Chair of High-Power Converter Systems
Technical University of Munich Prof. Marcelo Lobo Heldwein

Arcisstr. 21 Email: hlu@ed.tum.de Tel.: +49 (0)89 289 28358
80333 Munich Web: www.epe.ed.tum.de/hlu Fax: +49 (0)89 289 28336

Practical Course

Simulation and Optimization of Mechatronic Drive Systems for MSPE

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Haoheng Li / 03797669
Haojun Cao /

Experiment 1
Model of the DC Machine

1.5 Model of the DC Machine

1.) * The Laplace transform of euquations (1.5) are:

$$U_A(s) = E_A(s) + R_A I_A(s) + sL_A I_A(s) \tag{1.5a}$$

$$E_A(s) = C_M \Psi_E(s)\,\Omega_M(s) \tag{1.5b}$$

$$M_M(s) = C_M \Psi_E(s)\, I_A(s) \tag{1.5c}$$

$$U_E(s) = R_E I_E(s) + s\,\Psi_E(s) \tag{1.5d}$$

$$\Psi_E(s) = f(I_E(s)) \tag{1.5e}$$

$$M_M(s) - M_L(s) = s\Theta_M\,\Omega_M(s) \tag{1.5f}$$

The signal flow graph is shown in Figure 1.1.

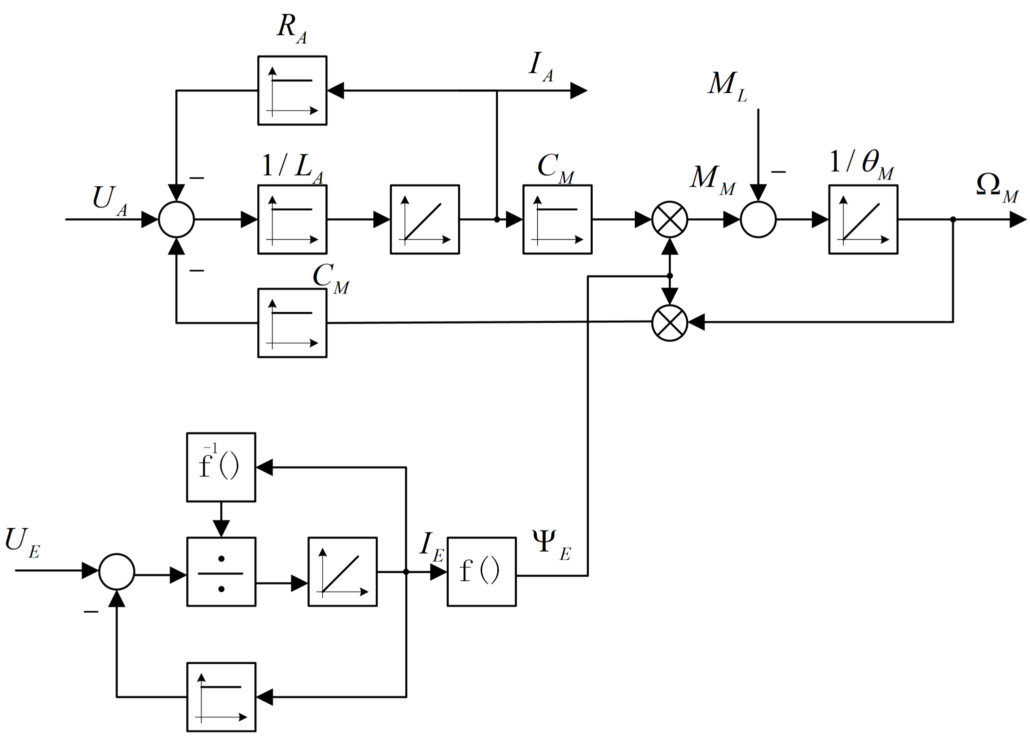

Figure 1.1: Signal Flow Graph of the DC Machine

2.) * The four wortking moed of the DC machine are shown in Figure 1.2.

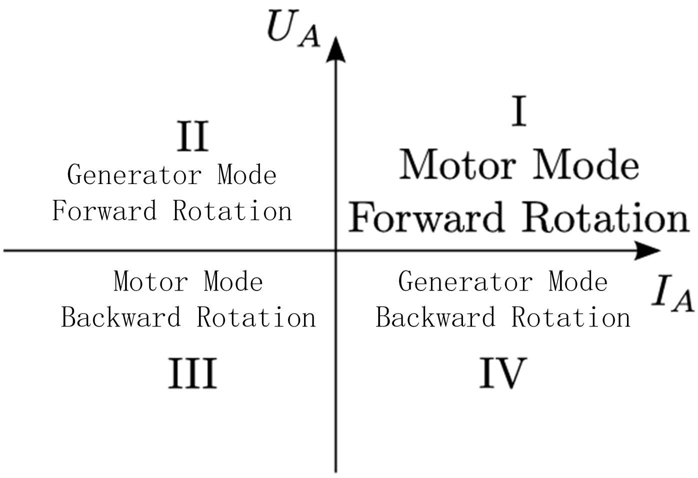

Figure 1.2: Four working modes of the DC machine

In a steady state, the load torque of working mode II and III must be positive.

3.) * The operating point of maximum mechanical power output is shown in Figure 1.3.

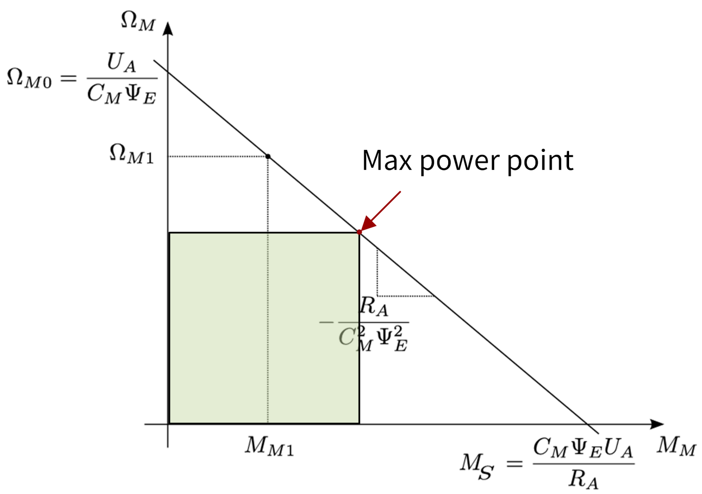

Figure 1.3: Operating point of maximum mechanical power output

The function of $\Omega_M(M_M)$ can be derived as follows:

$$\Omega_M(M_M) = \Omega_{M0}\left(1 - \frac{M_M}{M_S}\right) \tag{1.1}$$

the mechanical power output P_M is:

$$P_M(M_M) = \Omega_M(M_M)M_M = \Omega_{M0}\left(1 - \frac{M_M}{M_S}\right)M_M \tag{1.2}$$

To determine the maximum power, we differentiate with respect to the torque:

$$\frac{dP_M}{dM_M} = \Omega_{M0}\left(1 - \frac{2M_M}{M_S}\right) = 0 \tag{1.3}$$

when $M_M = \frac{1}{2}M_S$, the mechanical power output is maximum, which is $\frac{M_S\,\Omega_{M0}}{4}$.

1.5.1 Behavior of the DC Machine

4.) *

(a) The nominal torque M_{MN} can be calculated as follows:

$$M_{MN} = \frac{P_N}{\Omega_{MN}} = \frac{200W}{209.44rads} = 0.955N \cdot m \tag{1.4}$$

The excitation resistance R_E can be calculated as follows:

$$R_E = \frac{U_{EN}}{I_{EN}} = \frac{220V}{0.1A} = 2.2k\Omega \tag{1.5}$$

(b) The armature resistance R_A and armature inductance L_A can be calculated from the step response of the armature current $I_A(t)$, where $I_A(t)$ can be expressed as follows:

$$I_A(t) = \frac{U_A}{R_A}\left(1 - e^{-\frac{t}{\tau}}\right) \tag{1.6}$$

, where $\tau = \frac{L_A}{R_A}$ is the time constant.
The armature resistance R_A can be calculated as follows:

$$R_A = \frac{U_A}{I_{A\infty}} = \frac{U_A}{I_A} = 22\Omega \tag{1.7}$$

The armature inductance L_A can be calculated as follows:

$$L_A = \tau R_A = 0.017s \times 22\Omega = 374mH \tag{1.8}$$

(c) the machine constant C_M can be calculated as follows:

$$C_M = \frac{U_{AN} - R_A I_{AN}}{\Psi_E \Omega_{MN}} = \frac{220V - 1A \times 22\Omega}{1Vs \times 209.44rad/s} = 0.96 \tag{1.9}$$

(d) The derivative of the angular velocity during acceleration and deceleration can be calculated as follows:

$$\begin{cases} (\frac{d\Omega_M}{dt})_a = \frac{M_M - M_L}{\Theta_M} \\ (\frac{d\Omega_M}{dt})_d = \frac{-M_M - M_L}{\Theta_M} \\ M_M = C_M \Psi_E I_A \end{cases} \tag{1.10}$$

The moment of inertia Θ_M can be calculated as follows:

$$\Theta_M = \frac{2M_M}{(\frac{d\Omega_M}{dt})_a - (\frac{d\Omega_M}{dt})_d} = \frac{2 \times 0.96 \times 0.5A \times 1Vs}{756.31 rad/s^2} = 1.3g \cdot m^2 \tag{1.11}$$

1.5.2 Converter Supplied Operation

10.) * The maximum carrier frequency can be calculated as follows:

$$f_{c,max} = 0.5 r_{max} = 1kHz \tag{1.12}$$

11.) * The waveform of the command signals when $U_A^* = 0V$ is shown in Figure 1.4.

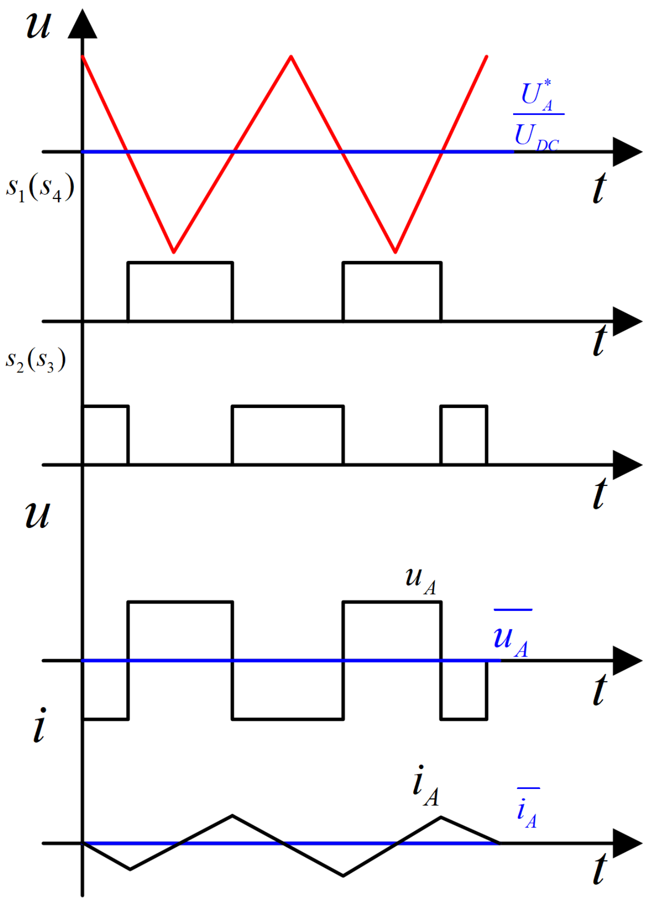

Figure 1.4: Waveform of the command signals when $U_A^* = 0V$

13.) * The transfer function of the power elctronic converter can be written as follows:

$$\frac{U_A(s)}{U_A^*(s)} = \frac{U_{dc}}{1 + sT_{PE}} \tag{1.13}$$

, where $T_{PE} = \frac{1}{f_c}$ is the time constant of the power electronic converter.