# Chapter 13

# DC-Motor Drives



- These drives continue to be used

# DC-Motor Structure

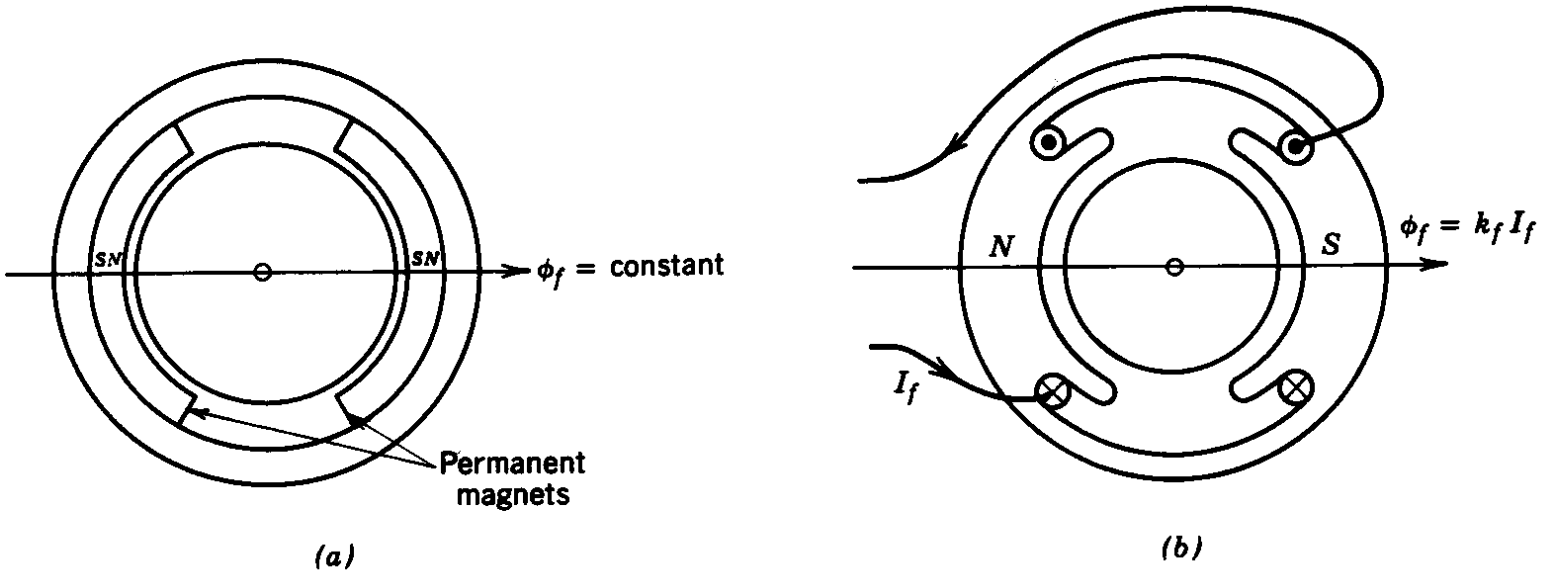


**Figure 13-1** A dc motor: (*a*) permanent-magnet motor; (*b*) dc motor with a field winding.

- With permanent magnets or a wound field

# DC-Motor Equivalent Circuit

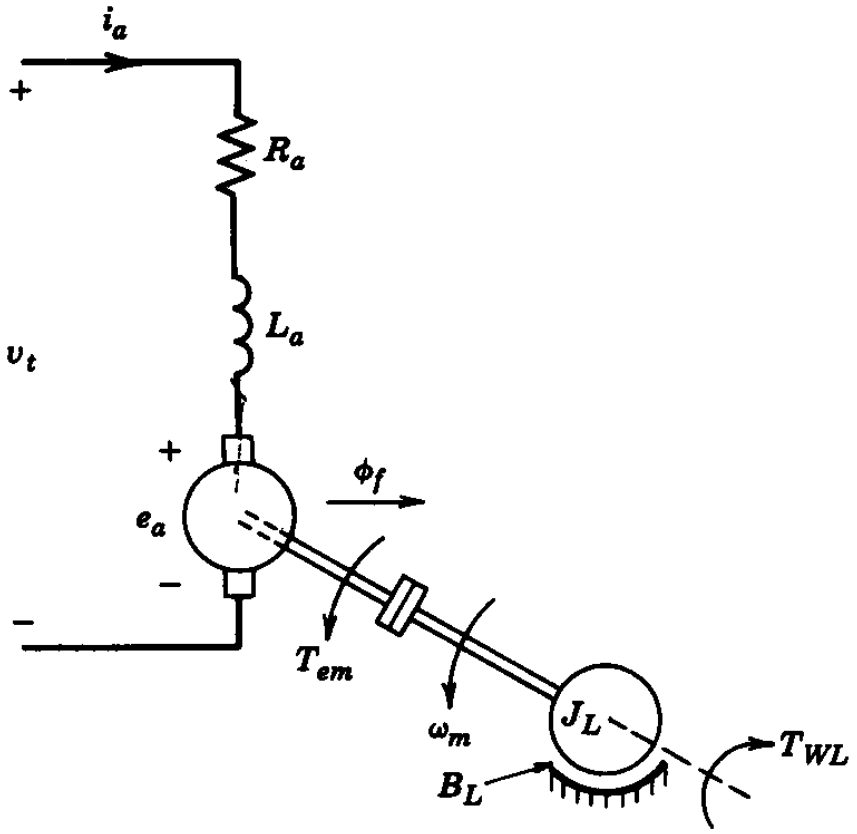


**Figure 13-2** A dc motor equivalent circuit.

- The mechanical system can also be represented as an electrical circuit

# Four-Quadrant Operation of DC-Motor Drives

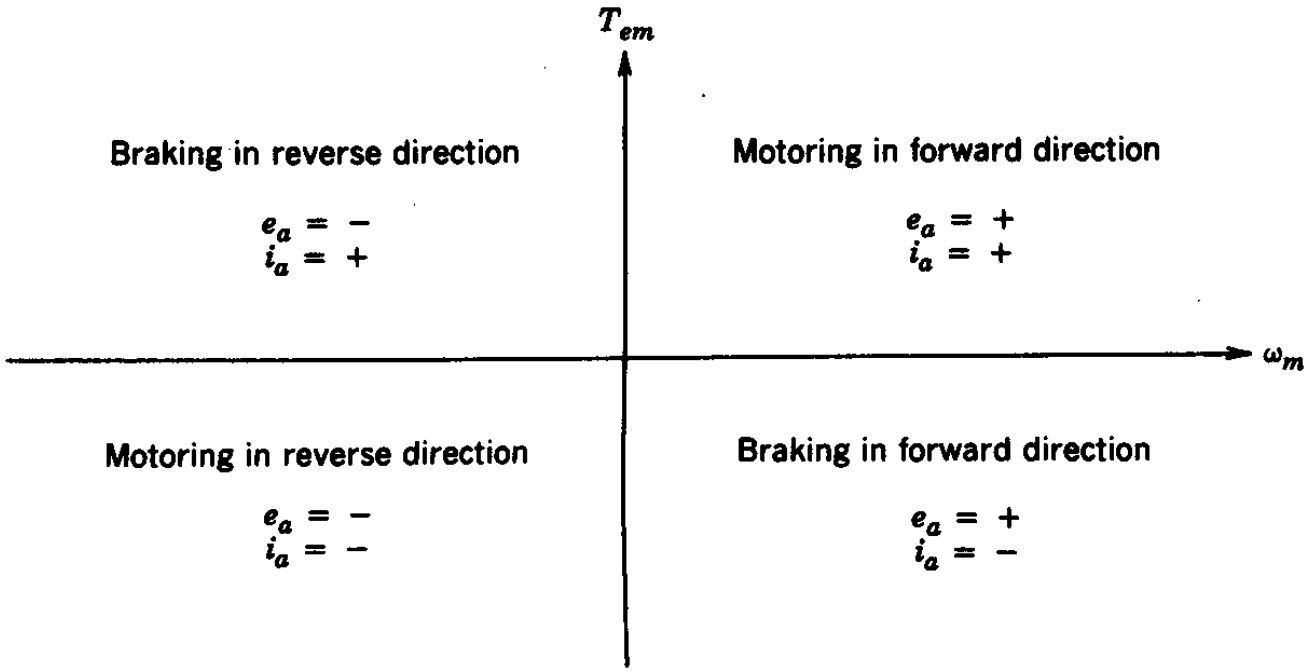


**Figure 13-3** Four-quadrant operation of a dc motor.

- High performance drives may operate in all four quadrants

# DC-Motor Drive Torque-Speed Characteristics and Capabilities

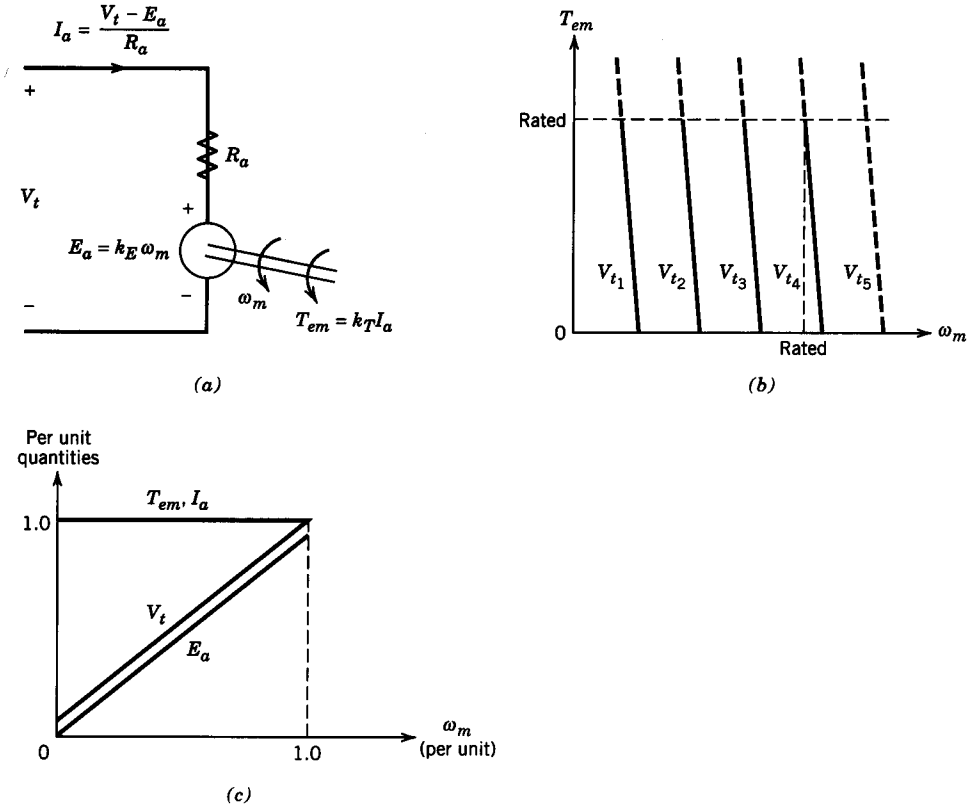


**Figure 13-4** Permanent-magnet dc motor: (*a*) equivalent circuit; (*b*) torque-speed characteristics: $V_{t5} > V_{t4} > V_{t3} > V_{t2} > V_{t1}$, where $V_{t4}$ is the rated voltage; (*c*) continuous torque–speed capability.

- With permanent magnets

# DC-Motor Drive Capabilities

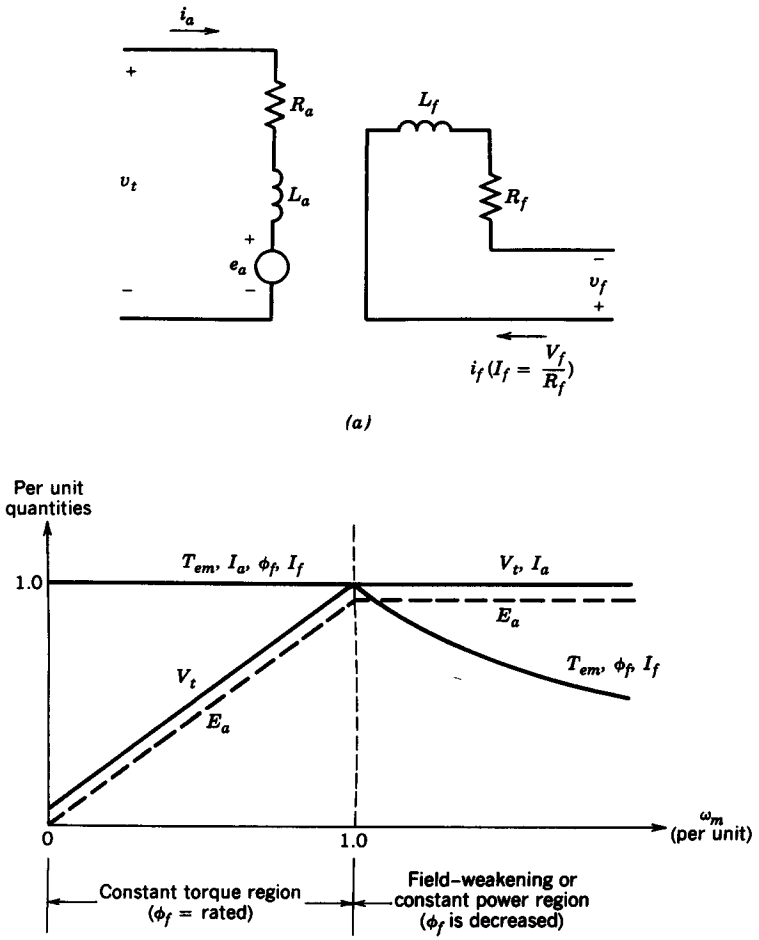


**Figure 13-5** Separately excited dc motor: (*a*) equivalent circuit; (*b*) continuous torque–speed capability.

- Separately-Excited field

# Controlling Torque, Speed and Position

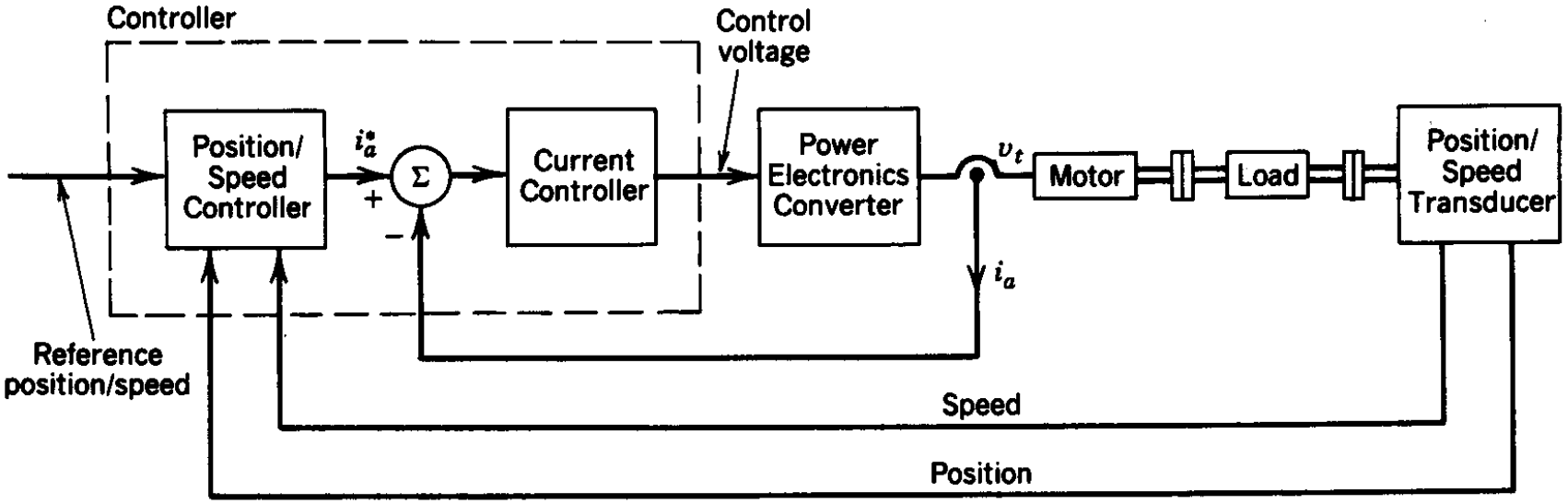


**Figure 13-6** Closed-loop position/speed dc servo drive.

- Cascaded control is commonly used

# Small-Signal Representation of DC Machines

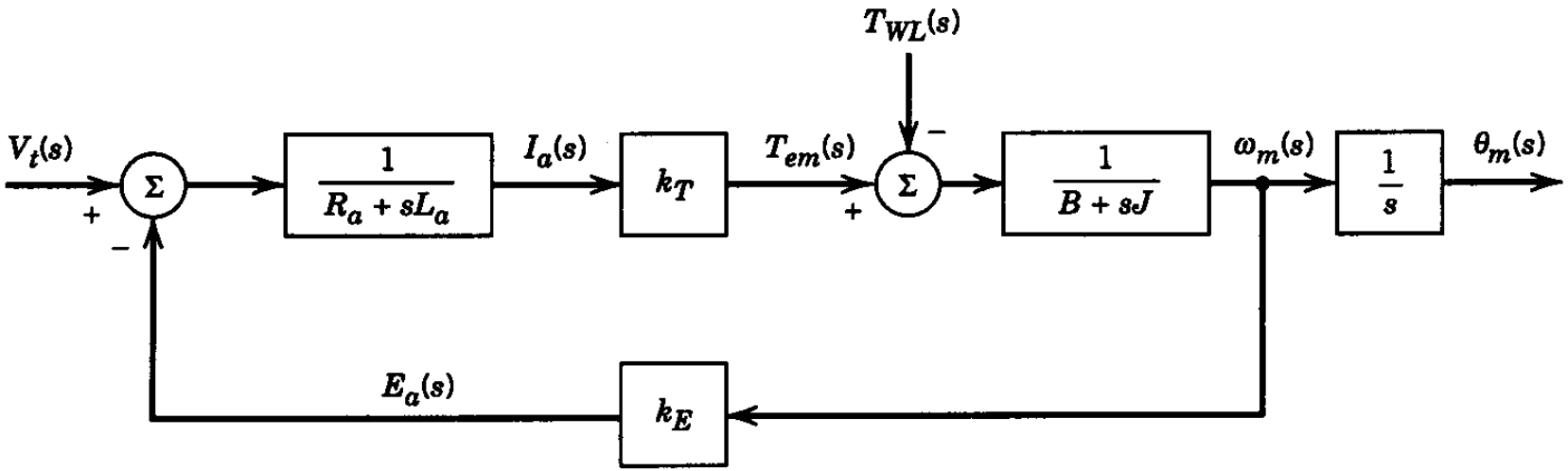


**Figure 13-7** Block diagram representation of the motor and load (without any feedback).

- Around a steady state operating point

# Electrical Time-Constant of the DC Machine

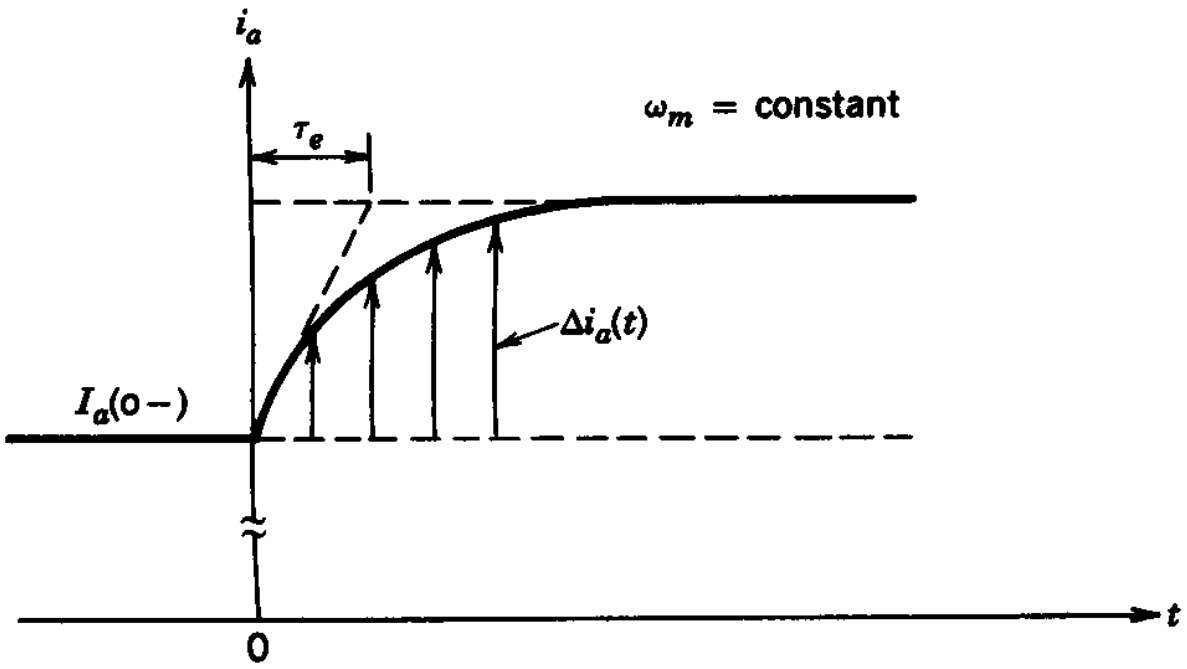


**Figure 13-8** Electrical time constant $\tau_e$; speed $\omega_m$ is assumed to be constant.

- The speed is assumed constant

# Mechanical Time-Constant of the DC Machine

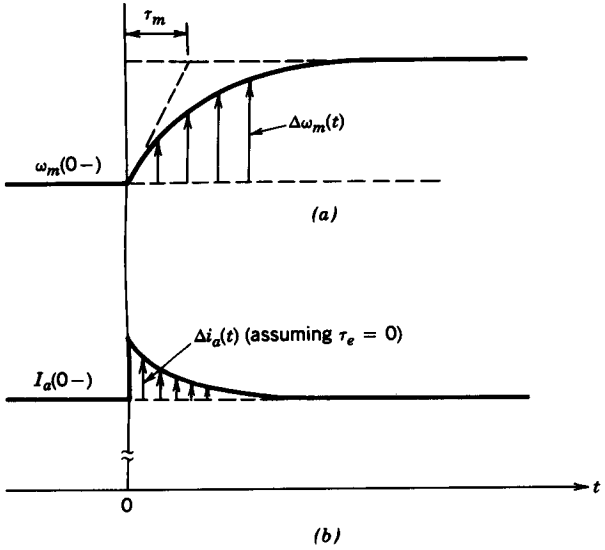


**Figure 13-9**
Mechanical time constant $\tau_m$; load torque is assumed to be constant.

- The load-torque is assumed constant

# DC-Motor Drive: Four-Quadrant Capability

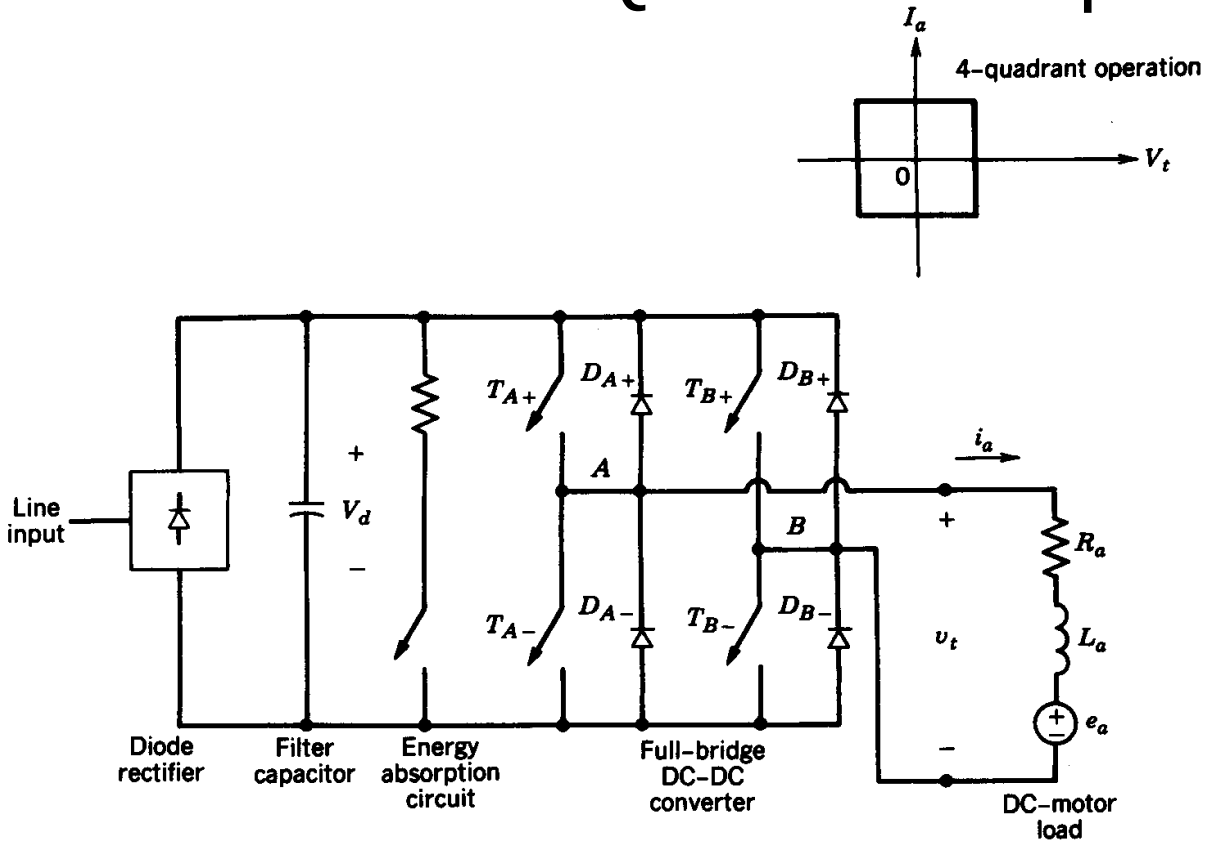


**Figure 13-10** A dc motor servo drive; four-quadrant operation.

- If a diode-rectifier is used, the energy recovered during regenerative braking is dissipated in a resistor

# Ripple in the Armature Current

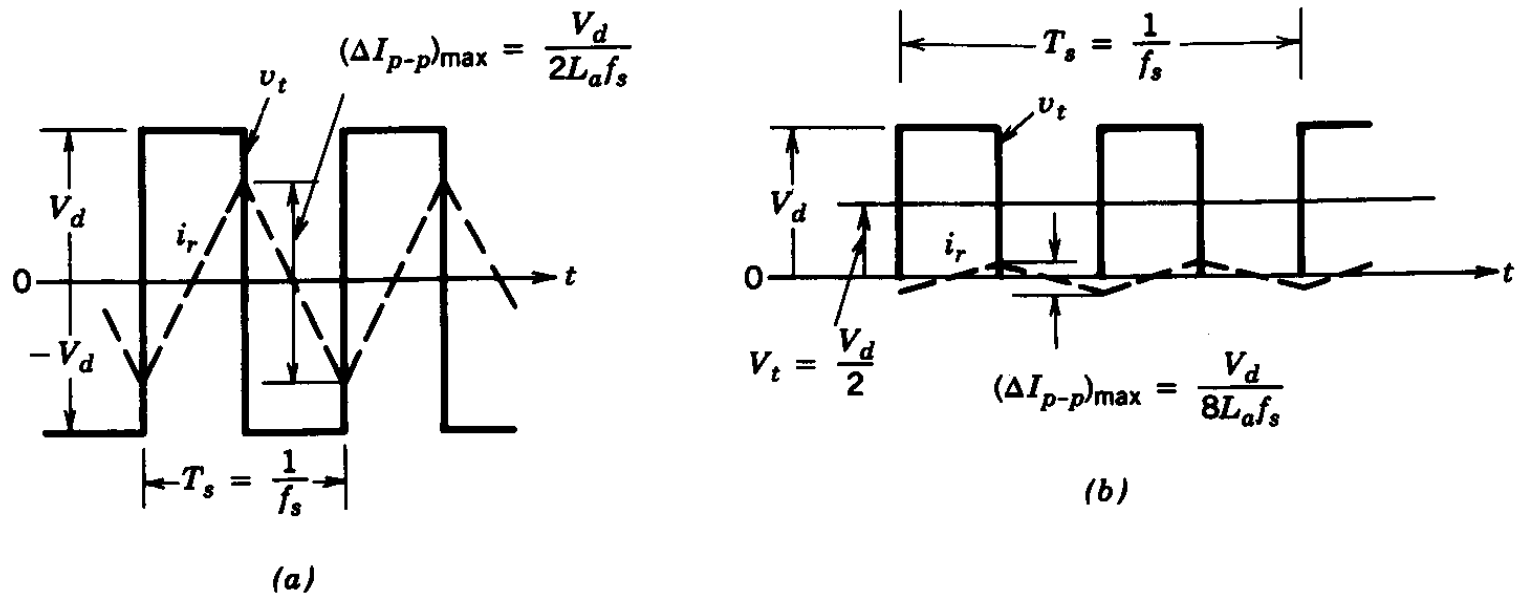


**Figure 13-11** Ripple $i_r$ in the armature current: ($a$) PWM bipolar voltage switching, $V_t = 0$; ($b$) PWM unipolar voltage switching, $V_t = \frac{1}{2}V_d$.

- Bi-polar and uni-polar voltage switchings

# Control of Servo Drives

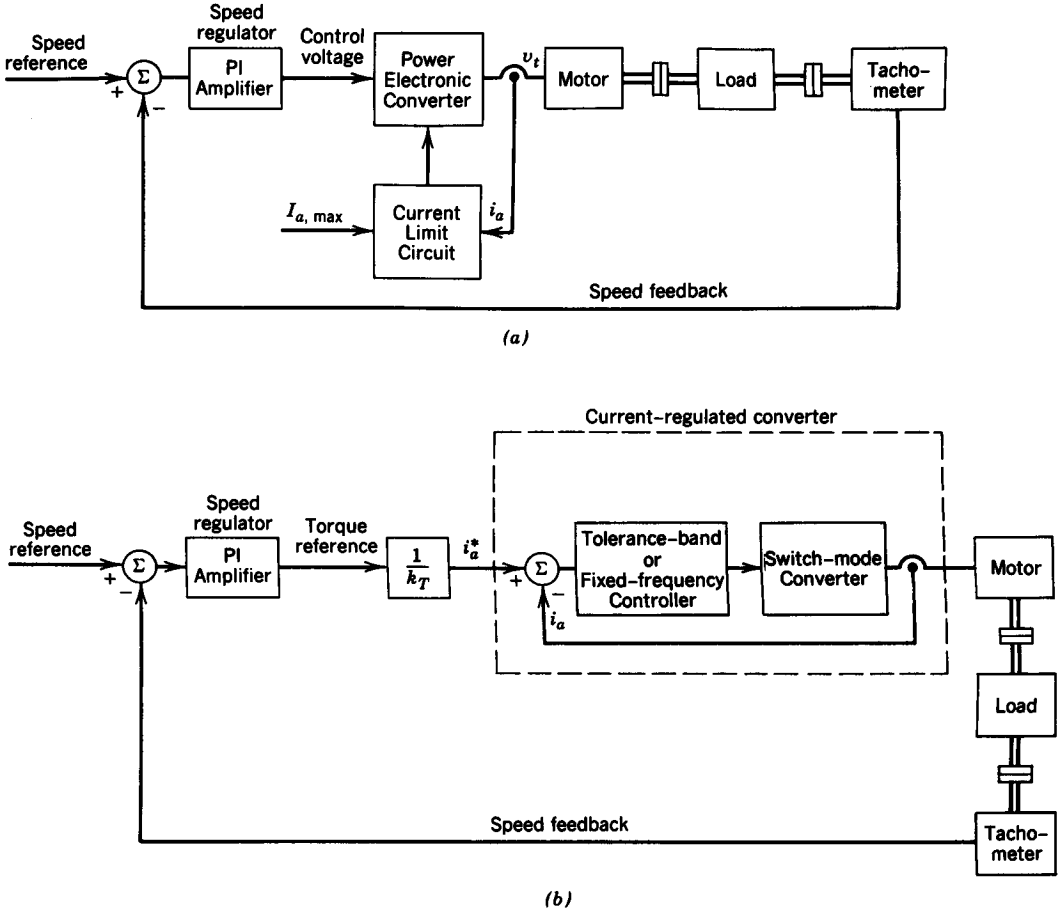


**Figure 13-12** Control of servo drives: (*a*) no internal current-control loop; (*b*) internal current-control loop.

- A concise coverage is presented in “Electric Drives: An Integrative Approach” by N. Mohan (www.MNPERE.com)

# Effect of Blanking Time

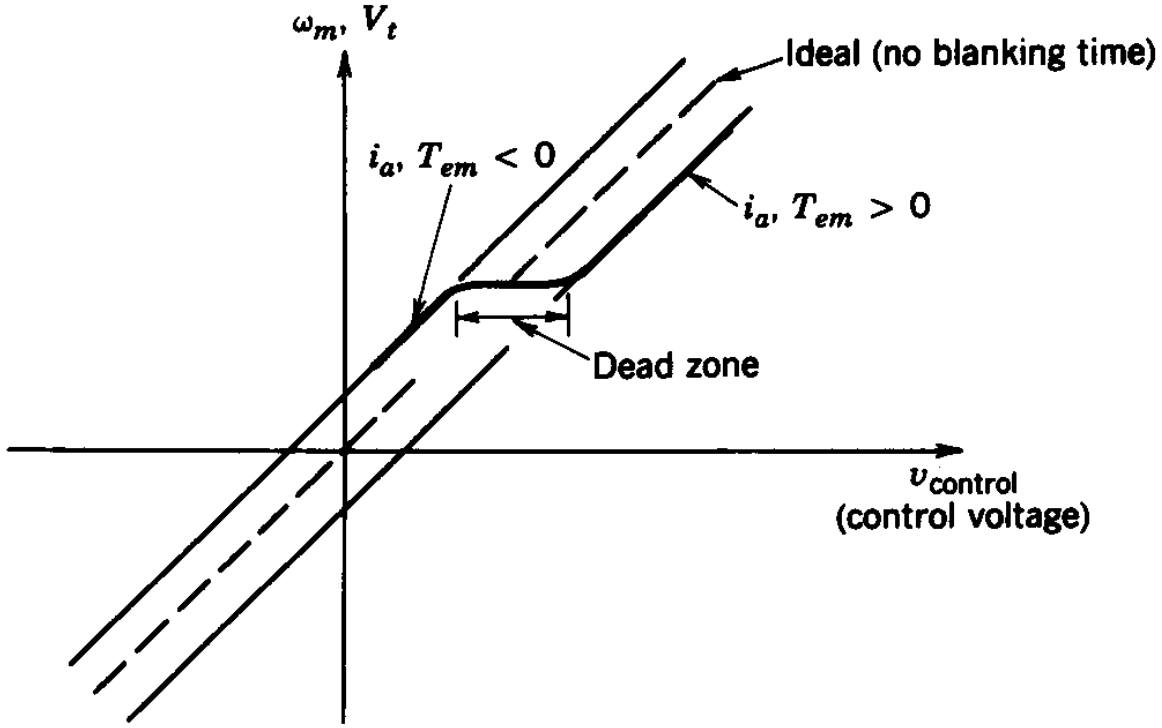


**Figure 13-13** Effect of blanking time.

- Non-linearity is introduced

# Converters for Limited Operational Capabilities

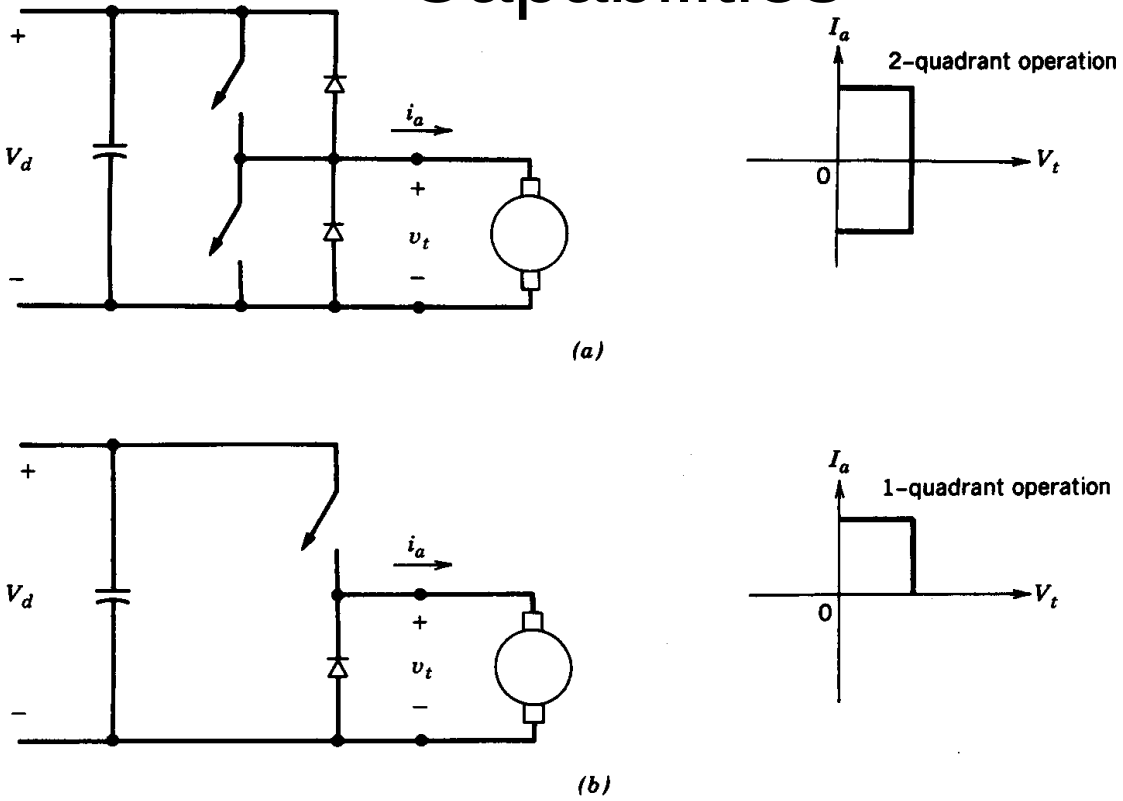


**Figure 13-14** (*a*) Two-quadrant operation; (*b*) single-quadrant operation.

- Two switches for 2-quadrant operation and only one switch for 1-quadrant operation

# Line-Controlled Converters for DC Drives

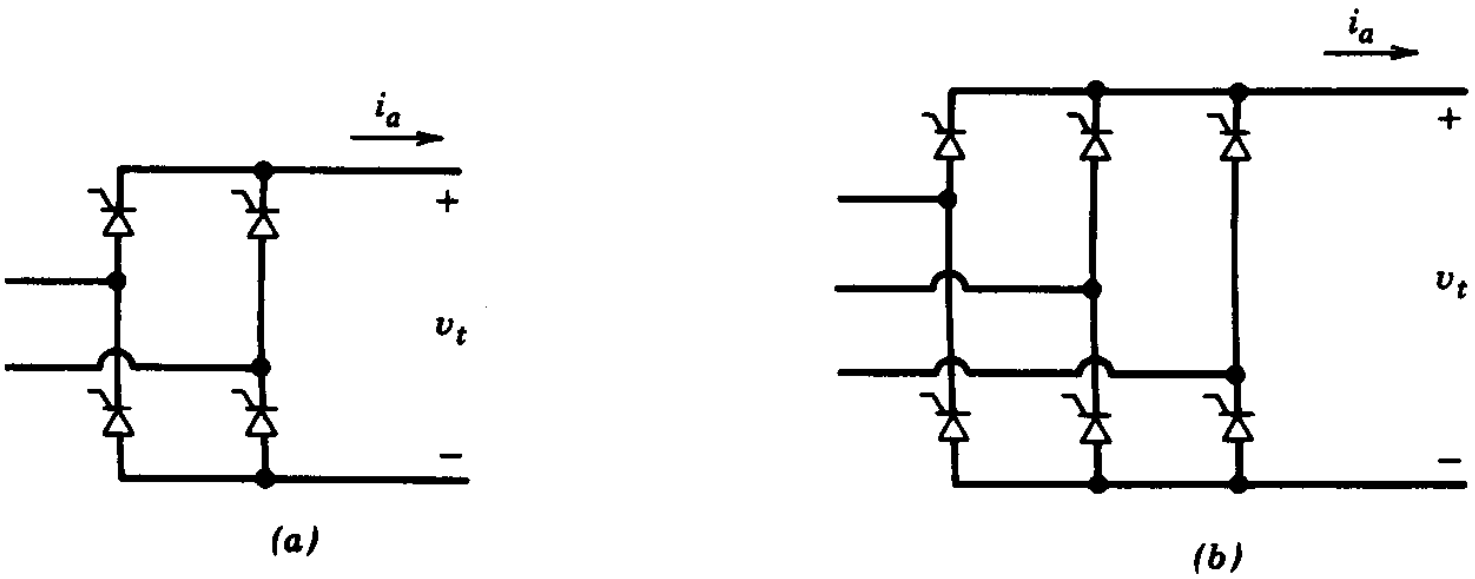


**Figure 13-15** Line-frequency-controlled converters for dc motor drives: (*a*) single-phase input; (*b*) three-phase input.

- Large low-frequency ripple in the dc output of converters

# Four Quadrant Operation using Line Converters

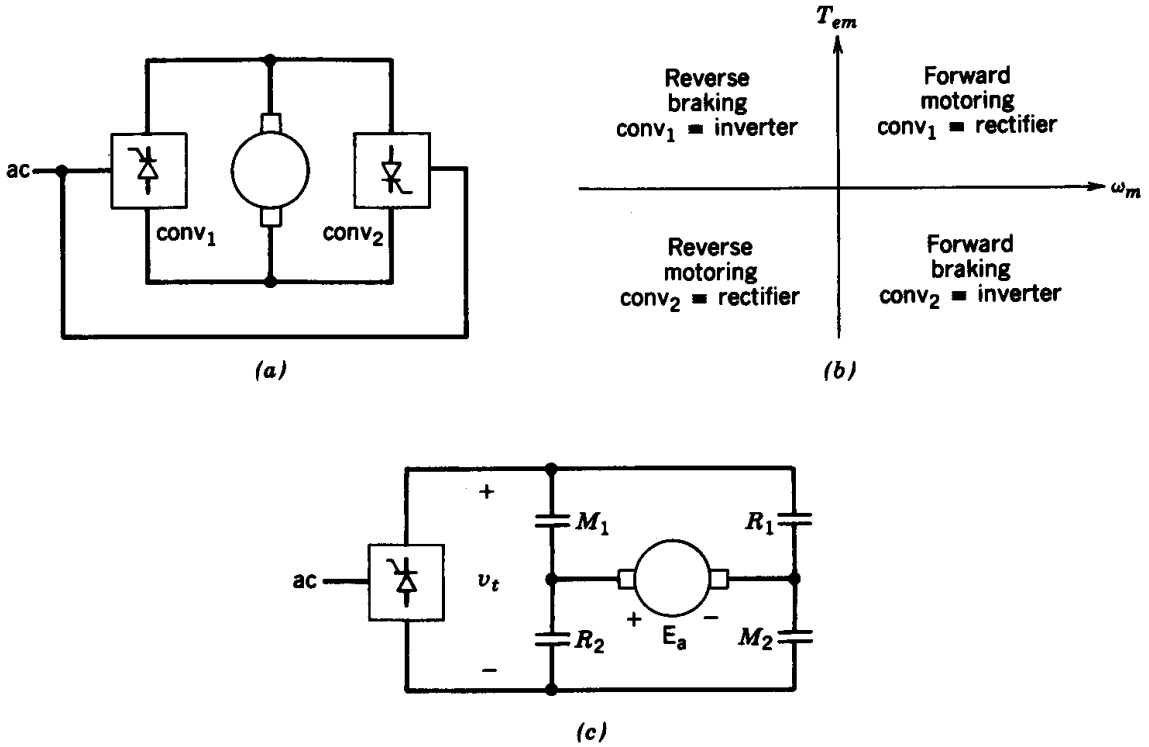


**Figure 13-16** Line-frequency-controlled converters for four-quadrant operation: (*a*) back-to-back converters for four-quadrant operation (without circulating current); (*b*) converter operation modes; (*c*) contactors for four-quadrant operation.

- Two options to achieve 4-quadrant operation

# Effect of Discontinuous Current Conduction

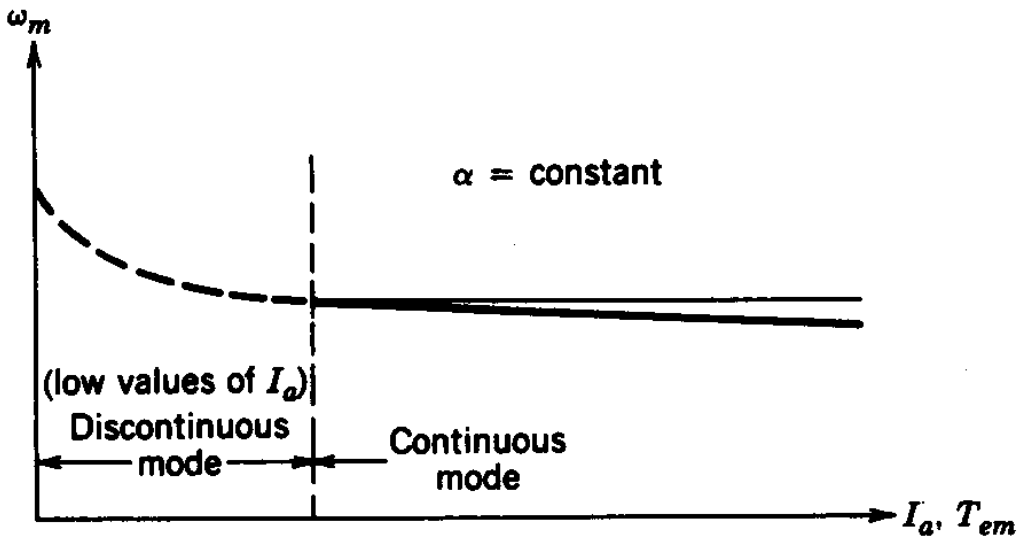


**Figure 13-17** Effect of discontinuous $i_a$ on $\omega_m$.

- Speed goes up unless it is controlled

# Open-Loop Speed Control

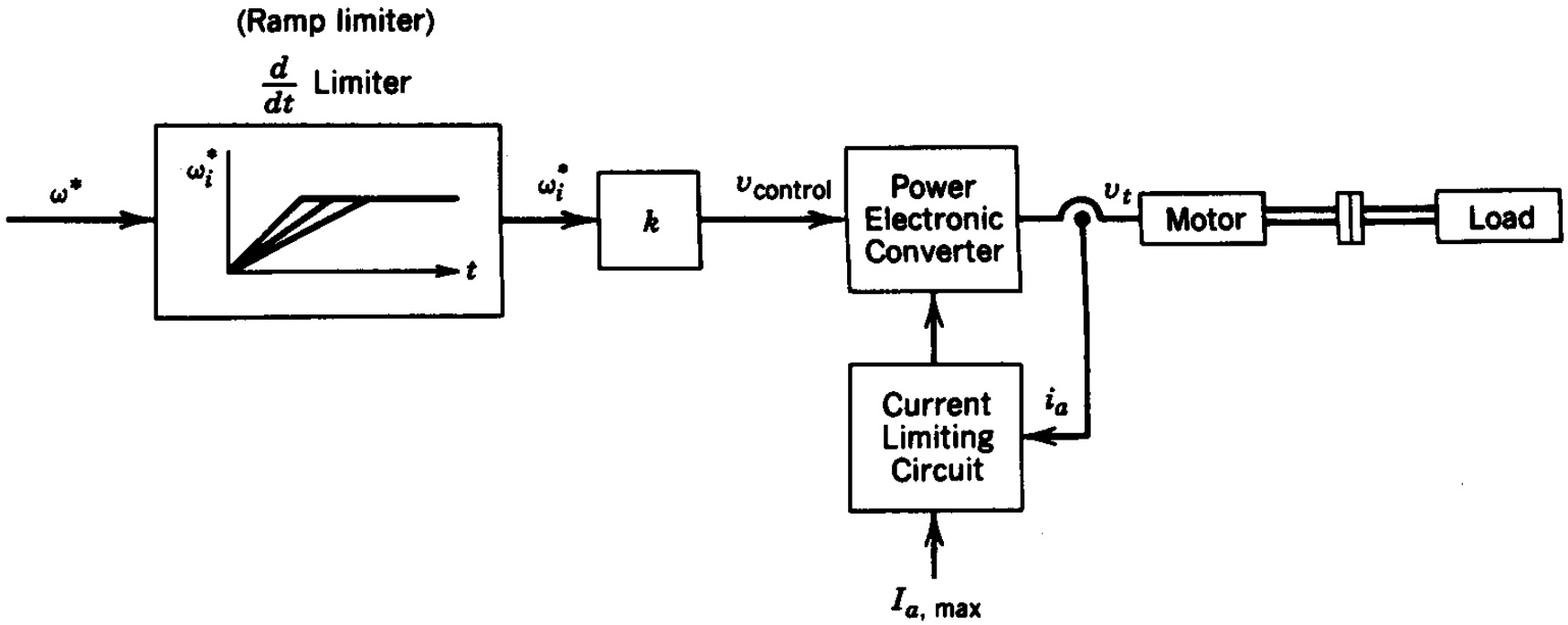


**Figure 13-18** Open-loop speed control.

- Adequate for general-purpose applications

# DC Drive Characteristics and Capabilities

- Line current in switch-mode and line-converter drives

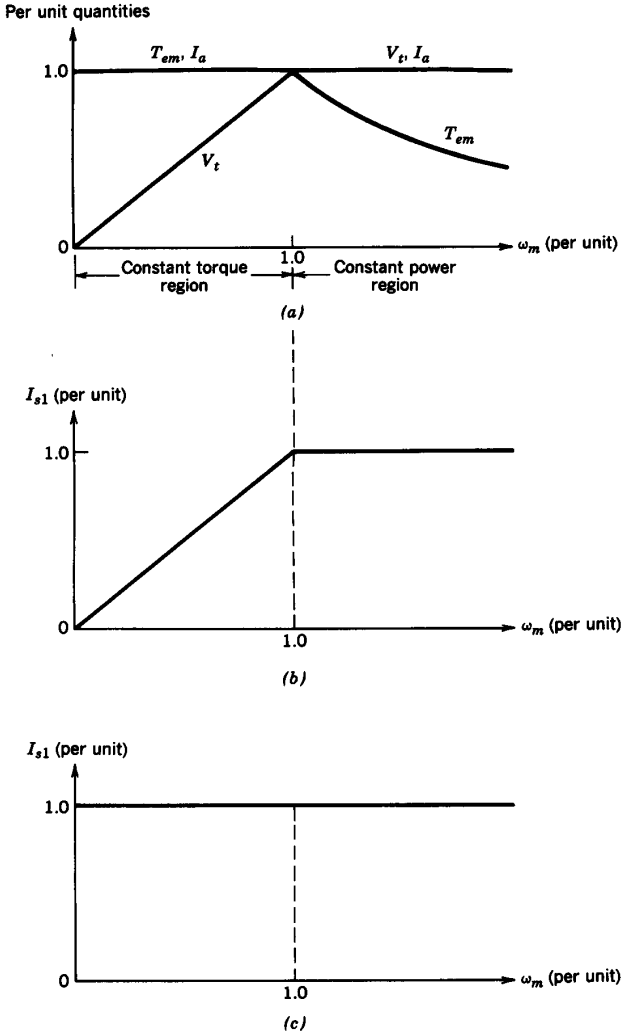


**Figure 13-19** Line current in adjustable-speed dc drives: (*a*) drive capability; (*b*) switch-mode converter drive; (*c*) line-frequency thyristor converter drive.