International Refereed Journal of Engineering and Science (IRJES)
ISSN (Online) 2319-183X, (Print) 2319-1821
Volume 7, Issue 8 Ver. I (Aug 2018), PP. 12-15

Control Of Synchronous Electromotor by Voltage Parameters Change in Stator Winding With Constant Excitation Current

Biya Motto Frederic[1k], Tchuidjan Roger[2], Ndzana Benoît[2], Tatsa Tchinda Colince[3].
1- *Faculty of Science, University of Yaounde I, PO.Box 812 Yaoundé, Cameroon;*
2- *National Advanced School of Engineering of Yaounde;*
3- *Mekin Hydroelectric Development Corporation, PO Box 13155 Yaoundek*
Corresponding Author:Biya Motto Frederic

ABSTRACT:*In this paper, we study the control algorithm of electromagnetic torque and rotation speed for a synchronous electromotor with constant excitation current.*

KEYWORDS*:Synchronous electromotor, Voltage parameters change, excitation current*

Date of Submission:28-11-2018 Date of acceptance: 14-12-2018

I. INTRODUCTION

A modern automatic AC drives have found application in metallurgy industry, e.g. of rolling mills. These AC electric drives are implemented as a system “frequency converter – synchronous motor”. Stator winding of the synchronous motor is usually supplied by the back-to-back converter, which consist of active front end (AFE) rectifier and voltage source inverter (VSI). Both the AFE and VSI operate on the principle pulse width modulation (PWM) [1,2].

Synchronous motors are selected for high power systems at a wide range of adjustable speed. The main advantages of synchronous drives are high energy efficiency [3] and good energy characteristics.

Operation of all electric motors is determined on the basis of laws of electromagnetic induction. It makes possible generalizing properties of electric motors into one model. A typical AC motor is described non-linear differential equations on the basis of a movement equation of electrodynamics system.

Solution the system of differential equations is complex because of variable coefficients. In the world literaturesuch equations are simplified by Park’s transformation a-b-c/d-q-0 and Clarck’s transformation a-b-c/α-β-γ. The transformation a-b-c/d-q-0 is a mathematical transformation of the reference frame of system a-b-c in the rotating system d-q-0. Thus, it allows one to replace the three – phase AC motor by the two – phase unified electrical machine and consider synchronous motor in the frame d-q [4].

The synchronous motor is considered in the frame d-q, because the closed-loop system has two closed current loops which are located on d-axis and q-axis. Formation of electromagnetic torque in a transient process is required determined response of both the closed current loop and the closed flux loop [5].

However, crucial importance for response is the closed current loop. Turning of the closed current loop and the closed flux loop is carried out by standard transient process, which accords to the Butterworth filter [6].

We shall assume that the supply ofexcitation winding is done from a system that ensures a constant excitation currenti_f. The stator winding supply is done from a frequency transducer. (Figure 1)
We should pay attention on the possibility of two sides exchange of energy between the electromotor and the sector.

If the frequency transducer has a single side energy transfer capability, then the synchronous machine can only function in motor regime.For the design of control algorithm of synchronous electromotor, we shall assume that the frequency transducer (FT) designs the phase voltages system:

$$U_S^T = [u_A u_B \ u_C]$$

The input signal of the transducer U_S^* corresponds with the voltageU_S. This could always be done by the choice of basic voltage value of control installation. The frequency transducer has high fast action, greater than the electromagnetic processes speed in synchronous electromotor and it is considered as a proportional element.

II. ENSURING A CONSTANT EXCITATION CURRENT

To ensure the constant magnetization current is possible by variation of excitation winding voltage u_f.For that purpose, it is necessary to design a stabilization system of excitation current. As excitation winding model, we use the equation:

$$R_f . i_f + (L_f + L_d^{'}) . Pi_f + L'_d . Pi_{1d} = u_f \qquad (1)$$

In per units system it can be transformed as follows:

$$(i_f^* + T_f.Pi_f^*).R_f^* = u_f^* - F^* \qquad (2)$$

Where $F^* = R_f^*.T_{df}.Pi_{1d}^*;\ T_f = (L_f + L'_d)/R_f;\ \ T_{df} = L'_d/R_f$

In that equation, the excitation winding current i_f^* is considered as output signal, the excitation winding voltage u_f^* as a control signal, F^* - as perturbation signal. The equation (2) matches with the structural circuit shown on figure 2.

When we install the excitation current regulator on technical optimum,

$$W_R = R_f^*/(2.R_0^*.T_f.P)$$

Where R_0^* - feedback coefficient on excitation winding current. The time constant of control loop for excitation winding current in that case is increased two times compared with open loop system.

The level of signal x_f^*can be recommended so that the excitation coefficient will have the value

$$\mu = E_f/U_B = 1$$

Where U_B- stator basic voltage;

$E_f = \omega_0.L_{dd}.i_f$.

From the equality$\mu = 1$, we have $i_f^* = 1/L_{dd}^*$and $x_f^* = R_0^*/L_{dd}^*$.

It should be noted that we can have a constant excitation current by the supply of excitation winding from constant voltage source. The time constant T_f is between $[0{,}15 - 0{,}3]$ seconds.

III. ALGORITHM OF CONSTRUCTION OF STATOR CURRENT DYNAMICS FOR SYNCHRONOUS ELECTROMOTOR

For the design of electromagnetic processes dynamics in synchronous machine stator winding, we use the following equations:

$$u_{1d} = R_1 i_{1d} + L''_d P i_{1d} - \omega.L''_q i_{1q}; \qquad (3)$$
$$u_{1q} - E_f = R_1.i_{1q} + L''_q.Pi_{1q} + \omega.L''_d i_{1d}$$

Where $E_f = \omega.L_{dd}.i_f(0);\ i_{1d} \approx i''_{1d};\ i_{1q} \approx i''_{1q}$

The variables i_{1d} and i_{1q} are considered as output signals.

u_{1d}andu_{1q} as control signals, whileE_f- as perturbation signal.

The structural circuit of simplified model for synchronous electromotor corresponding to equations (3) is represented on figure 3.

The time constants of regulators are chosen such that currents control loops will have etalon transient functions.

Control signals $V_d^*$and V_q^*constitute control signal vector$V_0{}^T = [V_d^*, V_q^*]$. The vector V_0 is given such that the value of electromagnetic torque is ensured.

IV. THE ALGORITHMS OF CONTROL SIGNALS VECTOR CONSTRUCTION

Electromagnetic torque of synchronous electromotor on pair of poles and pair of phases is defined as follows:

$$M = 2.L_m.i_{1d}.i_{1q} + L_{dd}.i_{1q}.i_f + (L_{dd}.i_{1q}.i_{2d} - L_{qq}.i_{1d}.i_{2q})$$

It has three components: the reactive, the synchronous (main) and the asynchronous.

The reactive component of electromagnetic torque is proportional toL_m, the synchronous proportional to L_{dd}.

The synchronous torque for constant excitation current i_f is proportional to stator currenti_{1q}.

The asynchronous electromagnetic torque depends on damping winding currentsi_{2d}, i_{2q}. Since they are equal to zero in stationnary functionning regime, the asynchronous electromagnetic torque can only occur in dynamic regime with $Pi_q \neq 0$and$Pi_d \neq 0$.

If we neglect asynchronous and reactive components, then $M = L_{dd}.i_{1q}.i_f$. Thus for constant excitation current i_f, the torque is determined only by the currenti_{1q}.

Therefore, we can stabilize the current i_{1d} and maintain in a given level, necessary to control the rotor rotation speed. If in per units $i_f^* = 1/L_{dd}^*$, then the synchronous electromagnetic torque$M^* = i_{1q}^*$. From there the control signals vector $V_0 = [0 \quad M^*]^T$

Another method to construct V_0 is based on that, to control electromagnetic torque with maximal value of energy efficiency coefficient:

$$E = \frac{M^*}{\Delta P_E} = \frac{2.L_m^*.i_{1d}^*.i_{1q}^* + L_{dd}^*.i_{1q}^*.i_f^*}{R_1^*.\left(i_{1d}^{*2} + i_{1q}^{*2}\right) + R_f^*.i_f^{*2}}$$

It has its maximal value for

$$i_{1q}/i_{1d} = C = \sqrt{1 + L_{dd}^2.R_1/(4L_m^2.R_f)}$$

By using that expression and the electromagnetic torque $M^* = 2.L_m^*.i_{1d}^*.i_{1q}^* + i_{1q}^*$, and $V_q^* = i_{1q}^* = \left[\sqrt{\frac{C.M^*}{8.L_m^*} + \left(\frac{C}{4.L_m^*}\right)^2} - \frac{C}{4.L_m^*}\right] \approx M^*$;
$V_d^* = i_{1d}^* = i_{1q}^*/c$,where $\mathrm{i}_\mathrm{f}^* = 1/\mathrm{L}_{\mathrm{dd}}^*$
Thus vector of control signal

$$\mathrm{V}_0^\mathrm{T} = \left[\mathrm{V}_\mathrm{d}^*\mathrm{V}_\mathrm{q}^*\right] \approx \mathrm{M}^*.[1/\mathrm{C} \qquad 1].$$

That expression ensures maximal energetic control efficiency of the synchronous machine.

V. INFORMATION INSURANCE OF CONTROL ALGORITHM FOR SYNCHRONOUS ELECTROMOTOR

For the realisation of synchronous machine control algorithm we need information about the rotor position represented in the aspect of rotation matrix$\nabla(\gamma)$,

Whereγ- rotation angle of magnetic symmetry axis d relatively to magnetic axis of phase A for stator winding.

To execute the control algorithm, we also need information on stator winding current vectorI_1. We can get it from stator currents in captors.

$$\mathrm{I}_s^* = [\mathrm{i}_\mathrm{A}^*.\mathrm{i}_\mathrm{B}^*\mathrm{i}_\mathrm{C}^*]^\mathrm{T}.$$

If we assume that stator currents I_s^* are represented in per units, then parameters matrix for feedback connection $\mathrm{K}_0 = 1$ and $\mathrm{I}_1^* = 2/3.\nabla(\gamma)^\mathrm{T}.\mathrm{D}_\mathrm{S}.\mathrm{I}_s^*$.

The presence of angle captor γ simplifies the construction of control signal for the frequency transducer.

$$\mathrm{U}_\mathrm{S}^* = \mathrm{D}_\mathrm{S}^\mathrm{T}.\nabla(\gamma).\mathrm{U}_1^*,$$

Where ${\mathrm{U}_1^*}^\mathrm{T} = \left[\mathrm{u}_{1\mathrm{d}}^*\mathrm{u}_{1\mathrm{q}}^*\right]$ is calculated according to the structural circuit figure 3a.

VI. CONCLUSIONS

For the construction of a given synchronous machine electromagnetic torque by the means of action on rotor voltage, we need rotor position captor and stator currents captors. The construction of stator currents $\mathrm{i}_{1\mathrm{d}}, \mathrm{i}_{1\mathrm{q}}$dynamics can be done by control loops with feedback connections. These destroy oscillating character of the dynamic processes and by proportionnal integral regulators. The input signal on stator currents vector is better constructed with consideration of optimal losses in stator winding.

The control of electromagnetic processes assumes the availability of information on rotor position. The evaluation of rotor position is possiblethrough information on rotor currents and rotor voltages.

REFERENCES

[1]. A.S. Maklakov, A.A. Radianov, EMC evaluation of three level NPC converter based on space vector PWM, Proceedings of the 2015 IEEE North West Russia Section Young Researchers in Electrical and Electronic Engineering Conference, ElConRusNW 2015.(2015) 236-240.DOI:10.1109/EIConRusNW.2015.7102269

[2]. A.A. Radianov,A.S. Maklakov, E.A Karyakina, New control method of back to back converter, 2015 International Siberien Conference on Control and Communications, SIBCON 2015 – Proceedings – (2015).DOI:10.1109/SIBIRCON.2015.7147135

[3]. A.A. Radianov, O.S. Malakhov, S.N. Baskov, A.S. Konkov, M.S. Davydkin, The design features of the converters for synchronous motors vector-pulsed launch control, Proceedings – 2010 IEEE Region 8 International Conference on Computational Technologies in Electrical and Electronics Engineering SIBIRCON-2010.(2010)608-610.DOI:10.1109/SIBIRCON.2010.5555140

[4]. O.V. Slezhanovskij, L.H. Dackovskij, I.S. Kuznecov, Sistemi podchinennogo regulirovanija jelektroprivodov peremennogo toka s ventil'nymi preobrazovateljami, Energoatomizdat, Moscow, 1983.

[5]. A.A. Radianov, S.A. Evdokimov, A.S. Karandaev, V.R. Khramshin, Information and measurement system for control of technical state of asynchronous electric motors with group supply from frequency converter, 12th International Conference on Actual Problems of Electronic Instrument Engineering, APEIE 2014 – Proceedings. (2014) 280-285.DOI:10.1109./APEIE.2014.7040897

[6]. P.V. Shilyaev, I. Yu. Andryushin, V.V. Golovin, A.A. Radianov, A.S. Karandaev, V.R. Khramshin, Algorithms of a digital automatic system for tension and loop control in a wide-strip hot-rolling mill, Russian Electrical Engineering. 84(10) (2013) 533-541. DOI:10.3103/S106837121310009X

FIGURES

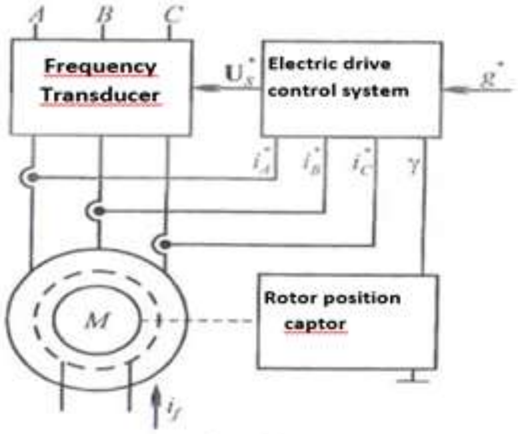

***Figure 1**: Electric drive of synchronous electromotor with frequency transducer*

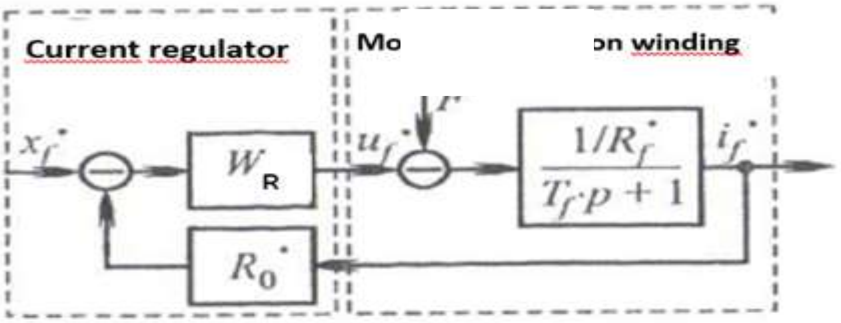

***Figure 2**: Control loop of excitation current*

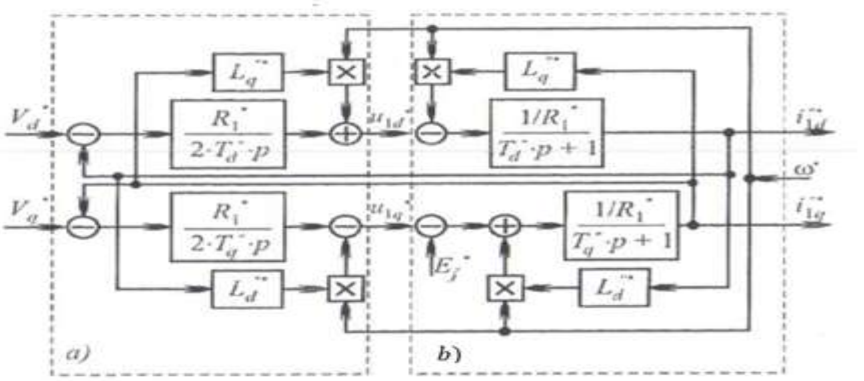

***Figure 3**: Structural circuit of stator currents control system*

a) Control system *b) Synchronous machine model*

Biya Motto Frederic"Control Of Synchronous Electromotor by Voltage Parameters Change in Stator Winding With Constant Excitation Current"International Refereed Journal of Engineering and Science (IRJES), vol. 07, no. 08, 2018, pp.12-15