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Practical Course

Simulation and Optimization of Mechatronic Drive Systems for MSPE

Summer Semester 2024

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Experiment 3
Model of the AC Machine

3.8 Signal Flow Diagram of the Fundamental Wave Model

3.8.1 Drawing of the Signal Flow Diagram

1.) From the differential equations of the rotor and stator flux, we can get the signal flow diagram:

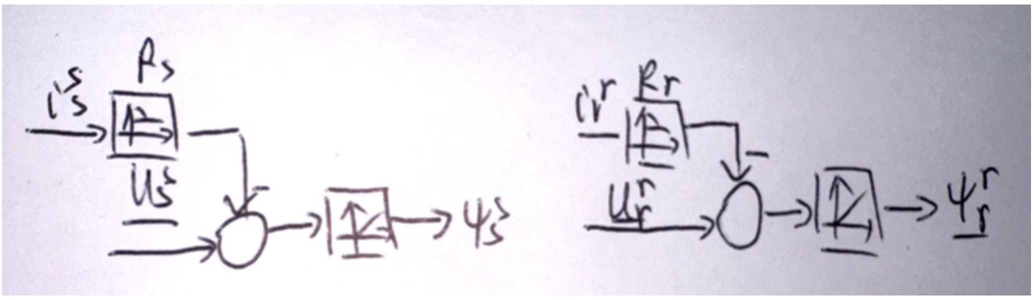

Figure 3.1: Signal Flow Diagram of flux

2.) The signal flow diagram of $\underline{\Psi}_h^s$ from $\underline{i}_s^s$ and $\underline{i}_r^r$ is:

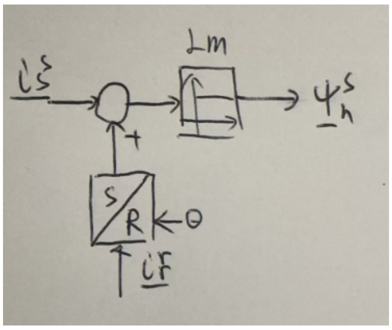

Figure 3.2: Signal Flow Diagram of $\underline{\Psi}_h^s$

The path for the calculation of $\underline{i}_s^s$ by means of $\underline{\Psi}_h^s$ and $\underline{\Psi}_s^s$ is:

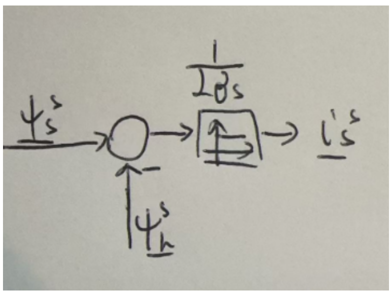

Figure 3.3: Signal Flow Diagram of $\underline{i}_s^s$

The path for the calculation of $\underline{i}_r^r$ by means of $\underline{\Psi}_h^r$ and $\underline{\Psi}_r^r$ is:

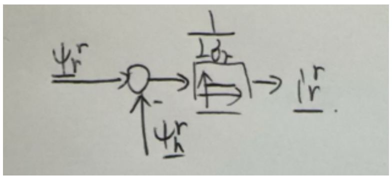

Figure 3.4: Signal Flow Diagram of $\underline{i}_r^r$

3.) The path for the calculation of M_M is:

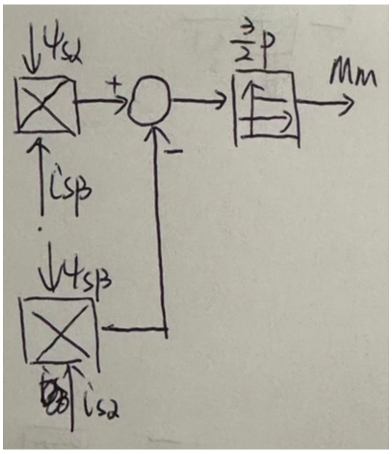

Figure 3.5: Signal Flow Diagram of M_M

4.) The signal flow diagram for the mechanic subsystem with M_M and M_L as an input and ω_m, θ_m and θ_{el} as an output is:

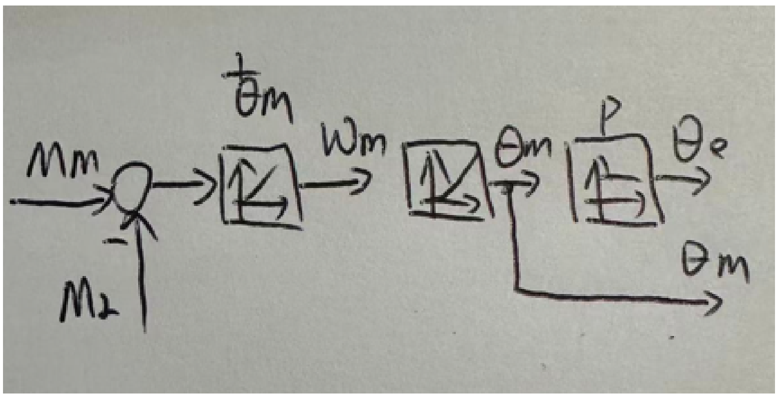

Figure 3.6: Signal Flow Diagram of the mechanical subsystem

5.) The complete signal flow diagram of the fundamental wave model is:

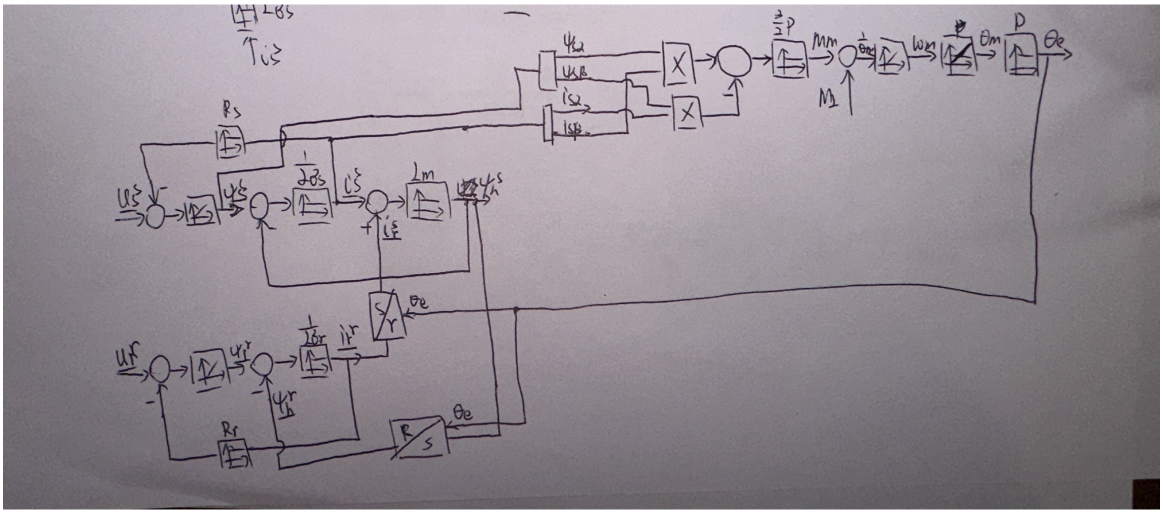

Figure 3.7: Complete Signal Flow Diagram of the fundamental wave model

6.) From the equation of the flux, we have:

$$\begin{cases} \underline{\Psi}_s^s = L_s \cdot \underline{i}_s^s + L_m \cdot \underline{i}_r^s \\ \underline{\Psi}_r^s = L_m \cdot \underline{i}_s^s + L_r \cdot \underline{i}_r^s \\ \underline{\Psi}_h^s = L_m \cdot (\underline{i}_s^s + \underline{i}_r^s) \end{cases} \tag{3.1}$$

From the equation, we can express $\underline{i}_s^s$ and $\underline{i}_r^s$ as a function of $\underline{\Psi}_s^s$ and $\underline{\Psi}_r^s$:

$$\begin{cases} \underline{i}_s^s = \frac{L_r \cdot \underline{\Psi}_s^s - L_m \cdot \underline{\Psi}_r^s}{L_s L_r - L_m^2} \\ \underline{i}_r^s = \frac{L_s \cdot \underline{\Psi}_r^s - L_m \cdot \underline{\Psi}_s^s}{L_s L_r - L_m^2} \\ \underline{\Psi}_h^s = \frac{L_m (L_r - L_m)}{L_s L_r - L_m^2} \underline{\Psi}_s^s + \frac{L_m (L_s - L_m)}{L_s L_r - L_m^2} \underline{\Psi}_r^s \end{cases} \tag{3.2}$$

7.) Therefore, the resulting whole signal flow diagram according to previous equations is:

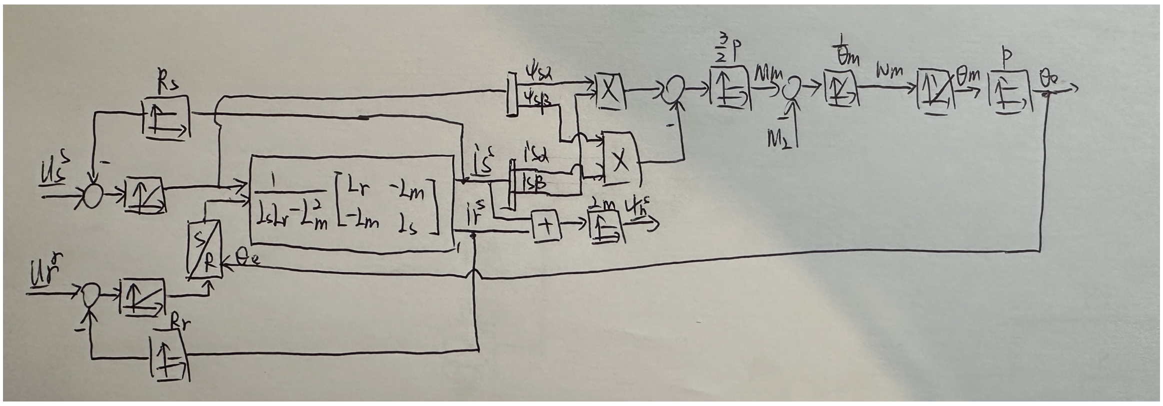

Figure 3.8: Final Signal Flow Diagram of the fundamental wave model

3.9 Model of the Asynchronous Machine with Squirrel Cage

8.) For an asynchronous machine with a squirrel cage rotor, the rotor windings are short-circuited. Therefore, the rotor voltage fulfills the condition:

$$\underline{u}_r^r = 0 \tag{3.3}$$

9.) The synchronous speed can be calculated as follows:

$$N_E = \frac{60f}{p} = \frac{60 \cdot 50}{p} = \frac{3000}{p}\ \text{rpm} \tag{3.4}$$

Because $N_N = 2980\text{rpm}$, the number of pole pairs is $p = 1$.

The nominal rotational speed ω_{MN}, the nominal torque M_{MN} and the nominal slip s_N are:

$$\begin{aligned} \omega_{MN} &= \frac{2\pi \cdot 2890}{60} \approx 302.8\,\text{rad/s} \\ M_{MN} &= \frac{2200}{302.8} \approx 7.27\,\text{Nm} \\ s_N &= \frac{3000 - 2890}{3000} \approx 0.0367\ (3.67\%) \end{aligned} \tag{3.5}$$

3.10 Model of the Permanent Magnet Synchronous Machine

18.) The stator current space vector as a function of the stator flux and the permanent magnet flux is:

$$i_s^s = \frac{1}{L_s}\left(\psi_s^s - \psi_{PM}^s\right) \tag{3.6}$$

Therefore, the signal flow diagram for the permanent magnet synchronous machine is:

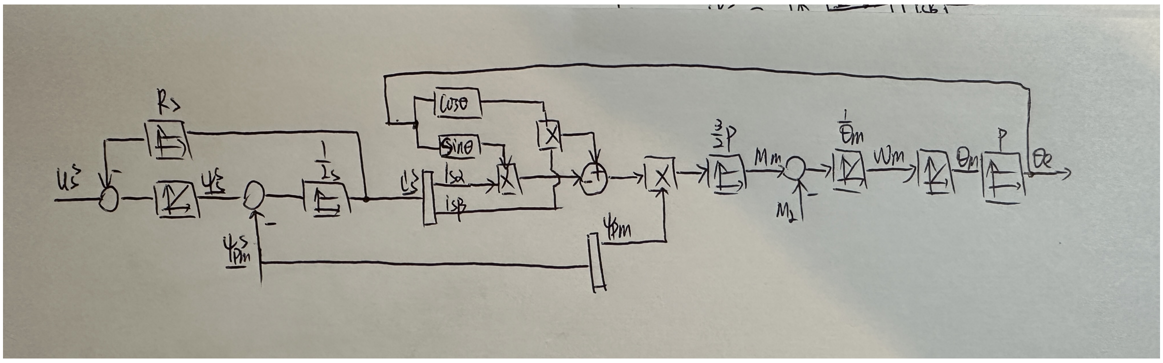

Figure 3.9: Signal Flow Diagram of the permanent magnet synchronous machine

19.) The nominal angular frequency ω_N and the nominal torque M_{MN} are:

$$\begin{aligned} \omega_N &= \frac{2\pi \cdot N_N}{60} = \frac{2\pi \cdot 2000}{60} \approx 209.44\,\mathrm{rad/s} \\ M_{MN} &= \frac{P_N}{\omega_N} = \frac{4400}{209.44} \approx 21.01 N \cdot m \end{aligned} \tag{3.7}$$