} p} = K_{r_1} + \frac{1}{T_{r_1} p}$$

Where$K_{r_1} = \frac{T_1}{T_{r_1}}$; $T_{r_1} = 2T_{E_1}$.

Let us study the algorithm of functioning for installation 4 (figure 2)

For thefunctioning in second zone, $|\omega^*| > 1$ and Ψ^* should change in respect of maintaining the module of e.m.f for armature rotation constant and equal to nominal value.

Thus in established regime in per-units e.m.f of armature rotation

$$|E^*| = |\omega^*.\Psi^*| = 1$$

From the later expression, the working signal of flux linkage loop V_2 for functioning in second zone must be

$V_2 = 1/|\omega^*|$where $|\omega^*| > 1$.

For the functioning in the first zone

$|\omega^*| < 1$ and Ψ^* should be equal to 1. Therefore, for $|\omega^*| < 1$, the working signal $V_2 > 1$. The analysis of dynamic processes with functioning in first and second zones can be done using the structural circuit shown in figure 3

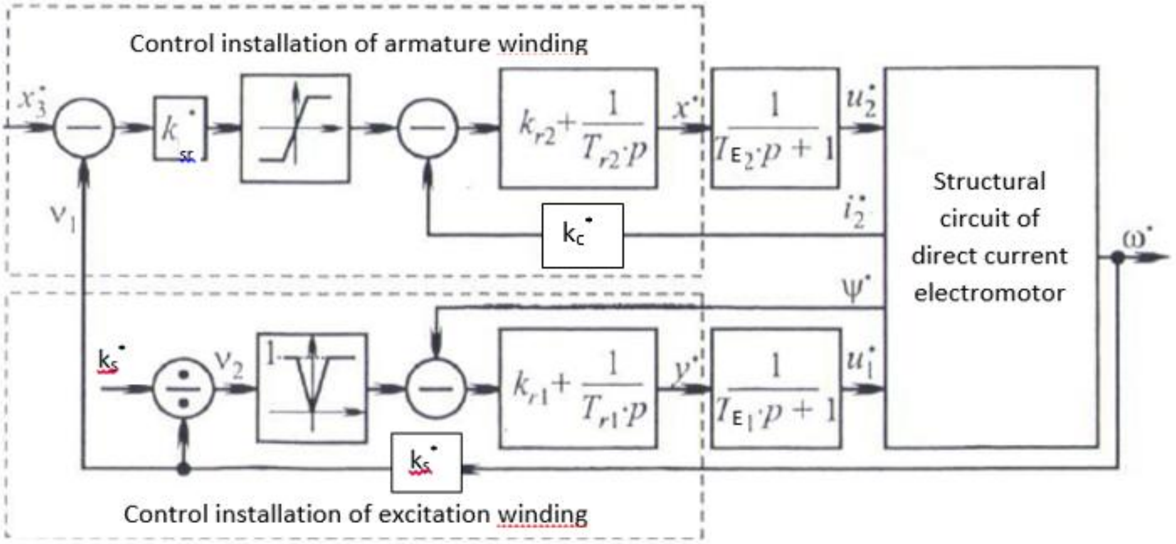

Figure 3: Structural circuit of mutual control for direct current electromotor in first and second zones with excitation current loop.

The electromechanical characteristic in second zone will be the same as the one in first zone. The electromagnetic moment in second zone

$M^* = \Psi^* i_2^*$, where$\Psi^* = 1/\omega^*$

Considering that $\omega^* = x_3^*/K_S^* - \left(\frac{4T_\mu}{T_{Mec\,h}}\right).I_S^*$, we can express the mechanical characteristic in second zone:

$$\omega^* = \frac{x_3^*/K_s^*}{1 + 4T_\mu/T_{Mech}.M^*} \approx \frac{x_3^*}{K_s^*}.(1 - \frac{4T_\mu}{T_{Mech}}.M^*)$$

If $i_2^* \geq I_{max}^*$, then the current loop that is included in first zone control installation will start limiting the current at level I_{max}^* . The limiting mechanical characteristic of second zone will be defined as follows: $\omega^* = I_{max}^* / M^*$.

The set of mechanical characteristics of direct current electric drive for two-zone rotation speed regulation is shown in figure 4

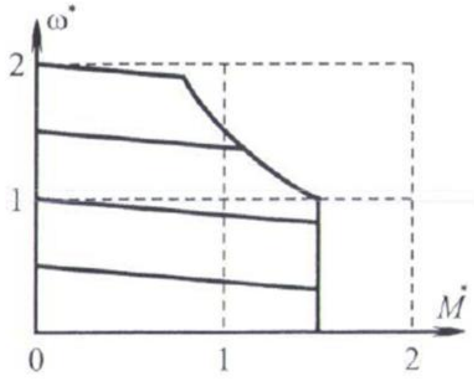

Figure 4 : The set of mechanical characteristics for two-zone speed regulation

For $K_S^* = 1/\omega_{max}^*$, the working signal on speed $x_3^* \in [0,1]$, where ω_{max}^* is the maximal rotation speed value in per-units (we often consider $\omega_{max}^* = 2$). The regulation characteristic in first and second zones is determined by the expression:
$\omega^* = x_3^*/K_S^*$.

III. Algorithm Of Common Control In First And Second Zones With Delay Feedback On Emf Armature Rotation In Excitation Winding Control Circuit

The described algorithm of combined control of voltages in armature and excitation winding is not unique. The stabilization of armature rotation e.m.f. in second zone can be done in a different manner. One of the alternative variant is as follows:
In the channel of excitation winding voltage control, we include a delay feedback:

$$E^* = u_2^* - R_2^*.i_2^*$$

Where u_2^*- voltage, R_2^*- resistance, i_2^* - armature winding current.
The structural control circuit of electromotor in first and second zones with delay feedback on armature rotation e.m.f. in excitation winding control circuit is shown in figure 5.

Between the flux linkage Ψ^* and rotation e.m.f. E^*in established regime, there is the following relation:

$$u_1^* = \Psi^* = \begin{cases} 1 \; if \; |E^*| \leq 1; \\ 1 - (|E^*| - 1).K_1^* \; if \; |E^*| > 1, \end{cases} \quad (1)$$

Where K_1^* - amplification coefficient of delay feedback
If$|E^*| \leq 1$, then the feedback on e.m.f. armature rotation E^*does not work and the voltage in excitation winding $u_1^* = 1$.
If $|E^*| > 1$ the feedback on variable E^* begins to reduce the voltage in excitation windingu_1^*, and the armature rotation speed ω^*will increase.

Thus excitation winding voltage control will take place through delay feedback on armature e.m.f. The feedbacks of first zone control installation will continue to function: stabilize the rotation speed and limit the armature current.
Let us study the definition of feedback parameter K_1^* in equation (1).
From (1), for $|E^*| \leq 1$ and establisher regime $u_1^* = \Psi^* = 1$.
For the decreasing of flux linkage Ψ^* and increasing of armature rotation speed ω^*, the e.m.f armature rotation

$$|E^*| = 1 + (1 - \Psi^*)/K_1^*$$

If the value $K_1^* \rightarrow \infty$, then $|E^*| \rightarrow 1$.For a limited value of K_1^* the module e.m.f rotation $|E^*|$ will be different from 1.

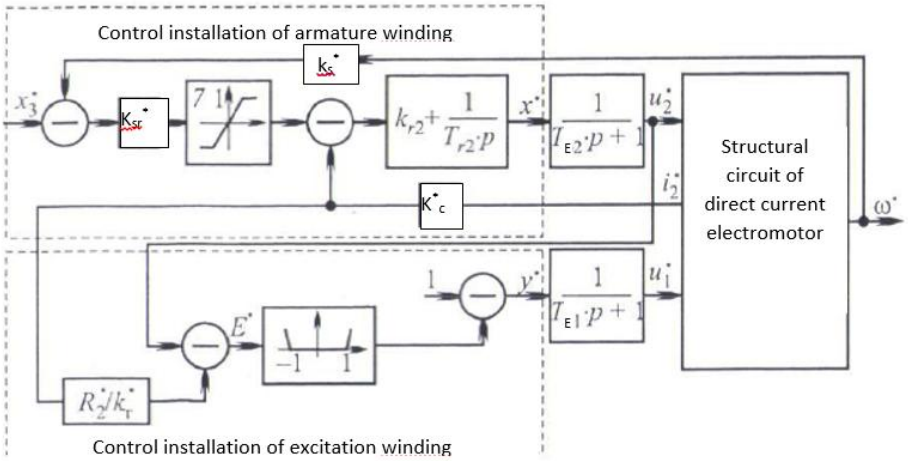

Figure 5: Structural circuit of common control for DC electromotor in first and second zones with delay feedback on rotation e.m.f of armature in the excitation winding control circuit.

For the value $\Psi^* = 1/\omega_{max}^*$, the stabilization error of armature rotation e.m.f
$\Delta|E^*| = (1 - 1/\omega_{max}^*)/\, K_1^*$,
Where ω_{max}^* - maximal value of rotation speed in per-units.
For given values of $\Delta|E^*|$ and ω_{max}^*, the amplification feedback coefficient

$$K_1^* = (1 - 1/\omega_{max}^*)/\Delta|E^*| \qquad (2)$$

For the high values of K_1^*, the system becomes not stable. For the calculation of K_1^* by equation (2) and to ensure the control system stability it is necessary to consider $\Delta|E^*| \geq R_2^*$.
The mechanical characteristic for first zone control is defined by equation

$$\omega^* = \frac{u_2^* - R_2^*.i_2^*}{u_1^*}$$

And for second zone control,

$$\omega^* = \frac{x_3^* - K_C^*.M^*/[K_{sr}^*.(1 + K_1^*)]}{K_s^* + K_C^*.M^*.K_1^*/[K_{sr}^*.(1 + K_1^*)]} = \frac{x_3^*}{K_s^*} - \frac{K_C^*.M^*.(K_s^* + x_3^*.K_1^*)}{K_s^{*2}.K_{sr}^*(1 + K_1^*)}$$

IV. Conclusions

The armature rotation speed control in the diapason from zero to limit speed (in first zone) and higher (in second zone) is done through combined voltage control of armature and excitation winding. The control of armature winding is done by a subordinate control circuit with internal armature current loop and external speed loop. The aim of electromotor armature winding control is the limitation of armature current and the stabilization of rotation speed.

The control of excitation winding is done so that the functioning in first zone will maintain a constant current for excitation winding. For the functioning in second zone, the current in excitation winding should be maintained so that the armature rotation e.m.f will be stabilized.

References

[1]. C. Battle, A. Doria "Modeling and control of electromechanical systems" Lectures for the II EURON/GEOPLEX, summer school on modeling and control of complex Dynamical Systems vol.7, n.3, pp 40-41, 2005

[2]. Basharin A.V., Novikov V.A, Sokolovsky G.G., Electric drive control, -L.: Energoizdat . 1982. -392 pp (in Russian).

[3]. ABB DCS 400, Rev. A Manual – Mode of access: http://www05.abb.com/global/scot/scot204.nsf/veritidisplay/037487c8b4d26468c1256f8c0048d6c/$file/3AD Manual-p-g.pdf

[4]. Siemens Simoreg DC master Operation Instructions. Mode of access: http://www.sea.siemens.com/us/internet_dms/PCD/Drivescomm/Drives/Doc/6RA70_operating_Inst_Edition_13.pdf

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