Power Electronics

Review

Switching Power Supply

Motor Drives

Review

Outlines

- Switching Power Supply
- Introduction to Motor Drives
- DC Motor Drives
- Induction Motor Drives

Review

Switching Power Supply

Requirements for dc Power Supplies

Regulated output;

Isolation;

Multiple output.

Major advantages of switching power supplies

- *higher energy efficiency*
- *reduced size and weight*

Review

Switching Power Supply

High Frequency Transformer

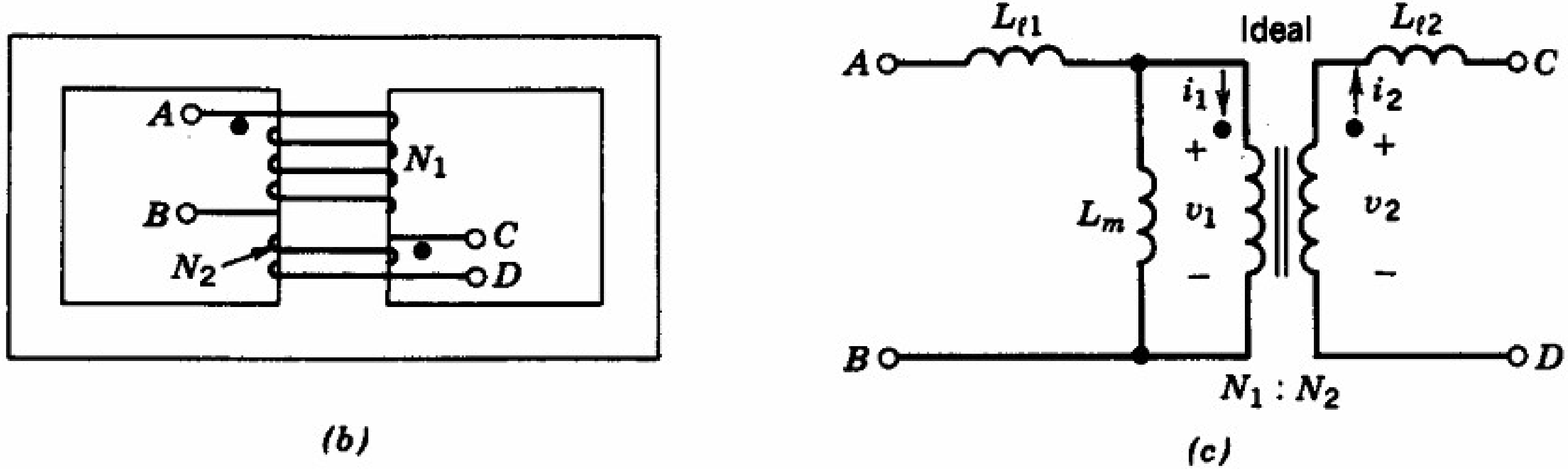
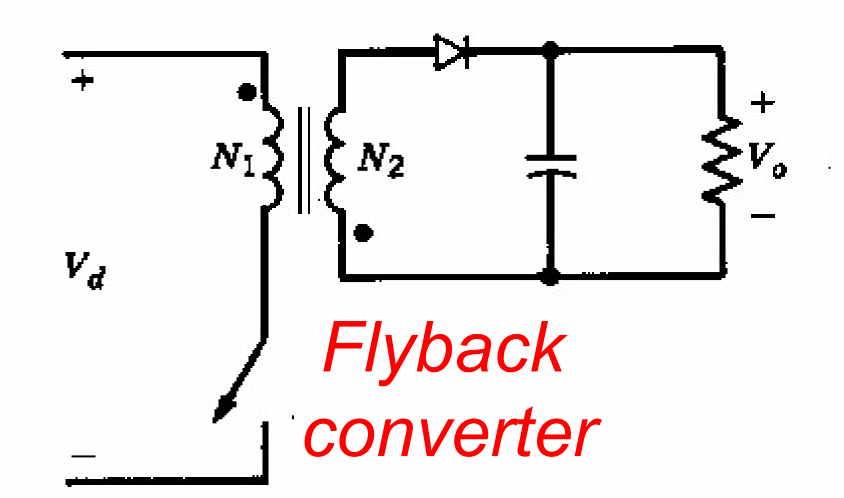
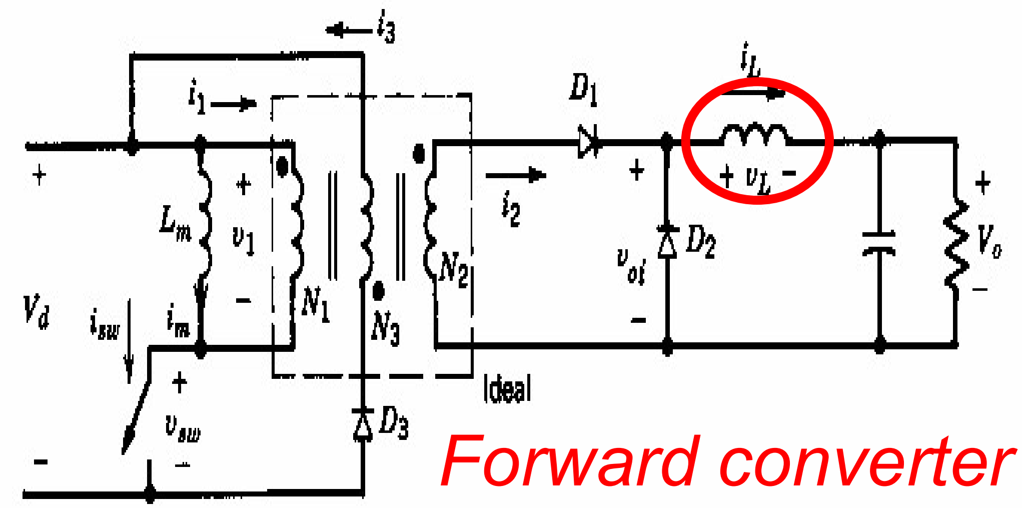


Figure 10-4 Transformer representation: (*a*) typical *B–H* loop of transformer core; (*b*) two-winding transformer; (*c*) equivalent circuit.

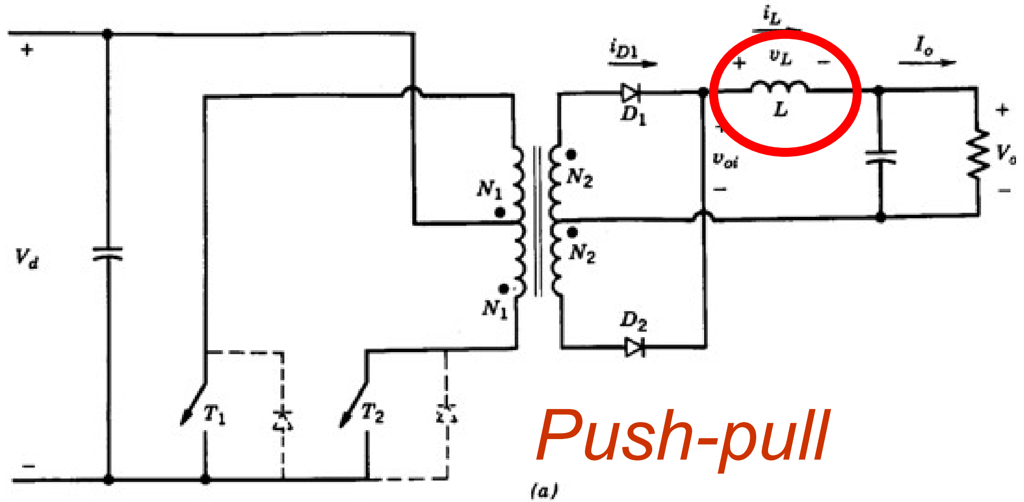
$$v_1 / v_2 = N_1 / N_2 \qquad i_1 N_1 = i_2 N_2$$



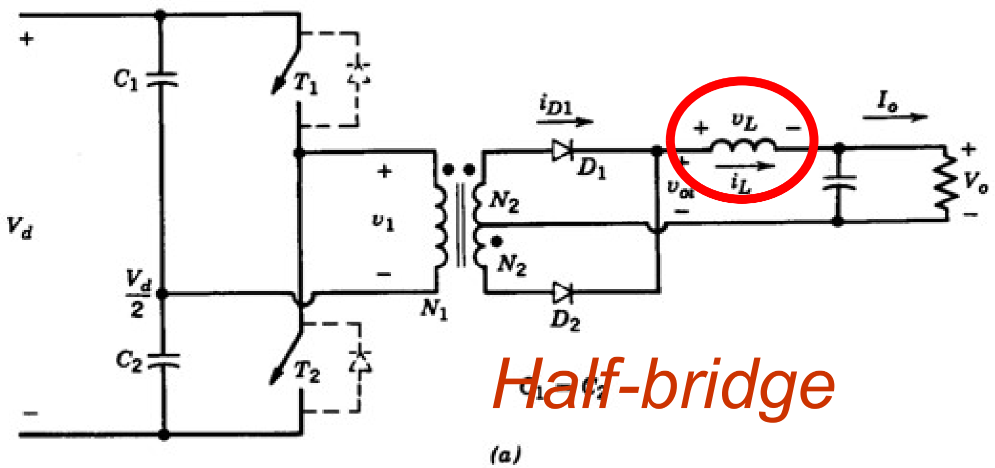
Flyback converter



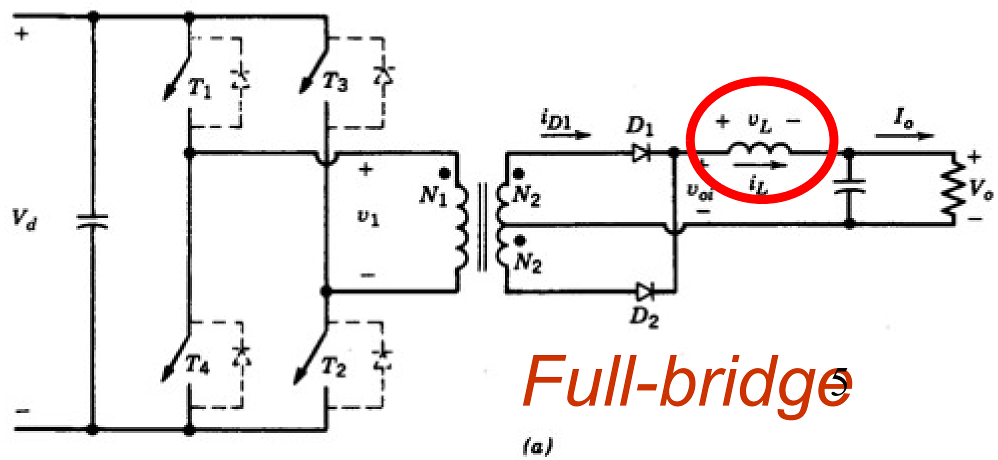
Forward converter



Push-pull



Half-bridge



Full-bridge

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Switching Power Supply

For the converters without output filter inductor

The change of flux through the core over one time period must be zero in steady state.

$$\phi(T_s) = \phi(0)$$

For the converters with output filter inductor

Equating the integral of the inductor voltage over one time period to zero.

Review

Switching Power Supply

***Important issue* —— Voltage transfer ratio**

Flyback converter $$\frac{V_o}{V_d} = \frac{N_2}{N_1}\frac{D}{1-D}$$

Forward converter $$\frac{V_o}{V_d} = \frac{N_2}{N_1}D$$

Push-pull converter $$\frac{V_o}{V_d} = 2\frac{N_2}{N_1}D \quad 0 < D < 0.5$$

Half-bridge converter $$\frac{V_o}{V_d} = \frac{N_2}{N_1}D \quad 0 < D < 0.5$$

Full-bridge converter $$\frac{V_o}{V_d} = 2\frac{N_2}{N_1}D \quad 0 < D < 0.5$$

Review

Introduction to Motor Drives

Basic Principles

Electromagnetic torque of motor

$$T - T_{\text{load}} = J\frac{d\omega}{dt}$$

$$T_{em} = J\frac{d\omega_m}{dt} + B\omega_m + T_{WL}(t) \qquad (\text{Eqs.}13-9)$$

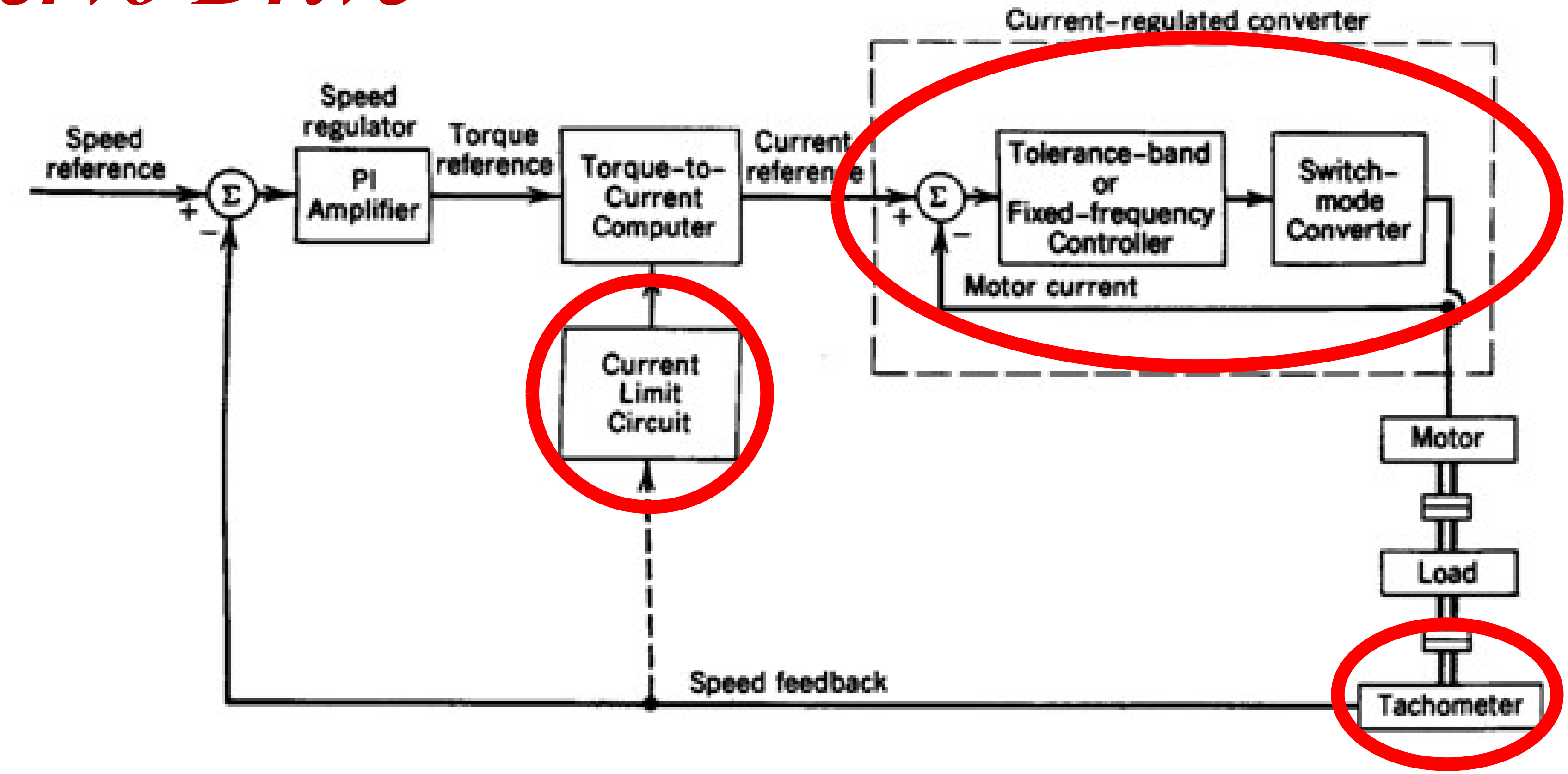
Total equivalent inertia J

Total equivalent damping B

Equivalent load torque T_{WL}

Introduction to Motor Drives

Servo Drive



- In servo drives, the response time and the accuracy with which the motor follows the speed and position commands are extremely important.

Review

Introduction to Motor Drives

Adjustable-speed Drive

- In a large number of applications, the accuracy and the response time of the motor to follow the speed command is not critical.

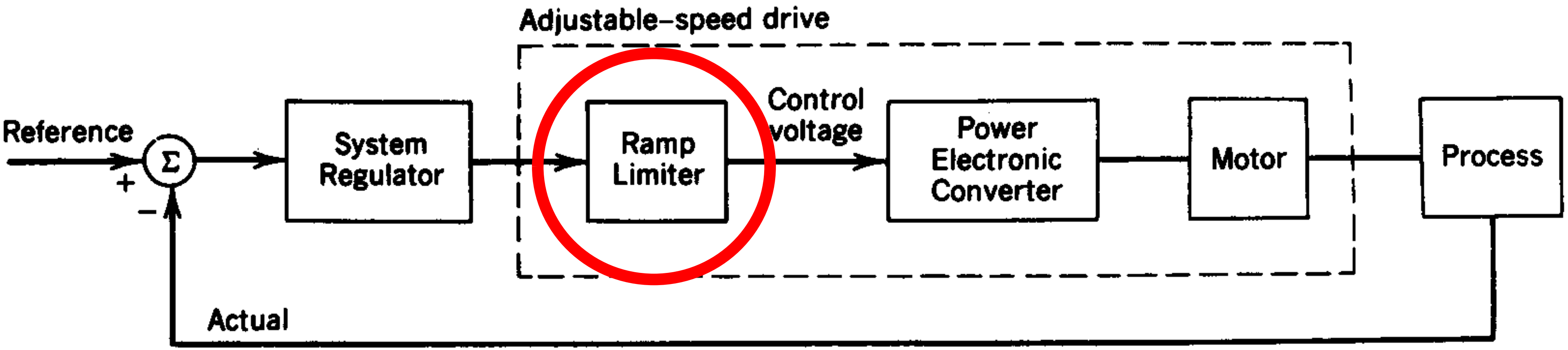


Figure 12-9 Ramp limiter to limit motor current.

By providing ramp limiters, drive can be prevented from "triping" under sudden changes.

Review

DC Motor Drives

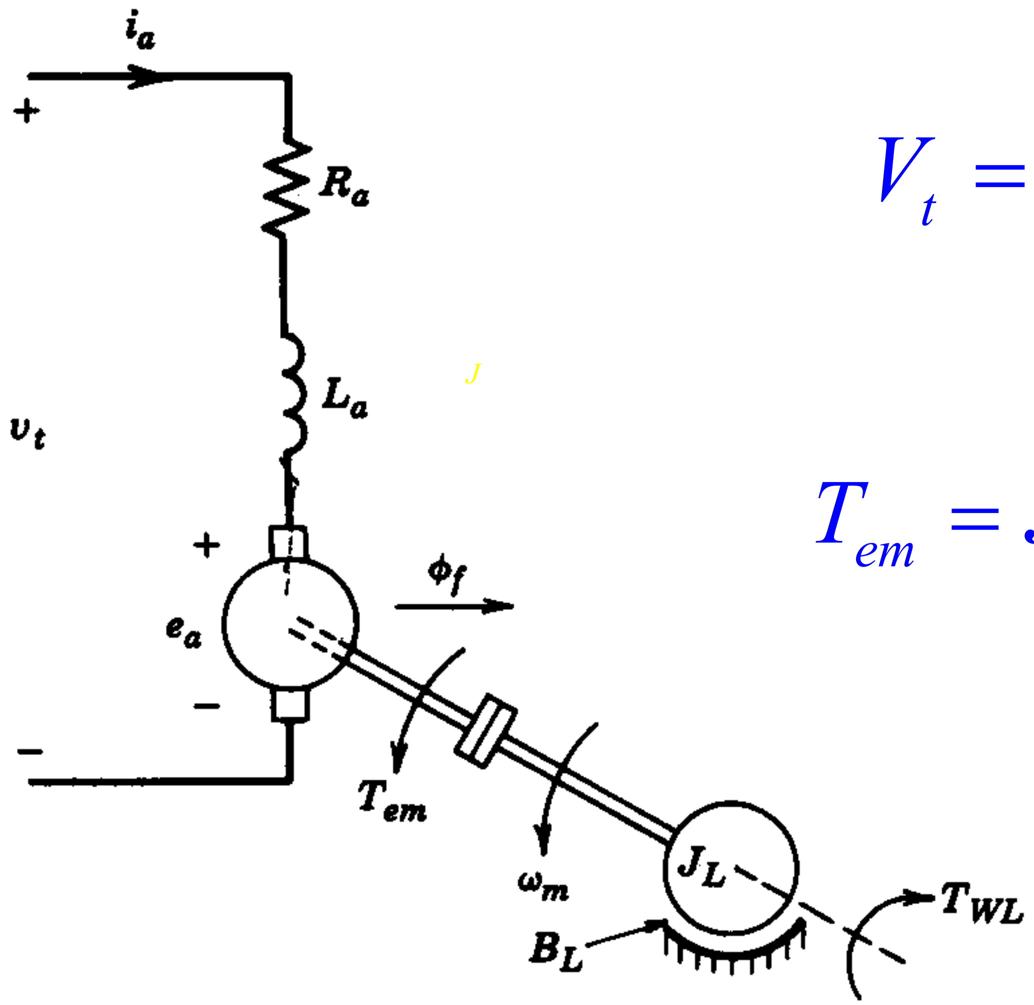


Figure 13-2 A dc motor equivalent circuit.

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

$$T_{em} = J \frac{d\omega_m}{dt} + B\omega_m + T_{WL}(t)$$

Total equivalent inertia J

Total equivalent damping B

Equivalent load torque T_{WL}

Review

DC Motor Drives

$$T_{em} = k_t \phi_f i_a \qquad e_a = k_e \phi_f \omega_m$$

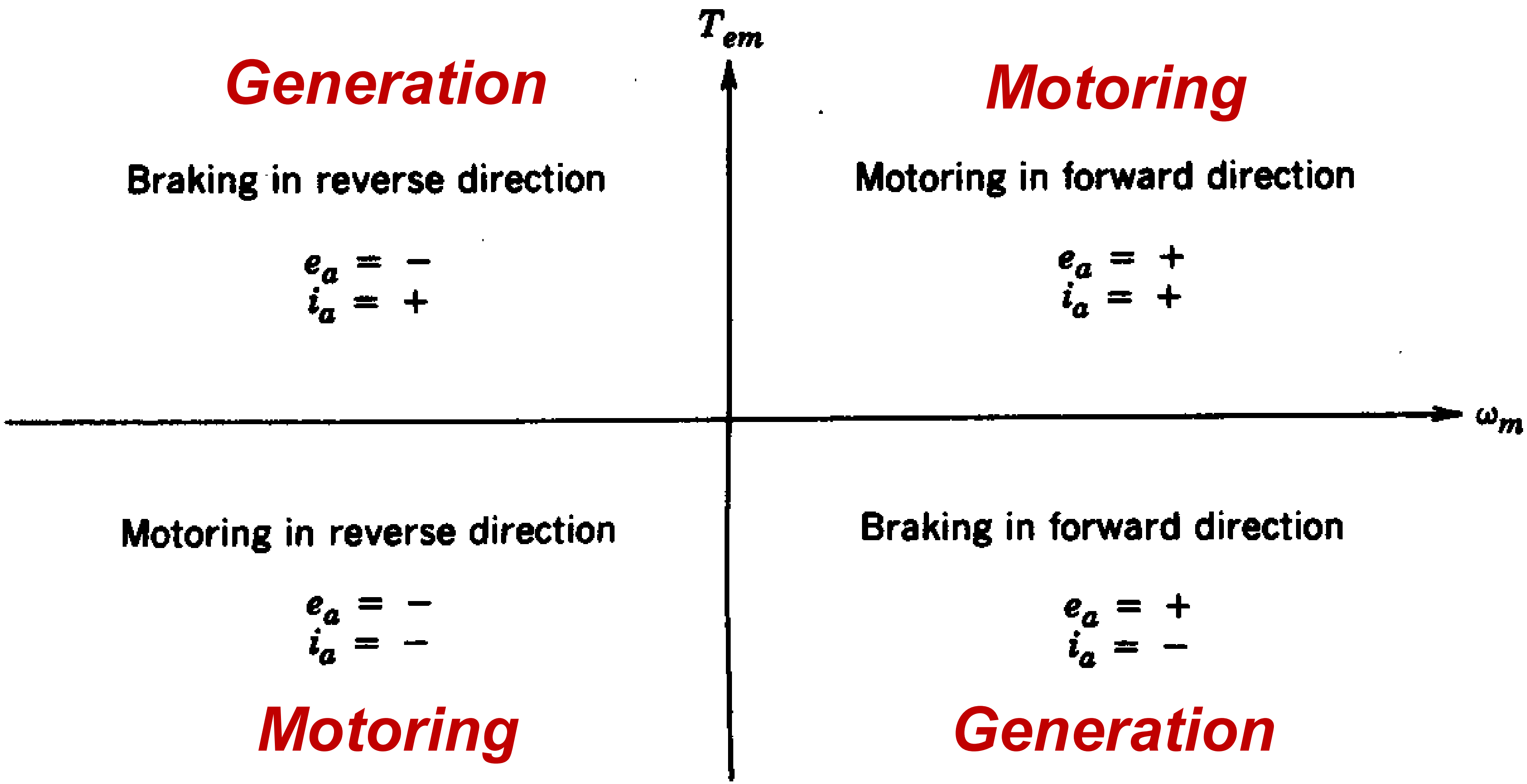


Figure 13-3 Four-quadrant operation of a dc motor.

Review

DC Motor Drives

Permanent Magnet DC Motor

- Electromagnetic torque

$$T_{\text{em}} = k_T I_a \qquad k_T = k_t \phi_f$$

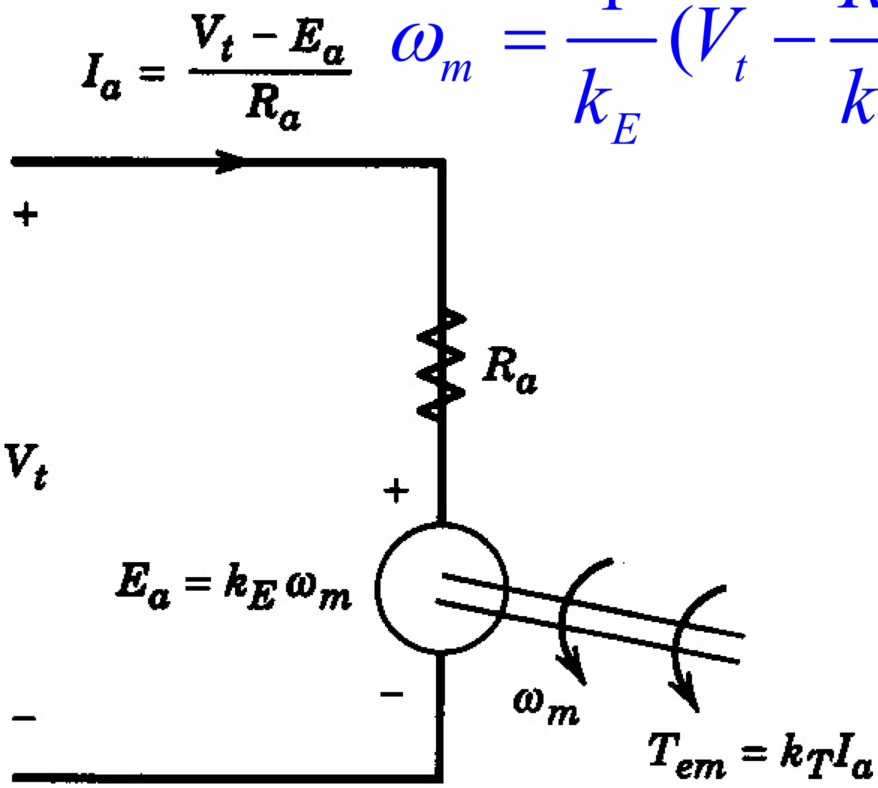
- Back-emf

$$E_{\text{a}} = k_E \omega_m \qquad k_E = k_e \phi_f$$

- Voltage equation

$$V_t = E_a + R_a I_a$$

$$\omega_m = \frac{1}{k_E}\left(V_t - \frac{R_a}{k_T} T_{em}\right)$$



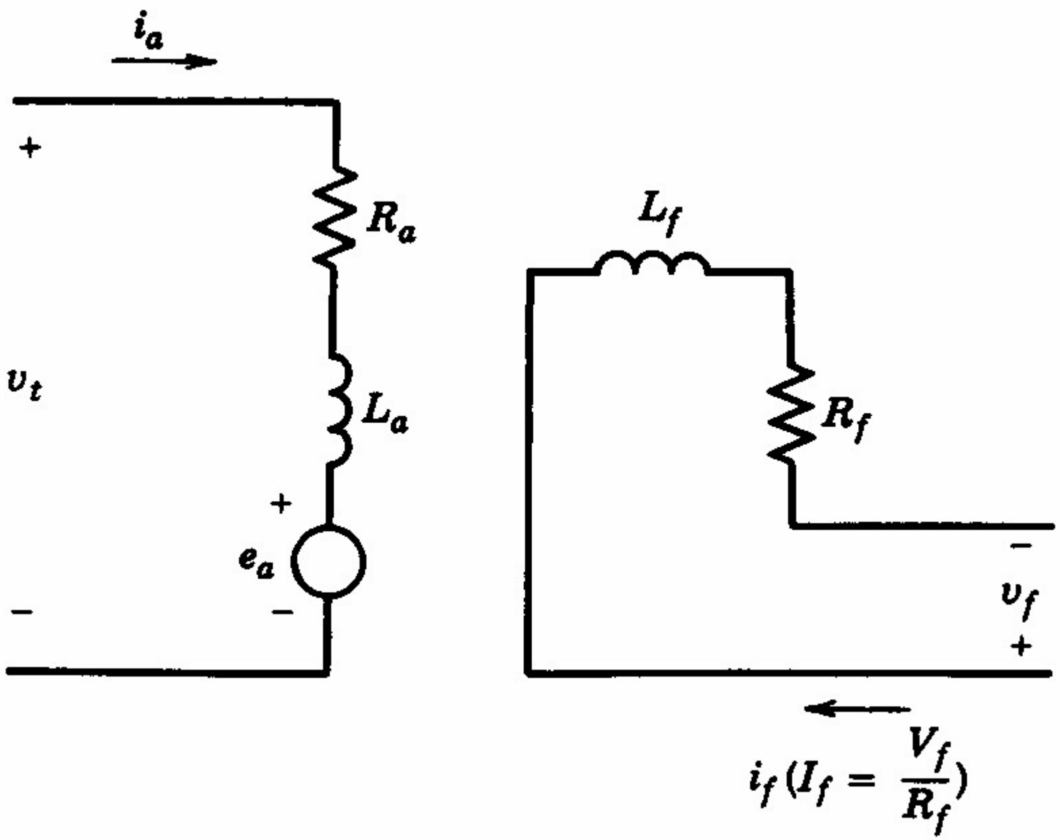
Equivalent circuit

DC Motor Drives

DC Motors with a Separately Excited Field Winding

$$I_f = \frac{V_f}{R_f}$$

$$\omega_m = \frac{1}{k_e \phi_f}\left(V_t - \frac{R_a}{k_t \phi_f} T_{em}\right)$$



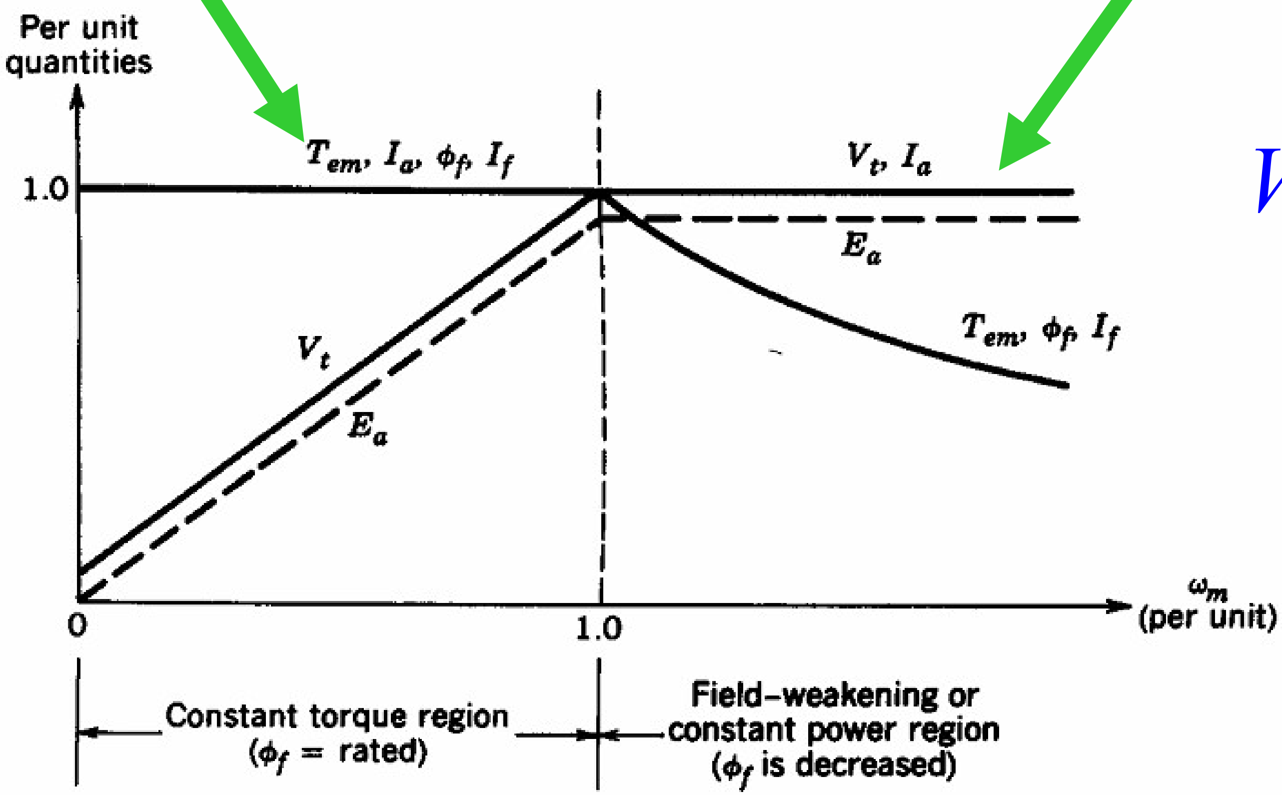
Equivalent circuit

Review

DC Motor Drives

DC Motors with a Separately Excited Field Winding

Constant torque control **Constant power control**



$$V_t = E_a + R_a I_a$$

$$E_a = k_e \phi_f \omega_m$$

$$T_{em} = k_t \phi_f i_a$$

Figure 13-5 Separately excited dc motor: (*a*) equivalent circuit; (*b*) continuous torque–speed capability.

Induction Motor Drives

Basic Principles

Table 14-1 Important Relationships

$$\omega_s = k_7 f$$
$$s = \frac{\omega_s - \omega_r}{\omega_s}$$
$$f_{sl} = sf$$
$$\%P_r = \frac{f_{sl}}{f - f_{sl}}$$
$$V_s \simeq k_3 \phi_{ag} f$$
$$I_r \simeq k_5 \phi_{ag} f_{sl}$$
$$T_{em} \simeq k_6 \phi_{ag}^2 f_{sl}$$
$$I_m = k_8 \phi_{ag} \quad \text{(from Eq. 14-5)}$$
$$I_s \simeq \sqrt{I_m^2 + I_r^2}$$

$$V_s \approx E_{ag}$$
$$\approx \frac{f}{f_{sl}} R_r I_r$$
$$\approx k_3 \phi_{ag} f$$

Stator frequency

VVVF control

Induction Motor Drives

VVVF Control - Torque-Speed Characteristics

- For small values of f_{sl} , keeping ϕ_{ag} constant results in a linear relationship between f_{sl} and T_{em} .

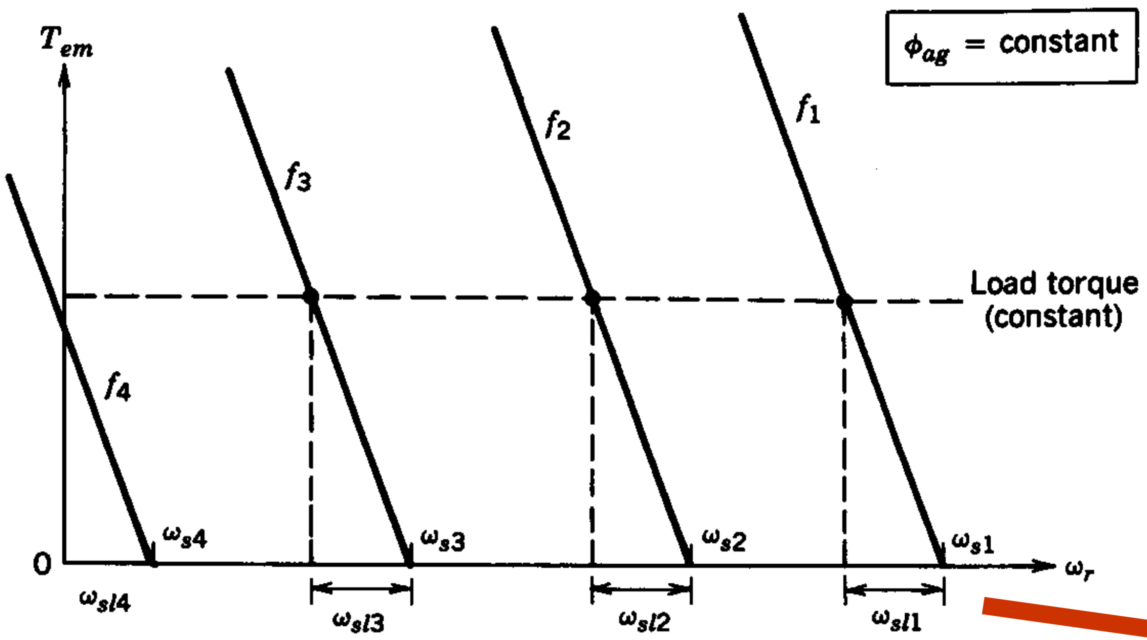


Figure 14-6 Torque–speed characteristics at small slip with a constant ϕ_{ag}; constant load torque.

$$T_{em} \approx k_9 f_{sl}$$

$$\omega_{sl} = \frac{f_{sl}}{f_s}\omega_s = \frac{4\pi}{p} f_{sl}$$

$$T_{em} \approx k_{10}\omega_{sl}$$

$$\omega_{sl1} = \omega_{sl2} = \omega_{sl3} = \omega_{sl4}$$

Review

Induction Motor Drives

VVVF Control – Voltage Boost

$$V_{\mathrm{s(rated)}} \approx k_{12} f_{\mathrm{rated}} + R_{\mathrm{s}} I_{\mathrm{r(rated)}}$$

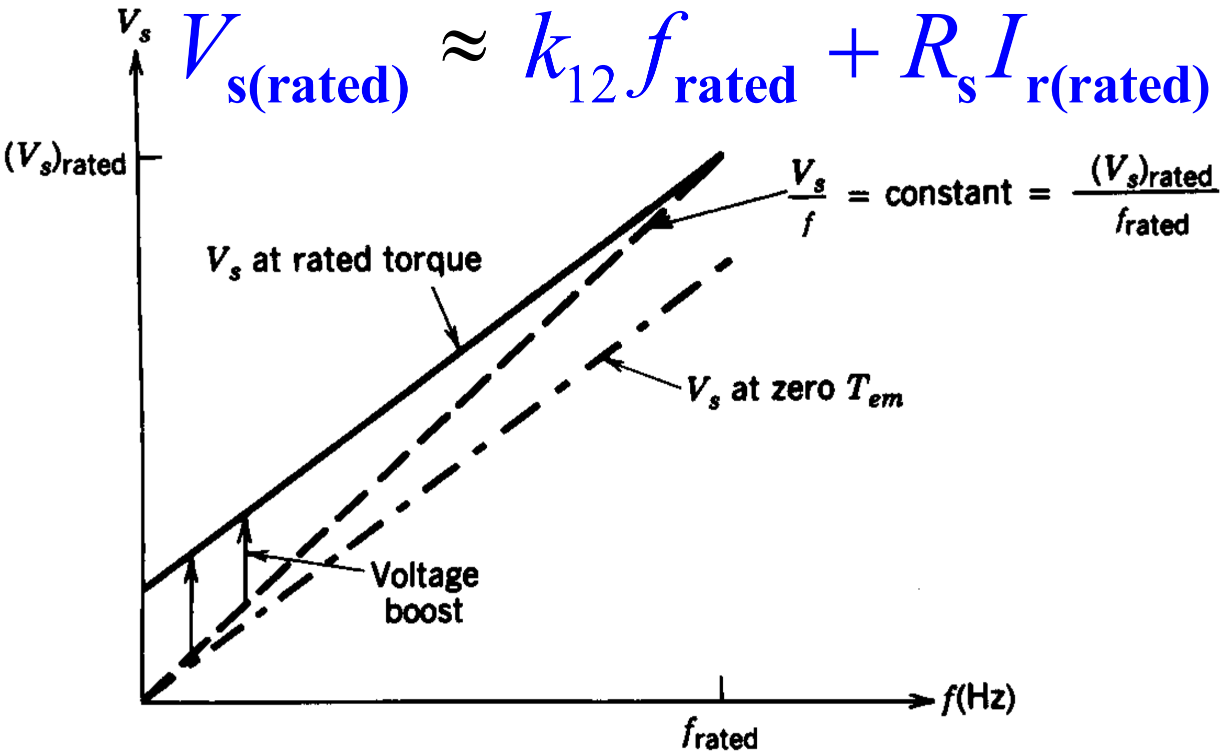


Figure 14-11 Voltage boost required to keep ϕ_{ag} constant.

If ϕ_{ag} *is kept constant.*

$$V_{\mathrm{s}} \approx k_{12} f + R_{\mathrm{s}} I_{\mathrm{r}}$$

proportional to T_{em}

Review

Induction Mot

Induction Motor Capability

Below the rated speed:
Constant-Torque Region

Beyond the rated speed:
Constant-Power Region

High speed operation:
Constant- f_{sl} Region

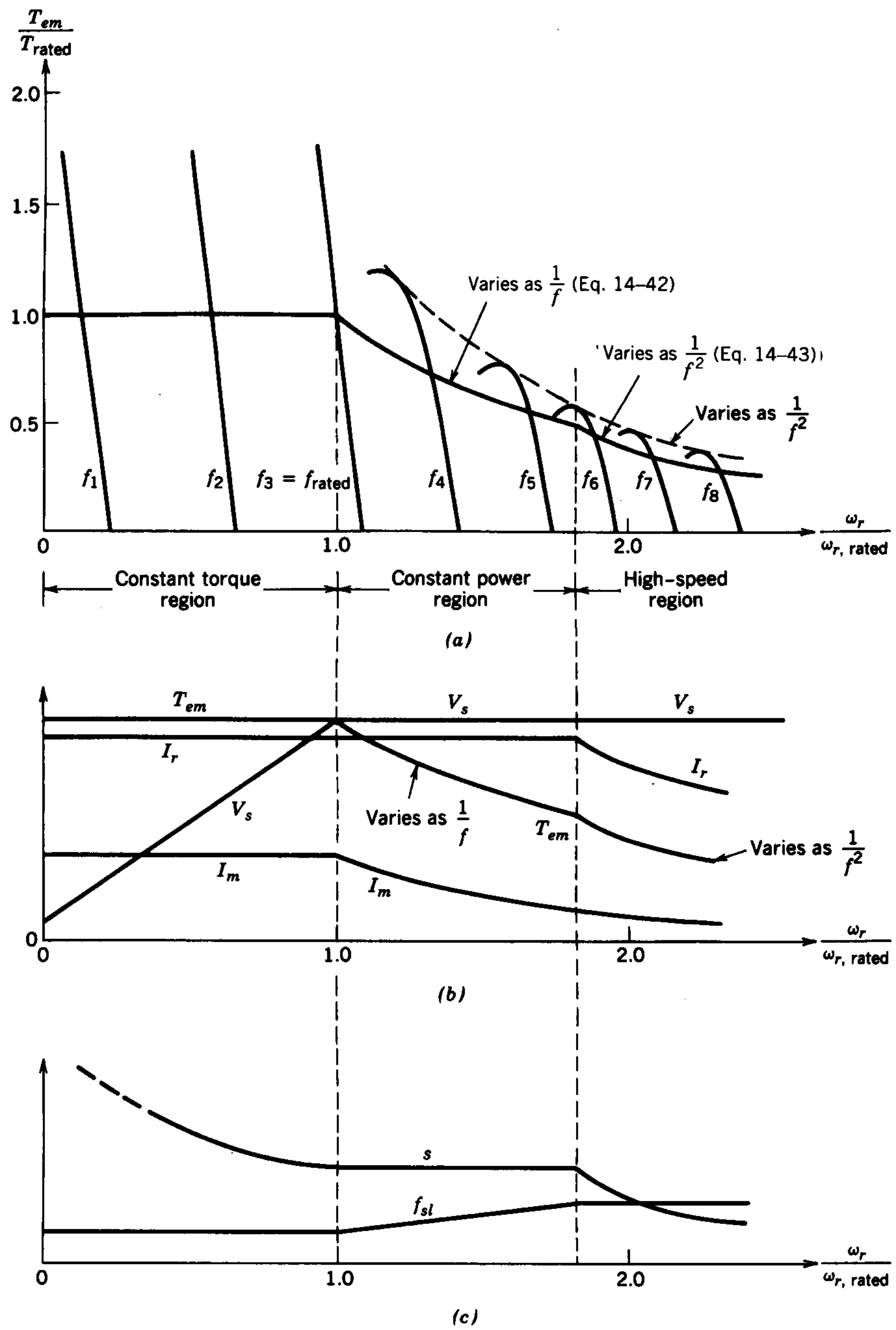
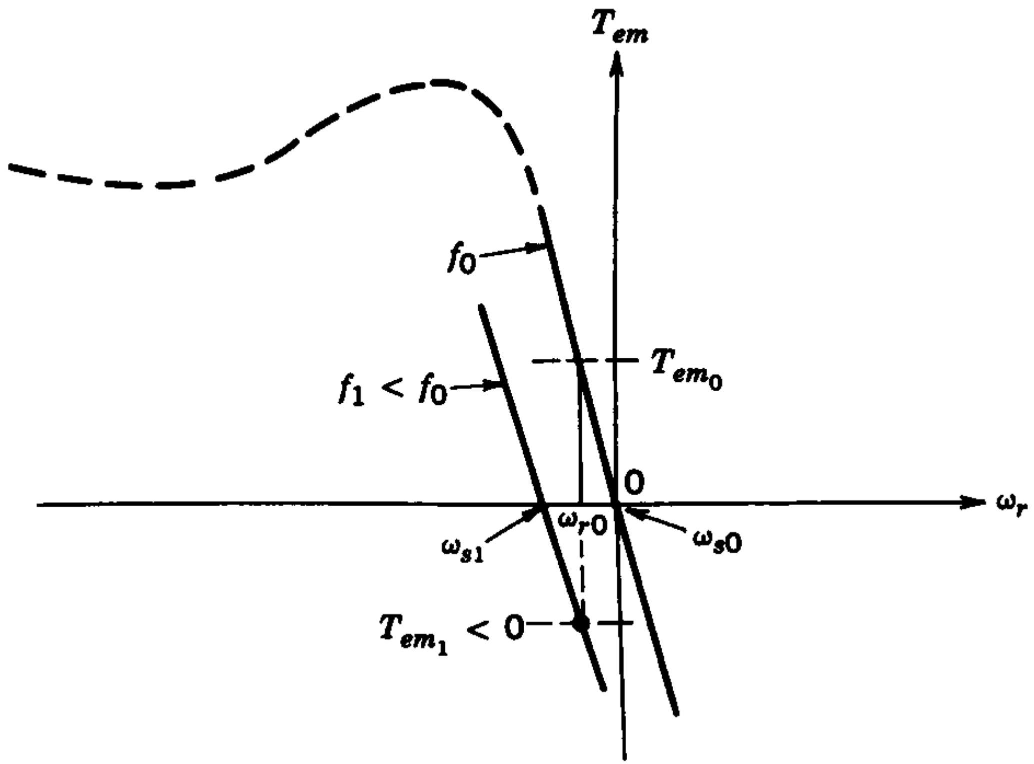


Figure 14-12 Induction motor characteristics and capabilities.

Braking in Induction Motors

• The negative T_{em} causes the motor speed to decrease quickly and some of the energy associated with the motor-load inertia is fed into the source connected to the stator.



Braking

$$f_0 \Rightarrow f_1$$

Figure 14-14 Braking (initial motor speed is ω_{r0} and the applied frequency is instantaneously decreased from f_0 to f_1).

Thanks &
Great wishes to you all
in 2025