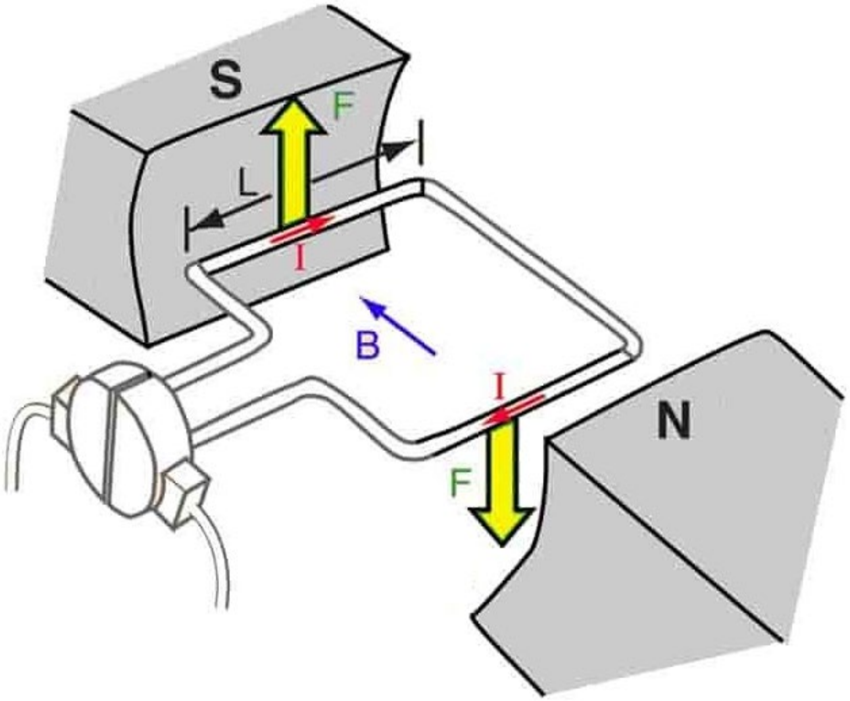
DC Machine Drive

- Theory of operation of DC motor
  - The electric current, i_a, passes through the armature winding via a commutator and brushes
  - When i_a passes through the armature winding in a magnetic field, a magnetic force, F_e, is induced
  - The magnetic force induces a torque, which turns the DC motor



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- Equivalent circuit of DC motor armature
  - R_a and L_a are the resistance and self-inductance of armature windings
  - e_a is the back emf voltage or induced voltage

$$e_a = K\phi_f\omega_m; \quad \phi_f = C\, i_f$$

where

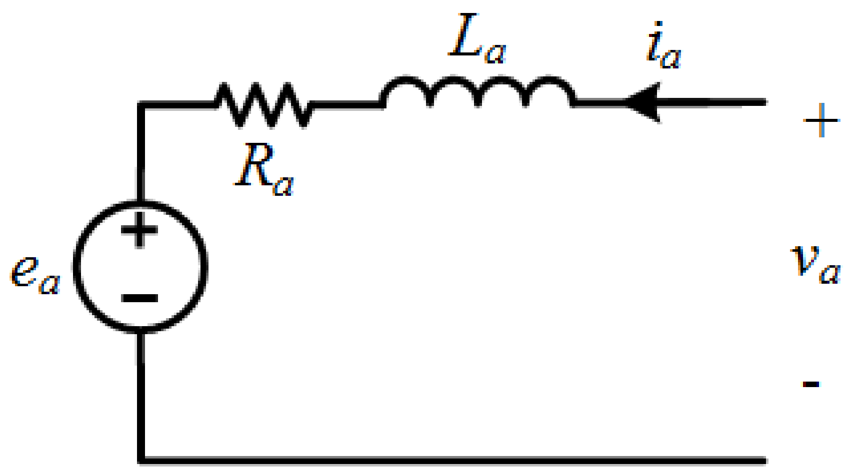
K is constant depends on machine's structure

ϕ_f is the machine's flux

ω_m is the machine's speed

C is constant (slop of magnetizing curve)

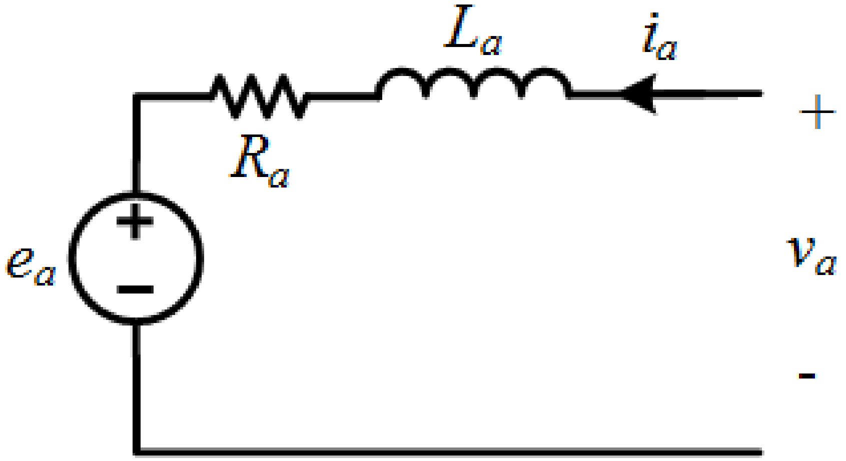
i_f is the field current



- Torque equation

KVL in the armature circuit

$$v_a = R_a i_a + L_a \frac{di_a}{dt} + e_a$$



Under steady state operation,

$$v_a = R_a i_a + e_a$$

$$\underbrace{v_a i_a}_{\text{Total input Power}} = \underbrace{R_a i_a^2}_{\text{Armature copper losses}} + \underbrace{e_a i_a}_{\text{Air-gap power}}$$

The air-gap power, P_a, is the effective power that has been transferred to mechanical power

$$P_a = e_a i_a = T_{el}\omega_m \Rightarrow T_{el} = \frac{e_a i_a}{\omega_m} = \frac{K\phi_f \omega_m i_a}{\omega_m} \Rightarrow T_{el} = K\phi_f i_a$$

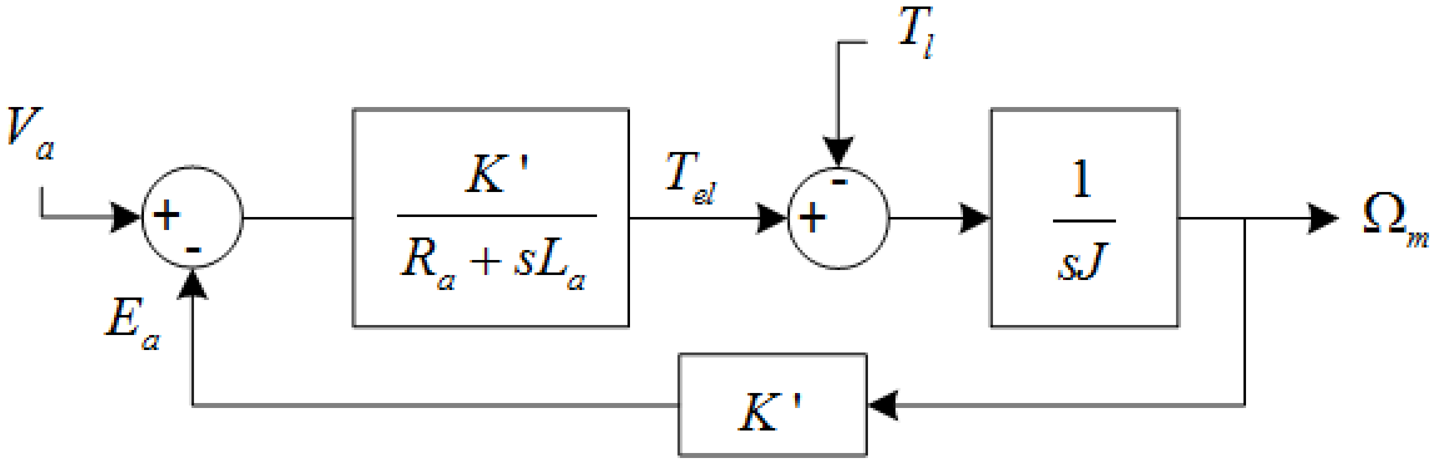
- Block diagram and transfer function of DC machine
  - Machine equations in time-domain

$$v_a = R_a i_a + L_a \frac{di_a}{dt} + e_a;\; e_a = K\phi_f \omega_m = K'\omega_m;\; T_{el} = K\phi_f i_a = K' i_a;\; T_{el} = T_l + J\frac{d\omega_m}{dt}$$

  - Machine equations in *s*-domain

$$V_a = \left(R_a + sL_a\right) I_a + E_a;\; E_a = K'\Omega_m;\; T_{el} = K' I_a;\; T_{el} = T_l + Js\Omega_m$$

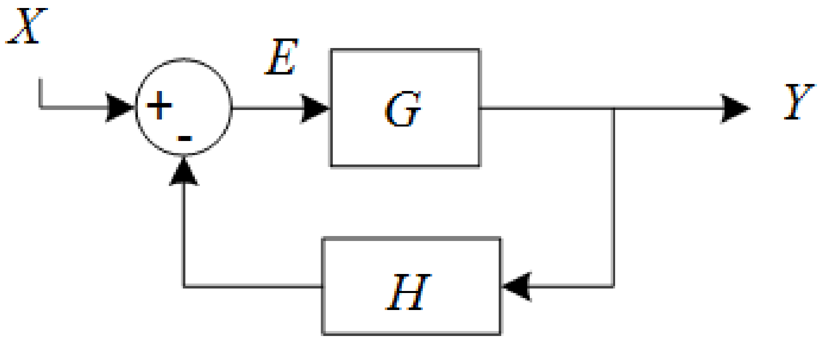
- Block diagram



$$\Omega_m = T_1 V_a + T_2 T_l$$

- T_1 is the transfer function when $T_l = 0$
- T_2 is the transfer function when $V_a = 0$

- Closed loop system



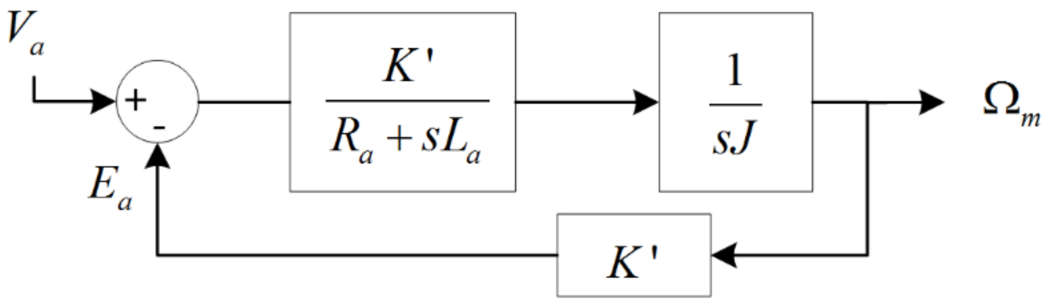
$$Y = GE$$

$$Y = G\left(X - HY\right) = GX - GHY$$

$$Y = TX; \quad T = \frac{G}{1+GH}$$

- G is the direct transfer function
- H is the feedback transfer function

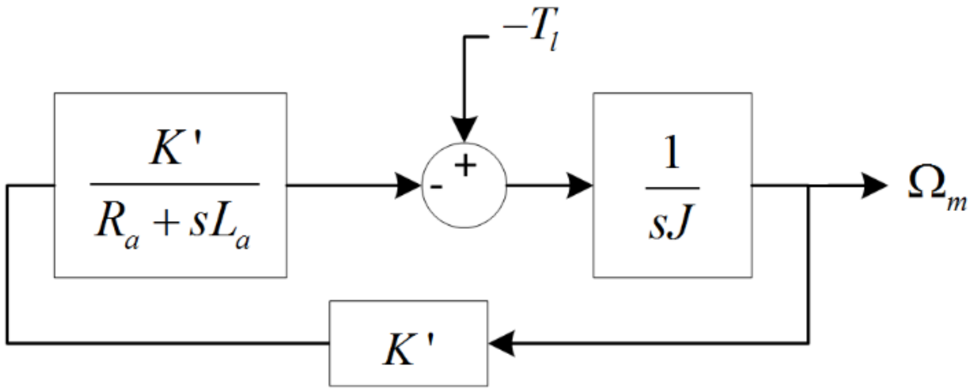
- T_1: $T_l = 0$



$$T_1 = \frac{G_1}{1 + G_1 H_1};$$

$$G_1 = \frac{K'}{sJ\left(R_a + sL_a\right)}; \quad H_1 = K'$$

- T_2: $V_a = 0$



$$T_2 = \frac{-G_2}{1 + G_2 H_2};$$

$$G_2 = \frac{1}{sJ}; \quad H_2 = \frac{K'^2}{R_a + sL_a}$$