直流馬達(有刷) (DC Motors)

- **Two basic equations:**

$$E_a = K_a \Phi \omega_m \begin{cases} \text{Generator : Generated voltage} \\ \text{Motor : Back emf (Lenz slaw)} \end{cases}$$

$$T = K_a \Phi I_a \begin{cases} \text{Motor: Generated torque} \\ \text{Generator: Retarding torque (Lenz's law)} \end{cases}$$

$$E_a I_a = T \omega_m (Neglecting\ losses)$$

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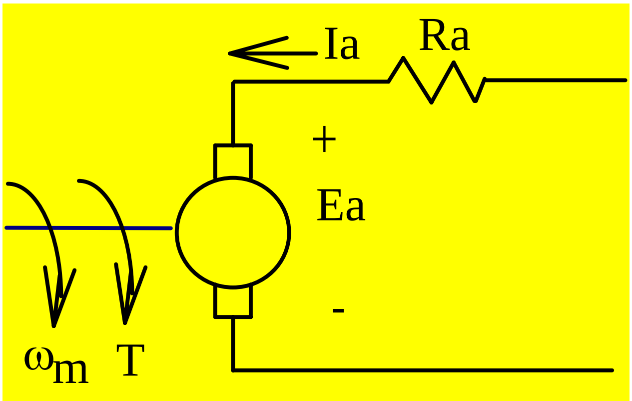


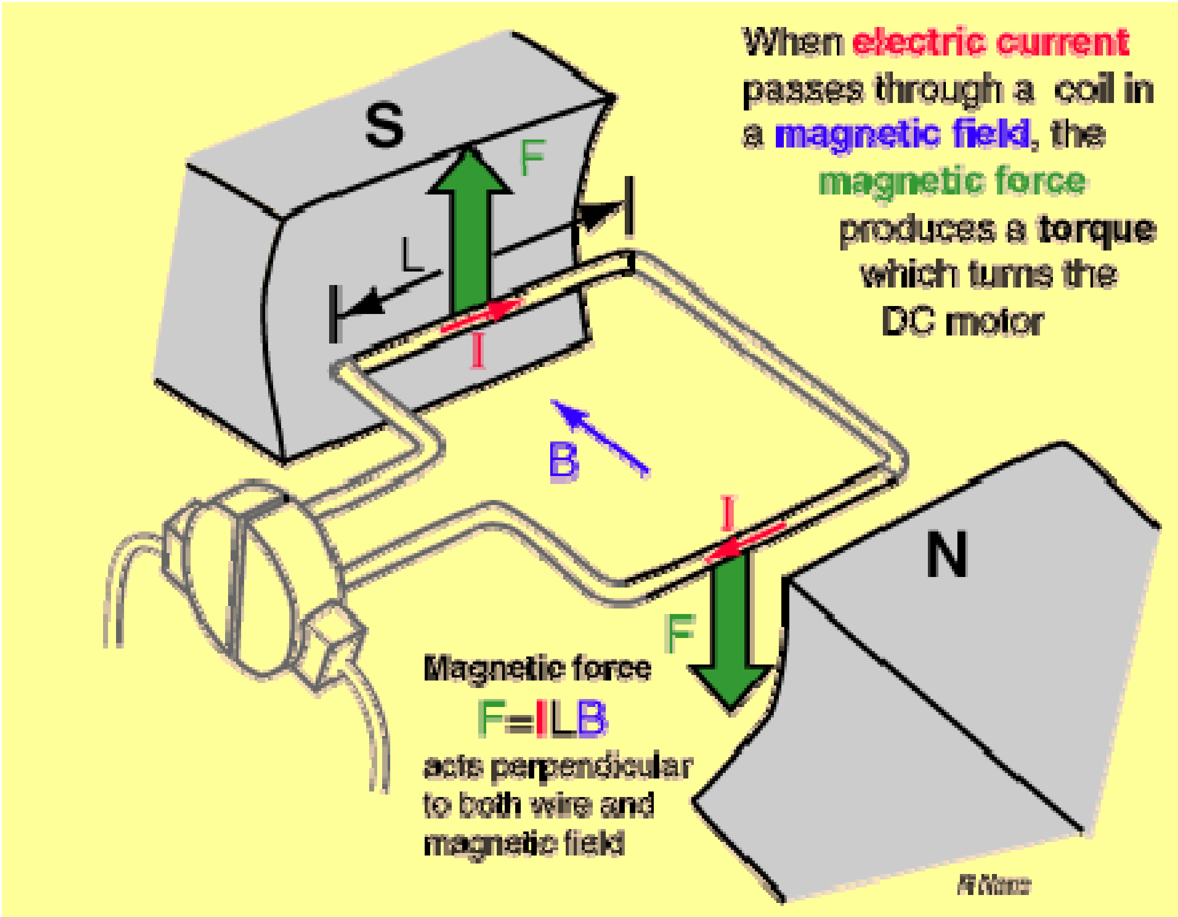
- 機電整合主導公式
- 馬達及轉換器之象限：

  Forward driving and regenerating braking

  Backward driving and regenerating braking

Torque in DC Motor

- Torque generating capability of a DC Motor is the best, since the flux and armature conductor current are kept in quadrature in nature.



Efficiency: $\eta \stackrel{\Delta}{=} P_o / P_{in}$

- Generator

$$P_o = V_t I_t (= P_{elec})$$
$$= P_{shaft} (= P_{in} = P_{mech}) - P_{rot} - I_a^2 R_a - I_f^2 R_f - I_t^2 R_{sr}$$

- Motor

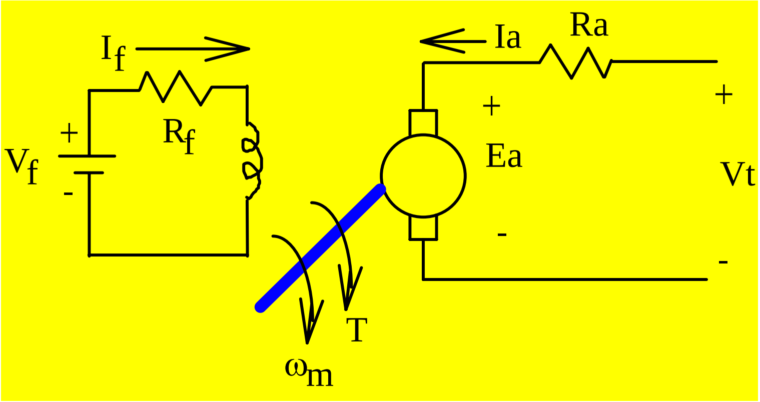
$$P_o = (P_{shaft} = P_{mech})$$
$$= P_{in} (= V_t I_t = P_{elec}) - I_t^2 R_{sr} - I_f^2 R_f - I_a^2 R_a - P_{rot}$$

Torque-Speed Characteristics

- 以它激馬達為例：

$$\omega_m = \frac{V_t - I_a R_a}{K_a \Phi} = \frac{1}{K_a \Phi} V_t - \frac{R_a}{(K_a \Phi)^2} T$$

V_t: *Control* T: *Load torque(Disturbance)*



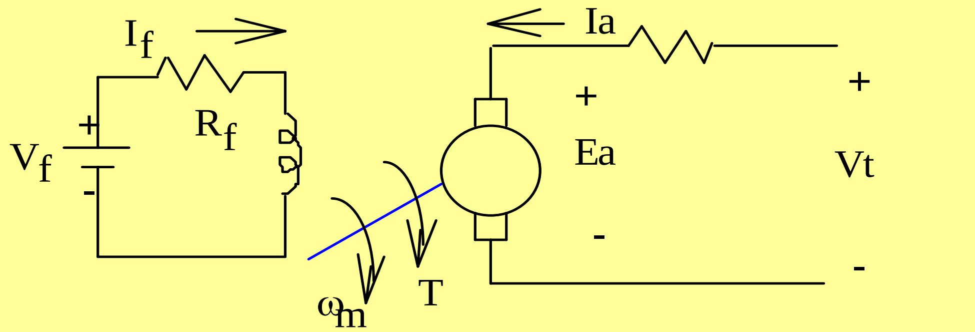
- 電樞反應效應 (Armature reaction (AR) effect)：去磁：

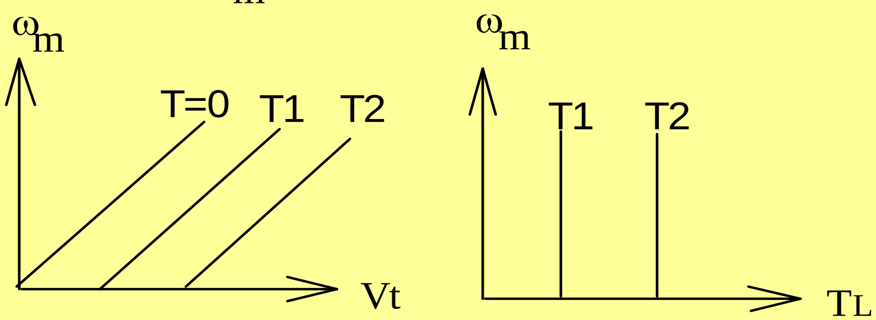
  - Motor: $Load \uparrow \Rightarrow \Phi \downarrow \Rightarrow \omega_m \uparrow$
  - Generator: $Load \uparrow \Rightarrow \Phi \downarrow \Rightarrow E_a \downarrow$

Speed control

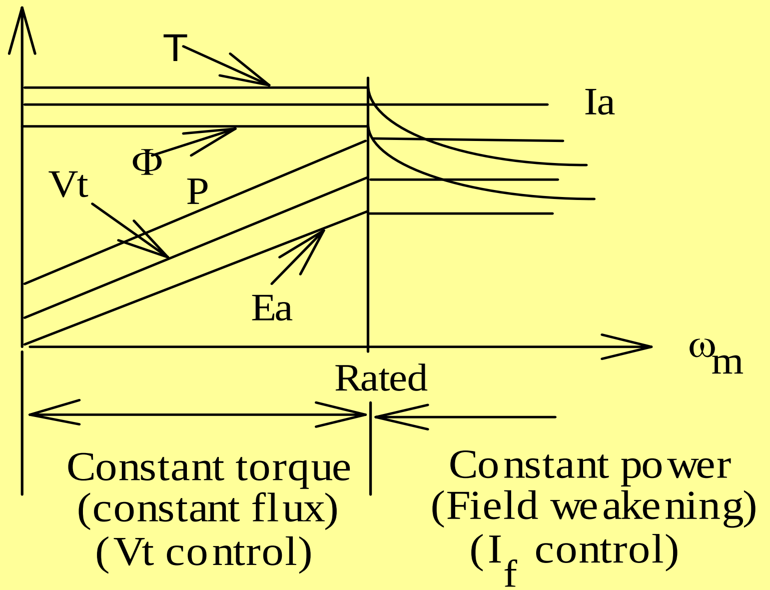
$$\omega_m = \frac{V_t - I_a R_a}{K_a \Phi} = \frac{1}{K_a \Phi} V_t - \frac{R_a}{(K_a \Phi)^2} T$$

- V_t *control* **(Constant-torque region, constant-flux),**
- Φ *control* **(Constant-power region, field weakening),**
- R_a *control*

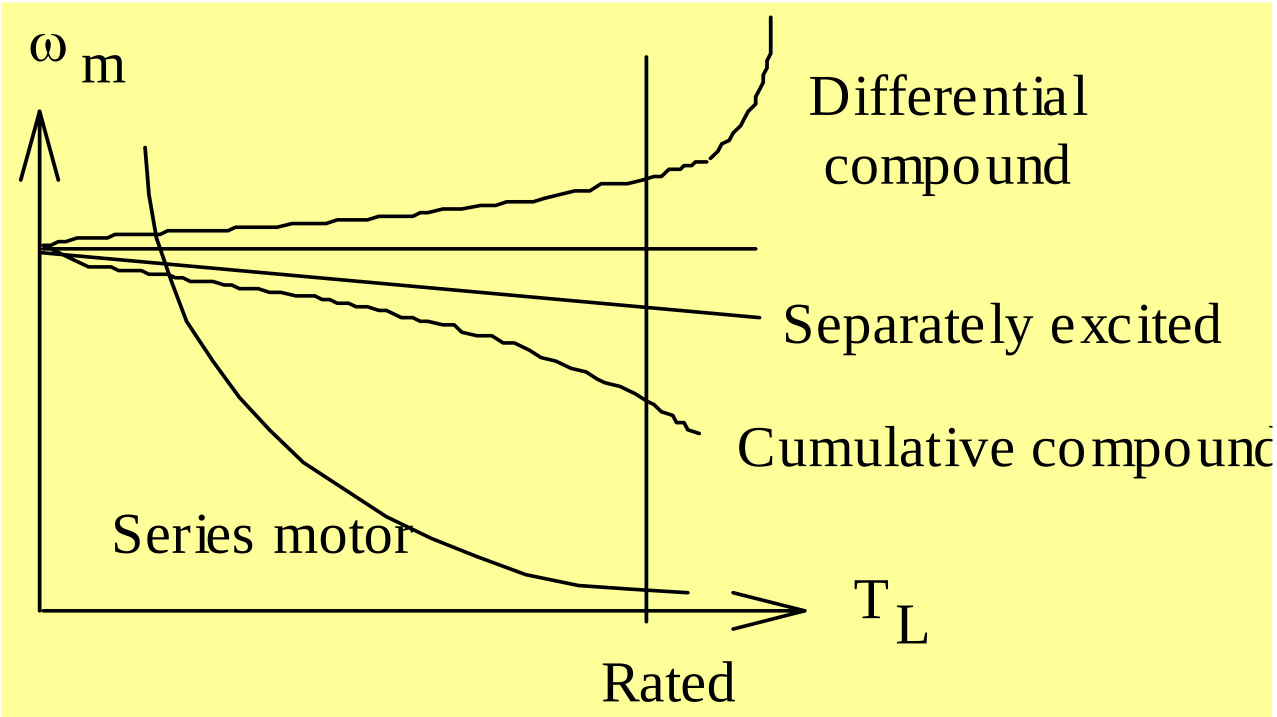




（機電特性）
T=定值，且
設Ia維持定
值



各式直流馬達之轉矩速度特性比較：



Series Motor

- **Universal motor: AC and DC are all okay.**
- **Large developed torque (large starting torque):**

$$T = K_t I_a^2$$

- **Speed will be dangerously large at light load.**

$$\omega_m = \frac{V_t}{\sqrt{K_{sr}}\sqrt{T}} - \frac{R_a + R_{sr} + R_{ae}}{K_{sr}}, \quad K_a \Phi = K_{sr} I_a$$

$$\omega_m \propto 1/\sqrt{T}, \; T = 0 \,(No\ load) \Rightarrow \omega_m \to \infty$$