

Derivation Of DC Servo Driver Current Loop Model

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Introduction - With the rapid development of science and technology, especially the rapid development of motor manufacturing and control technology, coupled with the development of large-scale integrated circuits, semiconductor power devices, and microprocessor technology, servo control systems have been widely used in industry. The performance of servo drives has also become the focus of attention.

The Cello product developed by Elmo Company can perform parameter self-tuning on the current loop of permanent magnet synchronous motors, resulting in higher current loop bandwidth and better current response. As the innermost loop of the entire control system, the bandwidth and response of the current loop directly affect the performance of the speed loop and the position loop. In order to explore the setting scheme for the permanent magnet synchronous motor current loop of Elmo products, the Bode diagram obtained from the upper computer of Elmo products is analyzed and its transfer function is inversely deduced, thereby obtaining the same current loop model of Elmo products. The accurate establishment of the current loop model is the basis for the model method parameter self-tuning.

Motor model

For SPMSM, the voltage equation when using $i_d=0$ control is:

$$\begin{cases} u_d = R_s i_d + L_d \frac{di_d}{dt} - \omega_e L_q i_q \\ u_q = R_s i_q + L_q \frac{di_q}{dt} + \omega_e L_d i_d + \omega_e \psi_f \end{cases} \quad (1)$$

From Equation (1), it can be seen that there is voltage coupling between the d and q axes, and a feedforward decoupling link with feedback is added to offset the voltage coupling relationship under the vector control strategy for permanent magnet synchronous motors.

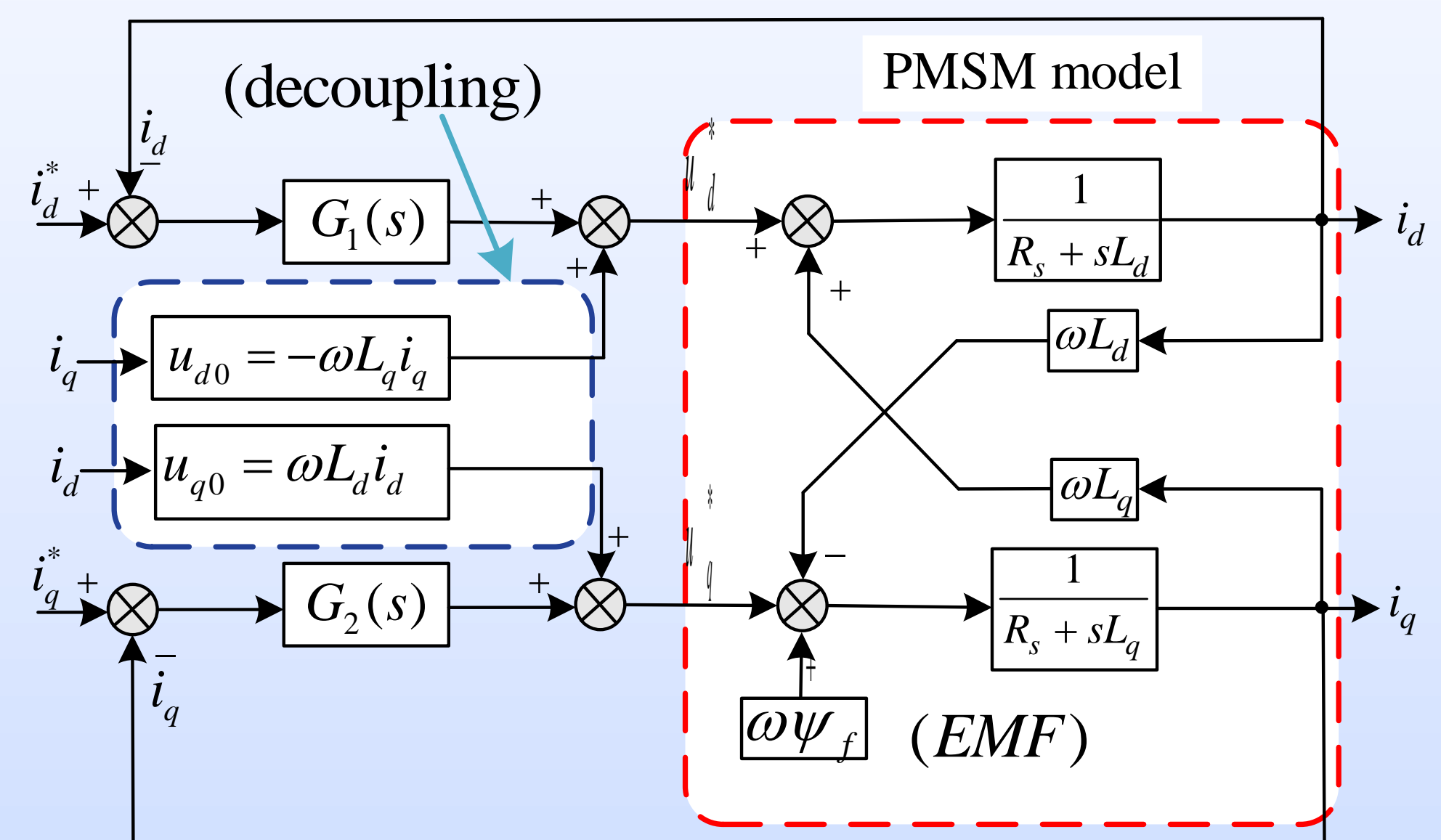


Fig. 1. Voltage decoupling diagram in d-q frame the transfer function of the motor model is as follows:

$$\frac{i_{dq}(s)}{u_{dq}(s)} = \frac{1}{Ls + R} \quad (2)$$

Controller model

The Elmo host computer provides the kp and ki parameters that can be set. It is speculated that its modeling of the controller is a traditional proportional integral (PI) controller, and the transfer function may take the following two forms:

$$G_{ACR}(s) = K_p + \frac{K_i}{s} \quad G_{ACR}(s) = K_p \left(1 + \frac{K_i}{s}\right) \quad (3)$$

Modeling of power electronic devices

$$G_{pwm}(s) = \frac{1}{Ts + 1} \quad (4)$$

under the condition of a single current sampling and a single duty cycle update, the update delay is 1.5 times the sampling period; Under the condition of double current sampling and double duty cycle updating, the update delay is 0.75 times the sampling period.

Tab.1 Delay of different manner of PWM update

Update Method	Current sampling delay	PWM update delay	Total delay
Single Sampling /Update	1Ts	0.5Ts	1.5Ts
double Sampling /Update	0.5Ts	0.25Ts	0.75Ts

$$G_{plant}(s) = \frac{1}{(Ls + R)(Ts + 1)(T_f s + 1)} \quad (6)$$

$$G_{plant}(s) = \frac{\omega_n^2}{(Ls + R)(s^2 + 2\xi\omega_n s + \omega_n^2)(\tau s + 1)} \quad (7)$$

Simulation experiment results

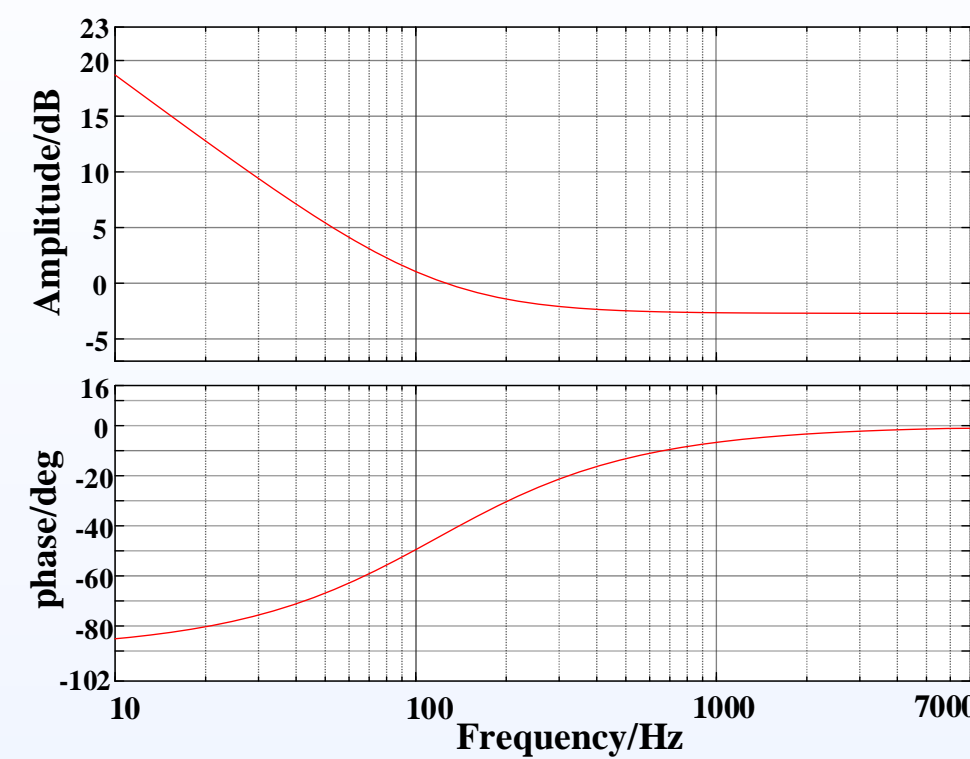


Fig. 5. controller bode

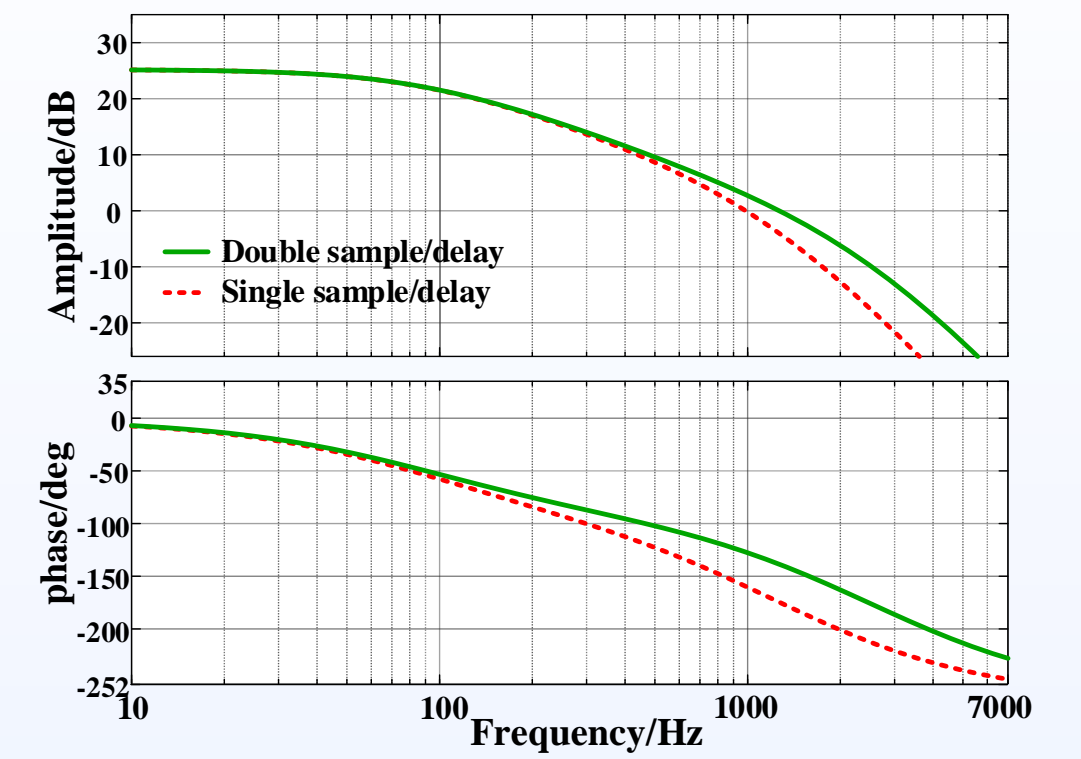


Fig. 6. plant bode with different update delay

Modeling of current sampling filter

Recursive (IIR) filters:

$$y(k) = \alpha y(k-1) + (1-\alpha)x(k)$$

$$G_{filter}(s) = \frac{1}{T_f s + 1} \quad T_f = T_s \frac{\alpha}{1-\alpha} \quad (5)$$

Modeling and analysis of Elmo product current loop

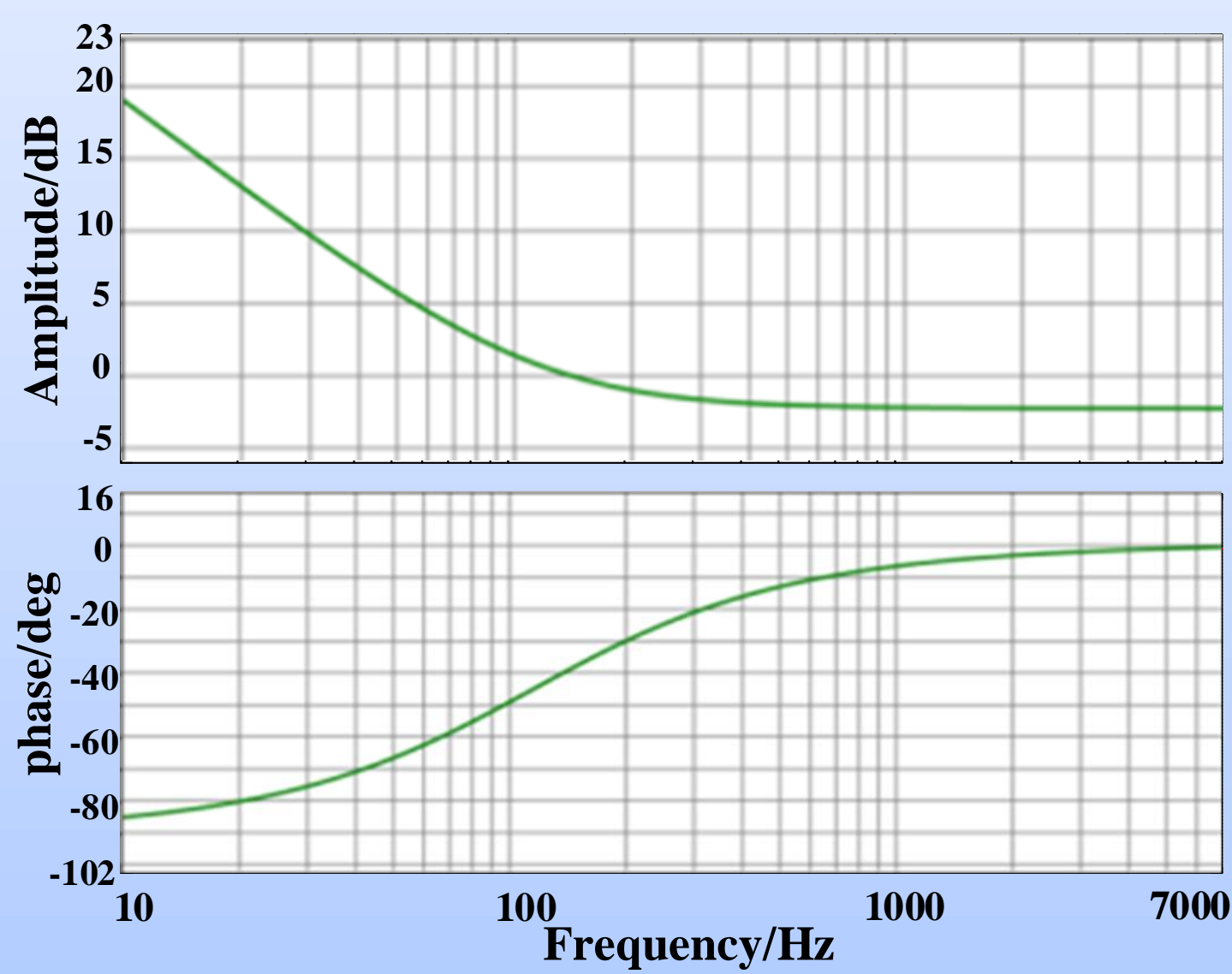


Fig. 2. Elmo controller bode diagram

the controller is traditional PI controller

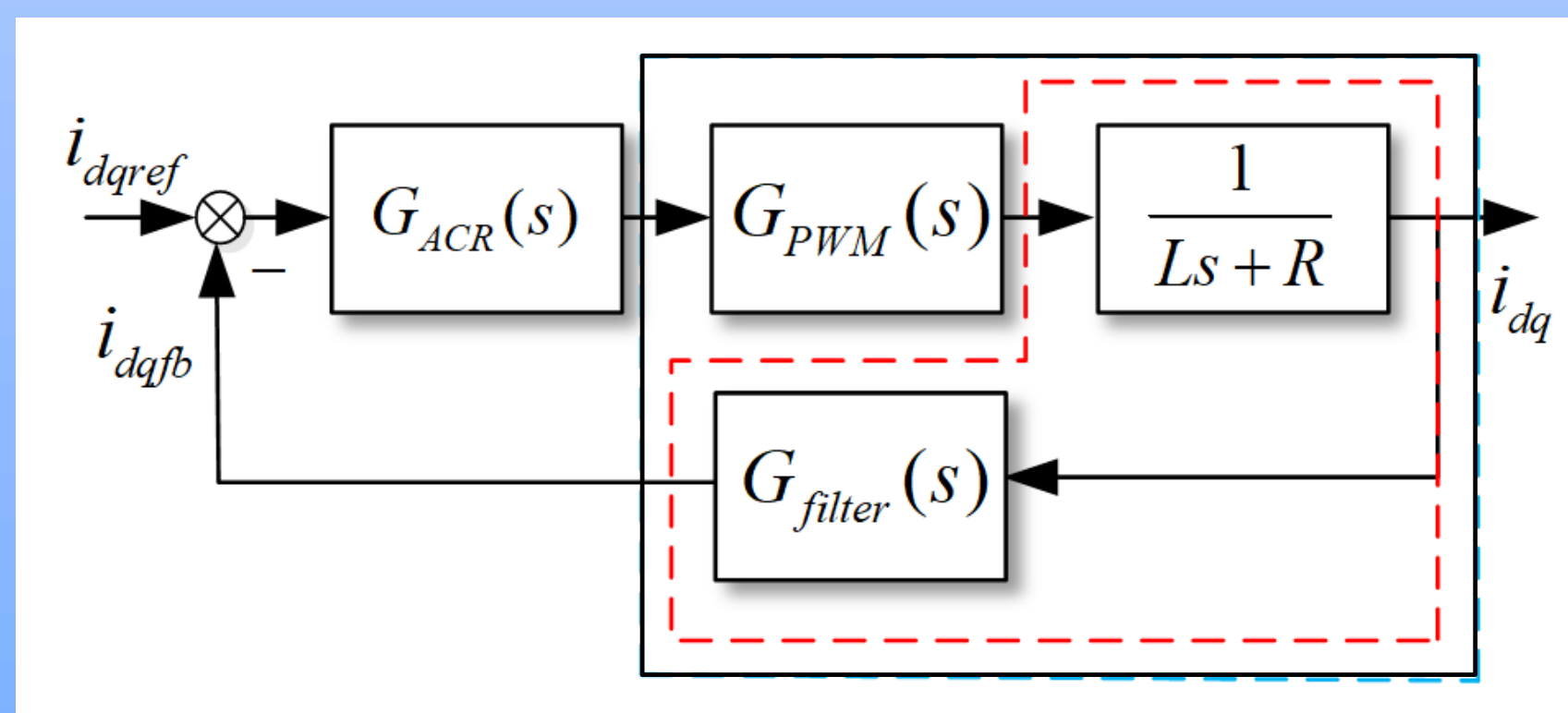


Fig. 3. Block diagram of current loop

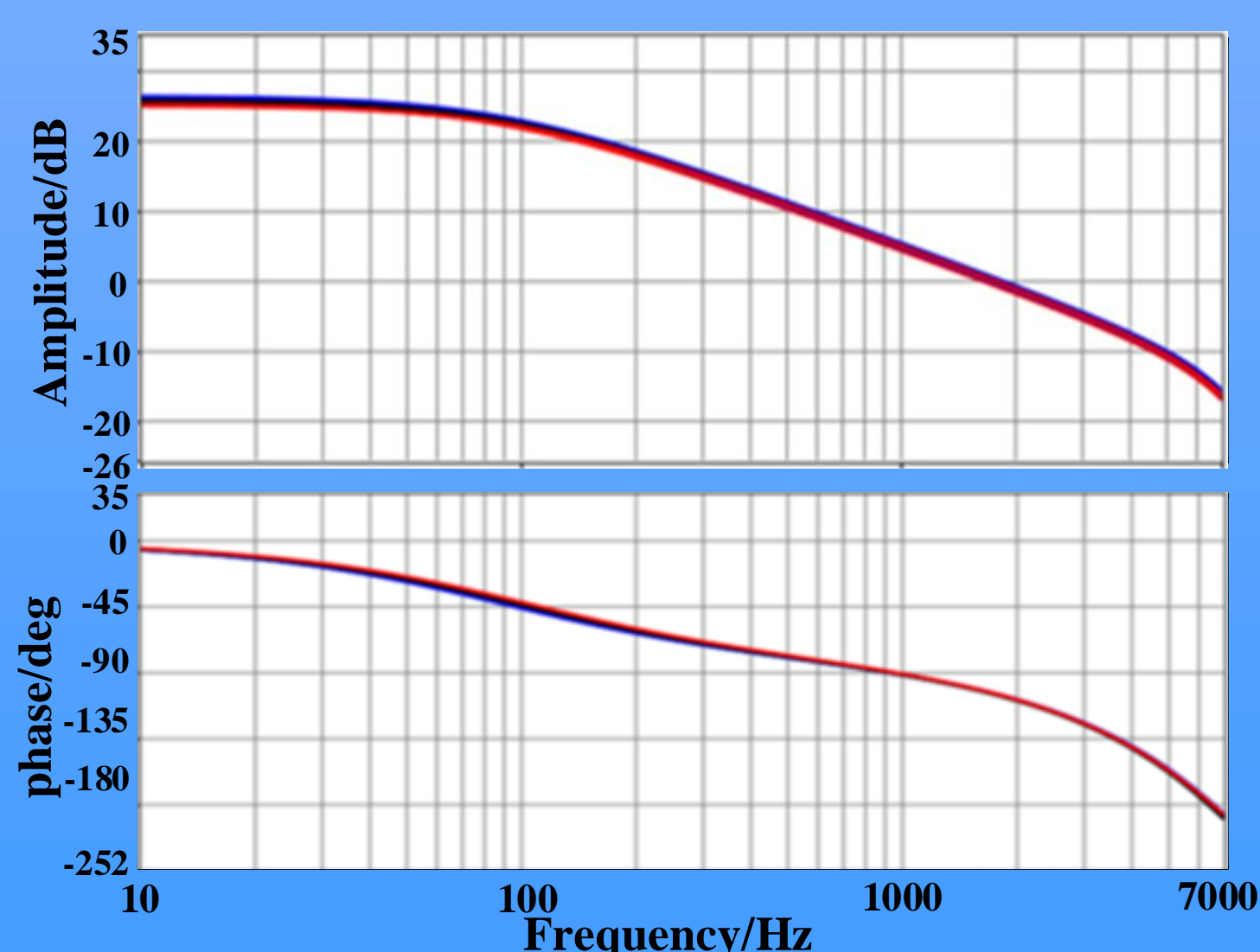


Fig. 4. Elmo plant bode diagram

The transfer function of the controlled object is modeled as follows:

motor 1 is kinavo SMH130-15030D8RNM (4 pairs of poles, 750 W, 48 V, 21.5 A, 3000 rpm); motor 2 is kinavo SMH60-203046RNM (3 pairs of poles, 200 W, 48 V, 5.9 A, 3 000 rpm); motor 3 is SYX060L05-32.5WRT1 (8 pairs of poles, 32.5 W, 24 V, 2.8 A, 500 rpm).

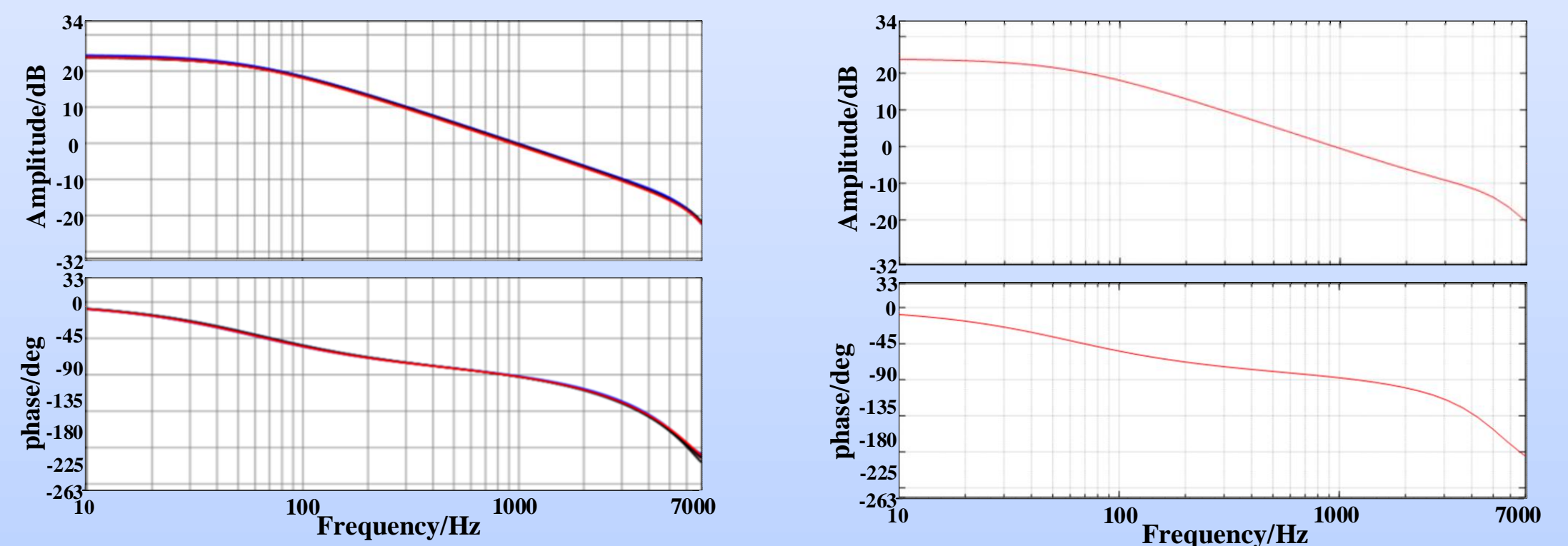


Fig. 7. bode diagram of PMSM.1 elmo and simulation

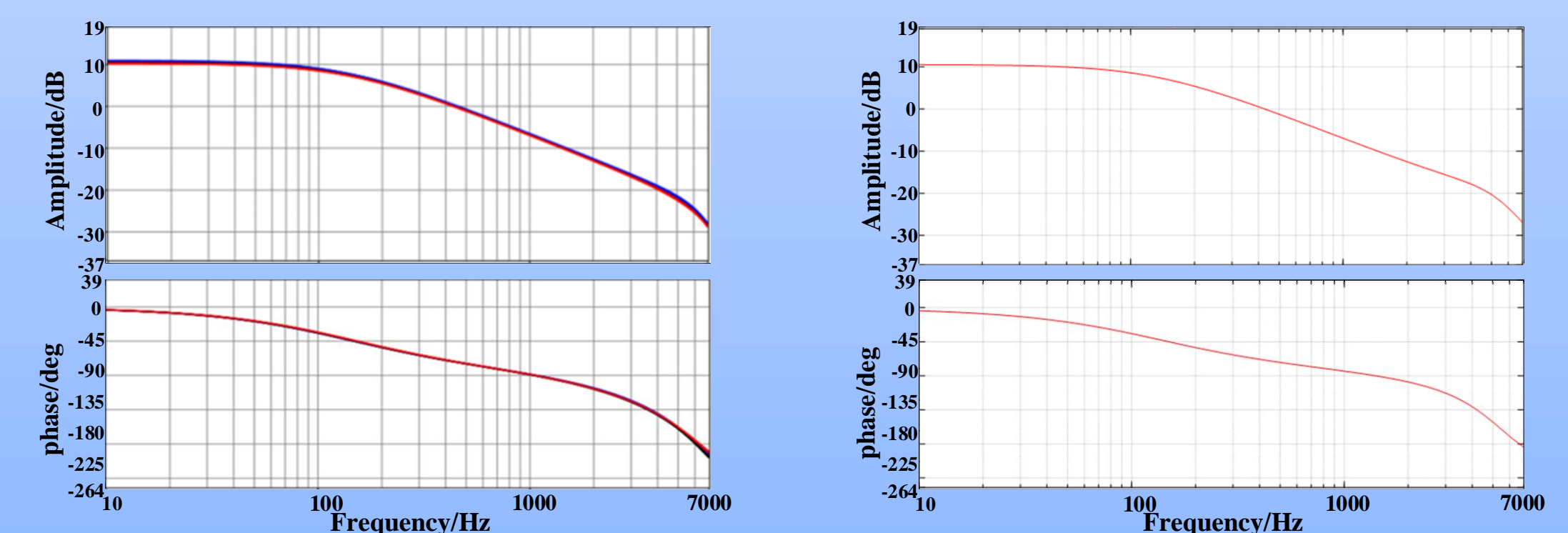


Fig. 8. bode diagram of PMSM.2 elmo and simulation

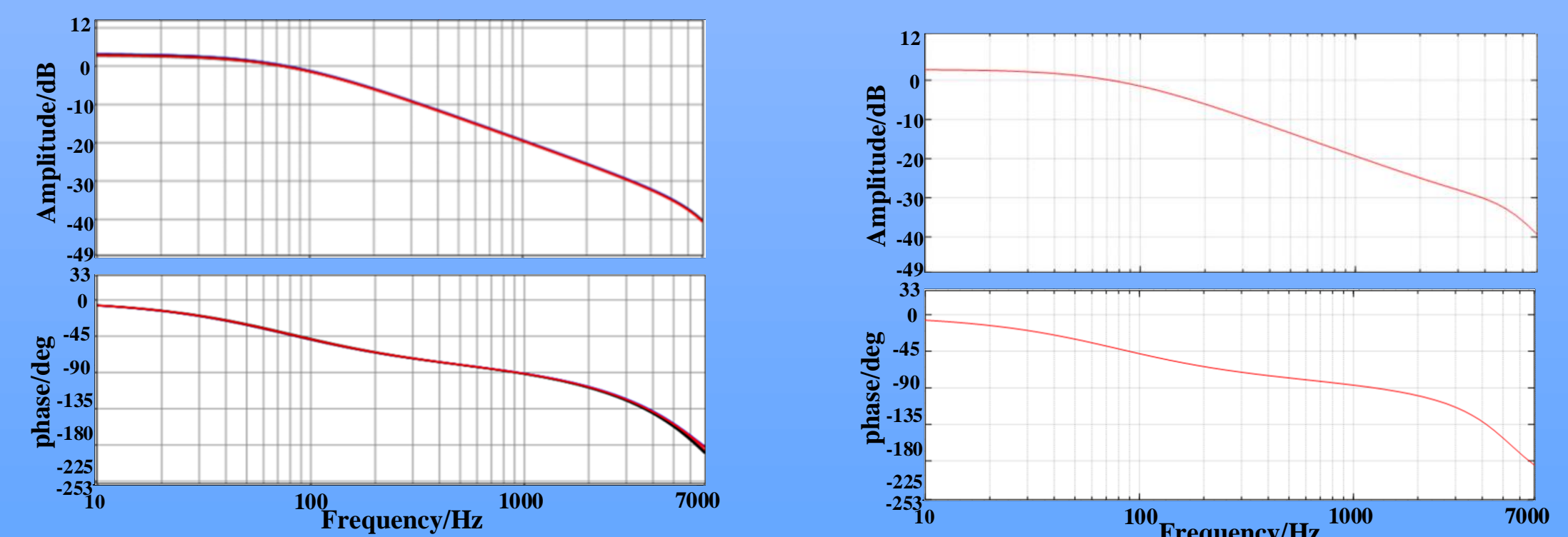


Fig. 9. bode diagram of PMSM.3 elmo and simulation

The simulation results show that: 1) The Elmo product's modeling of the current loop controller is the PI controller model shown in Equation (3). 2) The modeling of the current loop controlled object by Elmo products is the motor model shown in Equation (6), a typical second order filtering link on current feed-back, and a small inertia link caused by current sampling delay.