Diode Rectifiers

EE 442-642

Fall 2012

Half-Bridge Rectifier Circuit: R and R-L Load

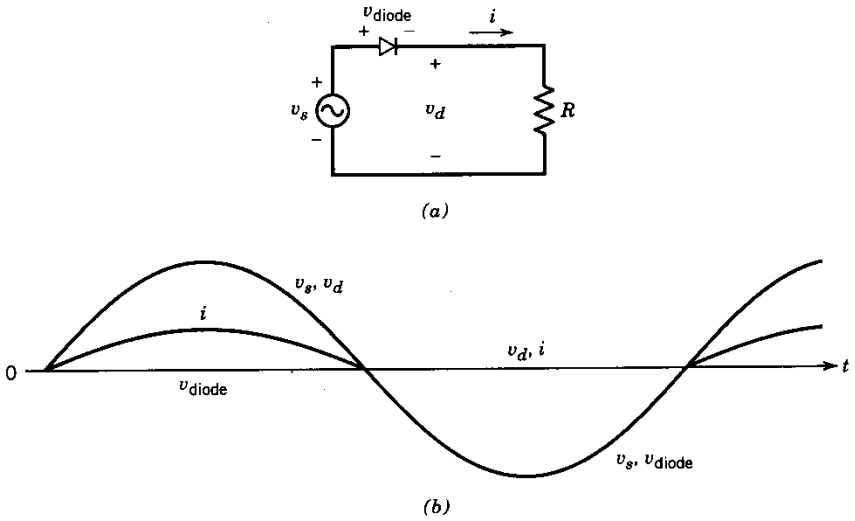


Figure 5-2 Basic rectifier with a load resistance.

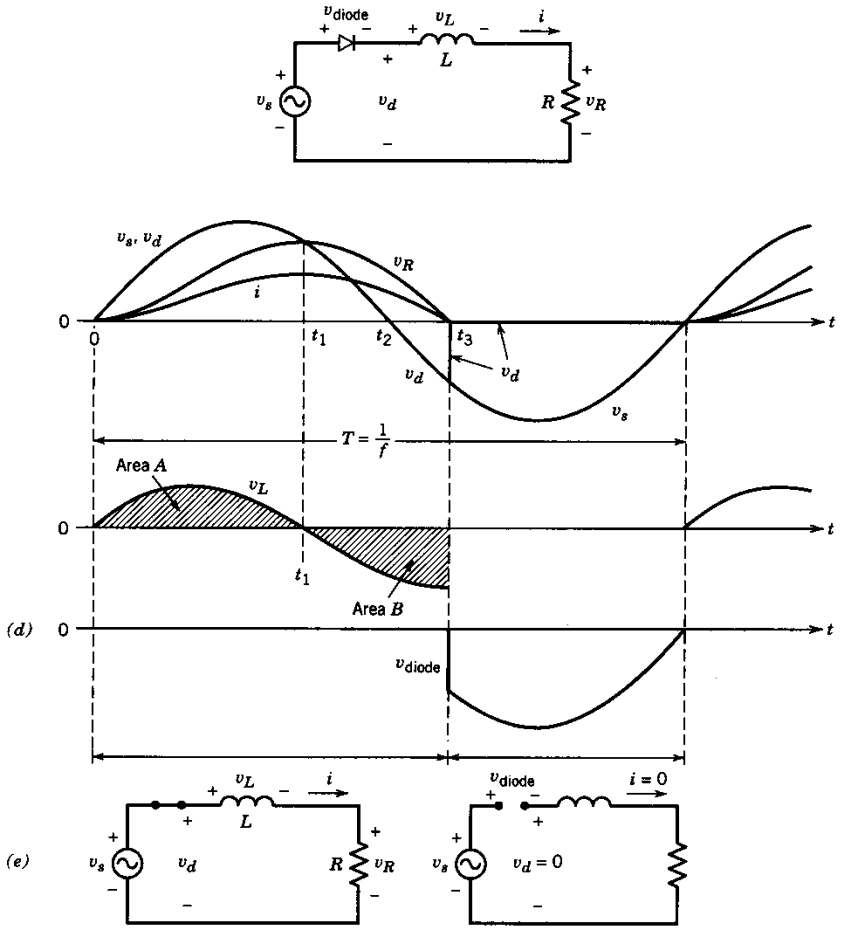
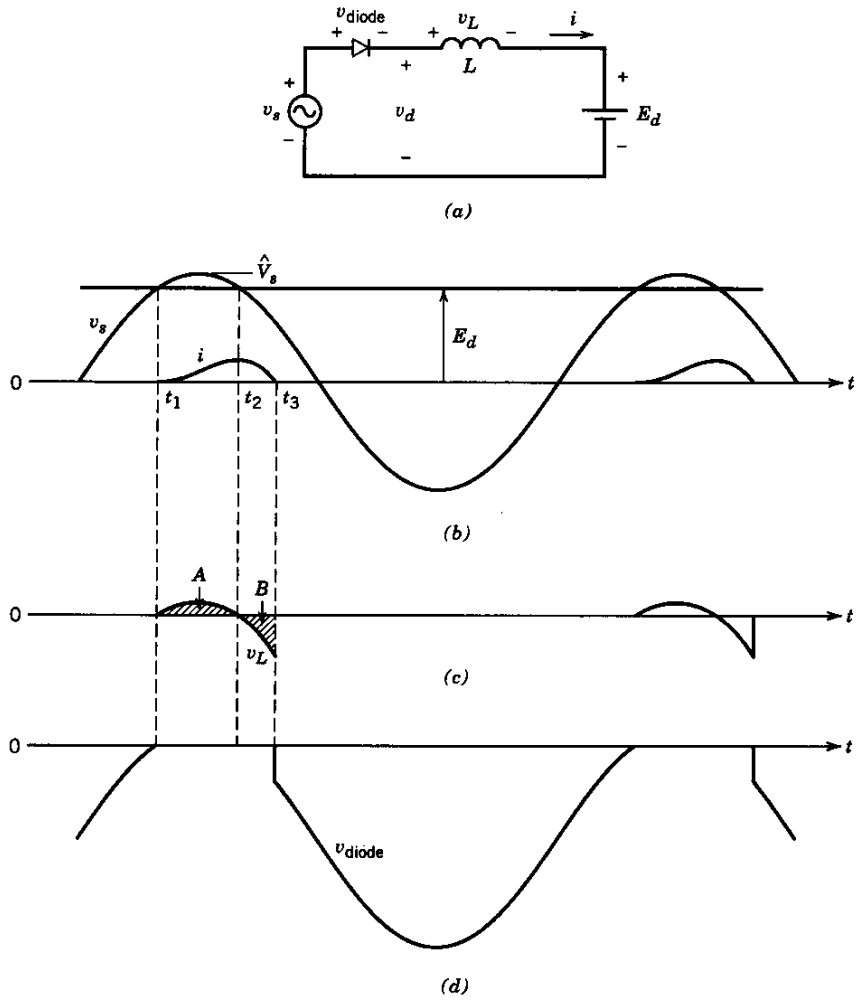


Figure 5-3 Basic rectifier with an inductive load.

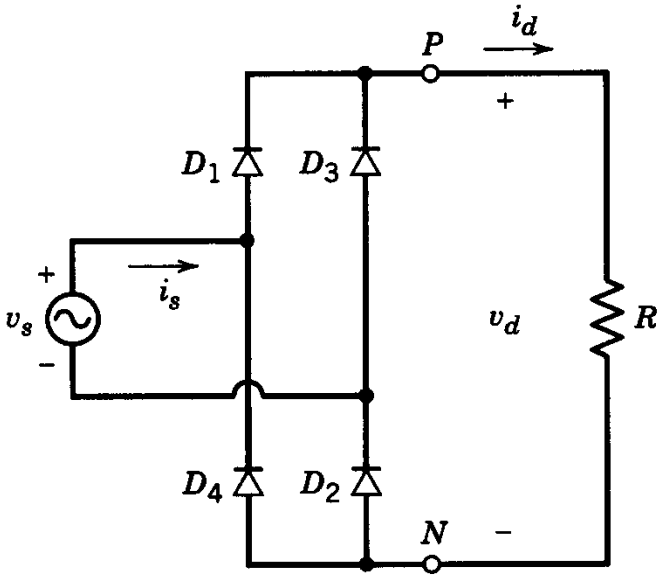
Current continues to flow for a while even after the input voltage has gone negative.

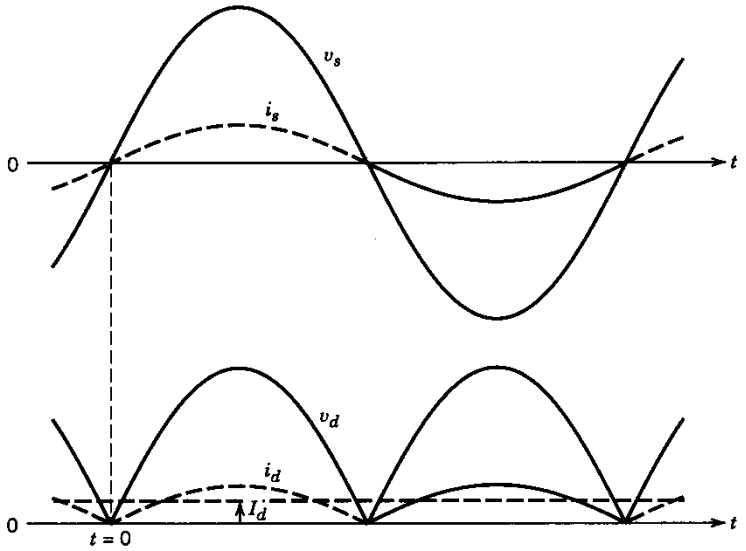
Half Bridge Rectifier Circuit: Load with dc back-emf



- Current begins to flow when the input voltage exceeds the dc back-emf.
- Current continues to flows for a while even after the input voltage has gone below the dc back-emf.

Full Bridge Rectifier – Simple R Load

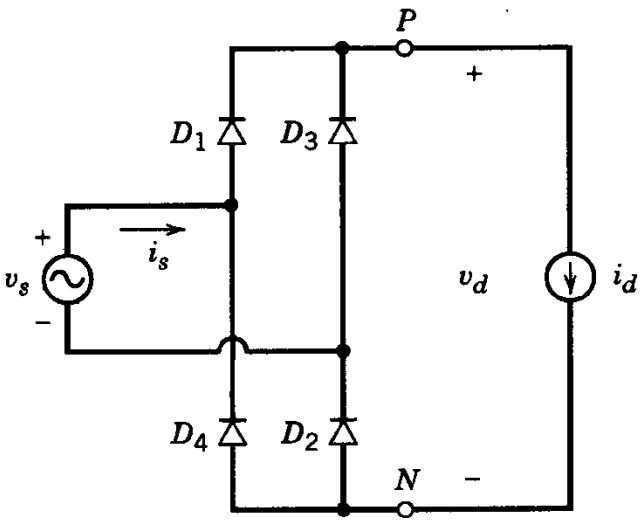


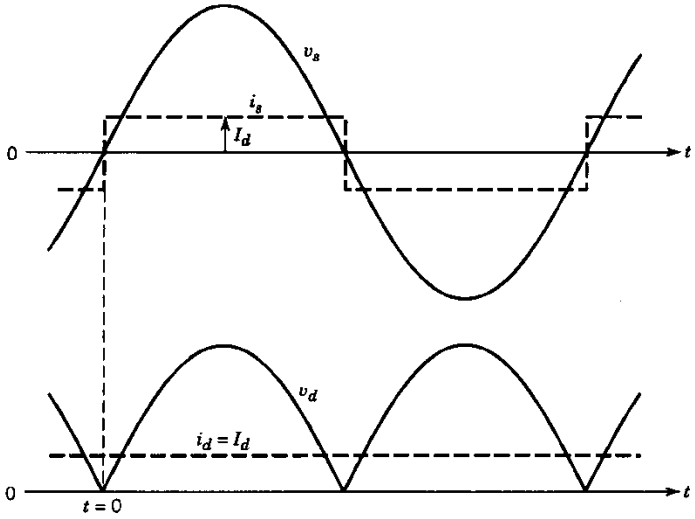


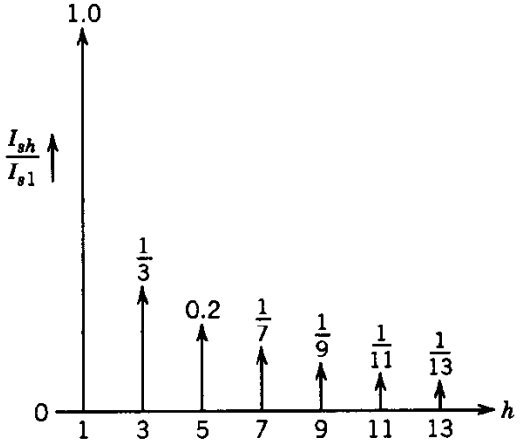
Average value of output voltage where V_s is the RMS value of input voltage.

$$V_{do} = (2\sqrt{2}/\pi)V_s \approx 0.9V_s$$

Full Bridge Rectifier – Simple Constant Load Current







RSM value of source current $I_s = I_d$

RMS value of fundamental current $I_{s1} = (2\sqrt{2}/\pi) I_d \approx 0.9 I_d$

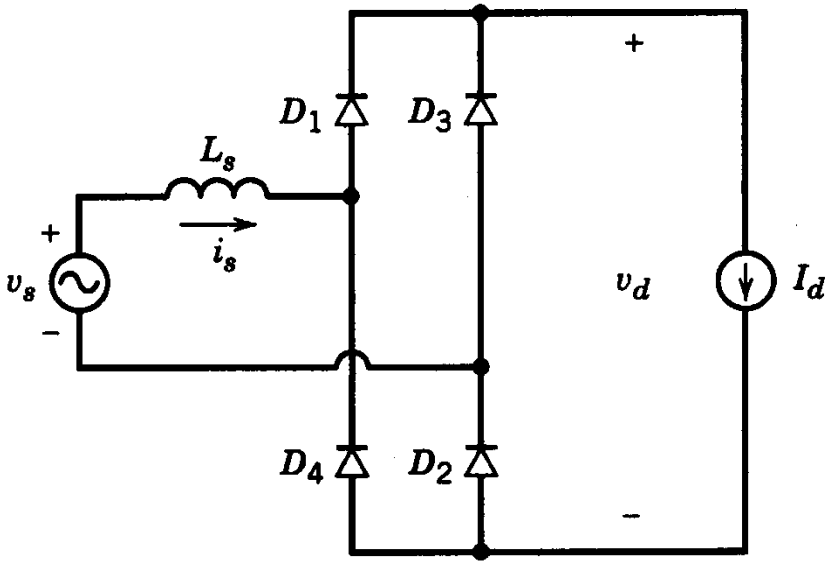
RMS value of harmonic current $I_{sh} = I_{s1}/h, \quad h = 3,5,7,...$

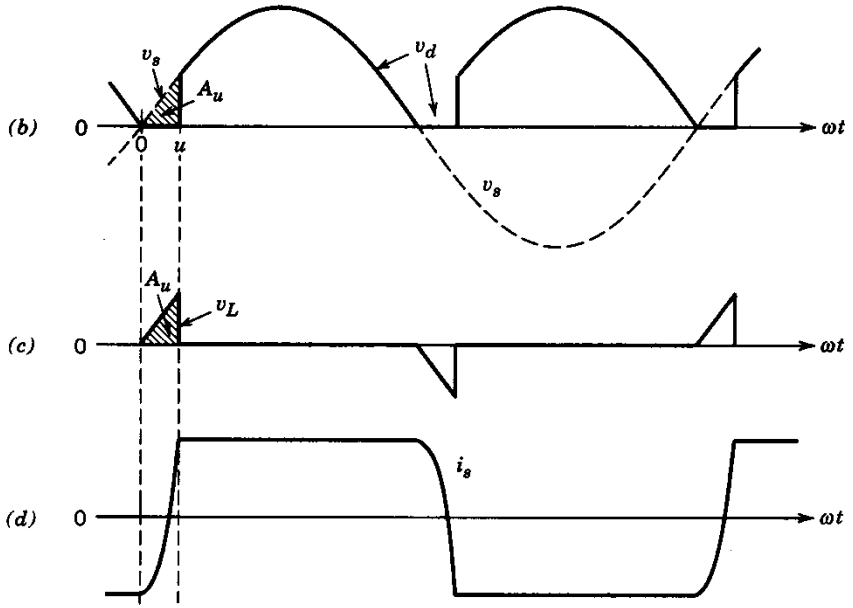
Current THD $THD = 100[\sqrt{(\pi^2/8) - 1}] = 48.43\%$

Displacement Power Factor $DPF = 1$

Power Factor $PF = 0.9$

Diode-Rectifier Bridge with AC-Side Inductance





Commutation angle: $$\cos\mu = 1 - \frac{2\omega L_s I_d}{\sqrt{2}V_s}$$

Average of DC-side voltage: $$V_d = 0.9V_s - \frac{2\omega L_s I_d}{\pi}$$

Full Bridge Rectifier with dc-side Voltage

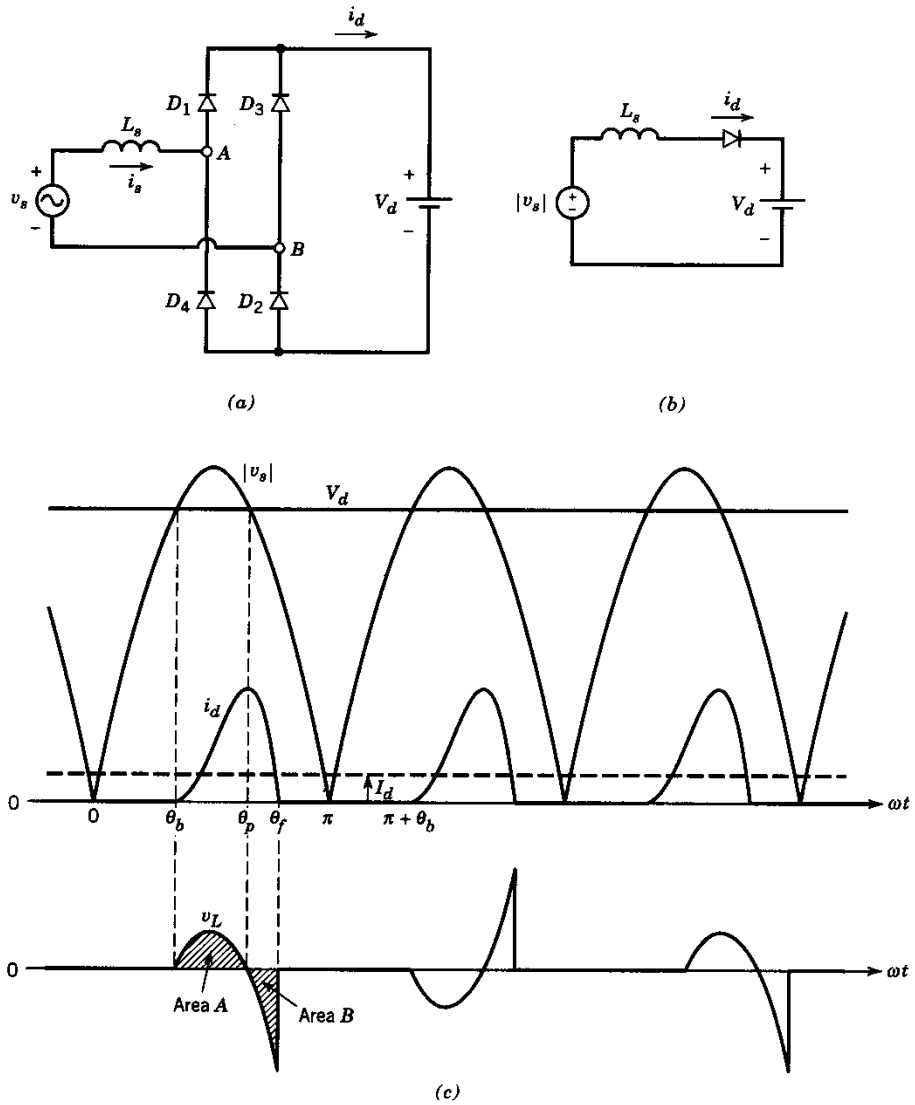


Figure 5-16 (*a*) Rectifier with a constant dc-side voltage. (*b*) Equivalent circuit. (*c*) Waveforms.

Average value of DC-side current (obtained numerically):

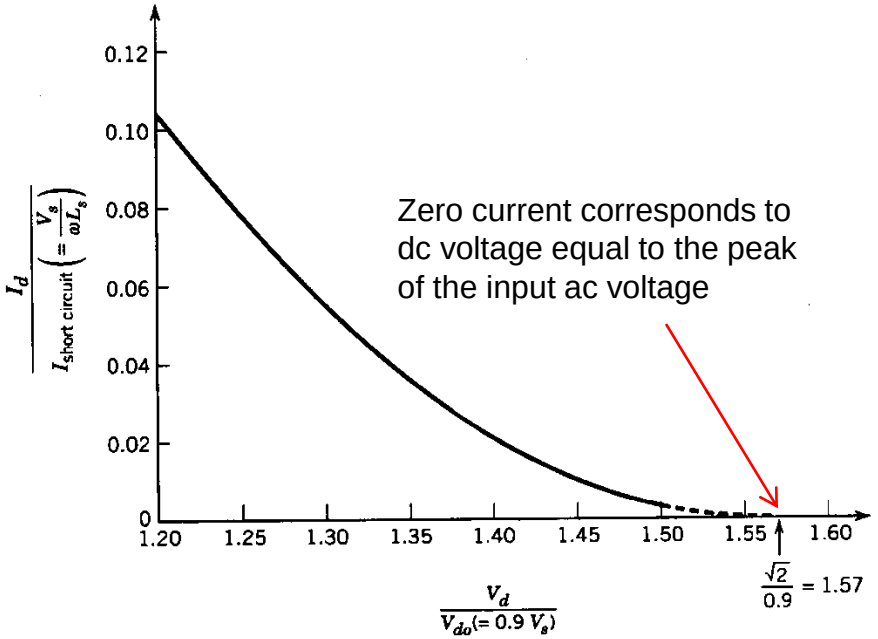


Figure 5-17 Normalized I_d versus V_d in the rectifier of Fig. 5-16*a* with a constant dc-side voltage.

Diode-Rectifier with a Capacitor Filter

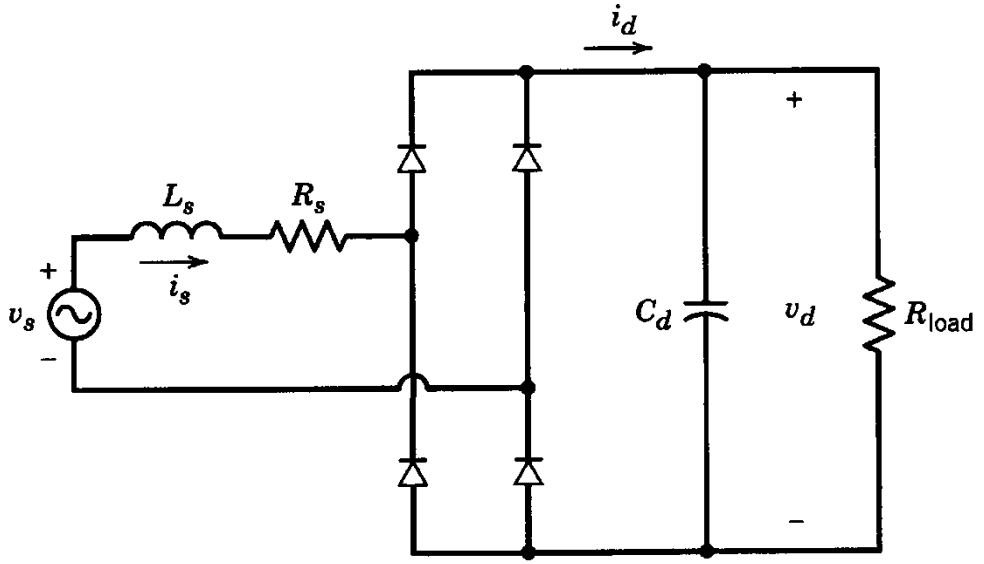


Figure 5-20 Practical diode–bridge rectifier with a filter capacitor.

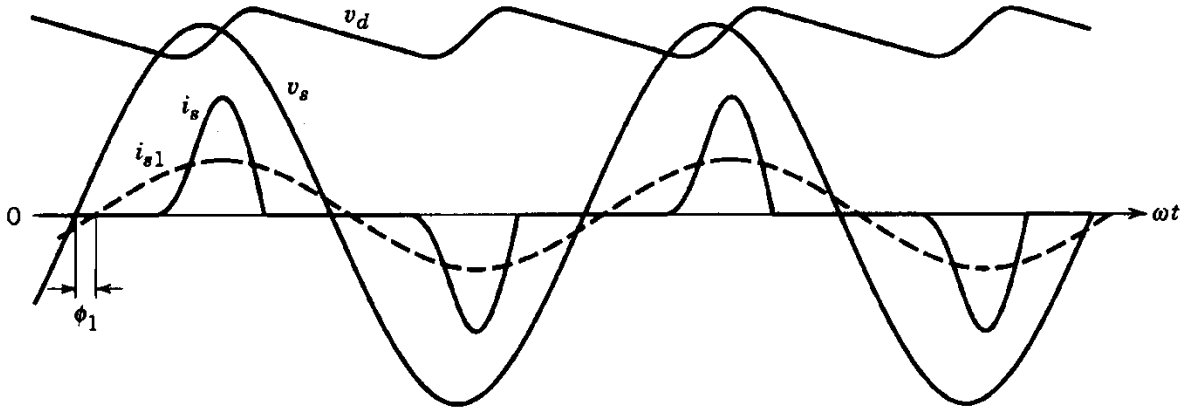


Figure 5-23 Waveforms in the circuit of Fig. 5-20, obtained in Example 5-2.

Voltage Distortion at PCC

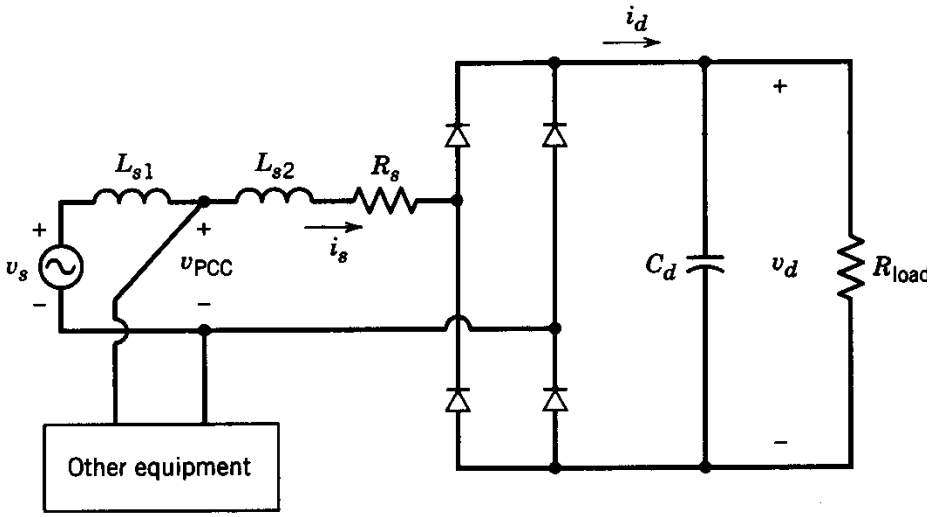


Figure 5-25 Line-voltage notching and distortion.

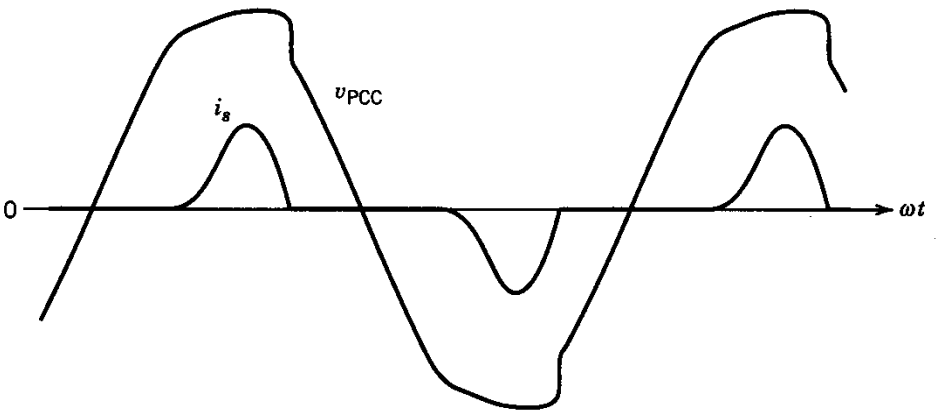


Figure 5-26 Voltage waveform at the point of common coupling in the circuit of Fig. 5-25.

- PCC is the point of common coupling
- Distorted current flow results in distorted voltage

Dual Voltage Rectifier

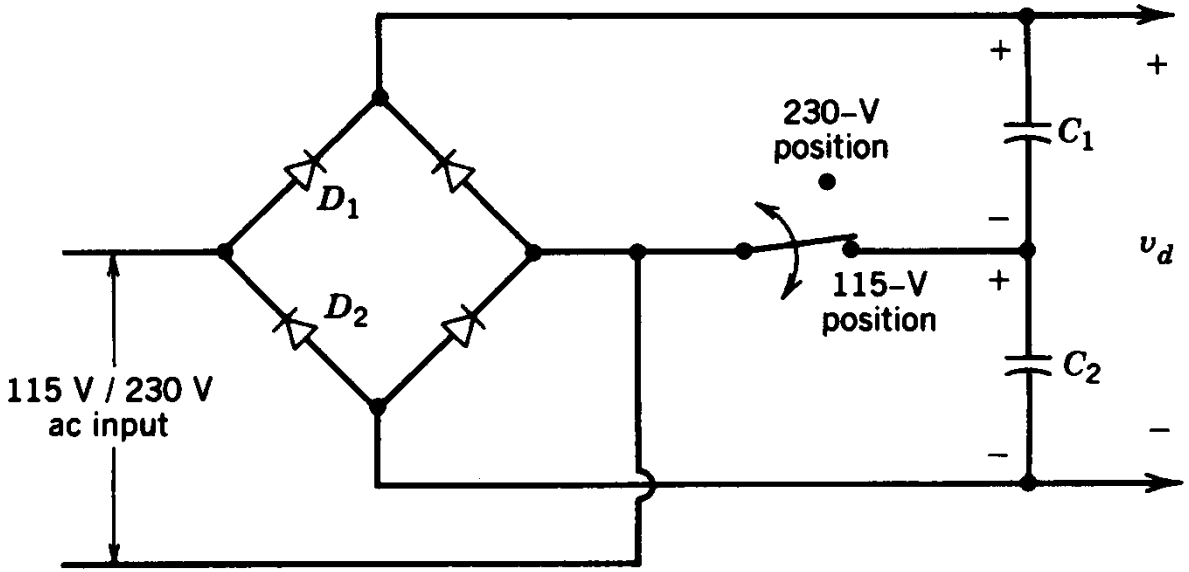


Figure 5-27 Voltage-doubler rectifier.

- In 115-V position, one capacitor at-a-time is charged from the input.

Three-Phase, Four-Wire System

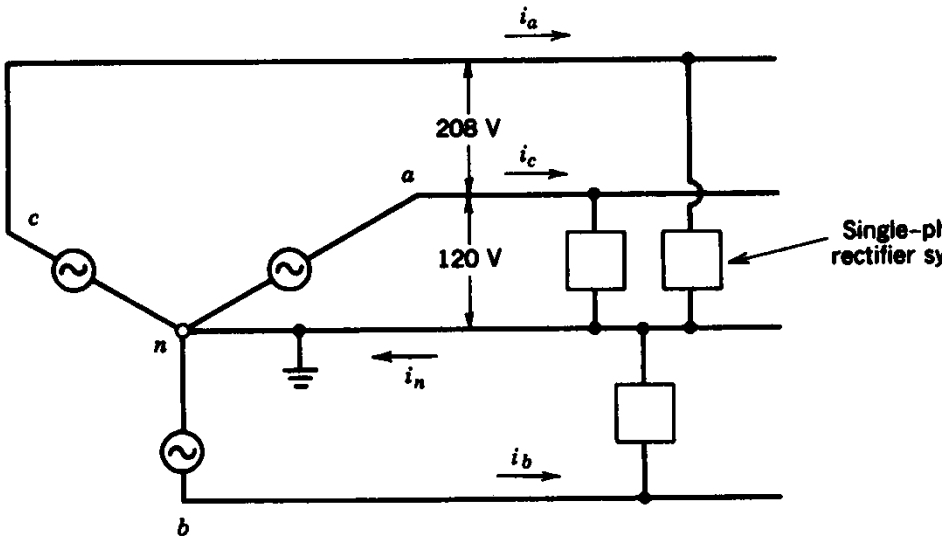


Figure 5-28 Three-phase, four-wire system.

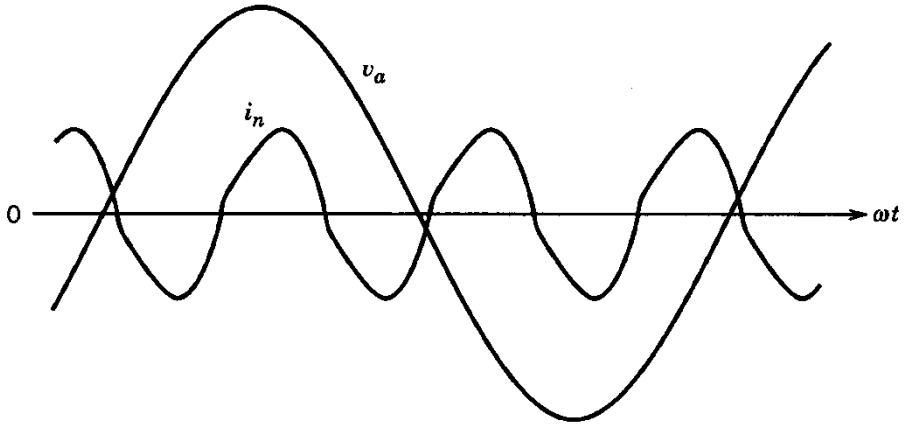
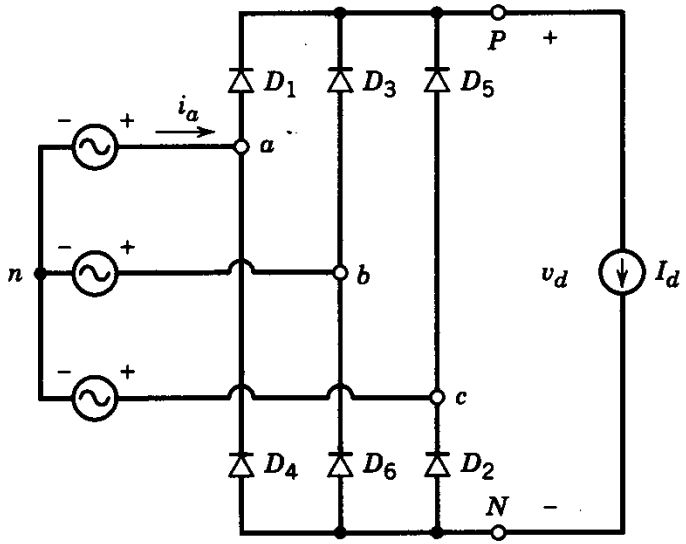


Figure 5-29 Neutral-wire current i_n.

- A common neutral wire is assumed
- The current in the neutral wire is composed mainly of the third harmonic and can be higher than the phase currents

Three-Phase, Full-Bridge Rectifier



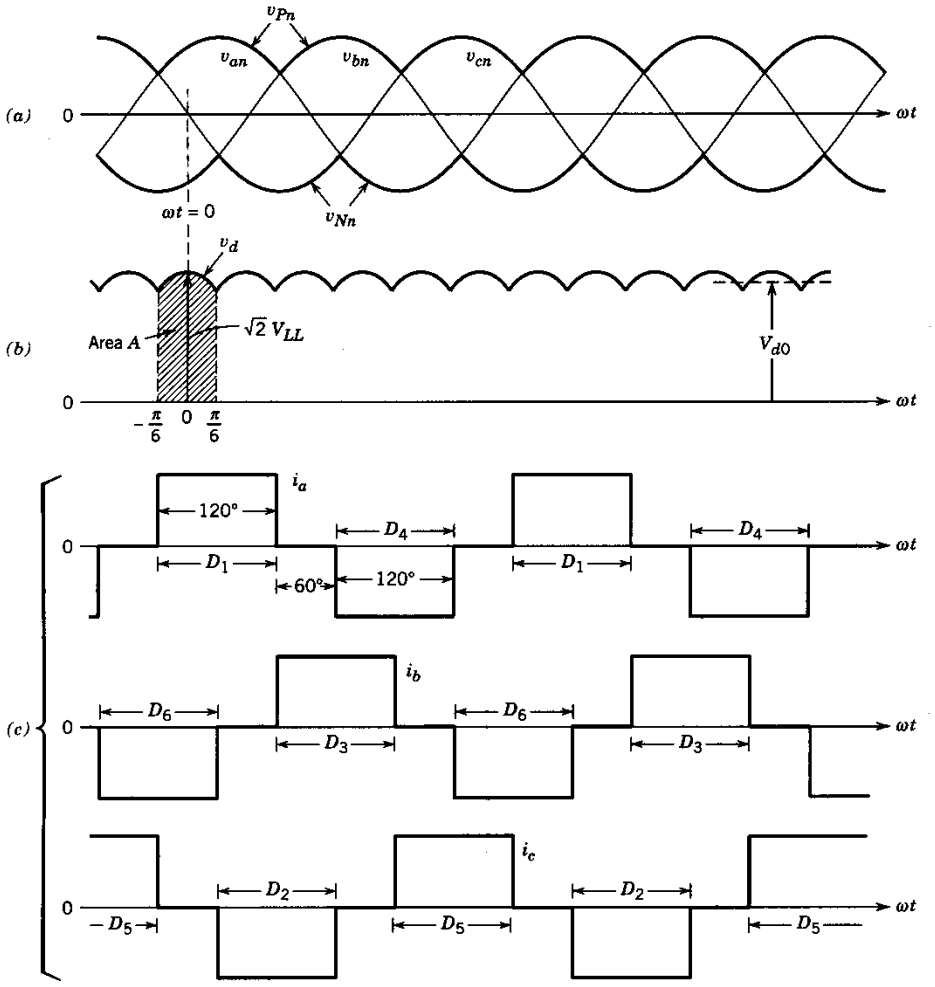


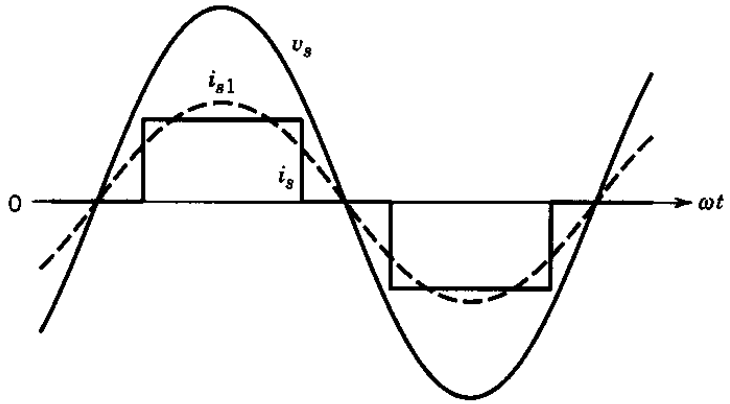
Figure 5-32 Waveforms in the circuit of Fig. 5-31.

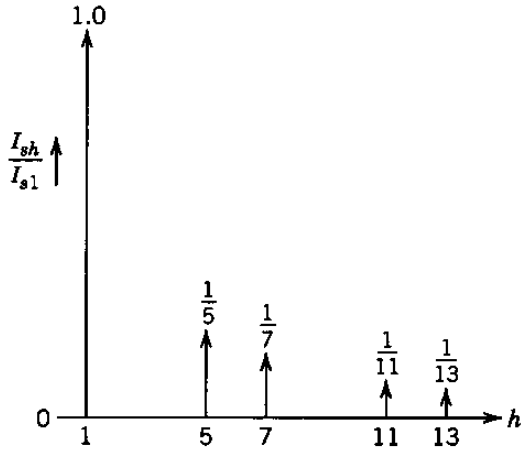
Average value of DC-side voltage:

$$V_{do} = \frac{3}{\pi}\sqrt{2}V_{LL} = 1.35V_{LL}$$

where V_{LL} is the rms value of the Line voltage

Three-Phase, Full-Bridge Rectifier





RSM value of source current

$$I_s = \sqrt{2/3} I_d = 0.816 I_d$$

RMS value of fundamental current

$$I_{s1} = (\sqrt{6}/\pi) I_d \approx 0.78 I_d$$

RMS value of harmonic current

$$I_{sh} = I_{s1}/h, \quad h = 3,5,7,...$$

Current THD

$$THD = 100[\sqrt{(\pi^2/9) - 1}] = 31\%$$

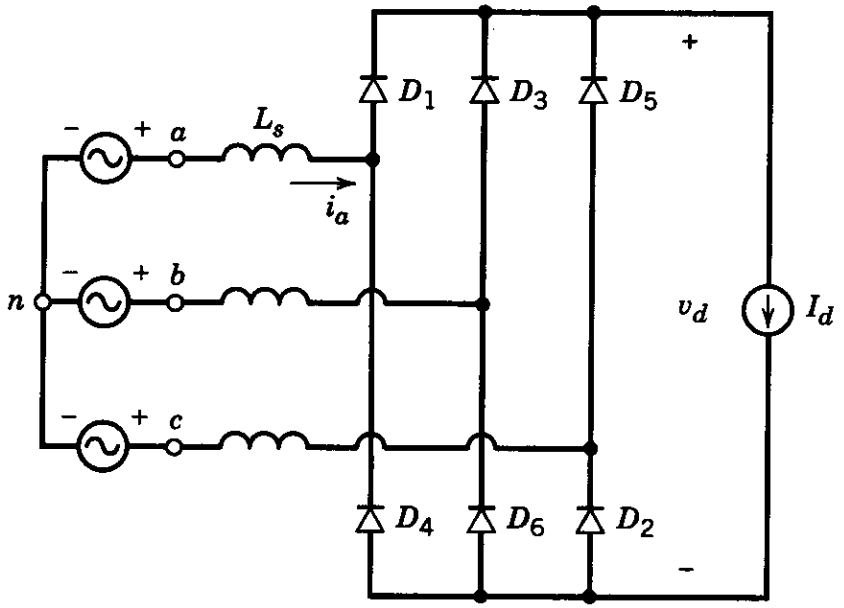
Displacement Power Factor

$$DPF = 1$$

Power Factor

$$PF = \frac{3}{\pi} = 0.955$$

3-Phase, Full-Bridge Rectifier with ac-side inductance



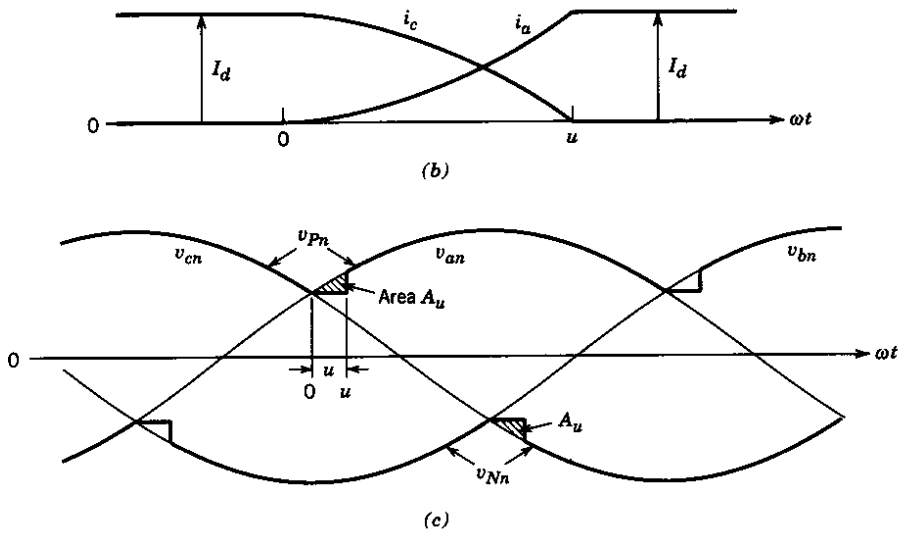
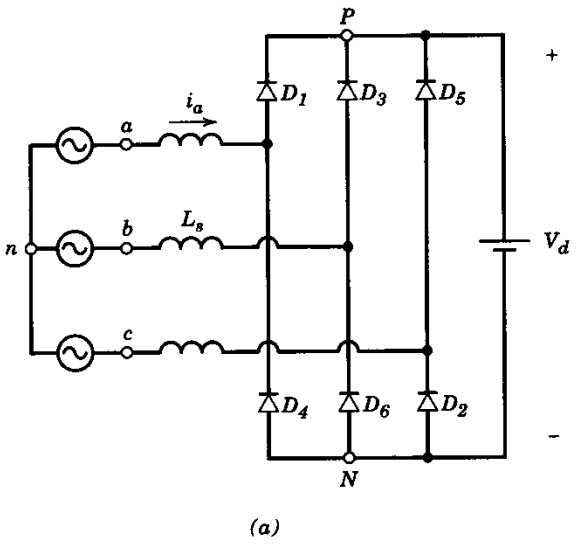


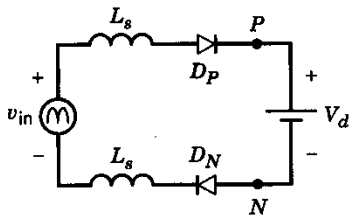
Figure 5-35 Current commutation process.

Commutation angle: $$\cos\mu = 1 - \frac{2\omega L_s I_d}{\sqrt{2}V_{LL}}$$

Average of DC-side voltage: $$V_d = 1.35V_{LL} - \frac{3\omega L_s I_d}{\pi}$$

3-Phase Rectifier with DC Source





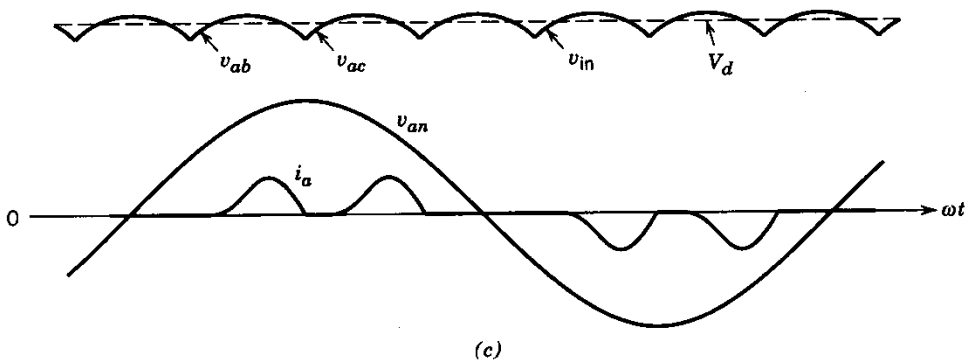


Figure 5-36 (*a*) Three-phase rectifier with a finite L_s and a constant dc voltage. (*b*) Equivalent circuit. (*c*) Waveforms.

Three-Phase Rectifier with Capacitor Filter

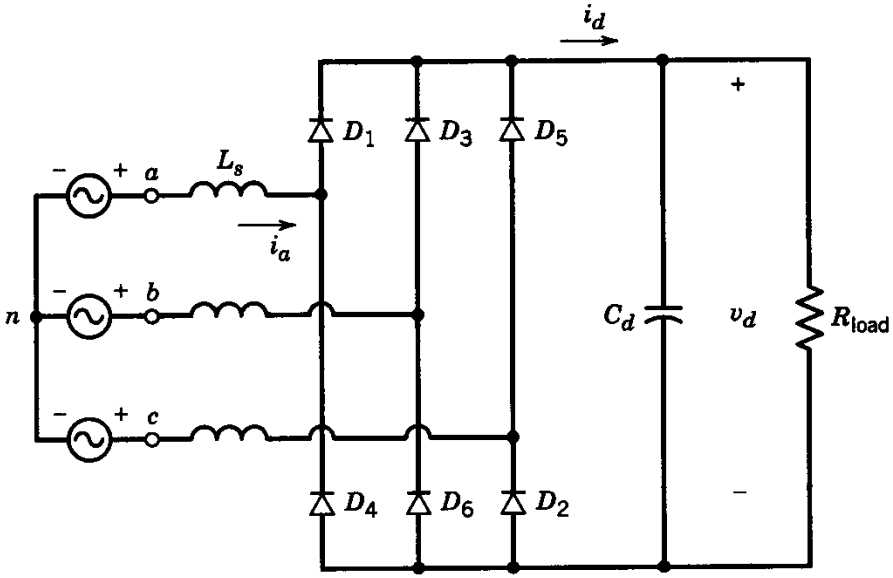


Figure 5-30 Three-phase, full-bridge rectifier.

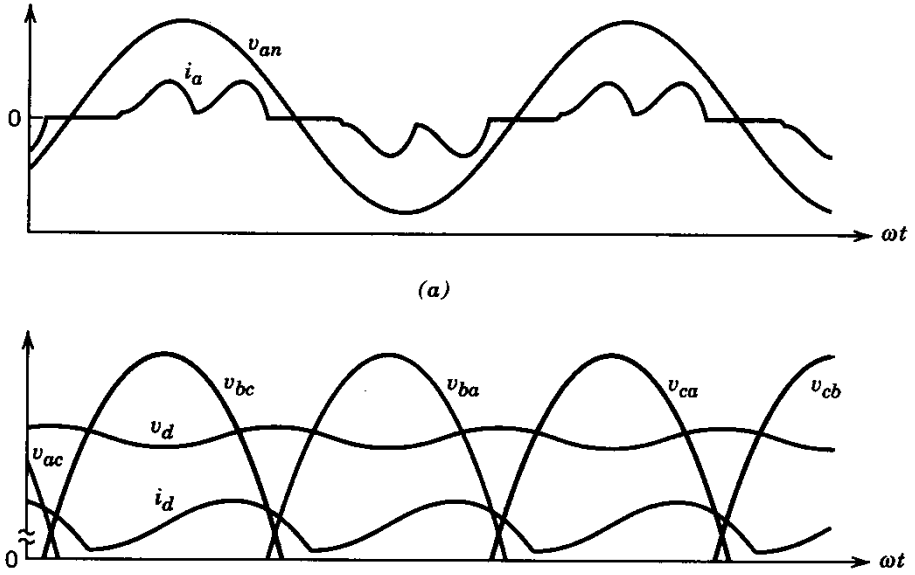


Figure 5-39 Waveforms in the rectifier of Fig. 5-30, obtained in Example 5-7.

- PSpice-based analysis

Inrush Current and Over-voltage at Turn ON

- Theroretical maximum voltage across the capacitor occurs when the capacitor is initially discharged and the AC input is switched at its peak:
  - twice the peak phase voltage (in 1-phase ckts),
  - twice the peak line voltage (in 3-phase ckts).
- Overvoltages and inrush currents that follow may be damaging to capacitors and diodes.
- Possible solution: Use current limiting resistor on the DC side between the rectifier output and filter capacitor. The resistor should be shorted out after few cycles to limit losses.