Lab 3. Synchronous motor drive modelling

Name: Zhu Chenhao

ITMO ID: 375462

Specialization: Automation

Objective

The purpose of the work is to get acquainted with the modeling of actuators based on synchronous machines with permanent magnets, the modeling of brushless DC motors and the development of vector control of synchronous motors.

Initial data

Parameter	R_s	L_s	Ψ_f	Z_p	J	U_{DC}	T_S
Value	17.566	0.0311	0.125	16	3.97	48	0.0001

1. Build a mathematical model of a sinusoidal pulse-width modulator in Matlab / Simulink.

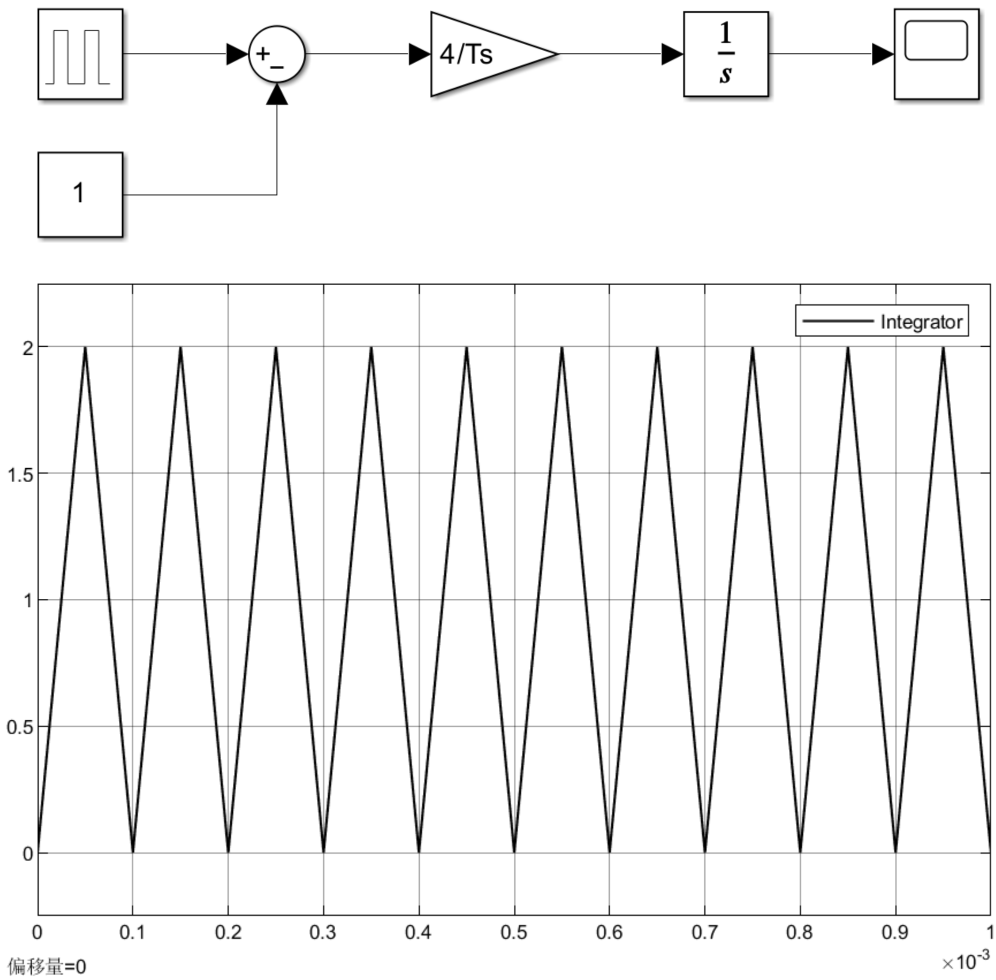

Figure 1a. Triangle wave signal generator.

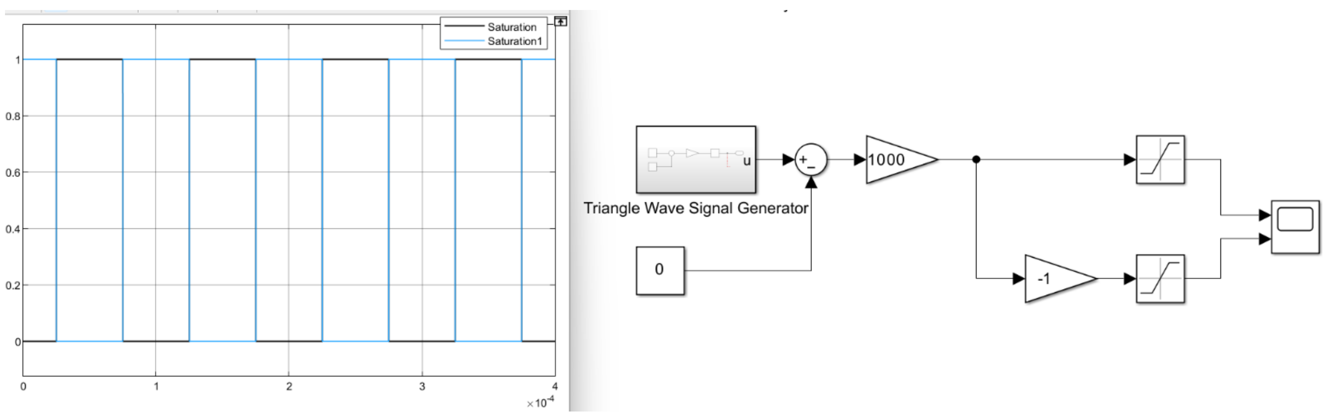

Figure 1b. PWM model.

2. Assemble a mathematical model of a three-phase inverter in Matlab / Simulink.

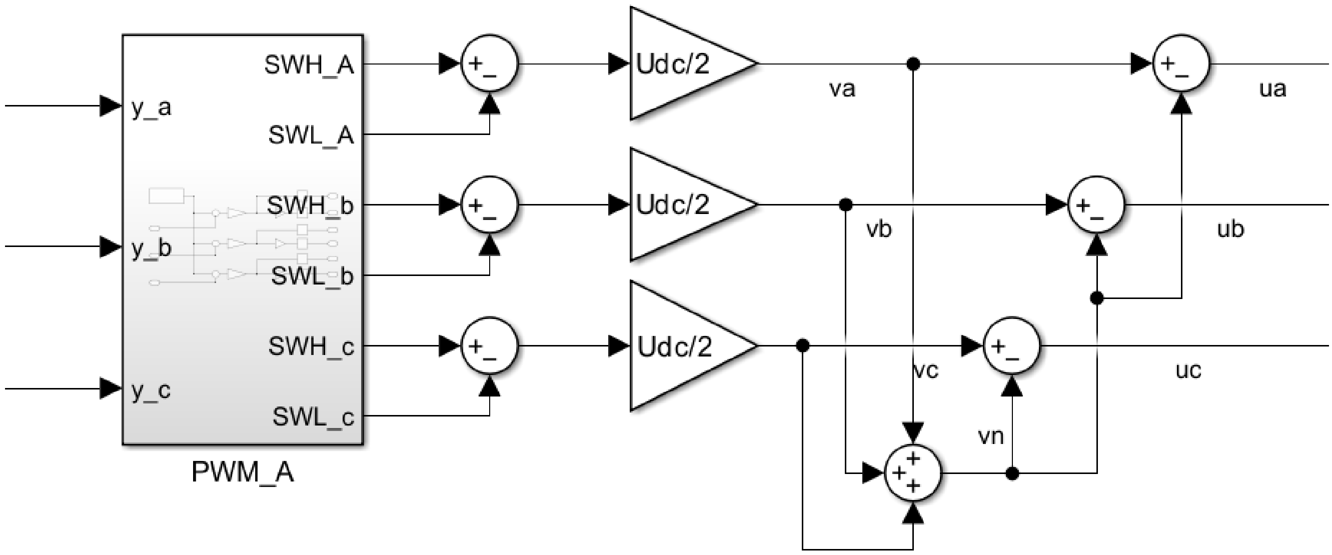

Figure 2. Mathematical model of three-phase inverter.

3. Assemble a mathematical model of a synchronous machine in the rotor coordinate system dq in Matlab/Simulink.

$$\frac{dI_d}{dt} = \frac{1}{L_s}\left(U_d - R_s I_d + Z_p L_s I_q \Omega\right)$$

$$\frac{dI_q}{dt} = \frac{1}{L_s}\left(U_q - R_s I_q - Z_p L_s I_d \Omega - Z_p \Omega \Psi_f\right)$$

$$\frac{d\Omega}{dt} = \frac{1}{J}\left(\frac{3}{2} Z_p \Psi_f I_q - T_{dist}\right)$$

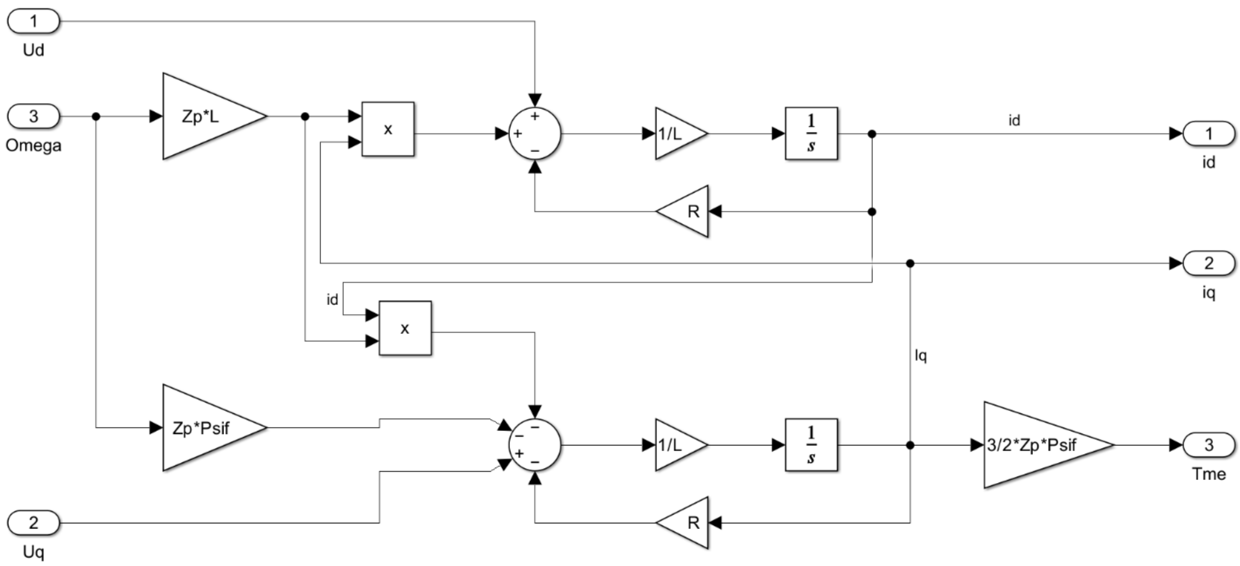

Figure 3a. Simulation model of PMSM (electrical part).

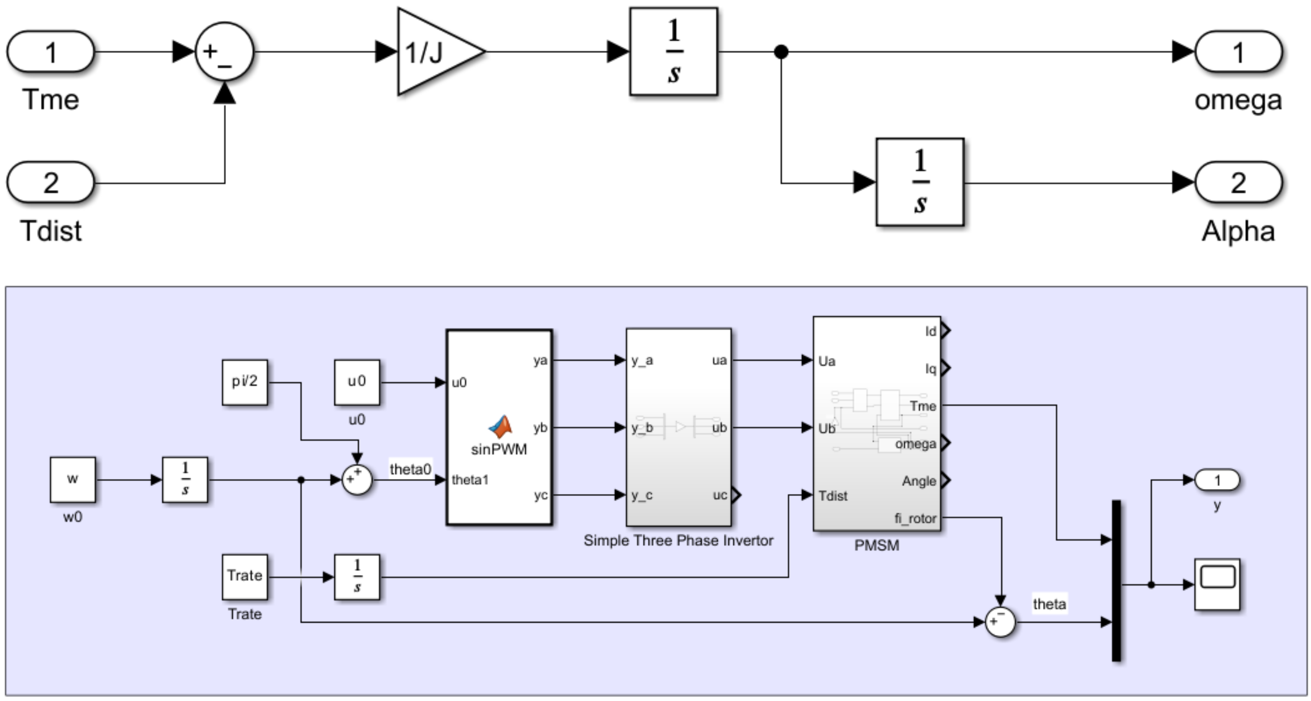

Figure 3b. Simulation model of PMSM (mechanical part).

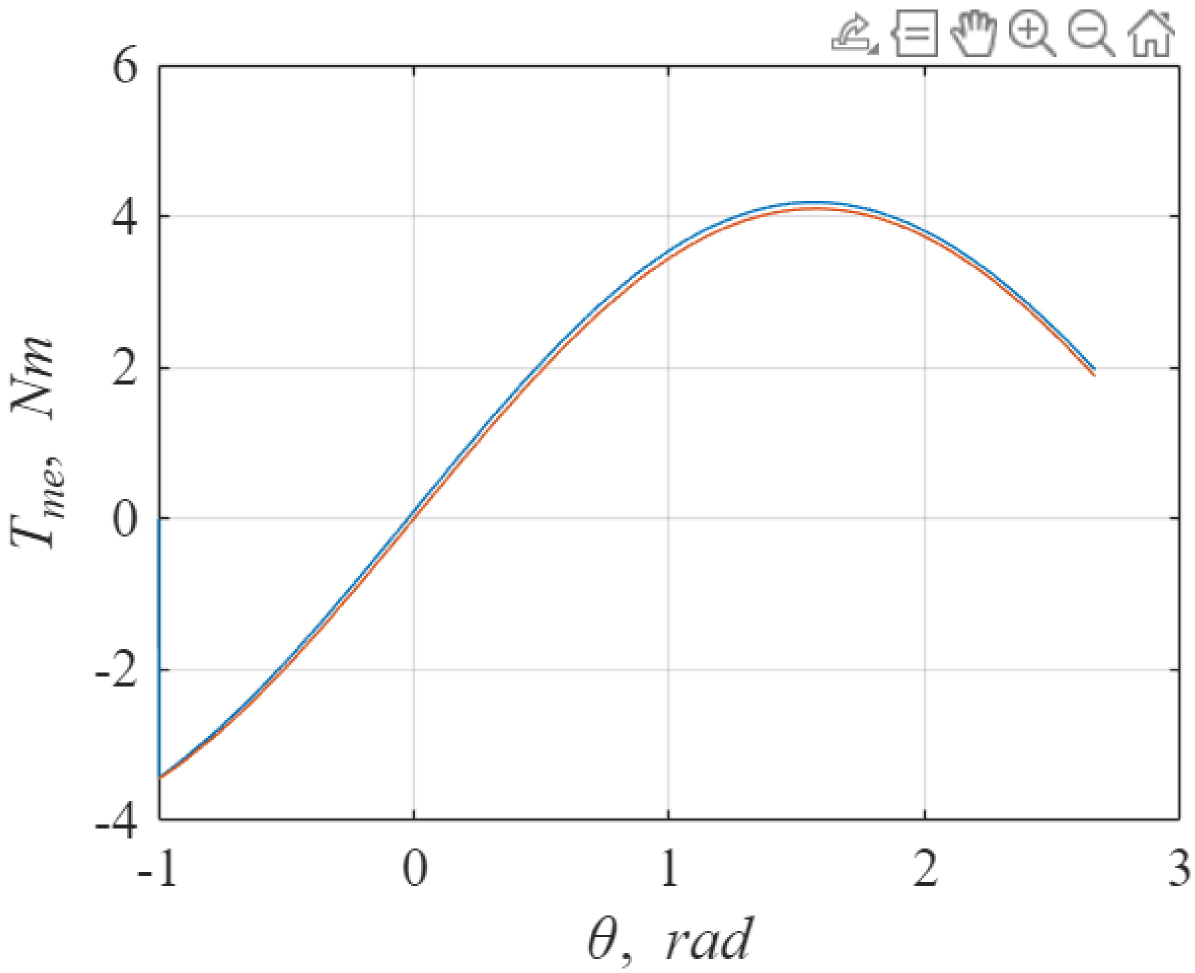

Figure 4. Experimental and calculated angle characteristics.

4. Assemble a brushless DC motor based on the obtained mathematical models in Matlab / Simulink.

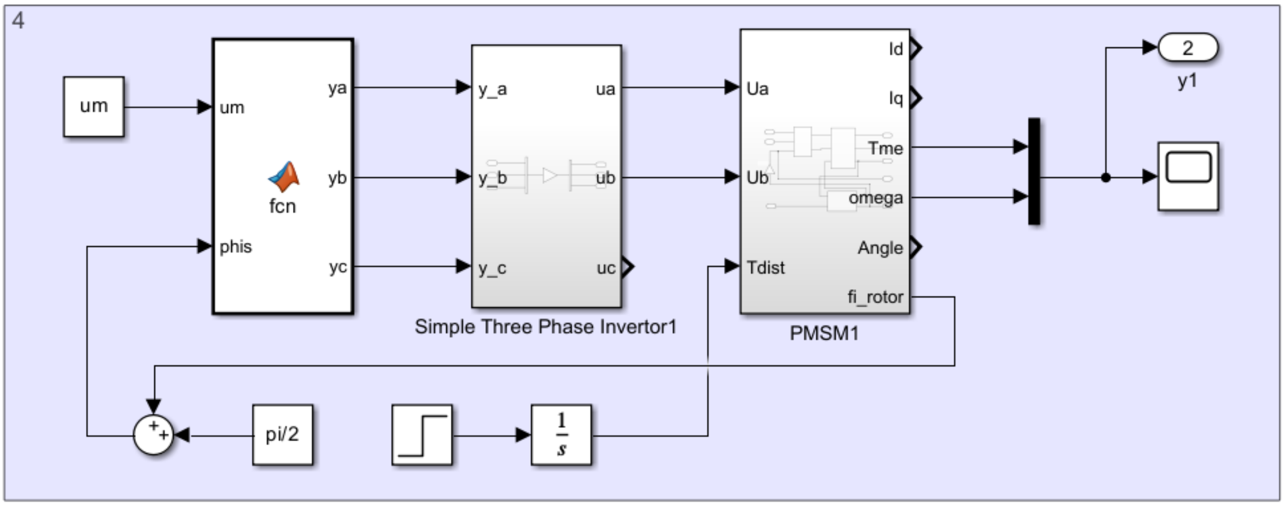

Figure 5. Simulation model of BLDC.

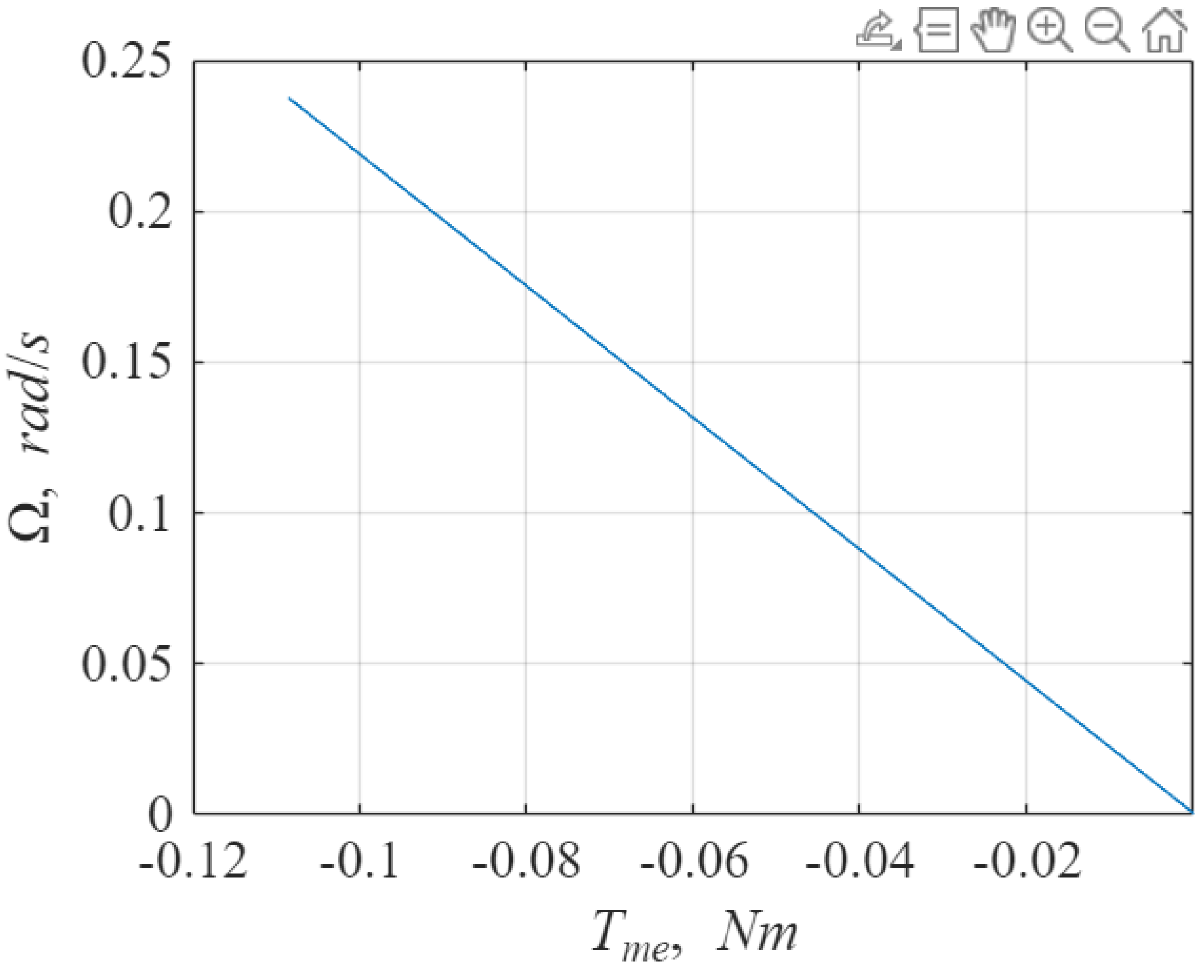

Figure 6. Experimental and calculated speed/torque characteristics.

5. Create a vector control of a permanent magnet synchronous machine in Matlab/Simulink.

For q-axis:

$$Kp = \frac{R_s T_q}{T_T}$$

$$Ki = \frac{R_s}{T_T}$$

$$W_{reg} = \frac{R_s T_q \cdot s + R_s}{T_T \cdot s}$$

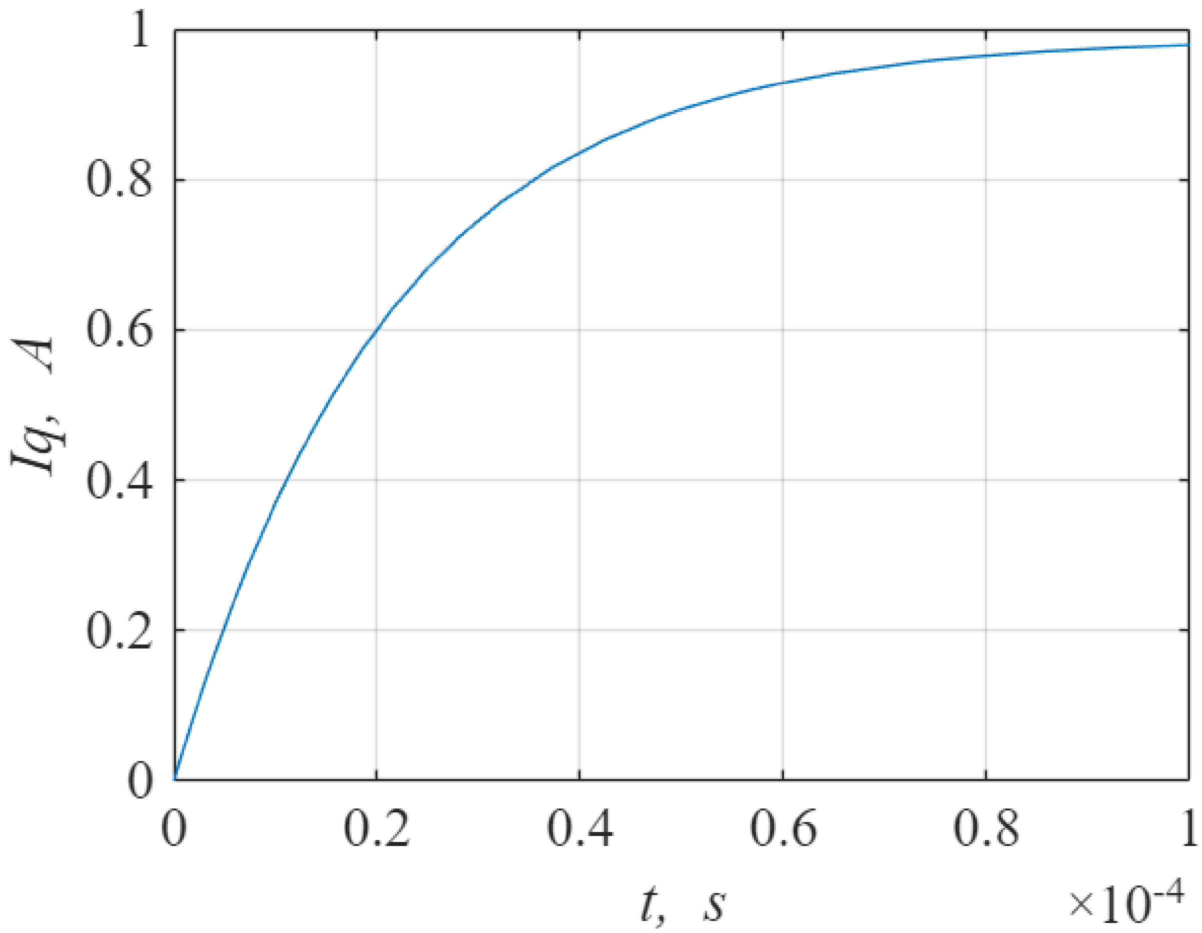

Figure 7. Transient process in current loop.

$$T_T = 0.05$$

$$Kp = 720$$

$$Ki = 175.67$$

$$Tq = 0.0018$$

$$W_{cl.cur}(s) = \frac{1}{T_T s + 1}$$

$$k_m = \frac{3}{2} Z_p \left[\Psi_f + (L_d - L_q) I_d \right]$$

$$I_d = 0 \quad \Rightarrow \quad k_m = \frac{3}{2} Z_p \Psi_f$$

$$Kp = \frac{J}{2T_T K_m}$$

$$Ki = \frac{J}{8{T_T}^2 K_m}$$

$$k_m = 3, T_T = 0.002$$

$$Kp = 331.15$$
$$Ki = 41394$$

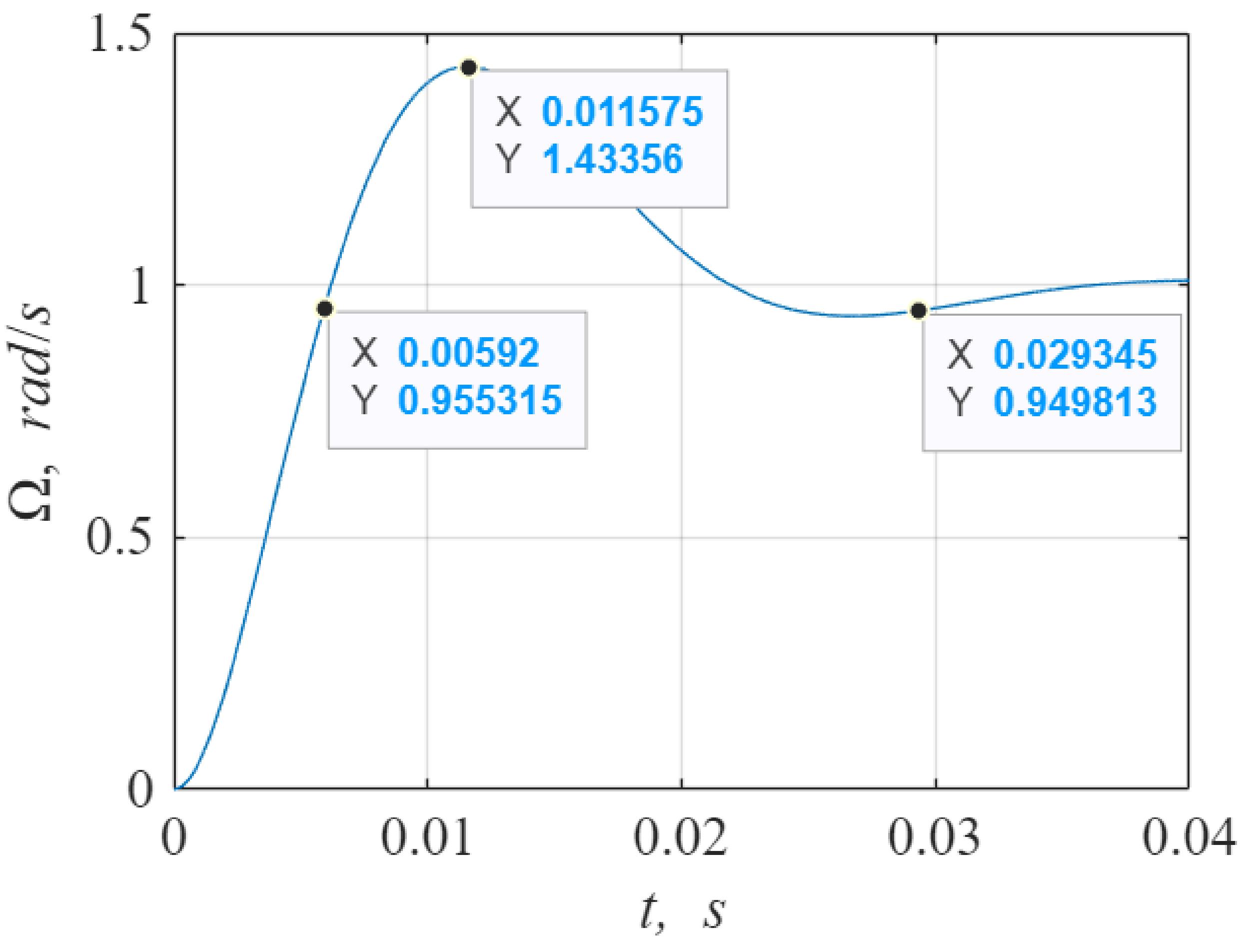

Figure 8. Transient process in speed loop.

Astaticism order: 2

Transient time(95%): tr = 14.5 * T_mu

Overshoot: 0.43

Conclusion:

*In this lab, the mathematical models of a sinusoidal PWM modulator, a three-phase inverter, and a synchronous machine in the dq coordinate system were successfully developed in Matlab/Simulink. Additionally, a brushless DC motor model was assembled, and vector control for a permanent magnet synchronous machine was implemented. The results demonstrated effective transient processes in both current and speed loops, with an astaticism order of 2, a transient time of 14.5 * T_mu, and an overshoot of 0.43. The work provided valuable insights into the modeling and control of synchronous motor drives, achieving the objectives set forth in the lab.*