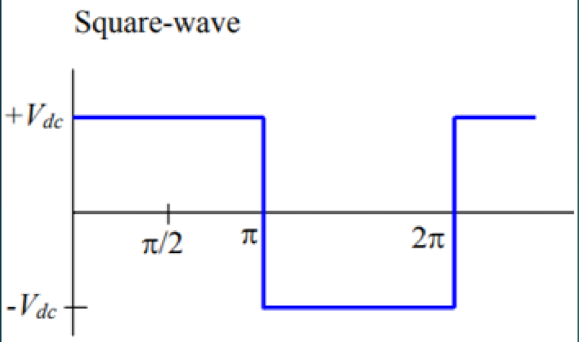
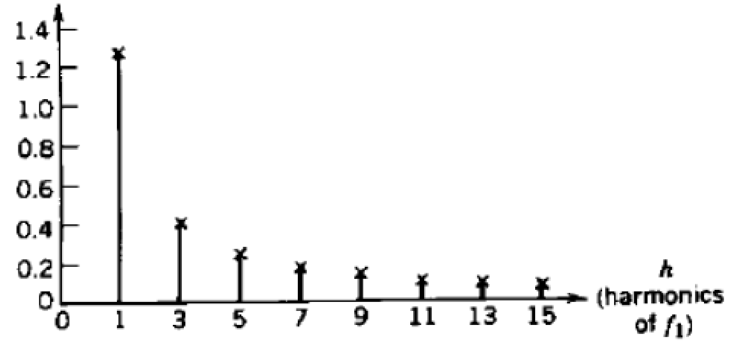
Power Electronics

EE312


بسم الله الرحمن الرحيم

Selective Harmonic Elimination based PWM





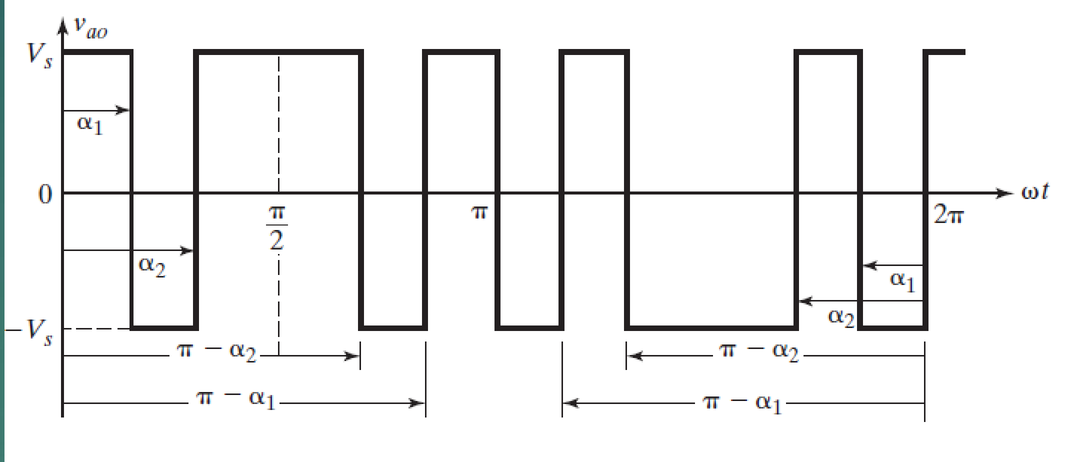
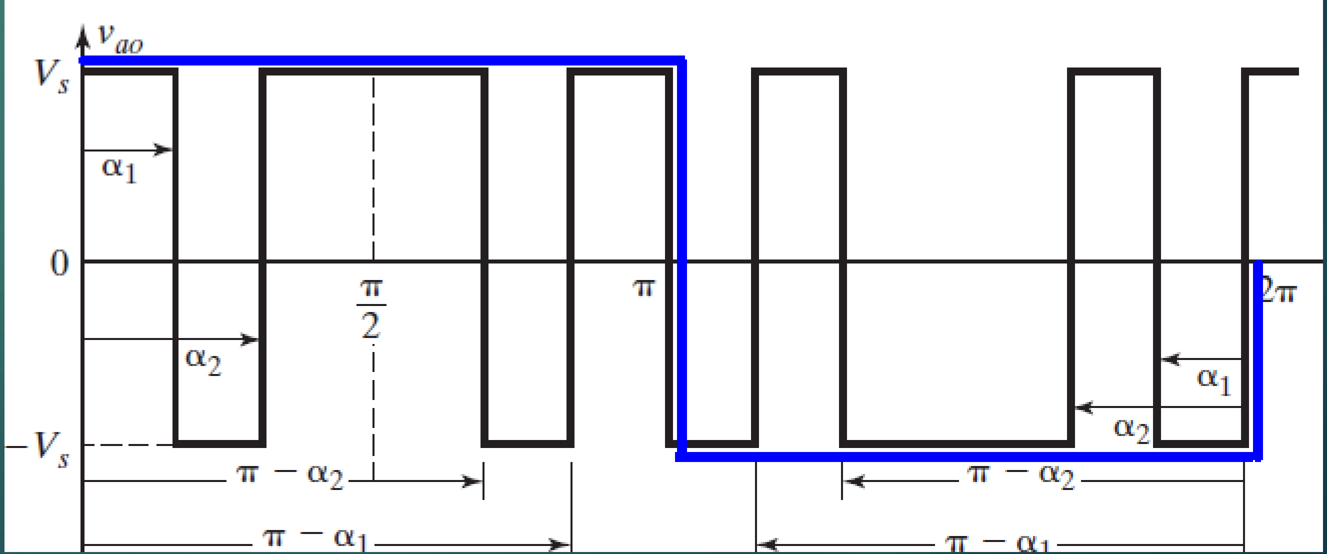


FIGURE 6.32

Output voltage with two bipolar notches per half-wave.



$$v_o = \sum_{n=1,3,5,\ldots}^{\infty} B_n \sin n\omega t$$

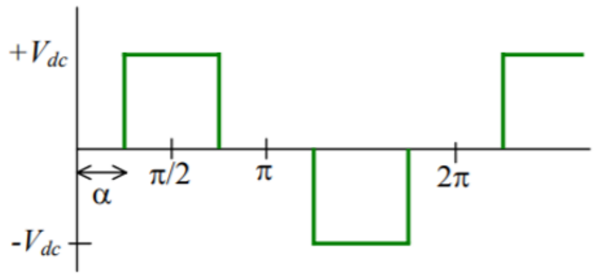
$$B_n = \frac{4V_s}{\pi}\left[\int_0^{\alpha_1} \sin n\omega t \, d(\omega t) - \int_{\alpha_1}^{\alpha_2} \sin n\omega t \, d(\omega t) + \int_{\alpha_2}^{\pi/2} \sin n\omega t \, d(\omega t)\right]$$

$$= \frac{4V_s}{\pi}\frac{1 - 2\cos n\alpha_1 + 2\cos n\alpha_2}{n} \qquad (6.92)$$

$$a_n = \frac{1}{\pi}\int_0^{2\pi} v_o(\omega t)\cos n\omega t \, d(\omega t)$$

$$b_n = \frac{1}{\pi}\int_0^{2\pi} v_o(\omega t)\sin n\omega t \, d(\omega t)$$

Quasi square-wave



$$b_n = \frac{4}{\pi}\int_{\alpha}^{\frac{\pi}{2}} v_o \sin(n\omega t) d(\omega t)$$

$$= \frac{4}{\pi}\int_{\alpha}^{\frac{\pi}{2}} V_{dc} \sin(n\omega t) d(\omega t)$$

$$= \frac{4V_{dc}}{n\pi}\left[-con(n\omega t\right]_{\alpha}^{\frac{\pi}{2}}$$

$$= \frac{4V_{dc}}{n\pi}\cos(n\alpha)$$

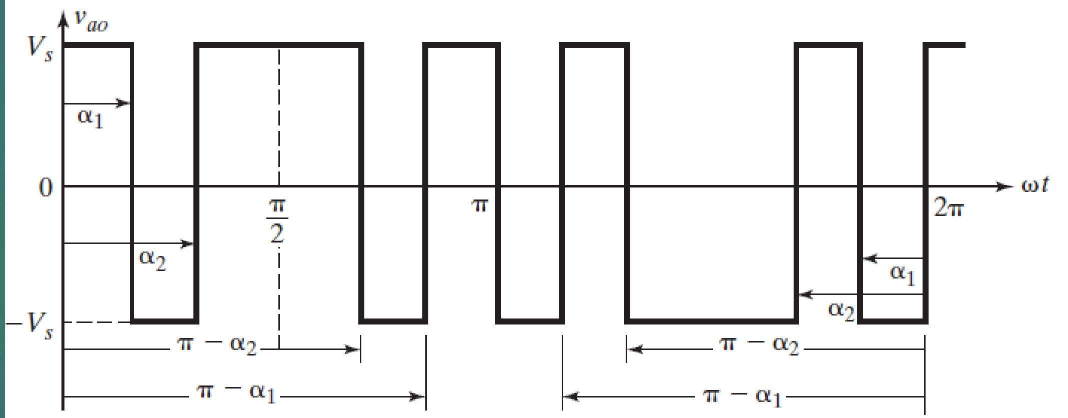


FIGURE 6.32

Output voltage with two bipolar notches per half-wave.

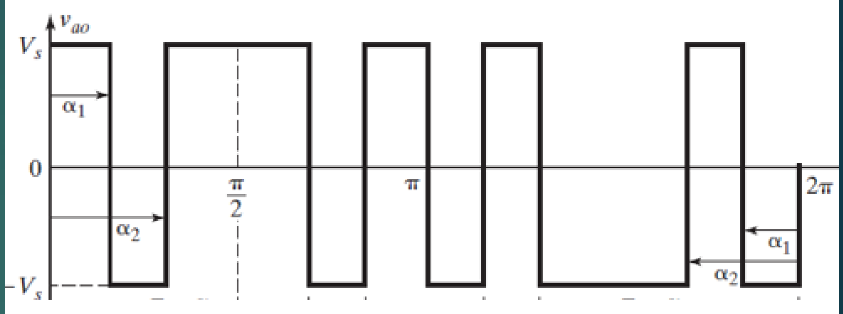
$$B_n = \frac{4V_s}{\pi}\left[\int_0^{\alpha_1} \sin n\omega t \, d(\omega t) - \int_{\alpha_1}^{\alpha_2} \sin n\omega t \, d(\omega t) + \int_{\alpha_2}^{\pi/2} \sin n\omega t \, d(\omega t)\right]$$

$$= \frac{4V_s}{\pi}\frac{1 - 2\cos n\alpha_1 + 2\cos n\alpha_2}{n} \qquad (6.92)$$

$$B_3 = B_5 = 0$$

$$1 - 2\cos 3\alpha_1 + 2\cos 3\alpha_2 = 0 \quad \text{or} \quad \alpha_2 = \frac{1}{3}\cos^{-1}(\cos 3\alpha_1 - 0.5)$$

$$1 - 2\cos 5\alpha_1 + 2\cos 5\alpha_2 = 0 \quad \text{or} \quad \alpha_1 = \frac{1}{5}\cos^{-1}(\cos 5\alpha_2 + 0.5)$$



$\alpha_1 = 23.62°$ and $\alpha_2 = 33.3°$

half

m notches per ~~quarter~~ cycle → m harmonics removable

$$B_n = \frac{4V_s}{n\pi}\left(1 - 2\cos n\alpha_1 + 2\cos n\alpha_2 - 2\cos n\alpha_3 + 2\cos n\alpha_4 - \cdots\right) \qquad (6.93)$$

$$B_n = \frac{4V_s}{n\pi}\left(1 - 2\cos n\alpha_1 + 2\cos n\alpha_2 - 2\cos n\alpha_3 + 2\cos n\alpha_4 - \cdots\right) \quad (6.93)$$

Example 6.6 Finding the Number of Notches and Their Angles

A single-phase full-wave inverter uses multiple notches to give bipolar voltage as shown in Figure 6.32, and is required to eliminate the fifth, seventh, eleventh, and thirteenth harmonics from the output wave. Determine the number of notches and their angles.

Solution

For elimination of the fifth, seventh, eleventh, and thirteenth harmonics, $A_5 = A_7 = A_{11} = A_{13} = 0$; that is, $m = 4$. Four notches per quarter-wave would be required. Equation (6.93) gives the following set of nonlinear simultaneous equations to solve for the angles.

$$1 - 2\cos 5\alpha_1 + 2\cos 5\alpha_2 - 2\cos 5\alpha_3 + 2\cos 5\alpha_4 = 0$$
$$1 - 2\cos 7\alpha_1 + 2\cos 7\alpha_2 - 2\cos 7\alpha_3 + 2\cos 7\alpha_4 = 0$$
$$1 - 2\cos 11\alpha_1 + 2\cos 11\alpha_2 - 2\cos 11\alpha_3 + 2\cos 11\alpha_4 = 0$$
$$1 - 2\cos 13\alpha_1 + 2\cos 13\alpha_2 - 2\cos 13\alpha_3 + 2\cos 13\alpha_4 = 0$$

Solution of these equations by iteration using a Mathcad program yields

$$\alpha_1 = 10.55^\circ \qquad \alpha_2 = 16.09^\circ \qquad \alpha_3 = 30.91^\circ \qquad \alpha_4 = 32.87^\circ$$

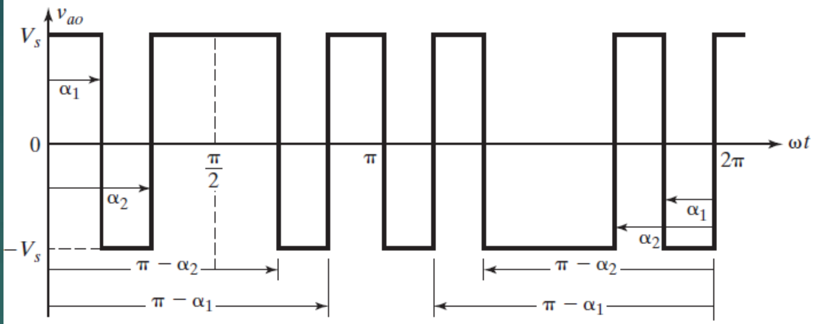
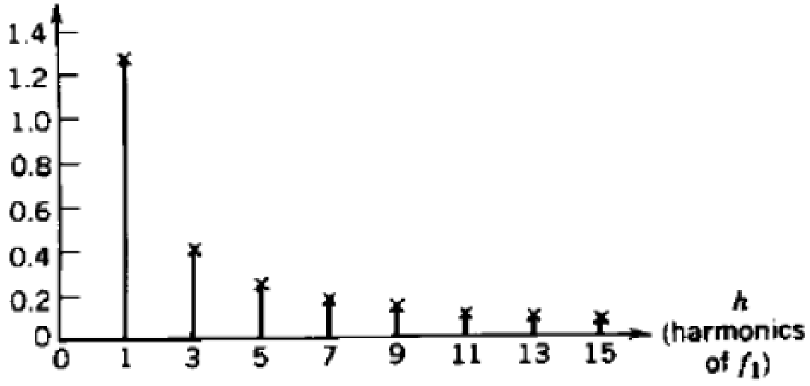


FIGURE 6.32

Output voltage with two bipolar notches per half-wave.



8-6-3 CURRENT-REGULATED (CURRENT-MODE) MODULATION

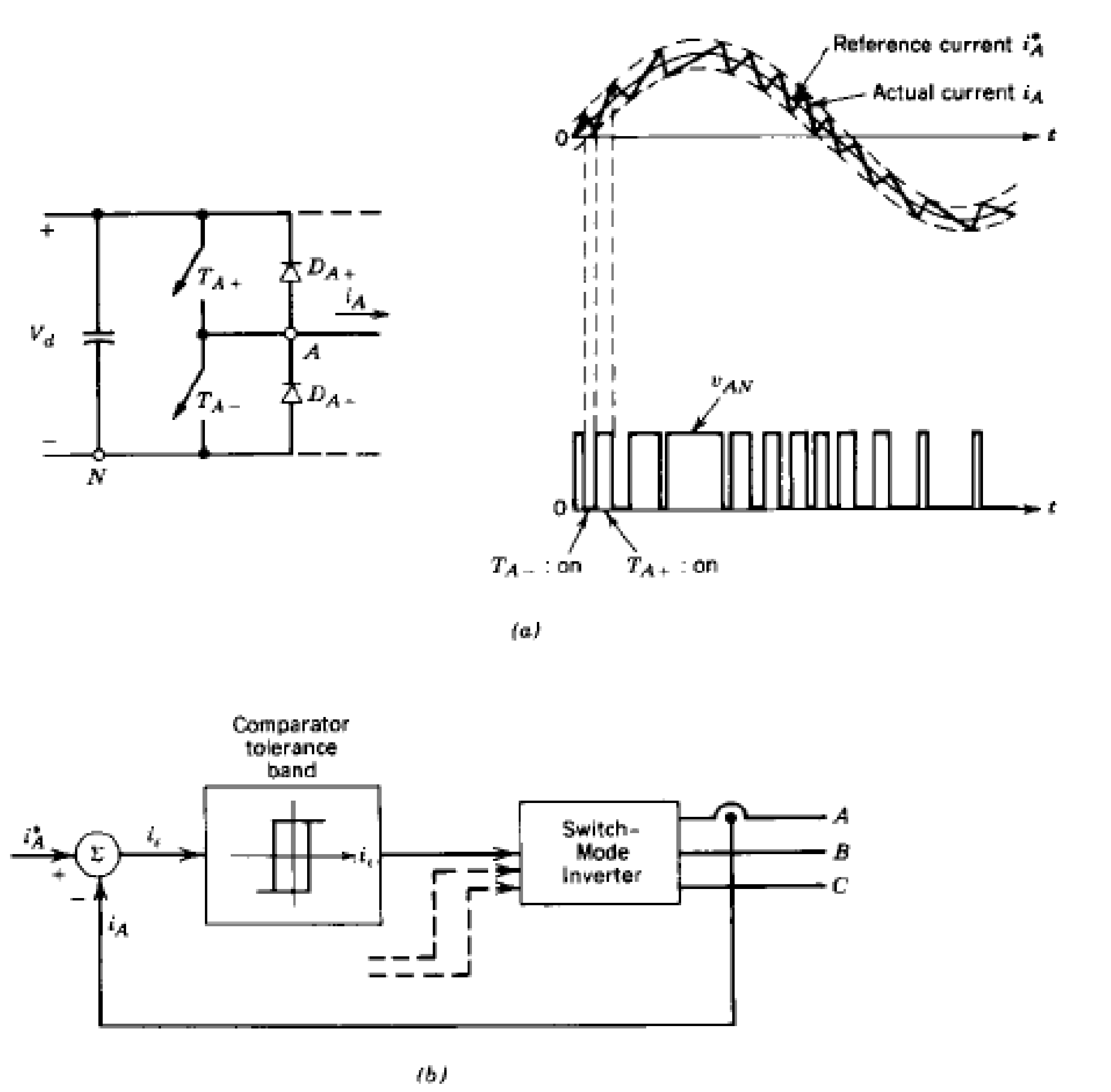


Figure 8-35 Tolerance band current control.

8-6-3-1 Tolerance Band Control

AC Motor Drives

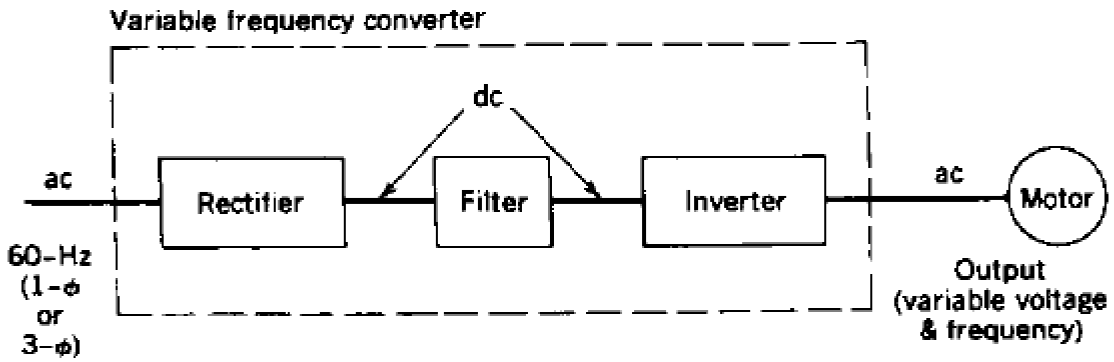
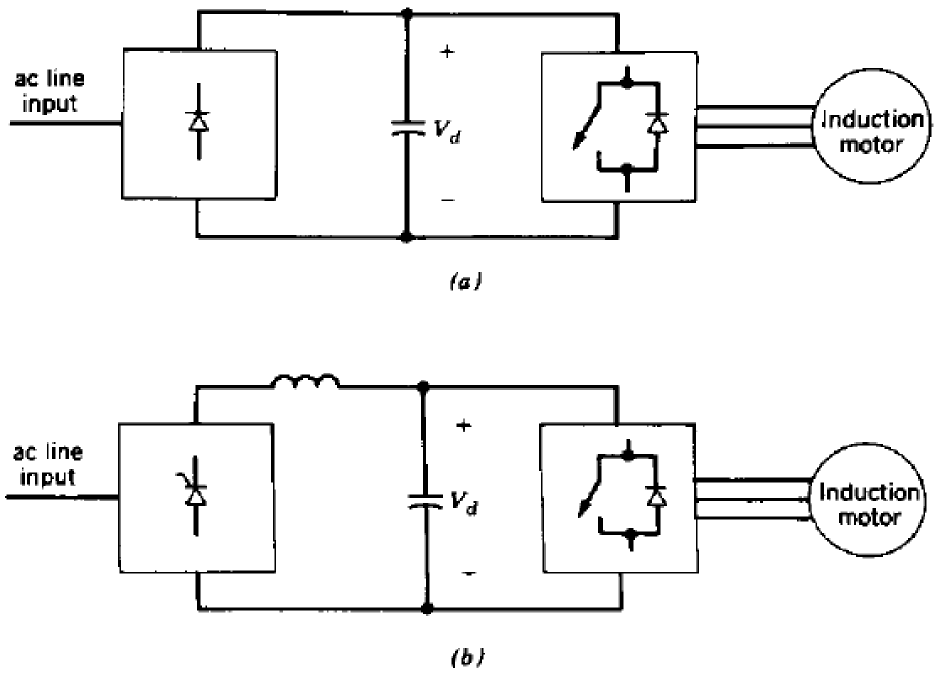
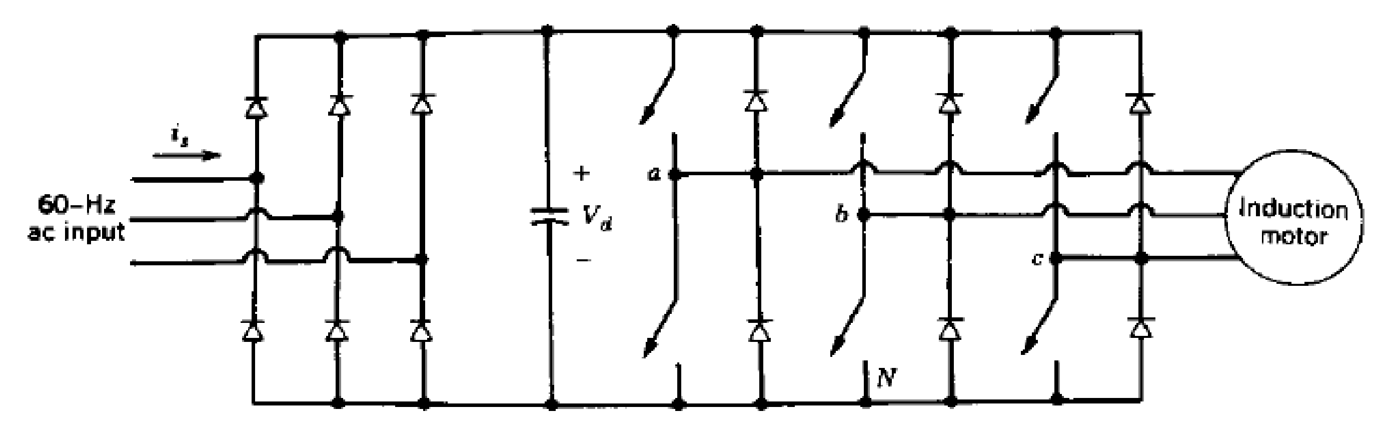
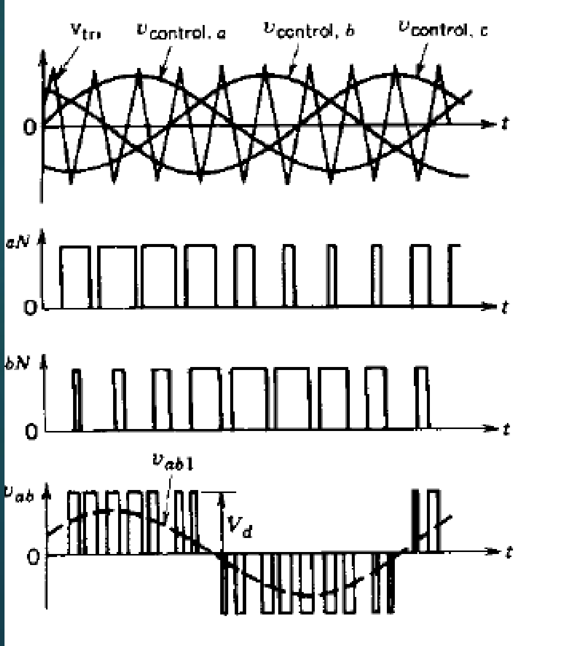


Figure 14-17 Variable-frequency converter.



14-7 VARIABLE-FREQUENCY PWM-VSI DRIVES



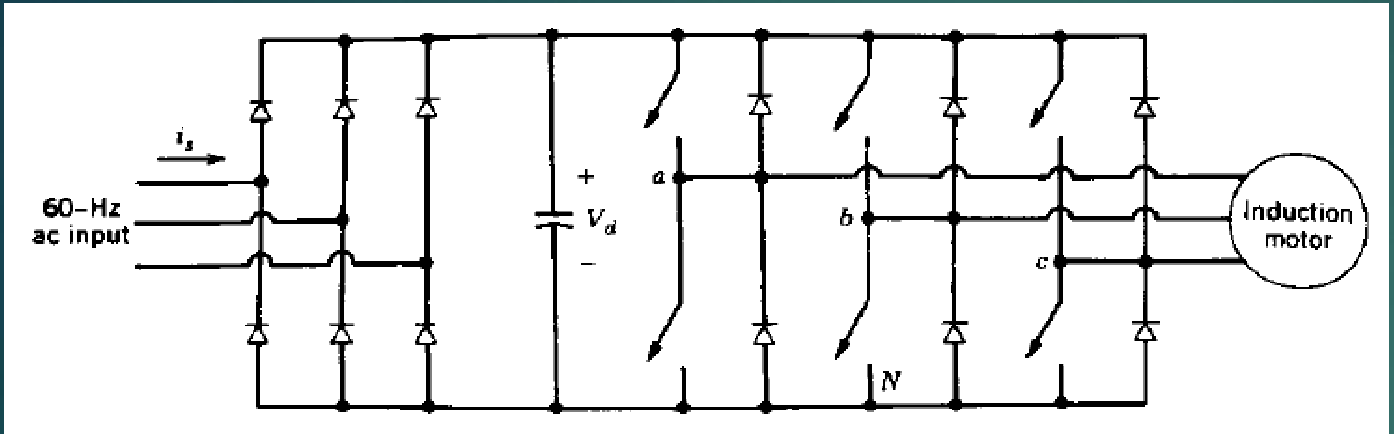


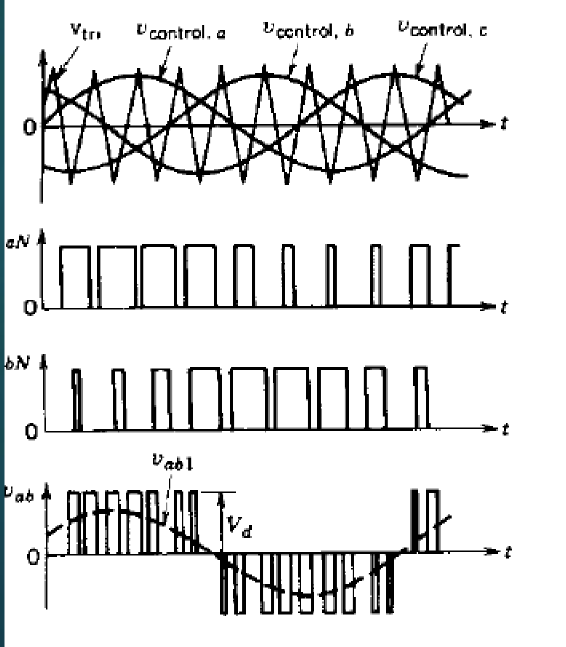
$$P_h/m^3 = \eta\, B_{max}^{1.6}\, f \qquad \text{Watts}$$

Or

$$P_h = \eta\, B_{max}^{1.6}\, f\, V \qquad \text{Watts}$$

14-7 VARIABLE-FREQUENCY PWM-VSI DRIVES





$$P_h/m^3 = \eta \, B_{max}^{1.6} \, f \qquad \text{Watts}$$

Or

$$P_h = \eta \, B_{max}^{1.6} \, f \, V \qquad \text{Watts}$$

Eddy Current Loss,

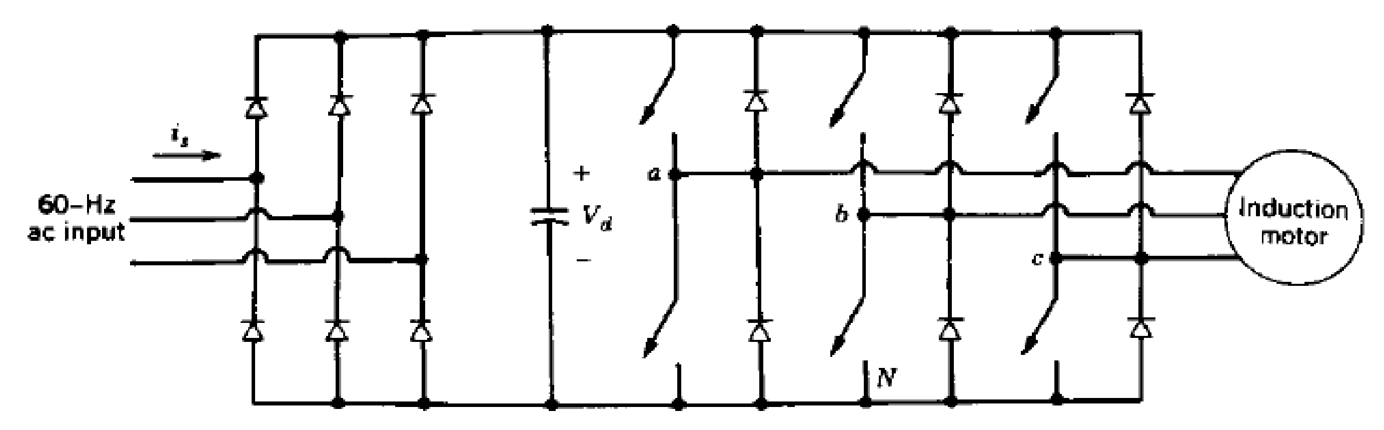
$$W_e = K_e B_m^2 t^2 f^2 V$$

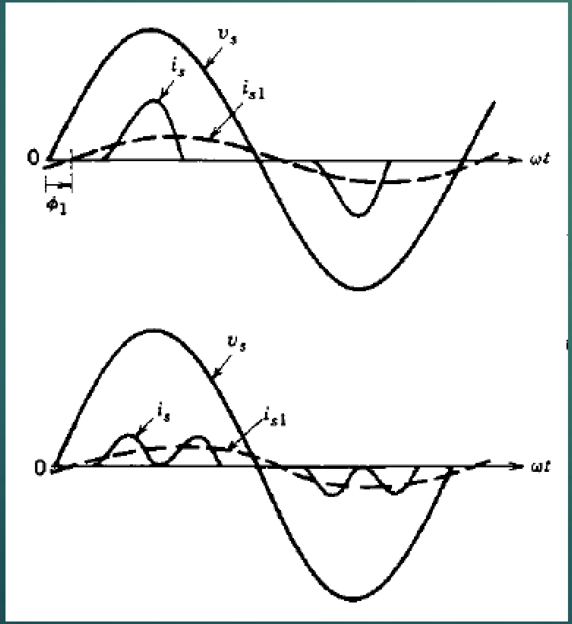
Where,

K_e = co-efficient of eddy current
B_m – maximum value of flux density in wb/m^2
T – thickness of lamination in meters
F – frequency in Hz
V – volume of magnetic material in m^3

14-7 VARIABLE-FREQUENCY PWM-VSI DRIVES

The input current





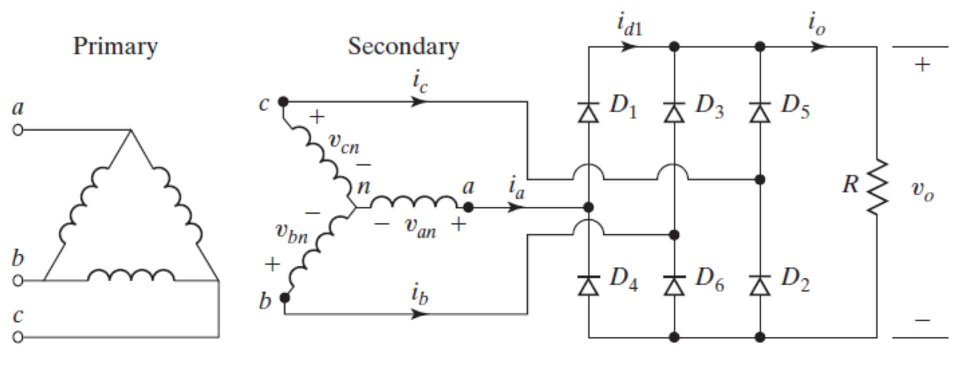
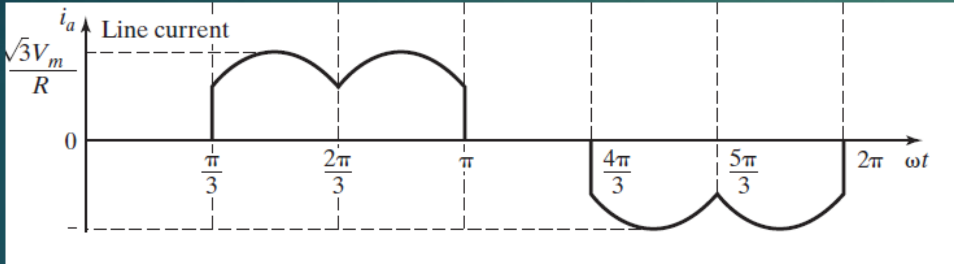


FIGURE 3.11

Three-phase bridge rectifier.



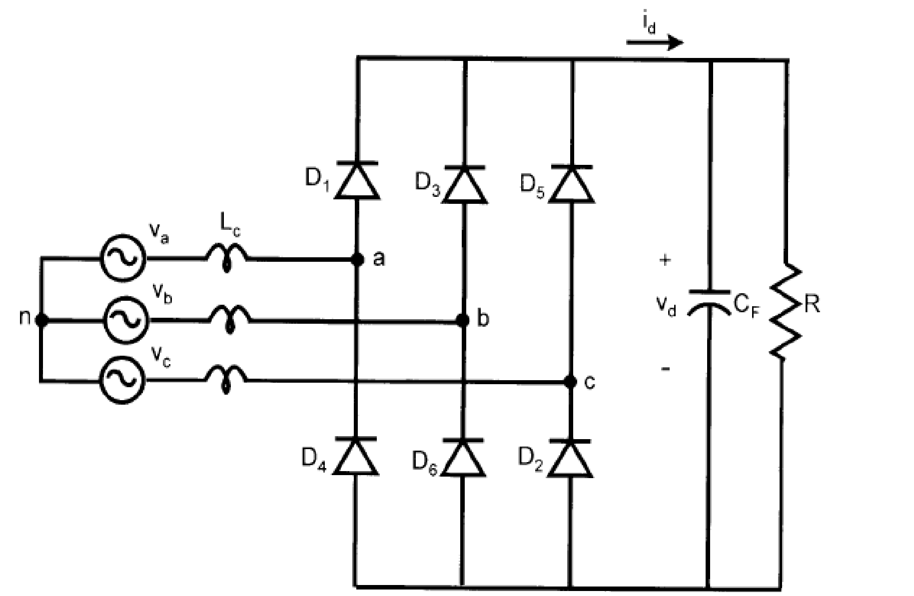
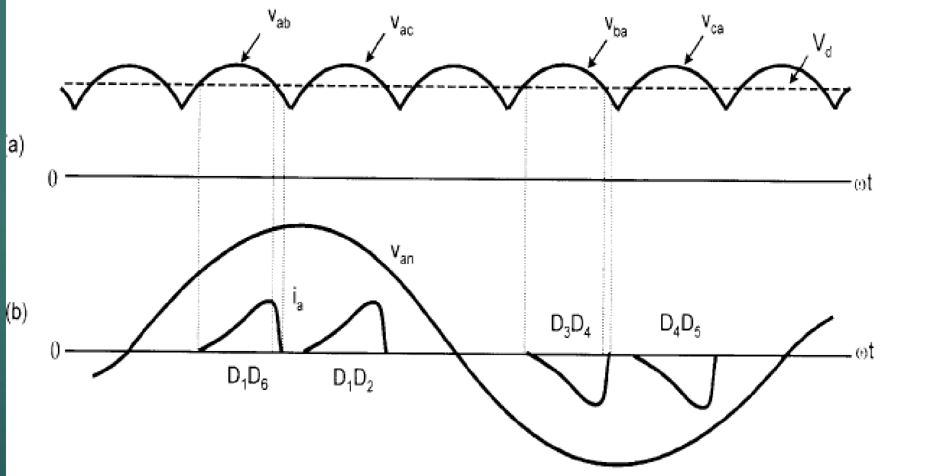
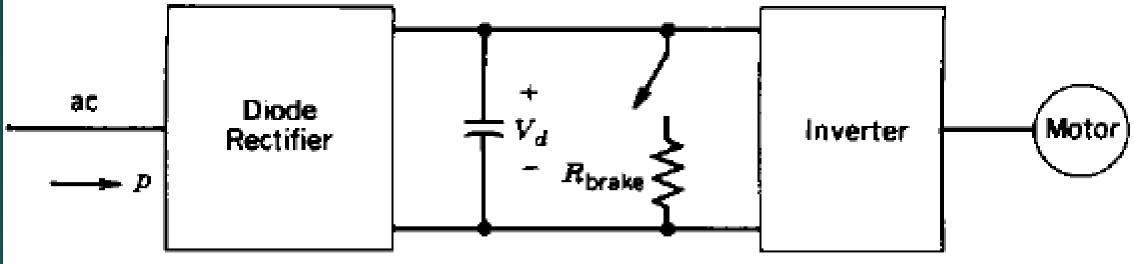


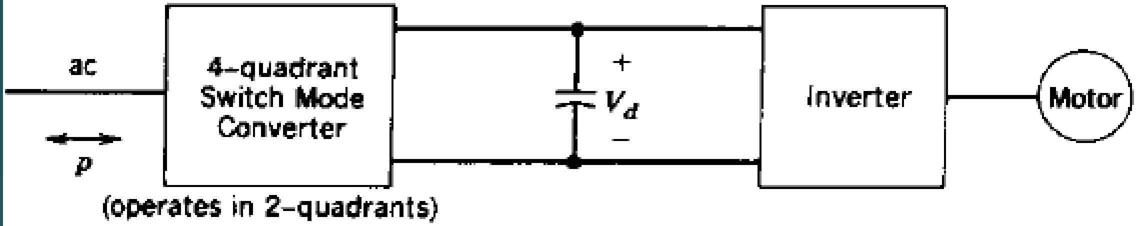
Figure 3.11 Three-phase diode bridge rectifier with *CR* load



14-7-3 ELECTROMAGNETIC BRAKING



(a)



(b)

Rectifier mode of operation of Inverters

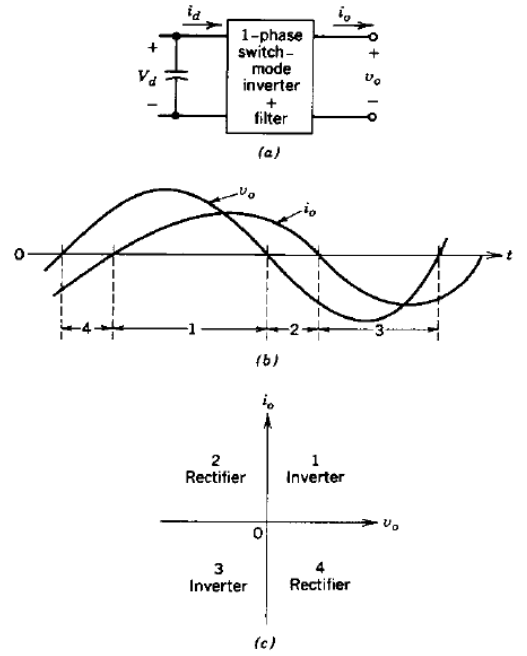
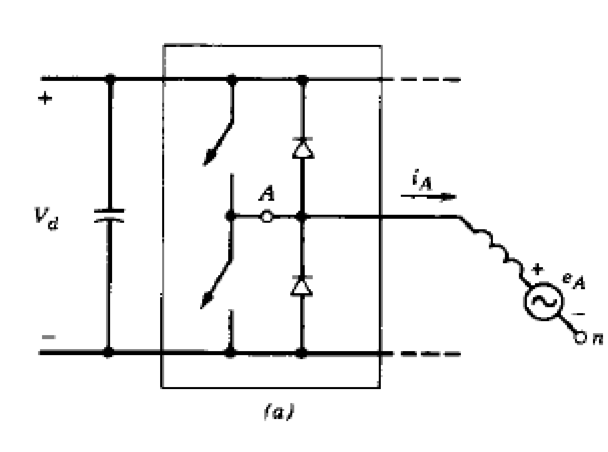
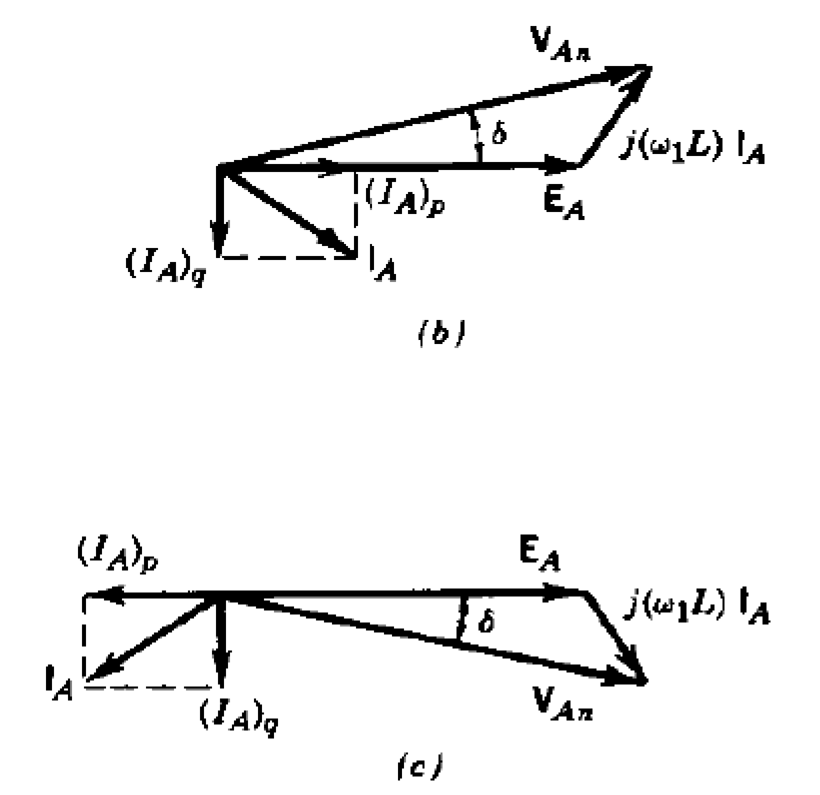


Figure 8-3 Single-phas
switch-mode inverter.

8-7 RECTIFIER MODE OF OPERATION



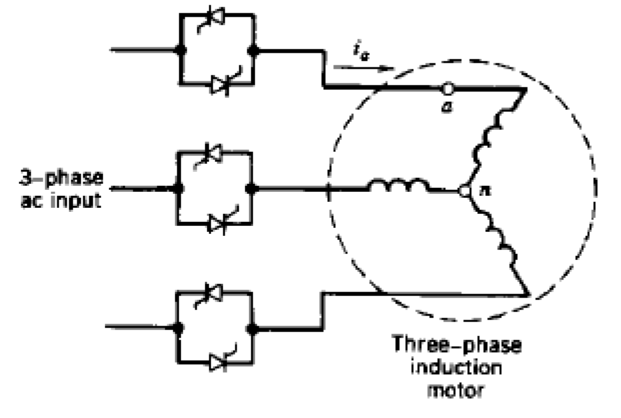
$V_{An} = (jwL)*I_A + E_A$



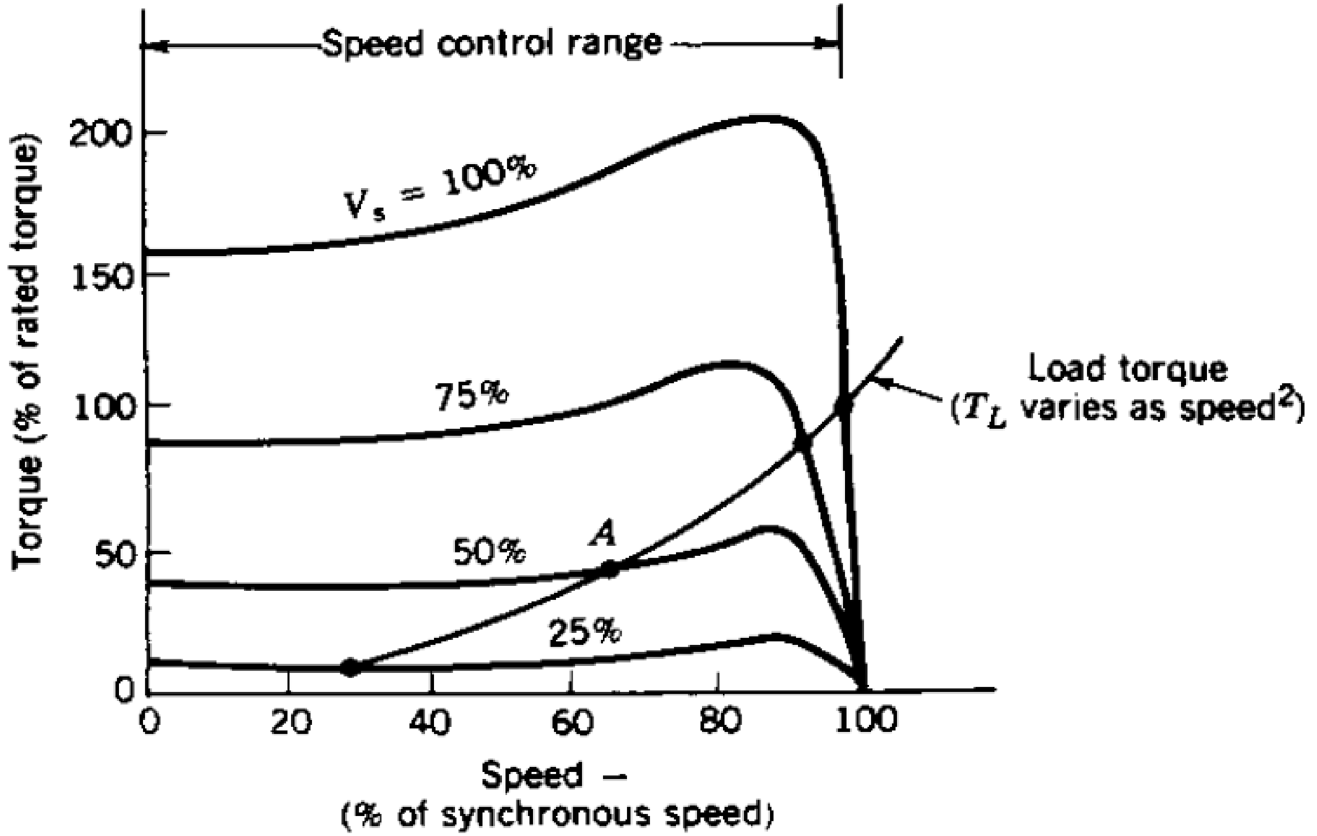
Inverter

Minor mistake in audio – at the start
Yahan pai samjhaata hoon kai PWM ~~Rectifier~~ ko
Rectifier mode main kaisai operate kerna hai

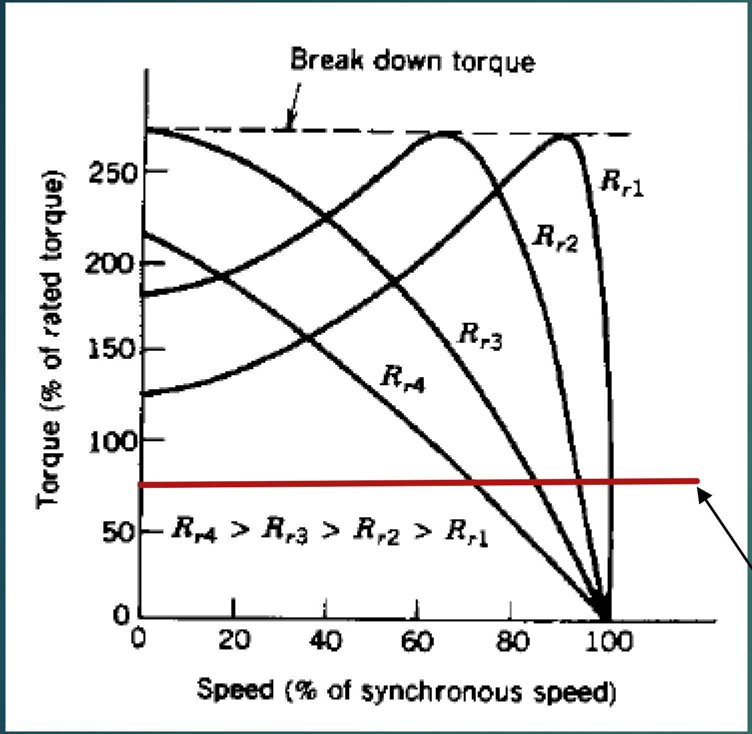
14-11 LINE-FREQUENCY VARIABLE-VOLTAGE DRIVES



(a)



14-13 SPEED CONTROL BY STATIC SLIP POWER RECOVERY



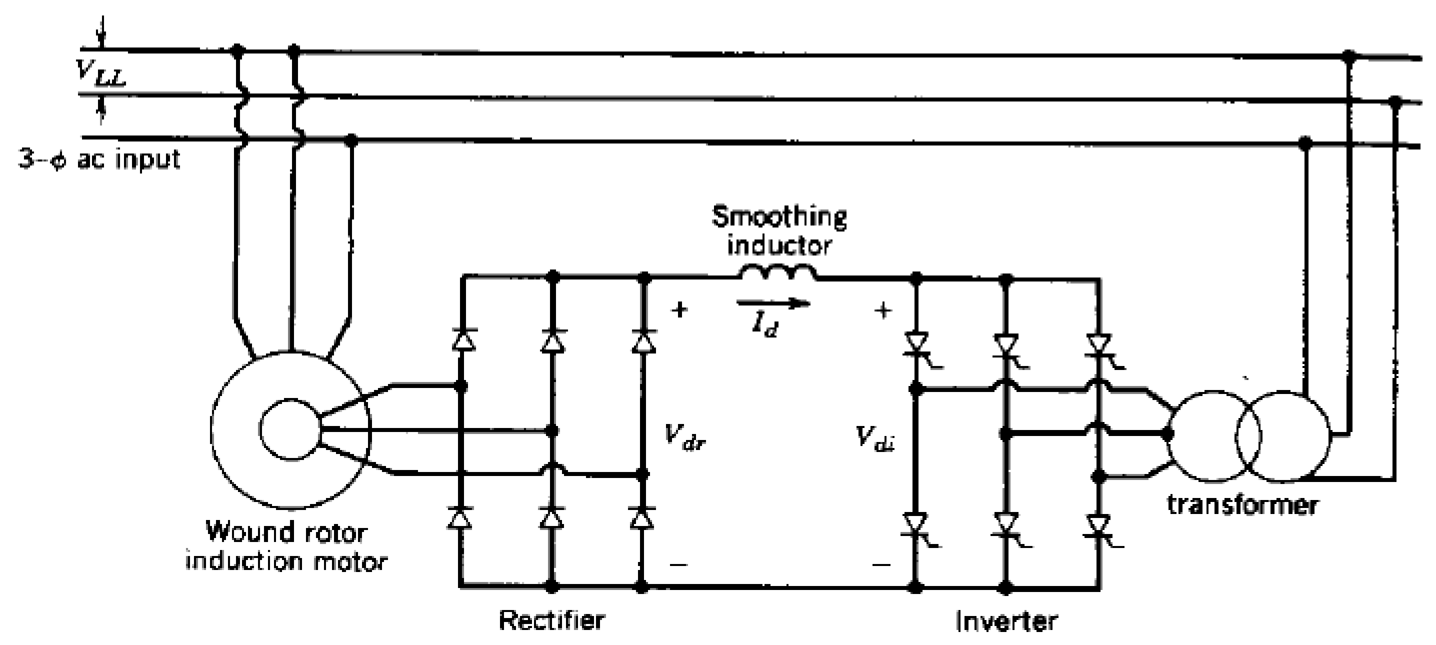
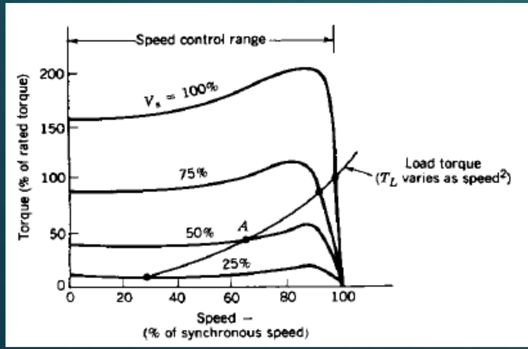


Figure 14-29 Static slip recovery.



Torque speed xtic for a constant torque load.
Notice that the operating points (intersection of black lines with brown line) shift back as Rr increases.