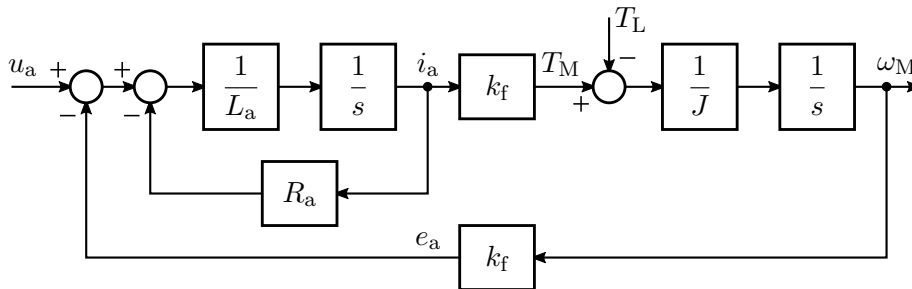**Problem 1: Transfer functions of a DC motor**

The block diagram of a DC motor is shown in the figure.

(a) Derive the transfer functions

$$G_{\omega u}(s) = \frac{\omega_{\mathrm{M}}(s)}{u_{\mathrm{a}}(s)} \quad \text{and} \quad G_{\omega T}(s) = \frac{\omega_{\mathrm{M}}(s)}{T_{\mathrm{L}}(s)}$$

(b) Replace the electric dynamics of the machine with the DC gain and formulate the transfer functions $G_{\omega u}(s)$ and $G_{\omega T}(s)$.

Problem 2: Current ripple

The parameters of a DC motor are: $R_{\mathrm{a}} = 1\ \Omega$, $L_{\mathrm{a}} = 10$ mH, and $k_{\mathrm{f}} = 4$ Vs. The average steady-state current taken by the motor is $I_{\mathrm{a}} = 100$ A and the rotor speed is 560 r/min. The motor is supplied from a four-quadrant DC-DC converter, where the unipolar PWM is applied. The DC-bus voltage is $U_{\mathrm{dc}} = 450$ V and the switching (carrier) frequency is $f_{\mathrm{sw}} = 4$ kHz. Calculate the peak-to-peak current ripple.