SYNTHESIS OF SYNCHRONOUS MOTOR SERVO SYSTEM IN MATLAB

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Abstract

Model of synchronous motor in this paper has been design for verification of designed structure of PID controller. Design of the servo system described in this paper has been verified by experiments, where properties of individual parts of the designed controllers were studied. Simulation results and real system behaviour are compared.

1 Introduction

This paper deals with control of a real system – servo system. PID controller for control of motor revs is designed by the pole placement method. Each of the designed control loops is verified by a simulation model before a test on the real system.

MATLAB-Simulink is the main simulation software. For the life test with the frequency drive MATLAB Simulink Real-Time Toolbox is used.

2 Design of PID controller

The controller is used in a closed loop unity feedback system according to Fig. 1. The simplified model of permanent magnet of synchronous motor (PMSM) is joined with PID controller; $G_p(s)$ is the transfer function of pre-correction, K_p, T_i, T_d – parameters of PID controller, T_{gm} – time constant of moment generator, J - moment of inertia, B – coefficient of viscose friction.

The parameters of PID controller are designed by pole placement method according to block scheme from Fig. 1 (without the pre-correction block).

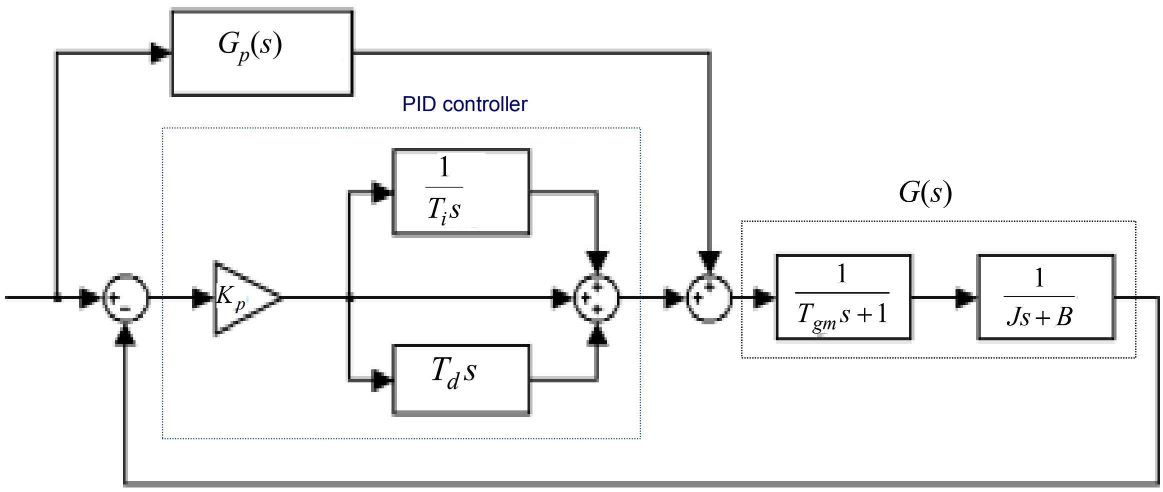

Figure 1: Block scheme of closed loop control system

Pole placement method is one of the classic control theories and its advantage in system control is for the possibility to control the system with desired performance. Theoretically, pole placement means to set the desired pole location and to move the pole location of the system to a desired pole location to get the desired system response. Mathematically, once the system transfer function is defined, the desired transfer function should be also defined, and then each coefficient in the same order in polynomial is compared to be the same.

Transfer function of the closed loop system is:

$$G_{URO}(s)=\frac{K_p\left(1+\frac{1}{T_i s}+T_d s\right)\frac{1}{T_{gm}s+1}\frac{1}{Js+B}}{1+K_p\left(1+\frac{1}{T_i s}+T_d s\right)\frac{1}{T_{gm}s+1}\frac{1}{Js+B}}=\frac{K_pT_iT_ds^2+K_pT_is+K_p}{T_iT_{gm}Js^3+T_i\left(T_{gm}B+J+K_pT_d\right)s^2+T_i\left(B+K_p\right)s+K_p}=$$

$$=\frac{\frac{K_pT_iT_ds^2+K_pT_is+K_p}{JT_iT_{gm}}}{s^3+\frac{T_{gm}B+J+K_pT_d}{JT_{gm}}s^2+\frac{B+K_p}{JT_{gm}}s+\frac{K_p}{JT_iT_{gm}}} \tag{1}$$

The desired poles are adjusted and the desired characteristic equation becomes:

$$\left(s^2+2\zeta\omega_0 s+\omega_0\right)\left(s+k\omega_0\right)=s^3+\left(k\omega_0+2\xi\omega_0\right)s^2+\omega_0^2\left(1+2\xi k\right)s+k\omega_0^3 \tag{2}$$

where k - complex conjugates poles shift towards simple pole,
ω_0- passband,
ξ - damping.

When the desired characteristic equation (2) is compared with the characteristic equation of the closed loop system, parameters of the PID controller are obtained:

$$k\omega_0+2\xi\omega_0=\frac{T_{gm}B+J+K_pT_d}{JT_{gm}}\Rightarrow T_d=\frac{\left(k\omega_0+2\xi\omega_0\right)JT_{gm}-T_{gm}B-J}{K_p}$$

$$\omega_0^2\left(1+2\xi k\right)=\frac{B+K_p}{JT_{gm}}\Rightarrow K_p=\omega_0^2\left(1+2\xi k\right)T_{gm}J-B \tag{3}$$

$$k\omega_0^3=\frac{K_p}{JT_iT_{gm}}\Rightarrow T_i=\frac{K_p}{kJT_{gm}\omega_0^3}$$

The chosen parameters are $\omega_0 = 2\pi f$ [rad/s], f = 15Hz , k = 4 a ξ = 1.

Transfer function of pre-correction is calculated:

$$G_p(s)=\frac{1}{G(s)}=\frac{1}{\frac{1}{T_{gm}s+1}\frac{1}{Js+B}}=K_2s^2+K_1s+K_0=T_{gm}Js^2+\left(T_{gm}B+J\right)s+B \tag{4}$$

3 Case study

Each of the designed control loops is verified by a simulation model before a test on the real system. MATLAB-Simulink is the main simulation software. For the life test with the frequency drive MATLAB Simulink Real-Time Toolbox is used. The frequency drive is connected via MF624 Input/Output card, providing 14-bits analogue inputs and outputs plus 8 digital inputs and outputs. Incremental speed sensor input is also used.

Real servo system consists of synchronous motor with permanent magnets, driven by industrial frequency drive UNIDRIVE and a DC motor serving as the driven load. In this design the DC motor is uncontrolled, acting as a passive load. At the controller design its parameters must be also taken into account.

Rotor PMSM uses permanent magnets as magnetic field source**.** This construction has advantages compared to rotors with field winding. Motors with electronic commuter are divided based on their construction: disc and cylindrical [2], see Fig. 2. Disc motors have very small moment of inertia, what allows to use them in dynamic demanding applications.

Motors with cylindrical rotor are divided by position of the magnets: external and internal. Rotor with external magnets position is similar to smooth-core rotor of asynchronous machines. Rotor with internal magnets position is similar to rotor with expressed poles.

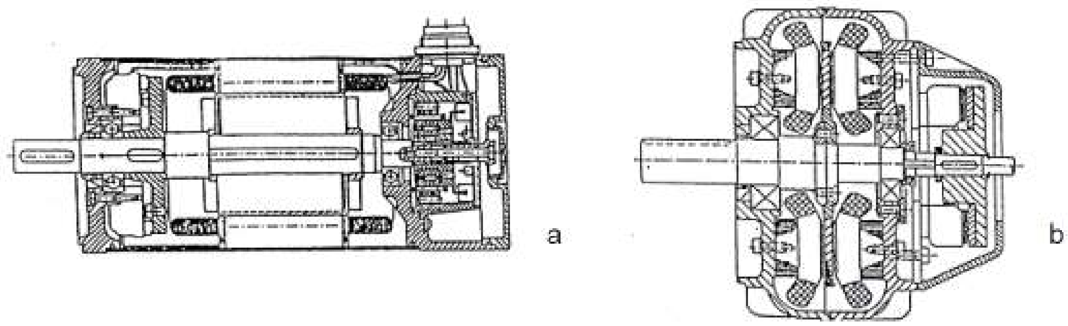

Figure 2: a) synchronous motor with cylindrical rotor
b) synchronous motor with disc rotor

Servo system consists of a synchronous motor "POWER T56SR0.5", which is a synchronous motor with cylindrical rotor (Fig. 2 a) and frequency drive "UNIDRIVE SP1401".

4 Simulation Results

The experiment is to run-up to desired angular velocity of 100 rad/s with master-slave control. The speed 100 rad/s was chosen because of physical limits of the real motor. Time responses of the angular velocity (ω), control error (e_w) and desired moment of motor (M_m) are shown in Fig. 3-5.

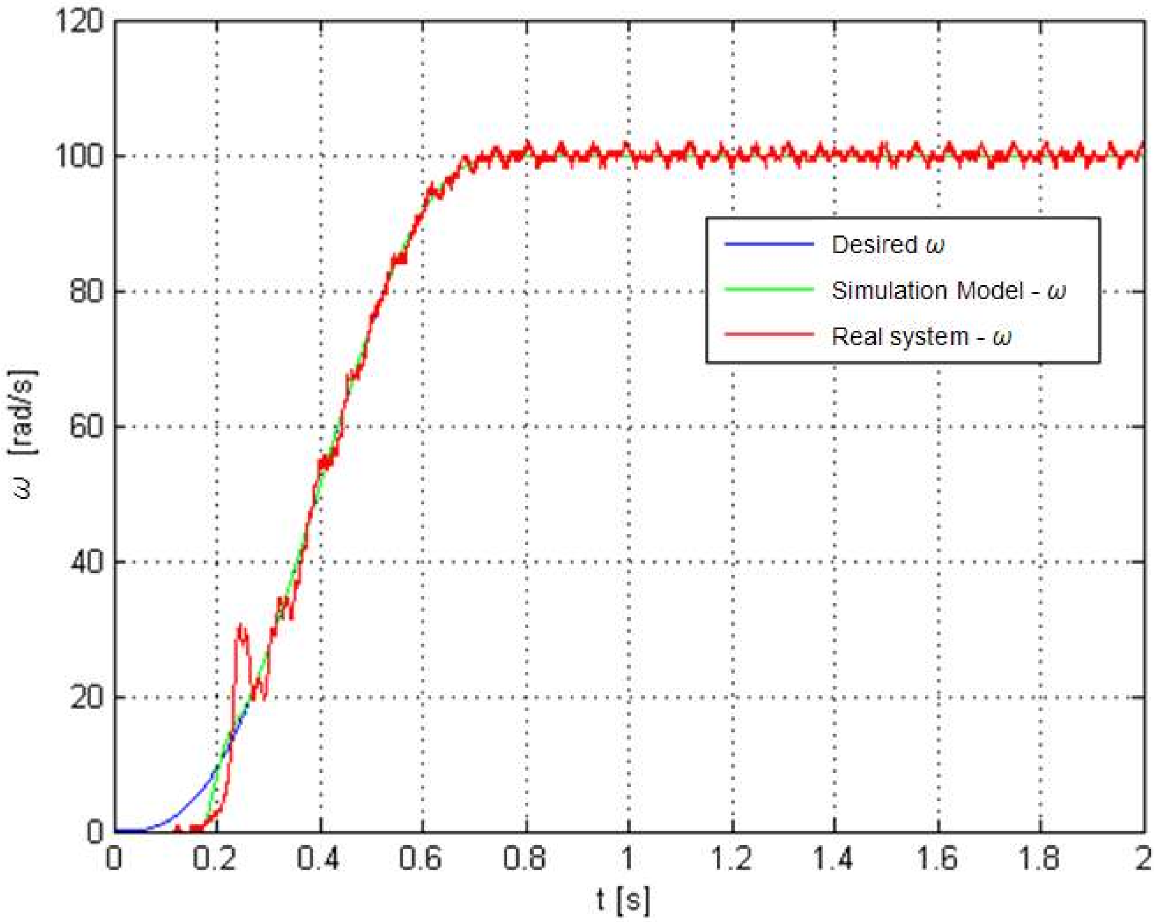

Figure 3: Time response of the angular velocity

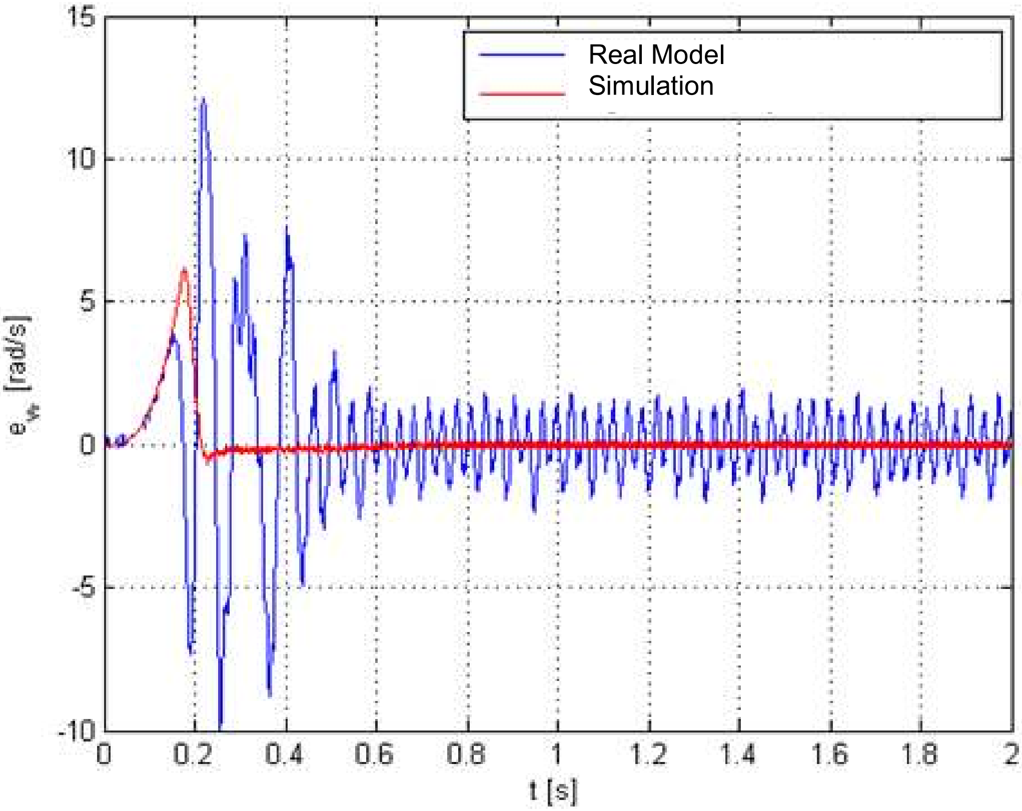

Figure 4: Time response of control error (ω=100 rad/s)

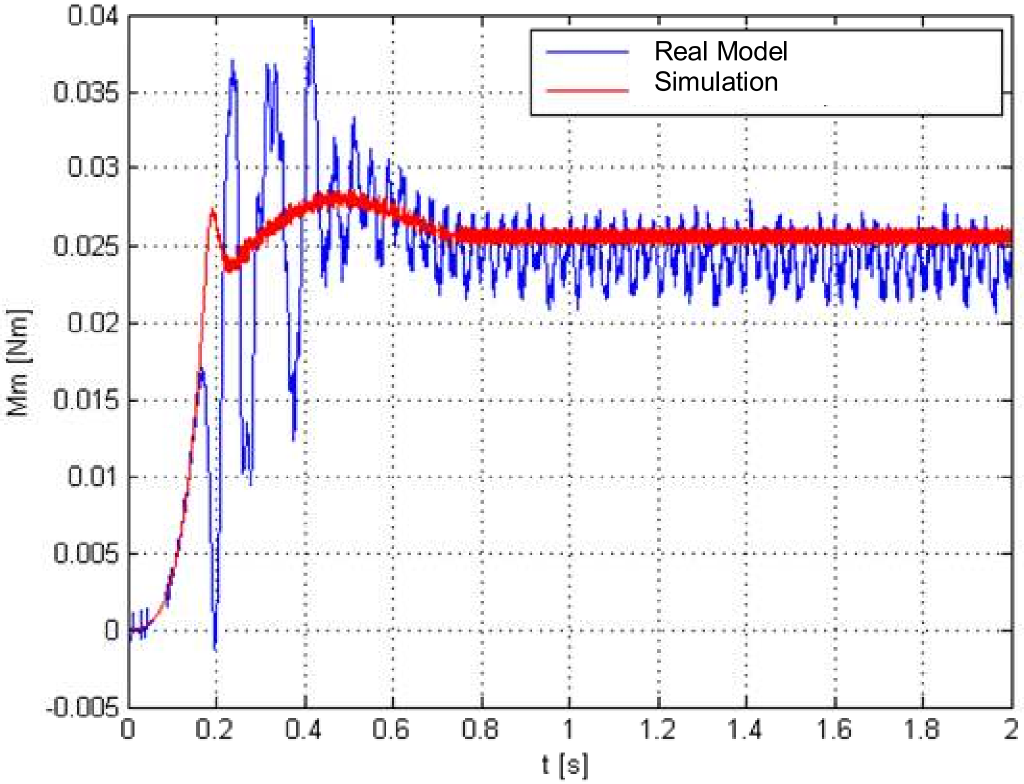

Figure 5: Time response of motor moment (ω=100 rad/s)

5 Conclusion

Based on the experiment, it is possible to say, that a mathematic model can be used to simulate the real time behaviour of a motor - frequency driver system. The differences between the time responses of real system and simulation model were caused by unmodeled dynamics of the motor. The differences at the motor run-up were mostly caused by dry friction in bearings of the motor. Oscillations of real motor rpm around the simulated rpm value were mostly caused by irregular position of magnetic flow caused by magnets position in rotor.

ACKNOWLEDGMENT

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References

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