Lab 3. Synchronous motor drive modelling

Name:Li Xin

ITMO ID:375334

Specialization: Automation

Varinat: 6

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	**19.8089**	**0.0311**	**0.125**	**16**	**3.5310**	**48**	**0.0001**

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

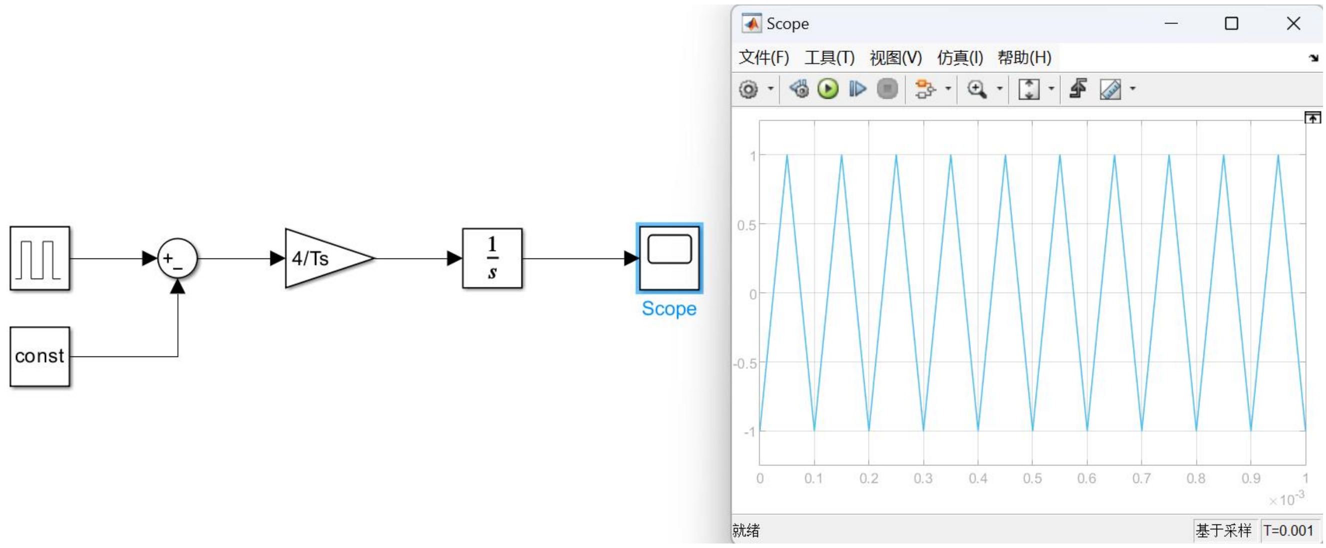

Figure 1a. Triangle wave signal generator.

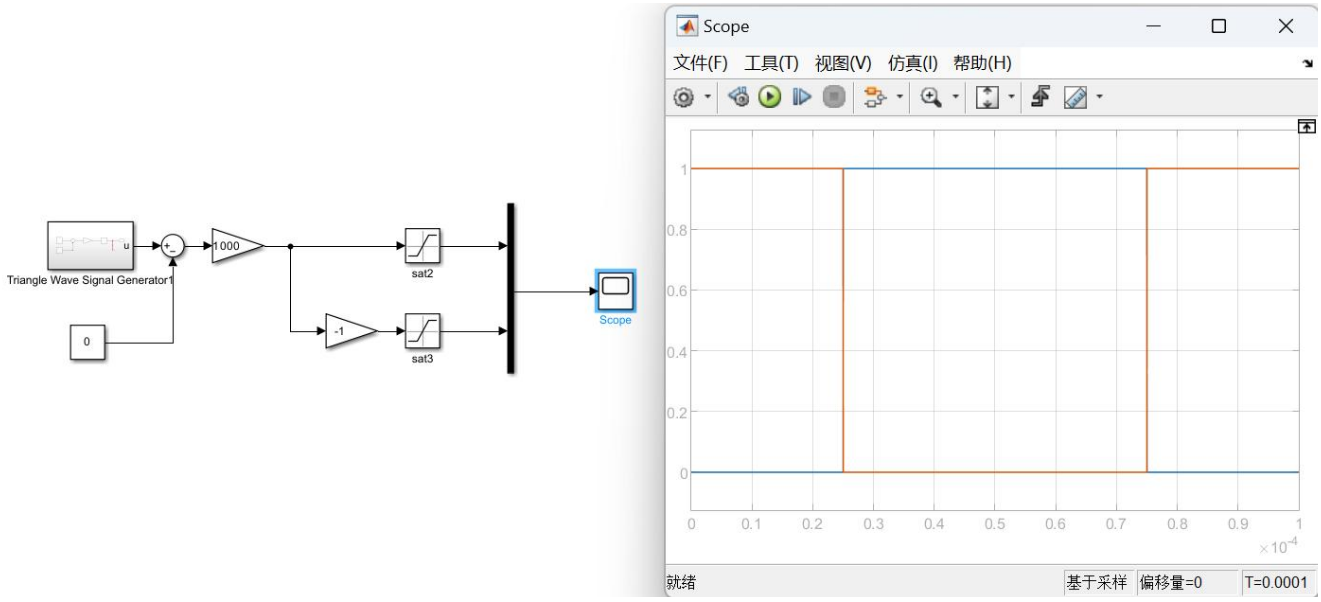

Figure 1b. PWM model.

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

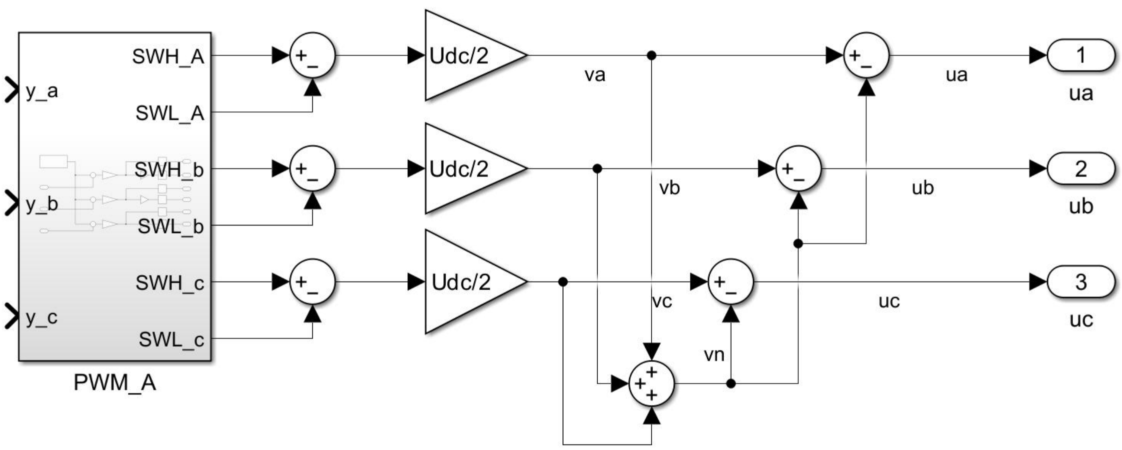

Figure 2. Mathematical model of three-phase inverter.

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

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

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

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

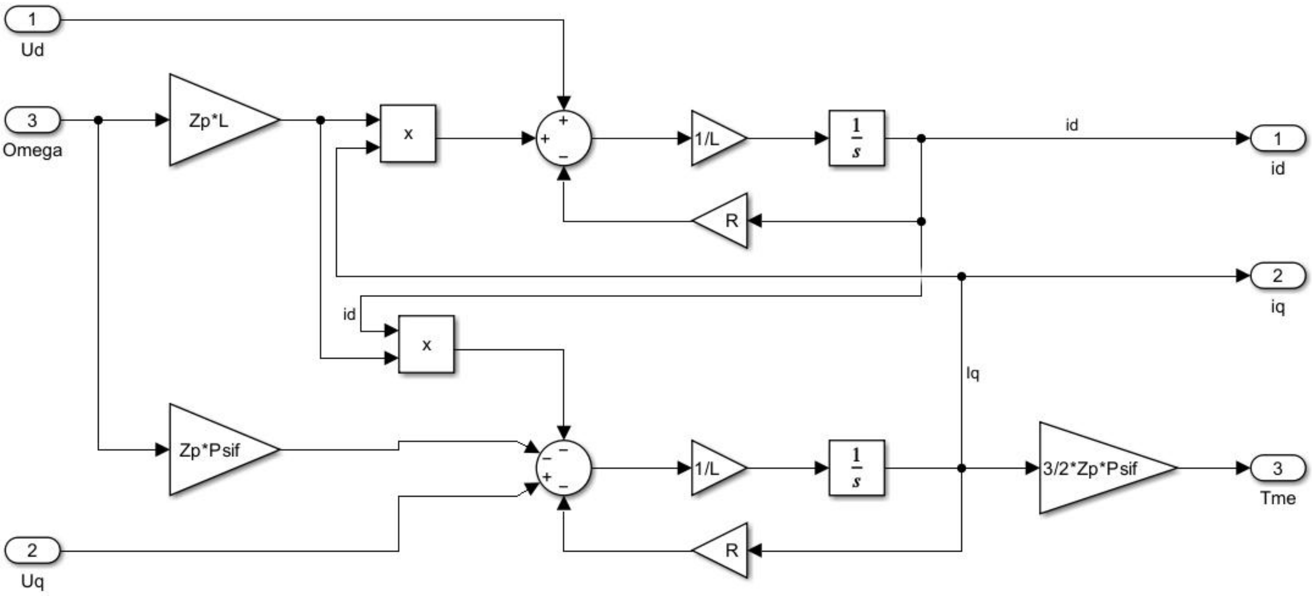

Figure 3a. Simulation model of PMSM (electrical part).

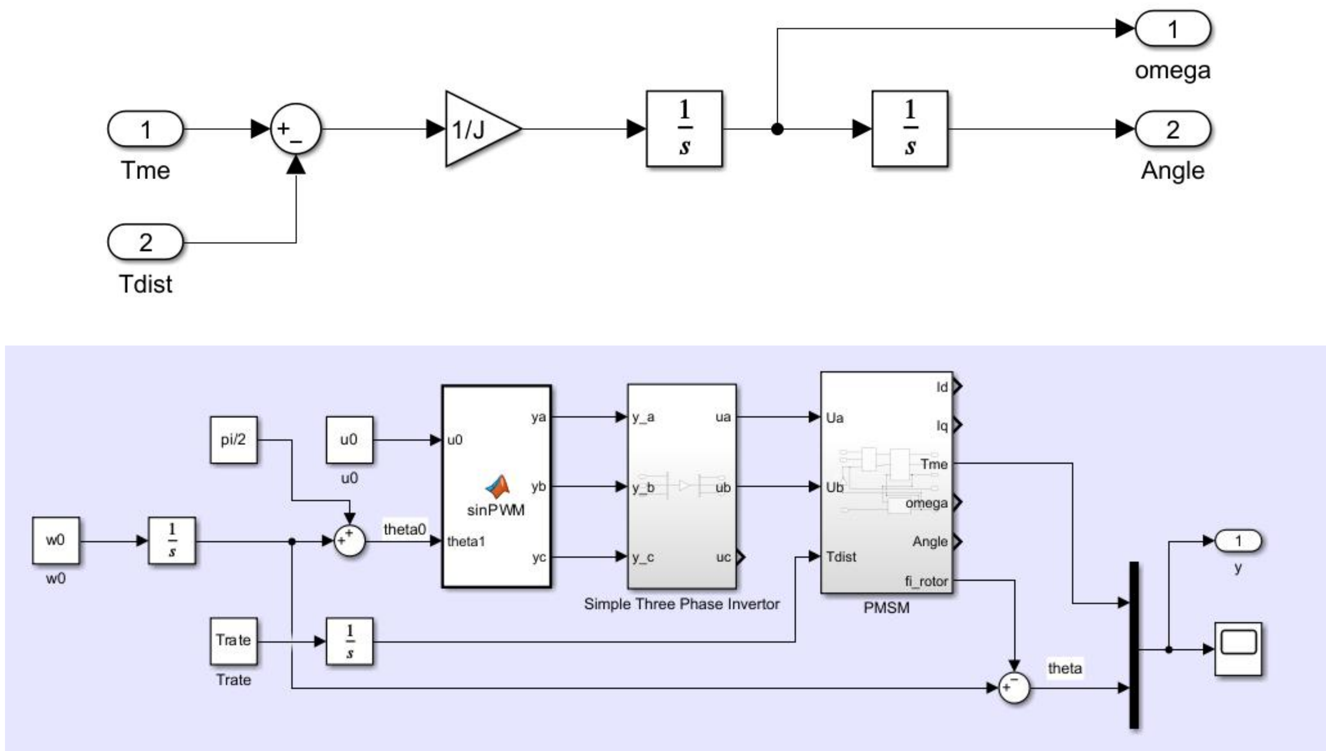

Figure 3b. Simulation model of PMSM (mechanical part).

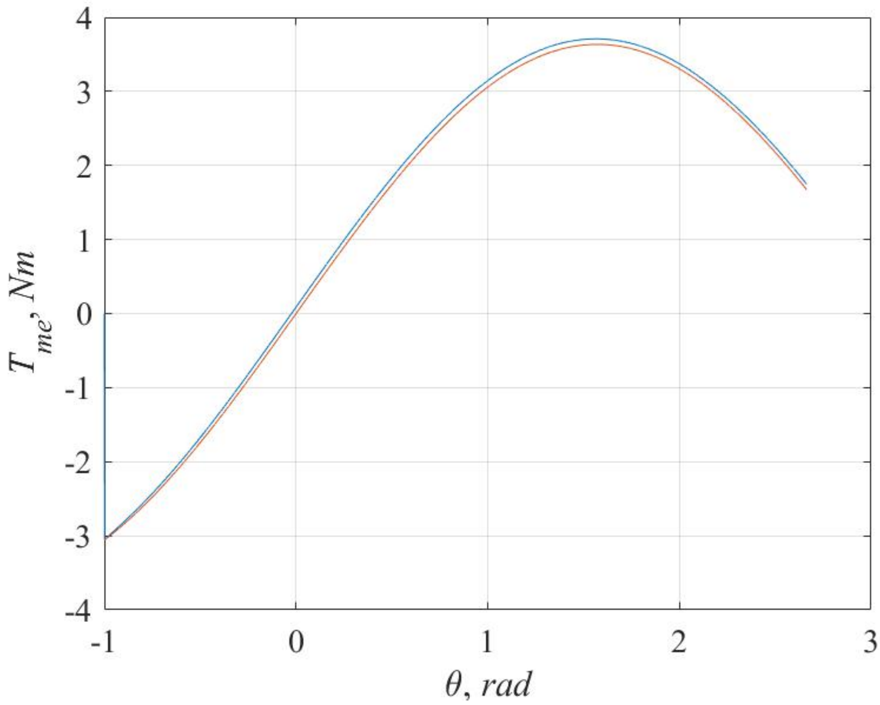

Figure 4. Experimental and calculated angle characteristics.

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

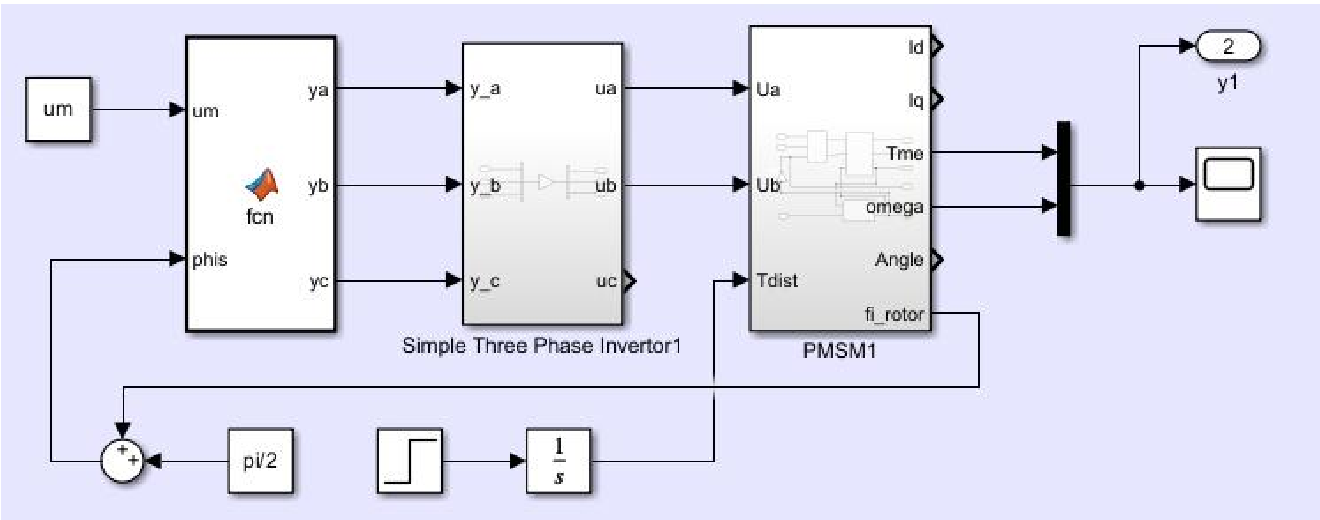

Figure 5. Simulation model of BLDC.

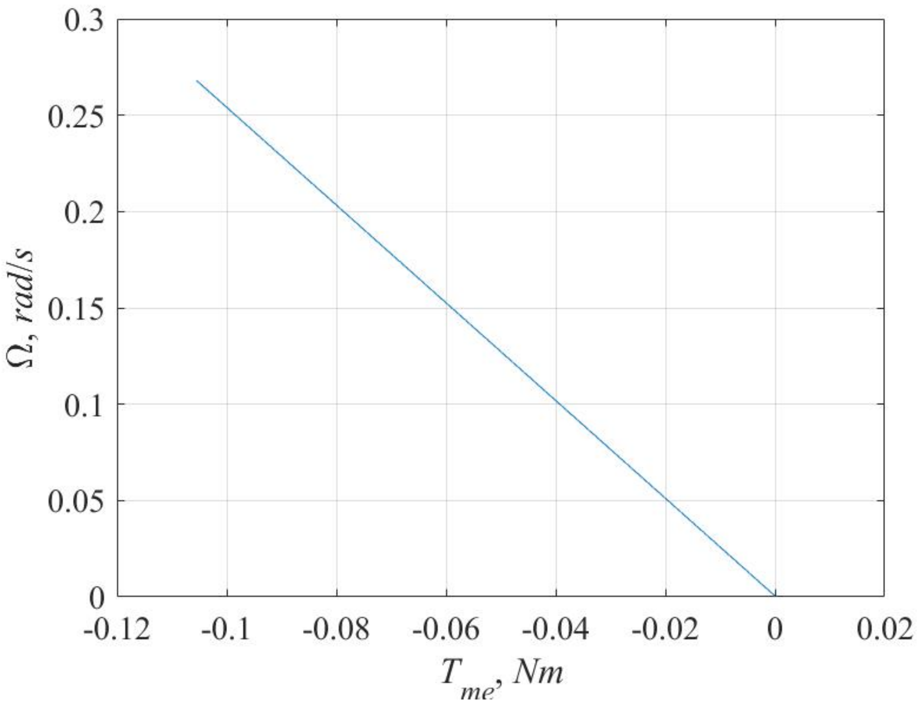

Figure 6. Experimental and calculated speed/torque characteristics.

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

We set T_t ***as 0.05s***

$$T_q = \frac{L}{R} = 0.0016$$

$$K_p = \frac{R_s \cdot T_q}{T_t} = 1440$$

$$K_i = \frac{R_s}{T_t} = 396.1771$$

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

```
Tq = L/R

Tq = 0.0016

T_T = 0.05

T_T = 0.0500

kp = R*Trate/T_T

kp = 1440

ki = R/T_T

ki = 396.1771
```

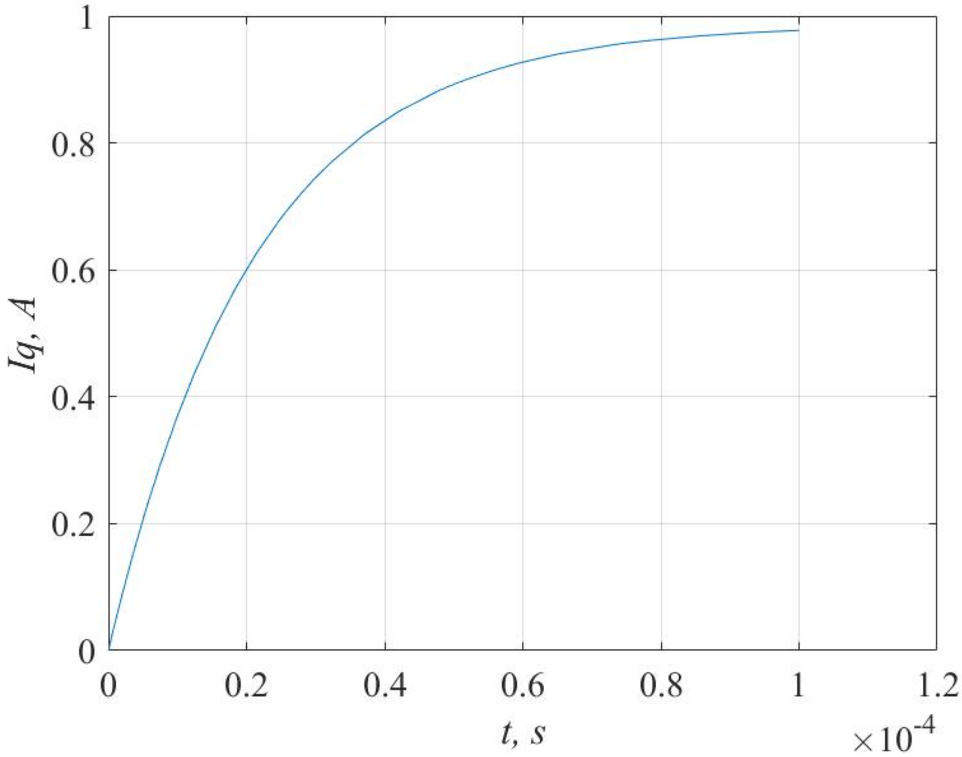

Figure 7. Transient process in current loop.

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

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

$$since\ I_d = 0 \rightarrow K_m = \frac{3}{2} Z_p \Psi_f = 3$$

$$K_p = \frac{J}{2 T_t K_m} = 294.2490$$

$$K_i = \frac{J}{8 {T_t}^2 K_m} = 36781$$

```
km = 3/2*Zp*Psif
```

```
km = 3
```

```
T_T = 0.002
```

```
T_T = 0.0020
```

```
kp = J/2/T_T/km
```

```
kp = 294.2490
```

```
ki = J/8/T_T^2/km
```

```
ki = 3.6781e+04
```

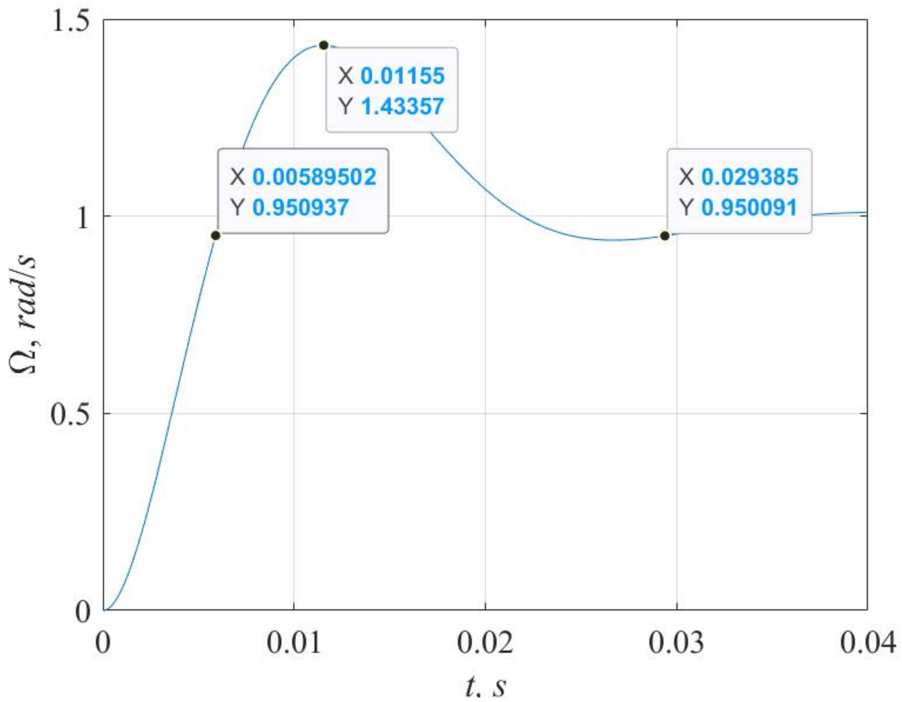

Figure 8. Transient process in speed loop.

```
t0 = t(1);
y0 = Omega(1);
yss = Omega(end);

D5 = 0.05*abs(yss-y0);
ind = abs(Omega-yss) >= D5;
tn = t(ind);
ttr5 = tn(end) - t0;
fprintf('transient time: %4.2f', ttr5);
```

```
transient time: 0.03
```

```
% Overshoot calculation
dy = abs(max(Omega)-yss)/abs(yss-y0)*100;
fprintf('Overshoot: %4.2f%%', dy);
```

```
Overshoot: 41.98%
```

Astaticism order: 2

Transient time(95%): 0.03s

Overshoot: 41.98%

Conclusion:

Through this lab, I successfully modeled and analyzed a synchronous motor drive system using Matlab/Simulink. The tasks included building a sinusoidal PWM modulator, a three-phase inverter, and a synchronous machine model in the dq rotor coordinate system. Additionally, I assembled a brushless DC motor model and implemented vector control for a permanent magnet synchronous machine (PMSM).

The results demonstrated the effectiveness of the control strategies, with the current loop and speed loop showing stable transient processes. The calculated parameters, such as the PI controller gains, ensured proper system performance, though the speed loop exhibited an overshoot of 41.98%, indicating room for further tuning. The astaticism order of 2 and a transient time of 0.03s confirmed the system's responsiveness.

Overall, this lab deepened my understanding of PMSM modeling, BLDC operation, and vector control principles. The hands-on experience with Simulink was invaluable for reinforcing theoretical concepts. Future work could focus on optimizing the control parameters to reduce overshoot and improve dynamic performance.