Chapter 5

Diode Rectifiers

Diode Rectifier Block Diagram

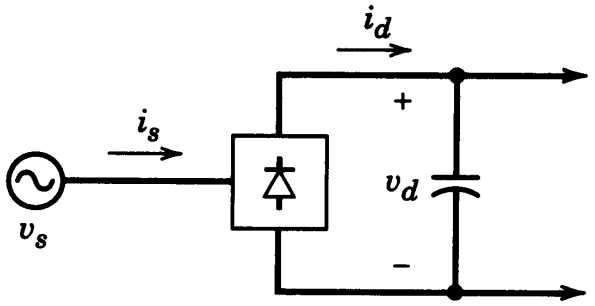


Figure 5-1 Block diagram of a rectifier.

- Uncontrolled utility interface (ac to dc)

A Simple Circuit

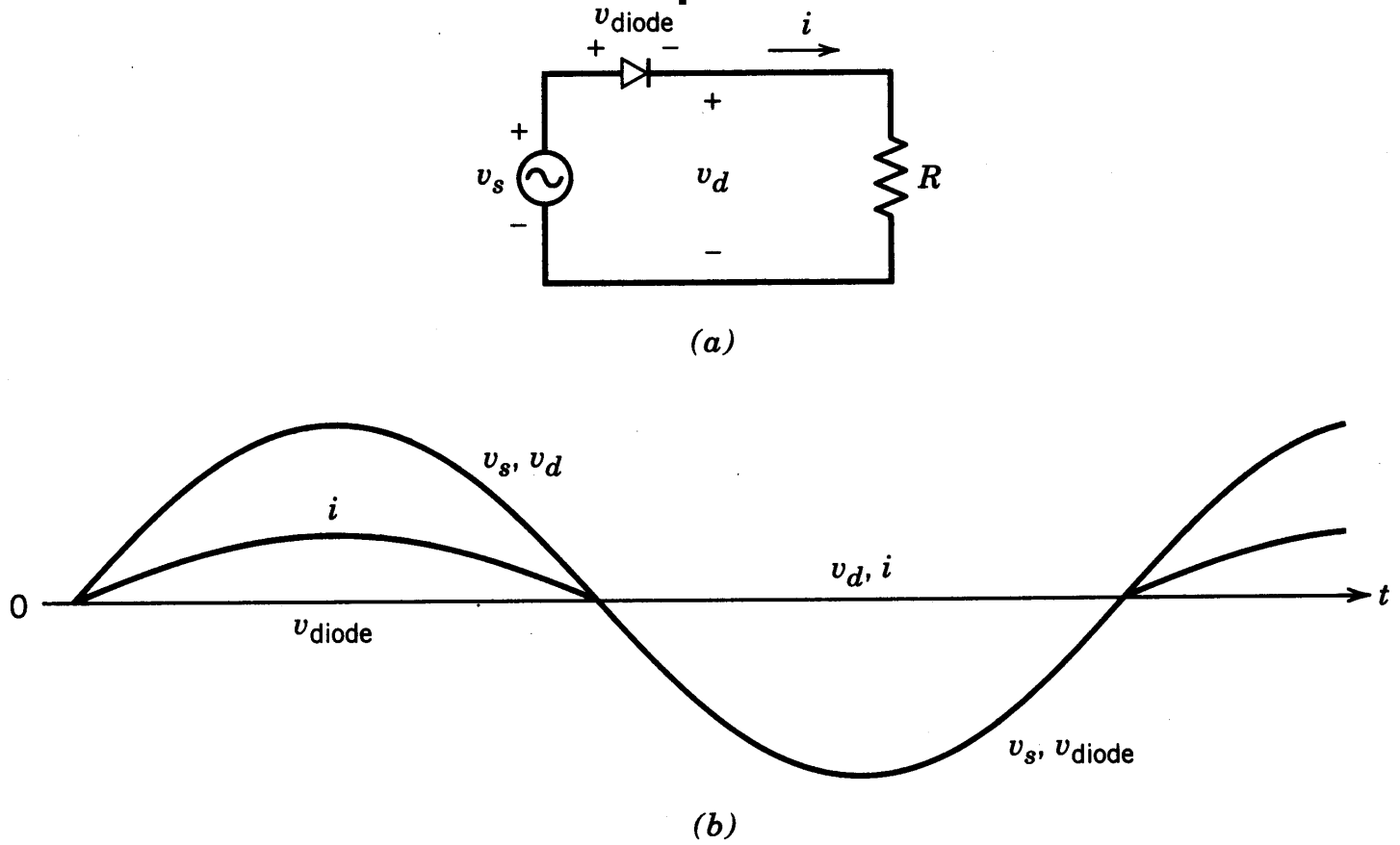


Figure 5-2 Basic rectifier with a load resistance.

- Resistive load

A Simple Circuit (*R-L* Load)

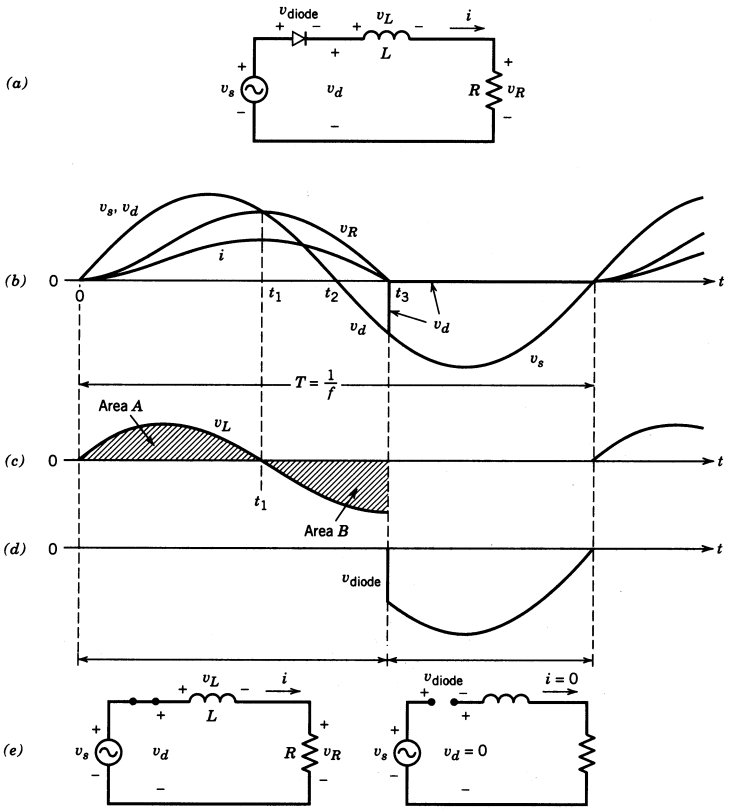


Figure 5-3 Basic rectifier with an inductive load.

- Current continues to flows for a while even after the input voltage has gone negative

A Simple Circuit (Load has a dc back-emf)

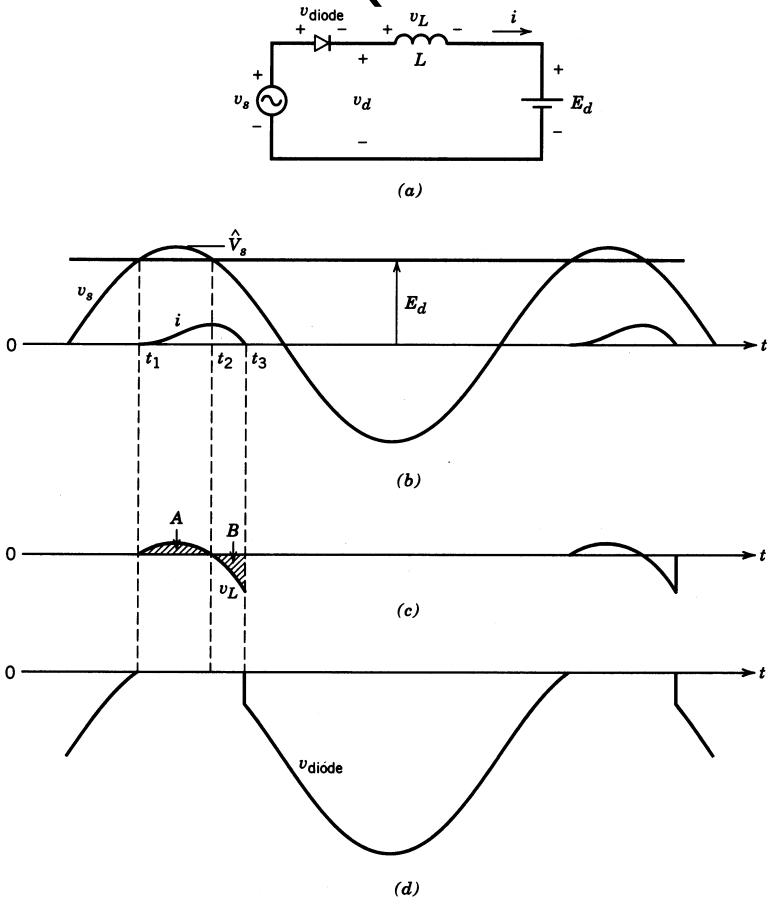


Figure 5-4 Basic rectifier with an internal dc voltage.

- 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

Single-Phase Diode Rectifier Bridge

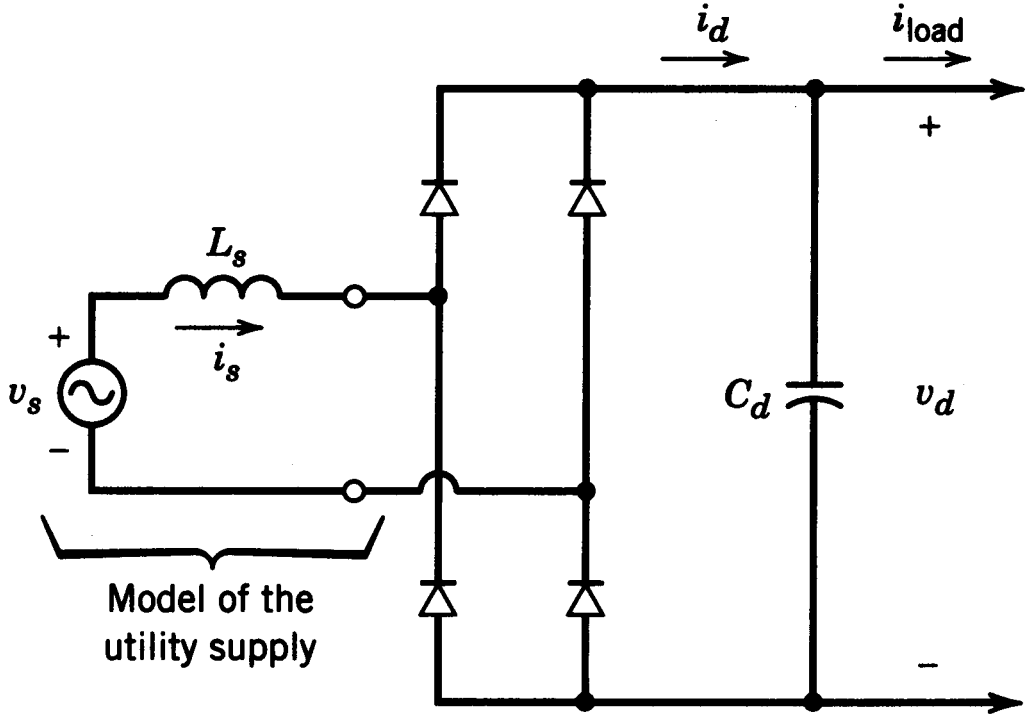


Figure 5-5 Single-phase diode bridge rectifier.

- Large capacitor at the dc output for filtering and energy storage

Diode-Rectifier Bridge Analysis

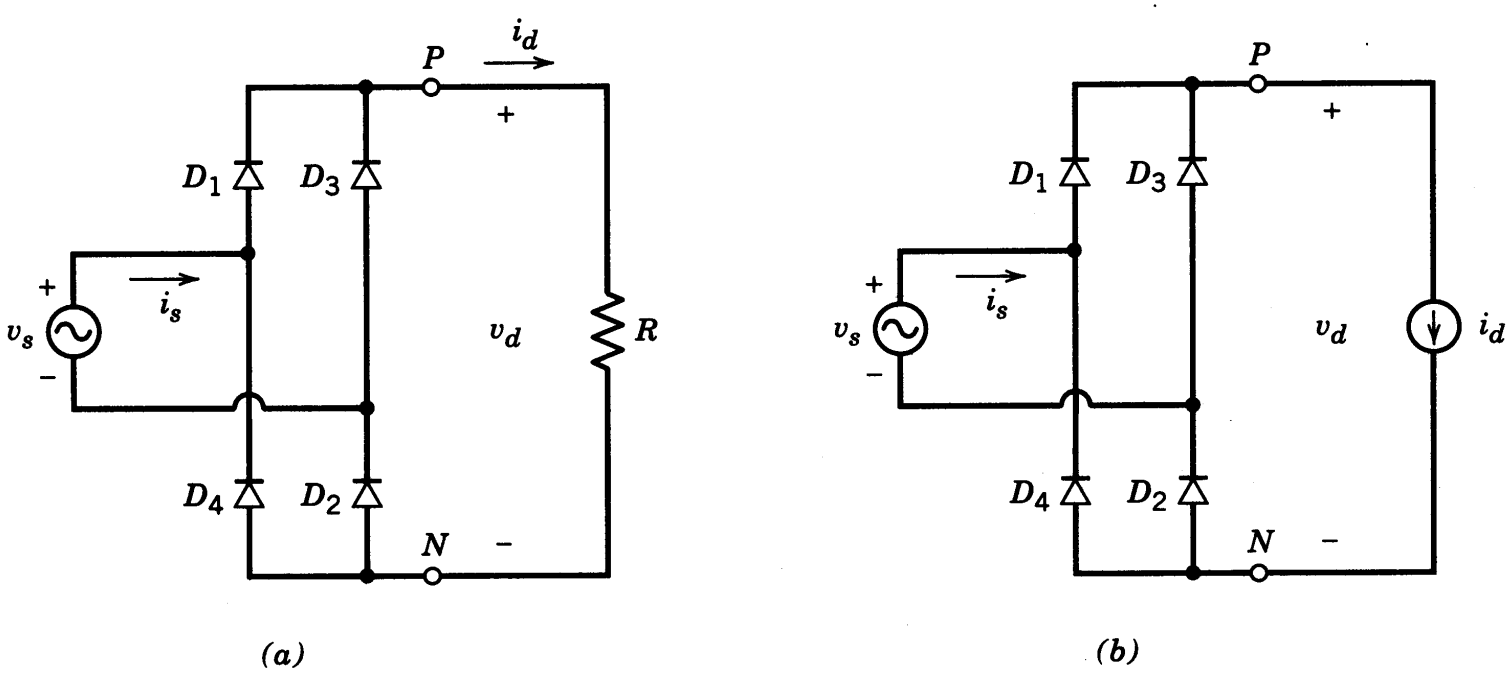


Figure 5-6 Idealized diode bridge rectifiers with $L_s = 0$.

- Two simple (idealized) cases to begin with

Redrawing Diode-Rectifier Bridge

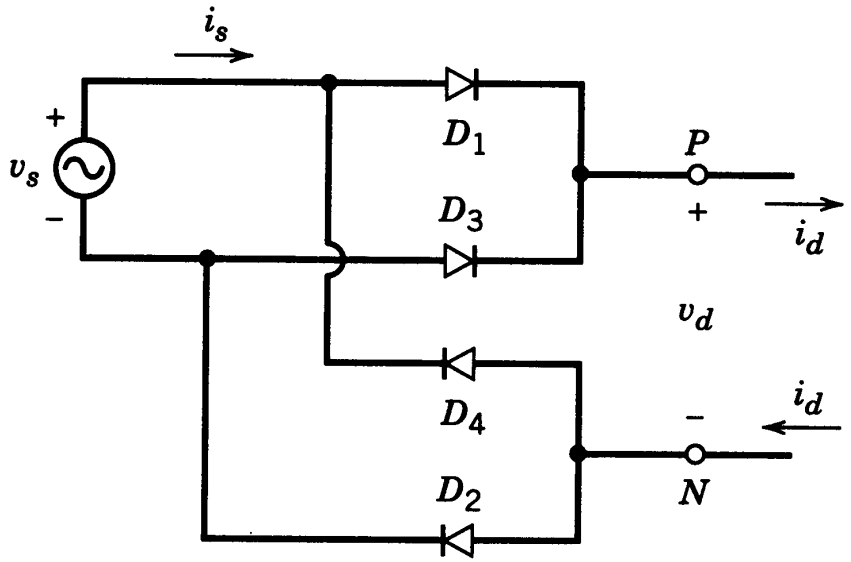
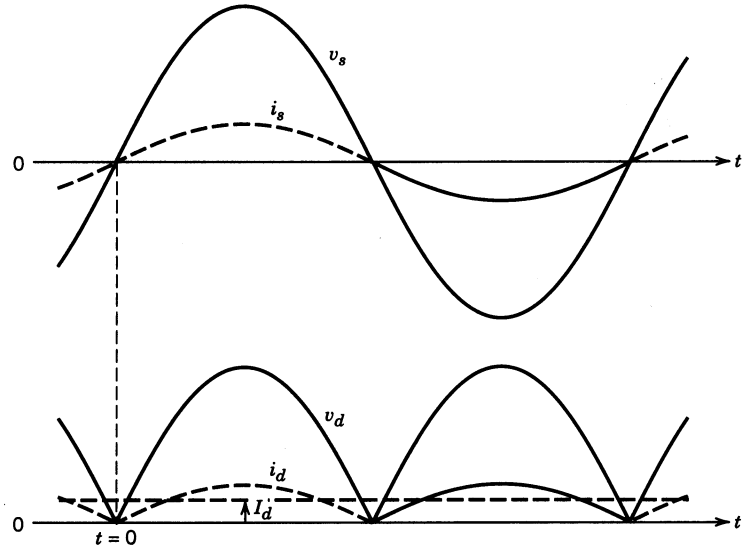


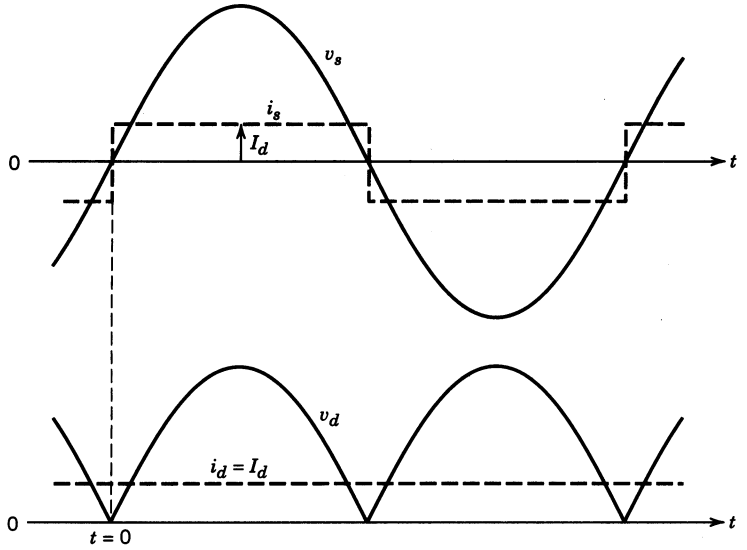
Figure 5-7 Redrawn rectifiers of Fig. 5-6.

- Two groups, each with two diodes

Waveforms with a purely resistive load and a purely dc current at the output



(a)



(b)

Figure 5-8 Waveforms in the rectifiers of (*a*) Fig. 5-6*a* and (*b*) Fig. 5-6*b*.

- In both cases, the dc-side voltage waveform is the same

Diode-Rectifier Bridge Input Current

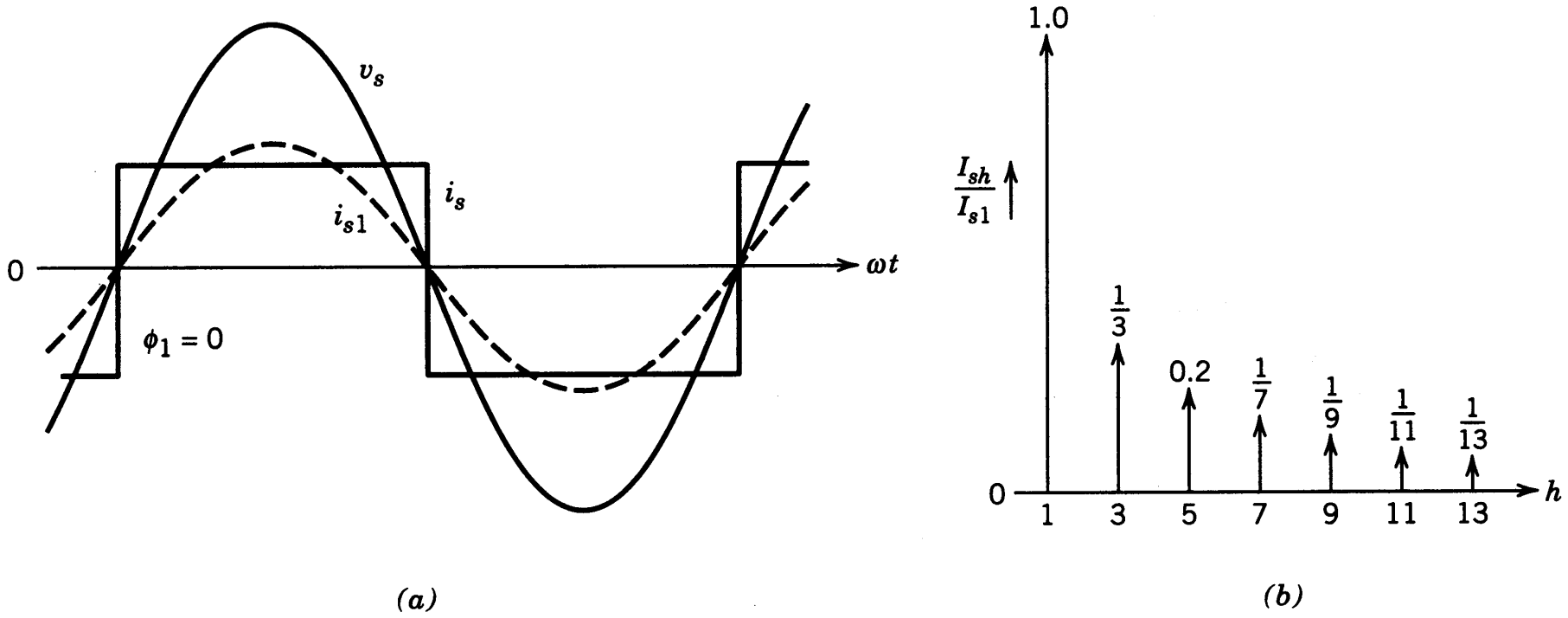


Figure 5-9 Line current i_s in the idealized case.

- Idealized case with a purely dc output current

Diode-Rectifier Bridge Analysis with AC-Side Inductance

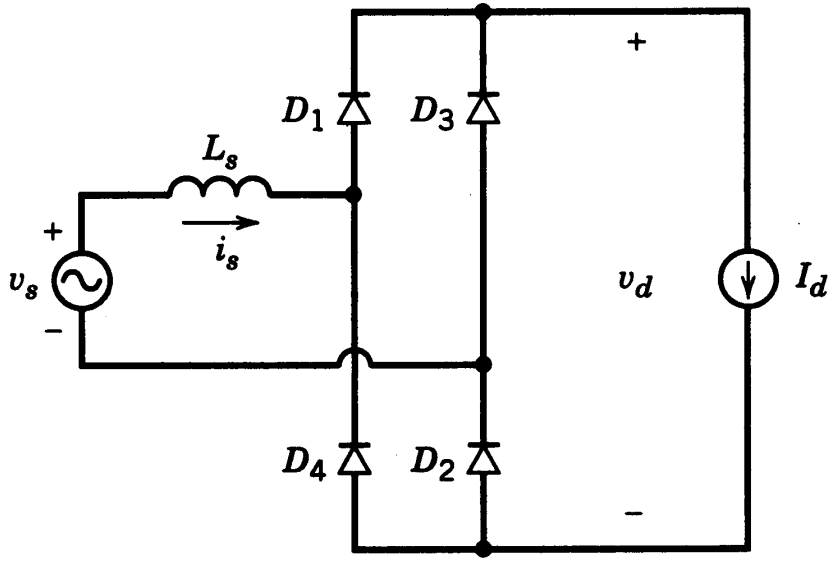


Figure 5-10 Single-phase rectifier with L_s.

- Output current is assumed to be purely dc

Understanding Current Commutation

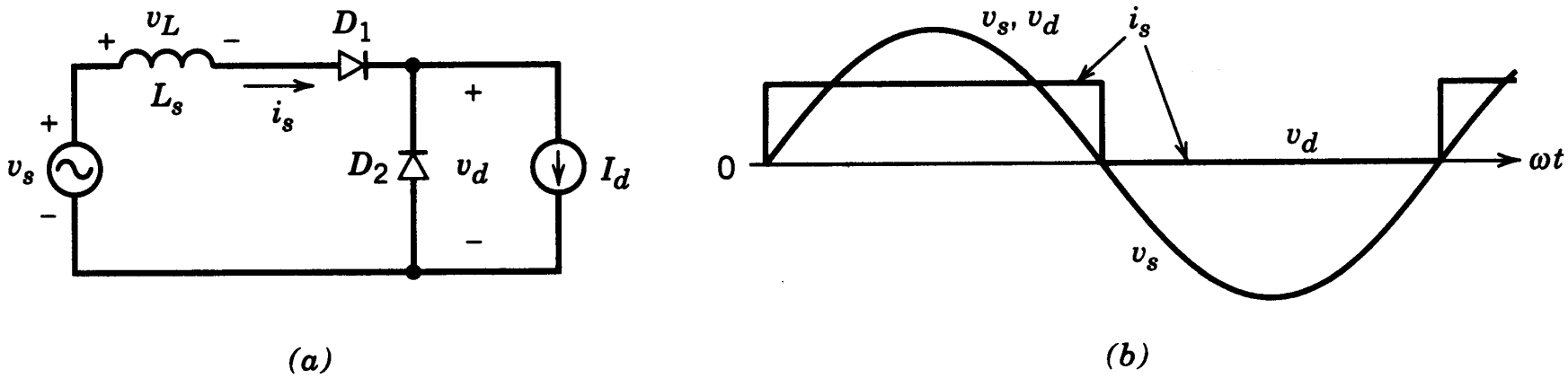


Figure 5-11 Basic circuit to illustrate current commutation. Waveforms assume $L_s = 0$.

- Assuming inductance in this circuit to be zero

Understanding Current Commutation (cont.)

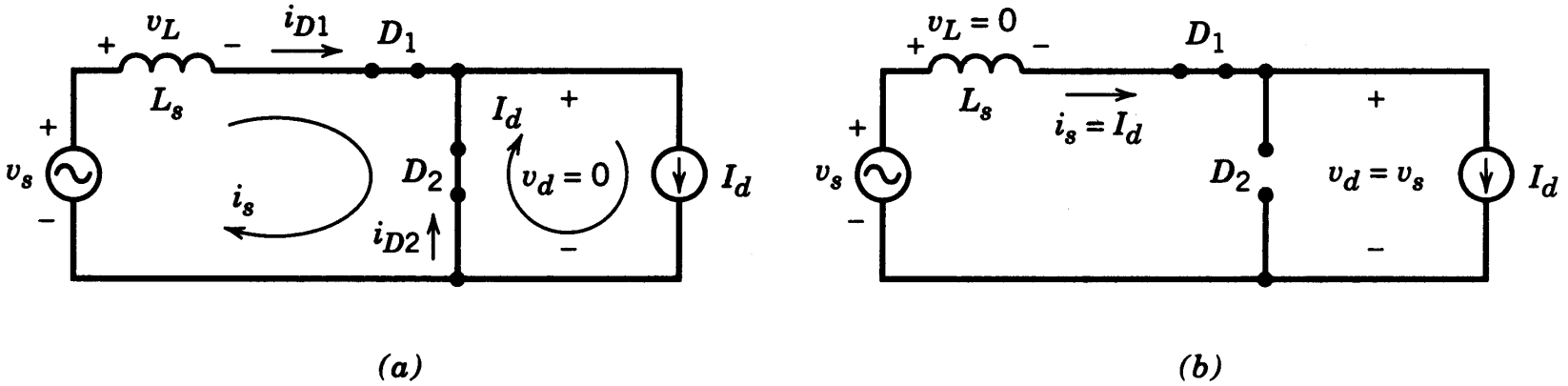


Figure 5-12 (*a*) Circuit during the commutation. (*b*) Circuit after the current commutation is completed.

- Inductance in this circuit is included

Current Commutation Waveforms

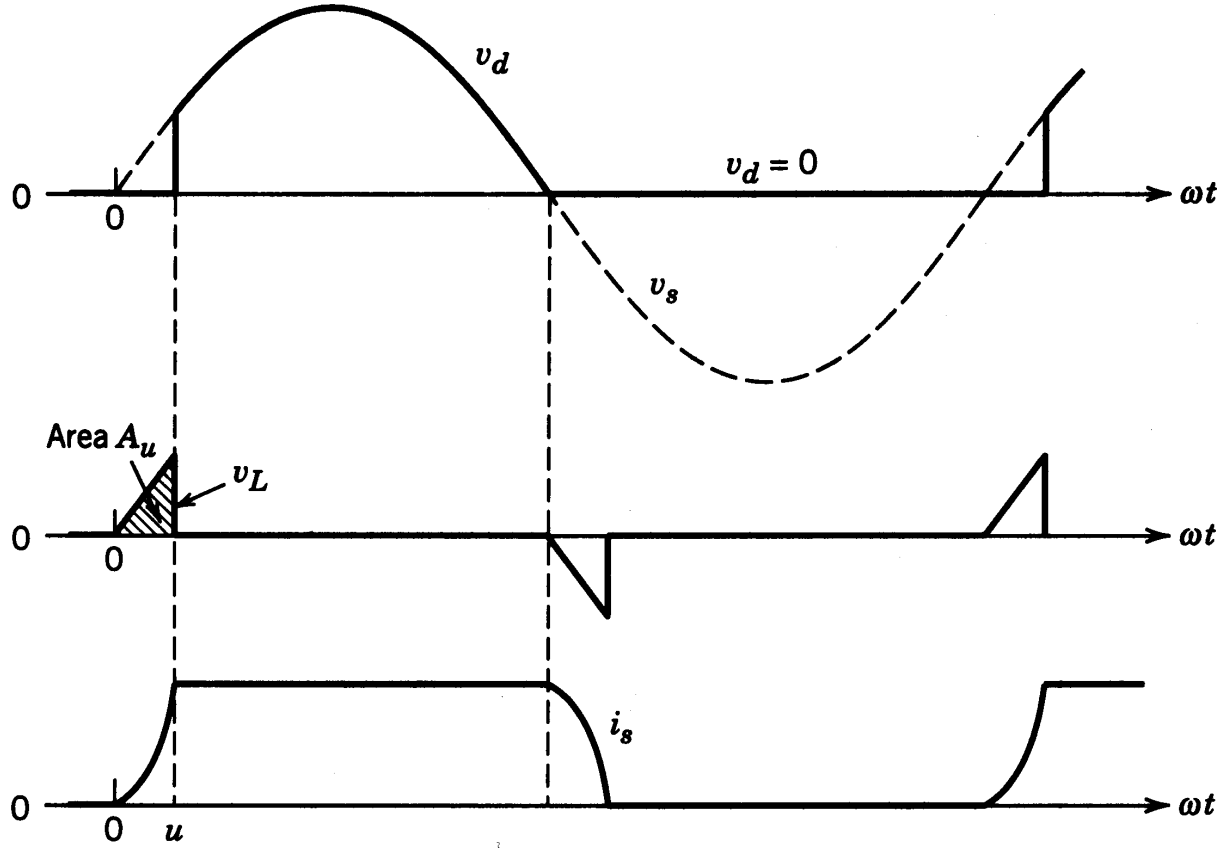


Figure 5-13 Waveforms in the basic circuit of Fig. 5-11. Note that a large value of L_s is used to clearly show the commutation interval.

- Shows the volt-seconds needed to commutate current

Current Commutation in Full-Bridge Rectifier

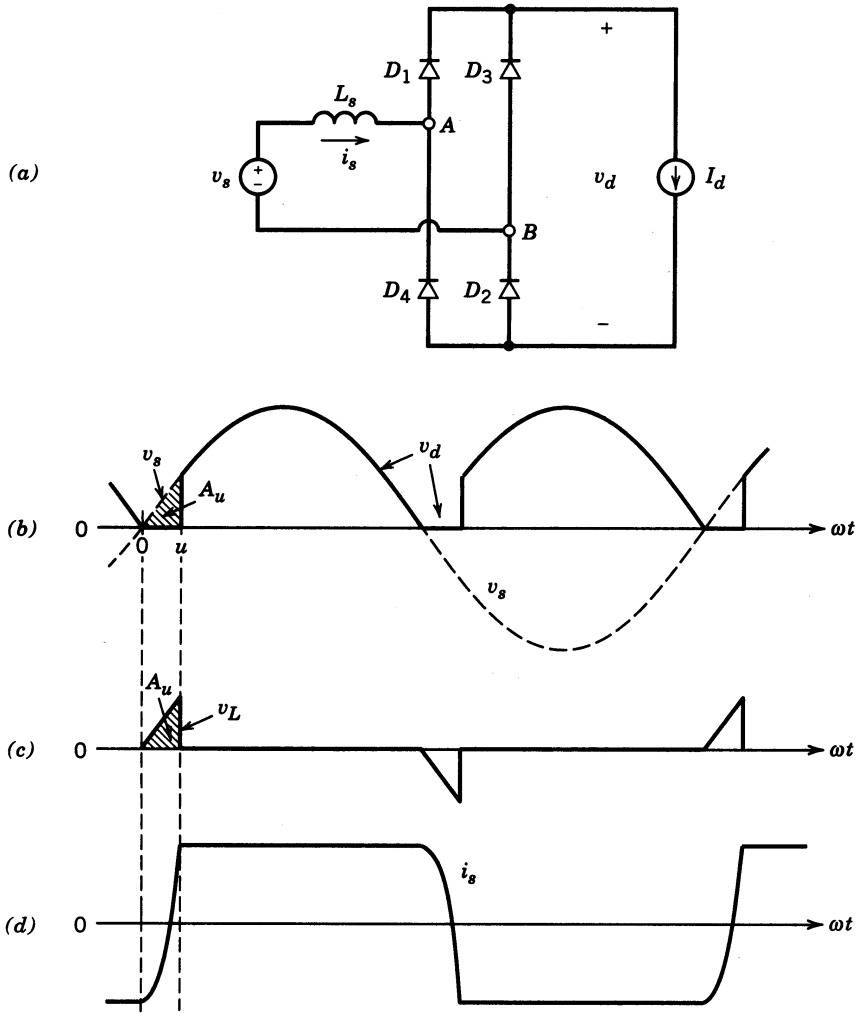


Figure 5-14 (*a*) Single-phase diode rectifier with L_s. (*b*) Waveforms.

- Shows the necessary volt-seconds

Understanding Current Commutation

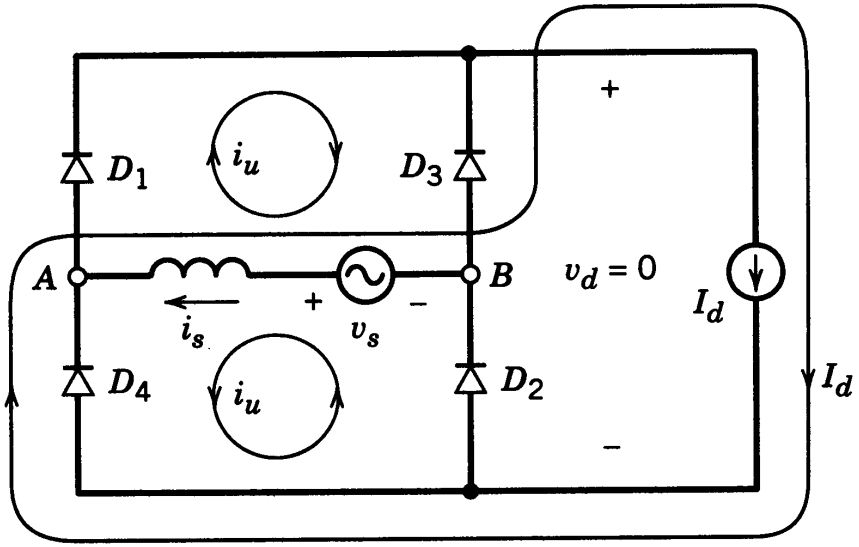


Figure 5-15 Redrawn circuit of Fig. 5-14*a* during current commutation.

- Note the current loops for analysis

Rectifier with a dc-side voltage

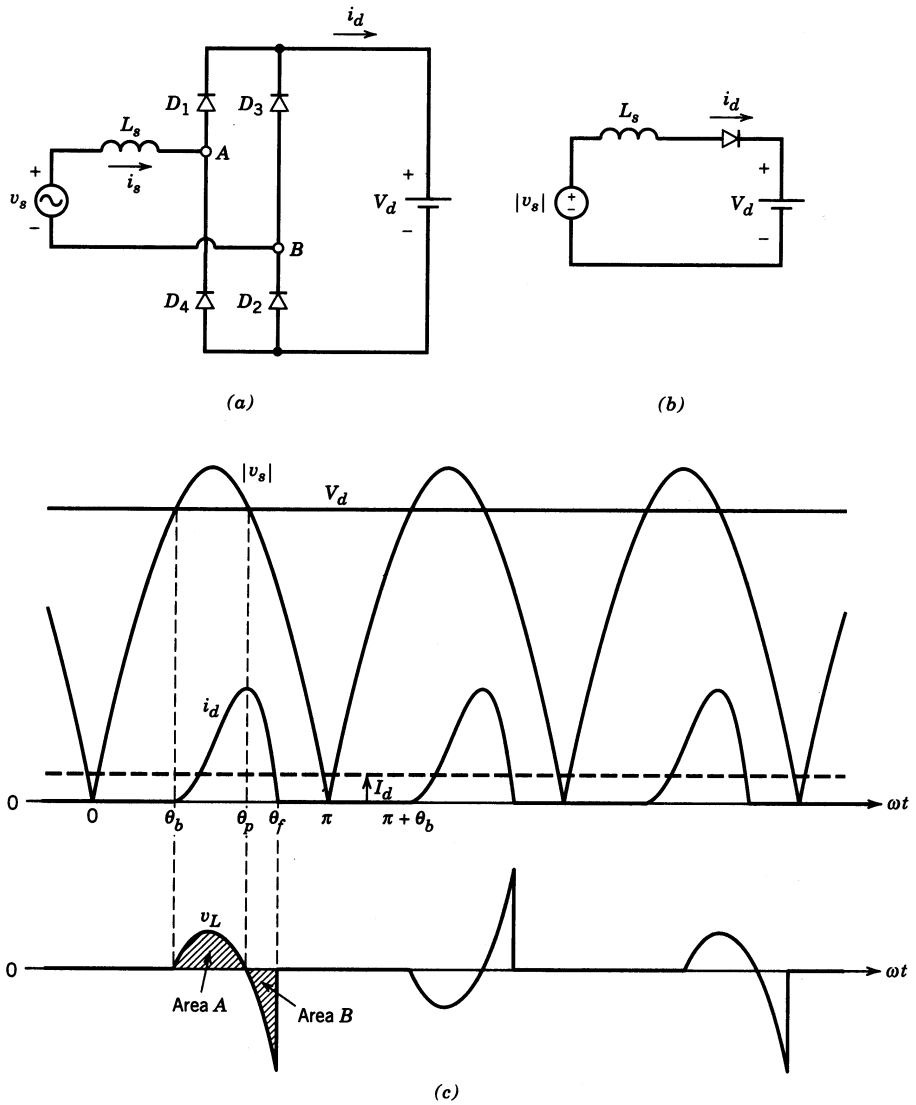


Figure 5-16 (*a*) Rectifier with a constant dc-side voltage. (*b*) Equivalent circuit. (*c*) Waveforms.

DC-Side Voltage and Current Relationship

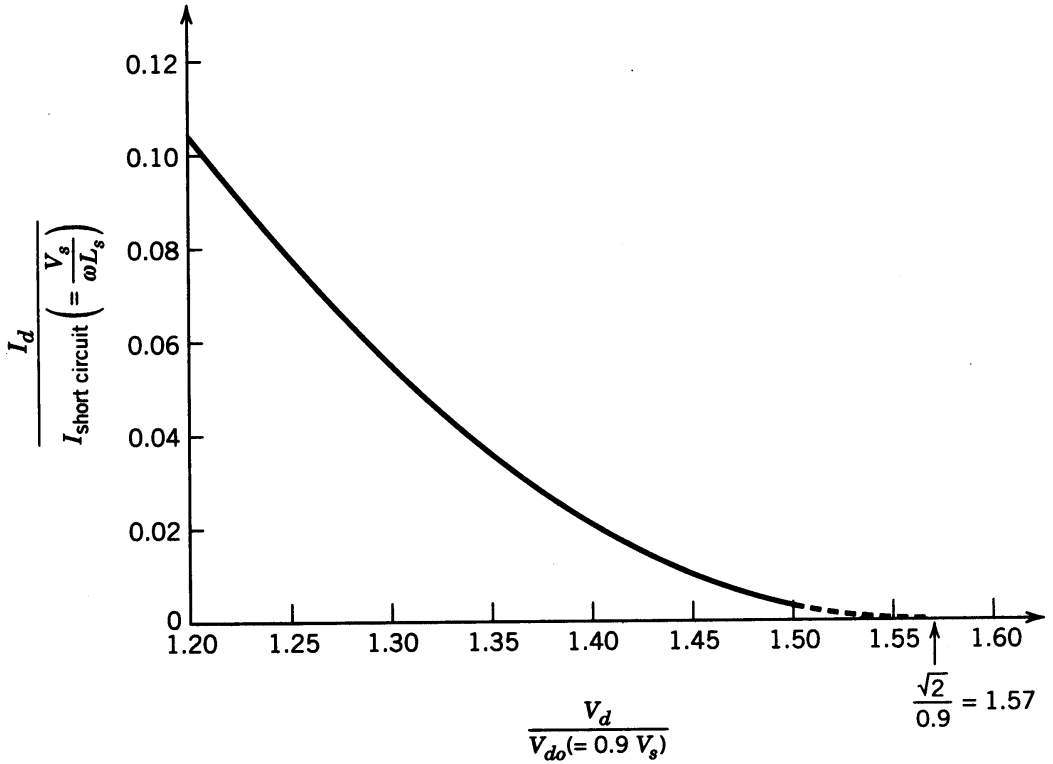


Figure 5-17 Normalized I_d versus V_d in the rectifier of Fig. 5-16*a* with a constant dc-side voltage.

- Zero current corresponds to dc voltage equal to the peak of the input ac voltage

Effect of DC-Side Current on THD, PF and DPF

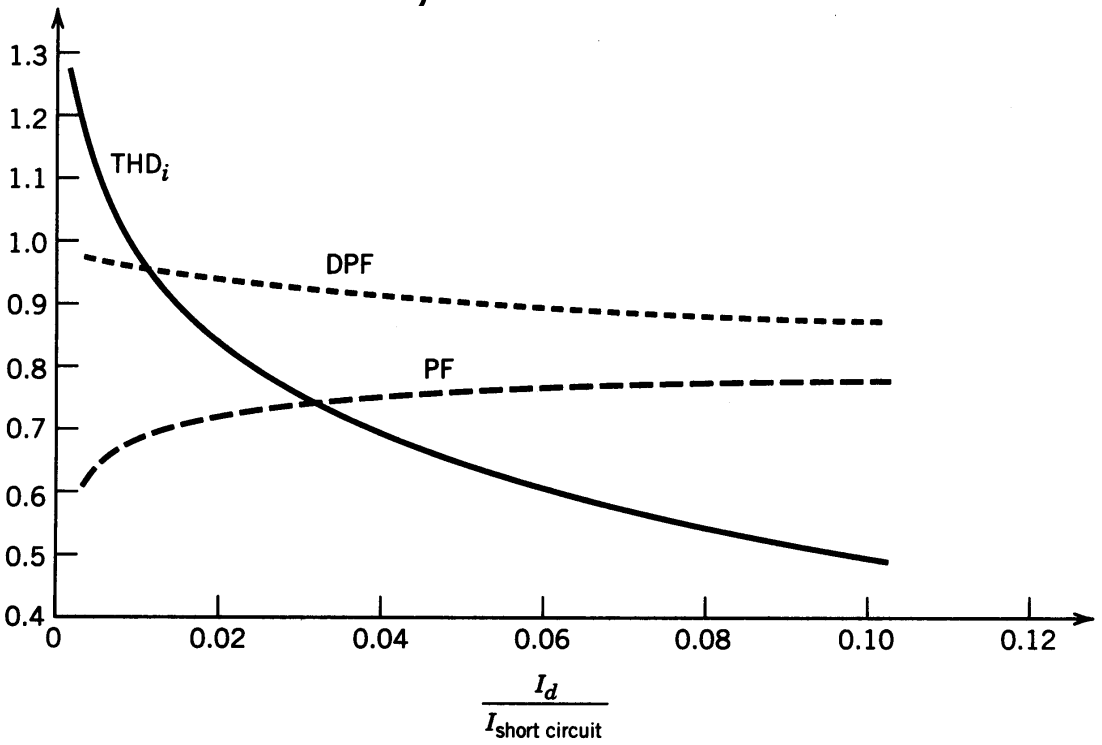


Figure 5-18 Total harmonic distortion, DPF, and PF in the rectifier of Fig. 5-16*a* with a constant dc-side voltage.

- Very high THD at low current values

Crest Factor versus the Current Loading

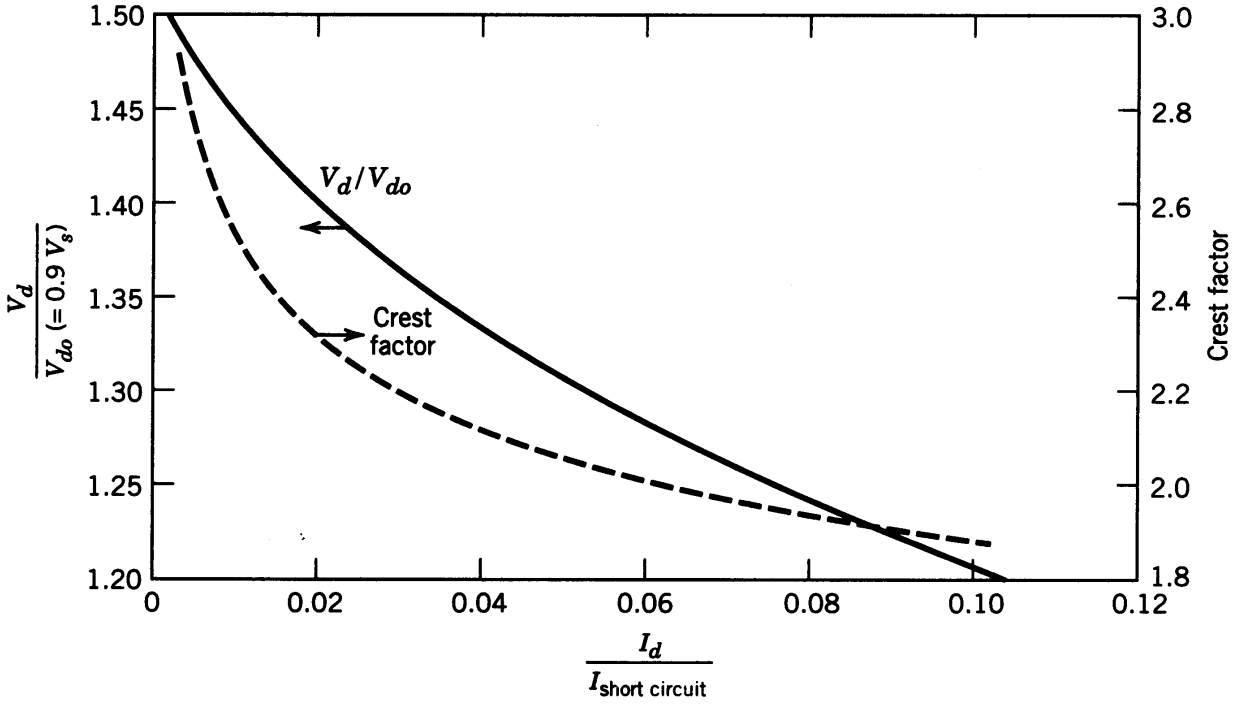


Figure 5-19 Normalized V_d and the crest factor in the rectifier of Fig. 5-16*a* with a constant dc-side voltage.

- The Crest Factor is very high at low values of current

Diode-Rectifier with a Capacitor Filter

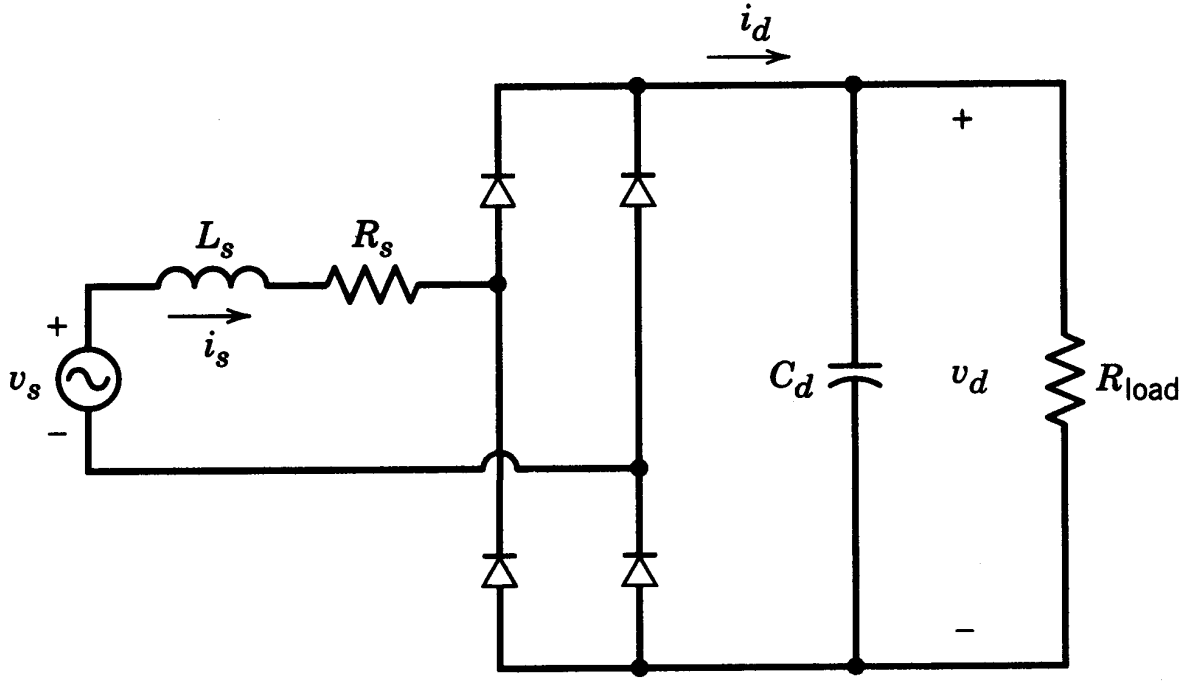


Figure 5-20 Practical diode–bridge rectifier with a filter capacitor.

- Power electronics load is represented by an equivalent load resistance

Diode Rectifier Bridge

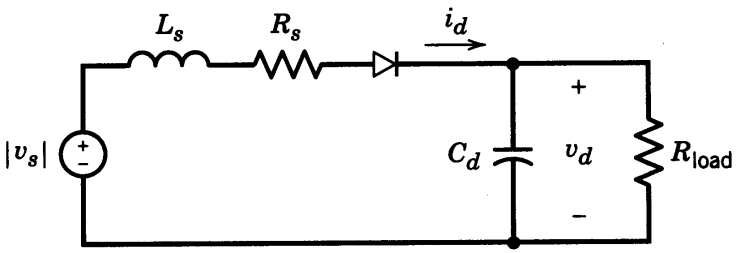


Figure 5-21 Equivalent circuit of Fig. 5-20.

- Equivalent circuit for analysis on one-half cycle basis

Diode-Bridge Rectifier: Waveforms

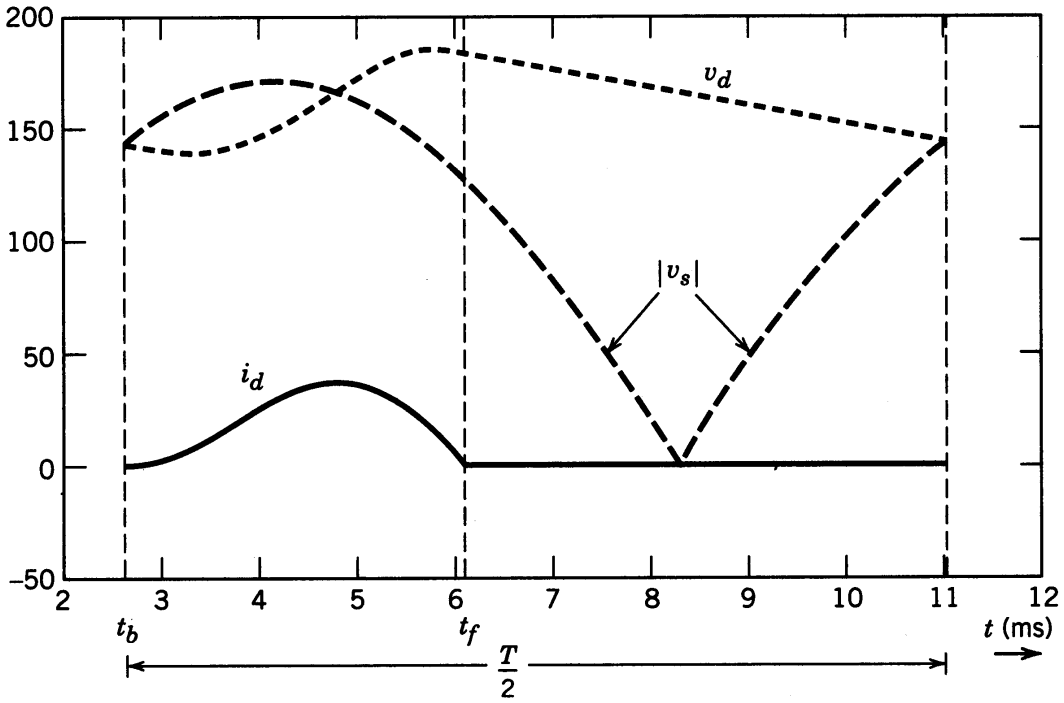


Figure 5-22 Waveforms in the circuit of Fig. 5-20, obtained in Example 5-1.

- Analysis using MATLAB

Diode-Bridge Rectifier: Waveforms

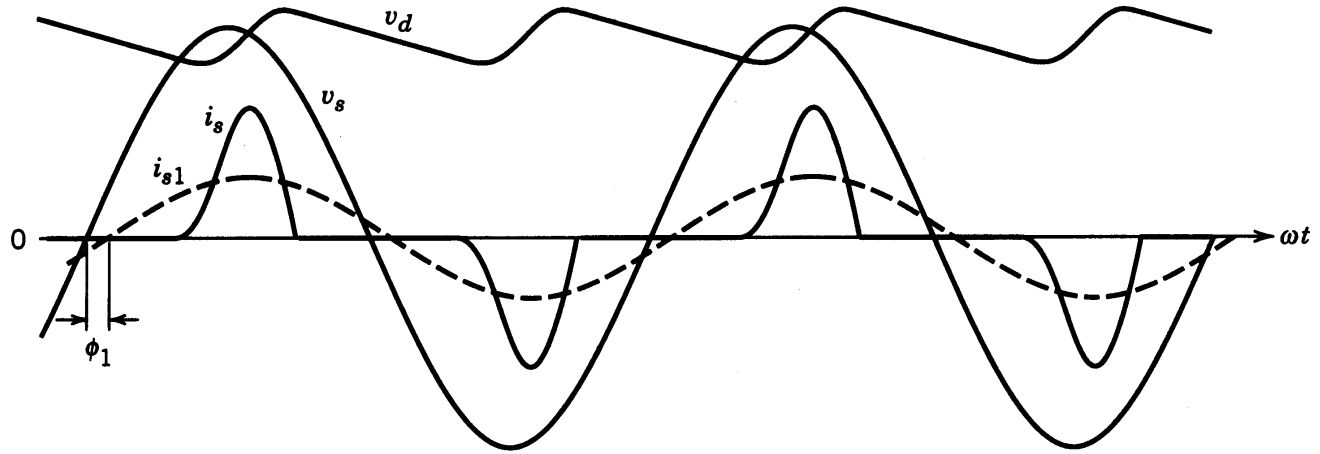


Figure 5-23 Waveforms in the circuit of Fig. 5-20, obtained in Example 5-2.

- Analysis using PSpice

Input Line-Current Distortion

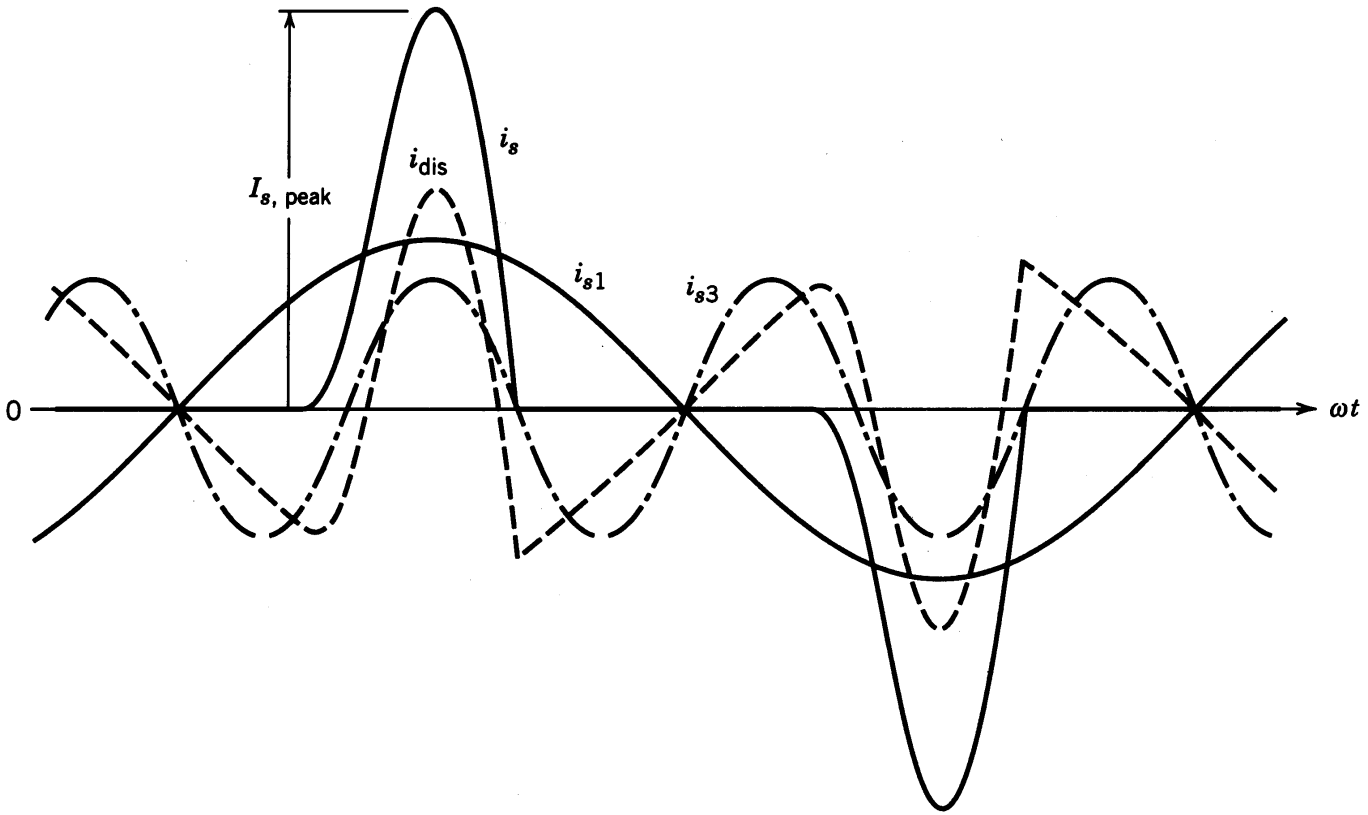


Figure 5-24 Distorted line current in the rectifier of Fig. 5-20.

- Analysis using PSpice

Line-Voltage Distortion

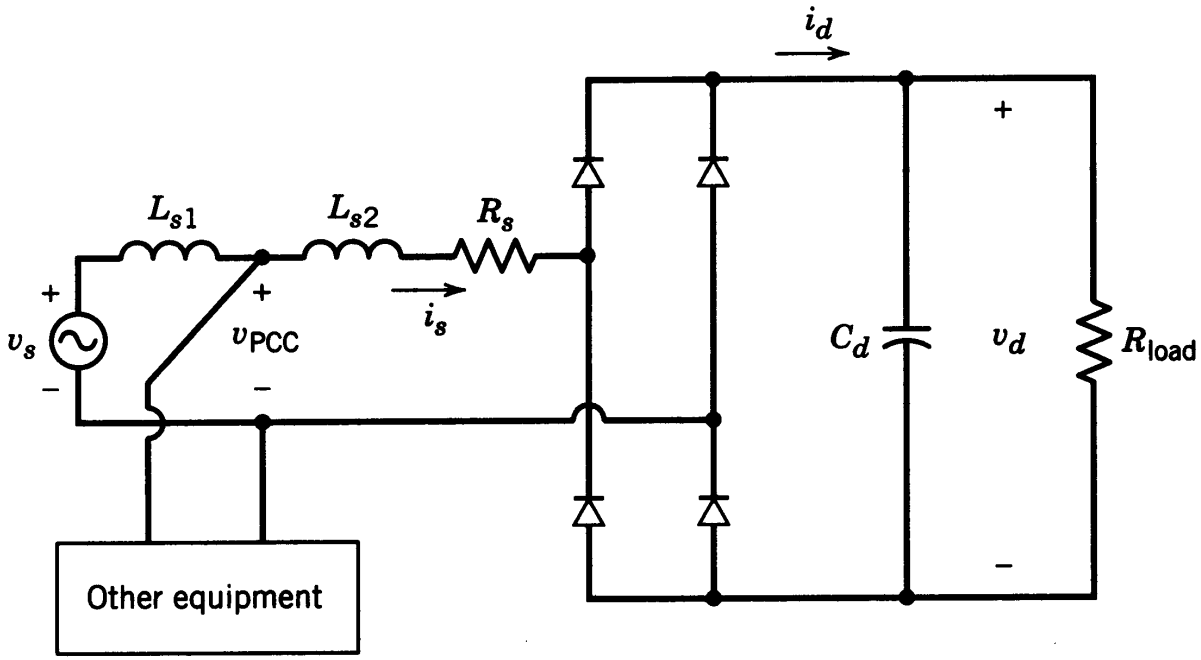


Figure 5-25 Line-voltage notching and distortion.

- PCC is the point of common coupling

Line-Voltage Distortion

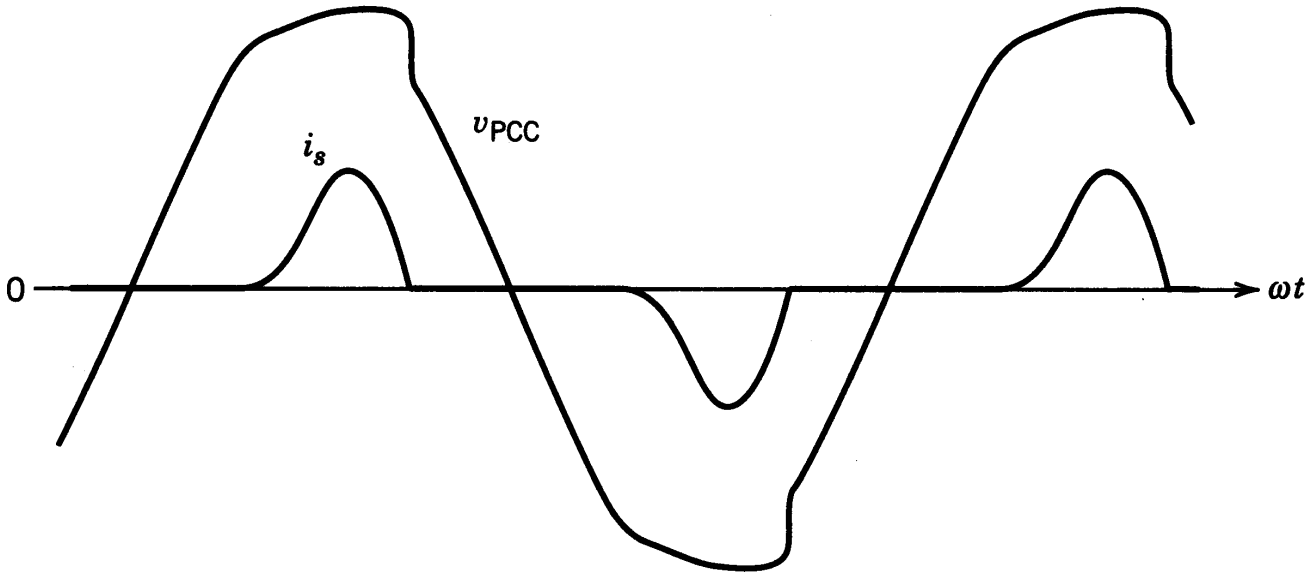


Figure 5-26 Voltage waveform at the point of common coupling in the circuit of Fig. 5-25.

- Distortion in voltage supplied to other loads

Voltage Doubler Rectifier

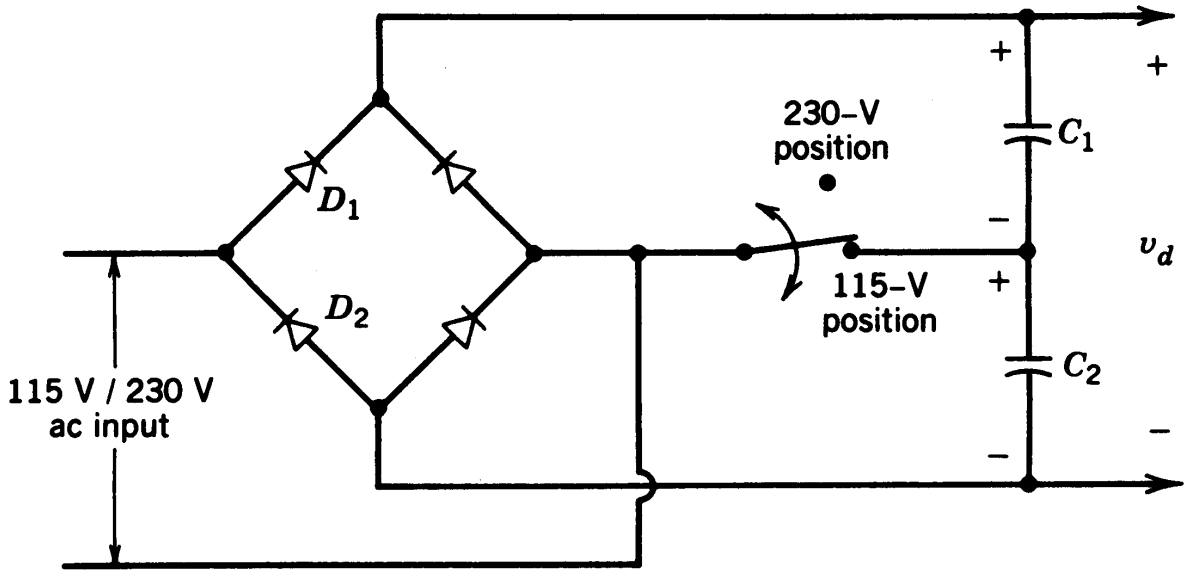


Figure 5-27 Voltage-doubler rectifier.

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

A Three-Phase, Four-Wire System

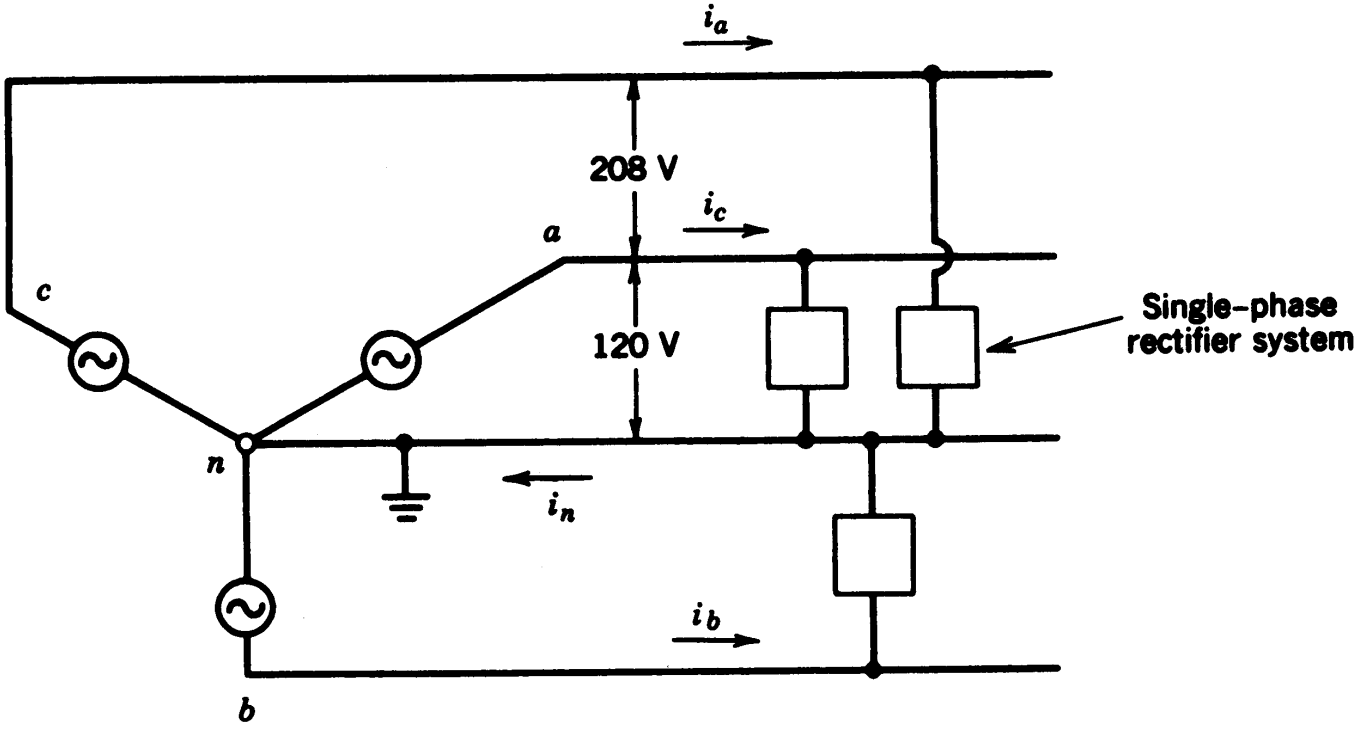


Figure 5-28 Three-phase, four-wire system.

- A common neutral wire is assumed

Current in A Three-Phase, Four-Wire System

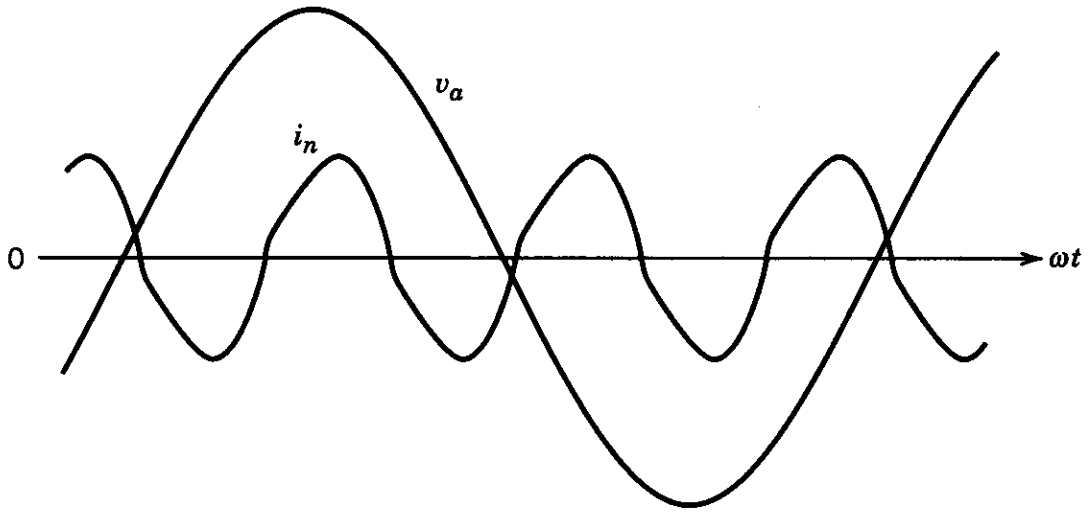


Figure 5-29 Neutral-wire current i_n.

- The current in the neutral wire can be very high

Three-Phase, Full-Bridge Rectifier

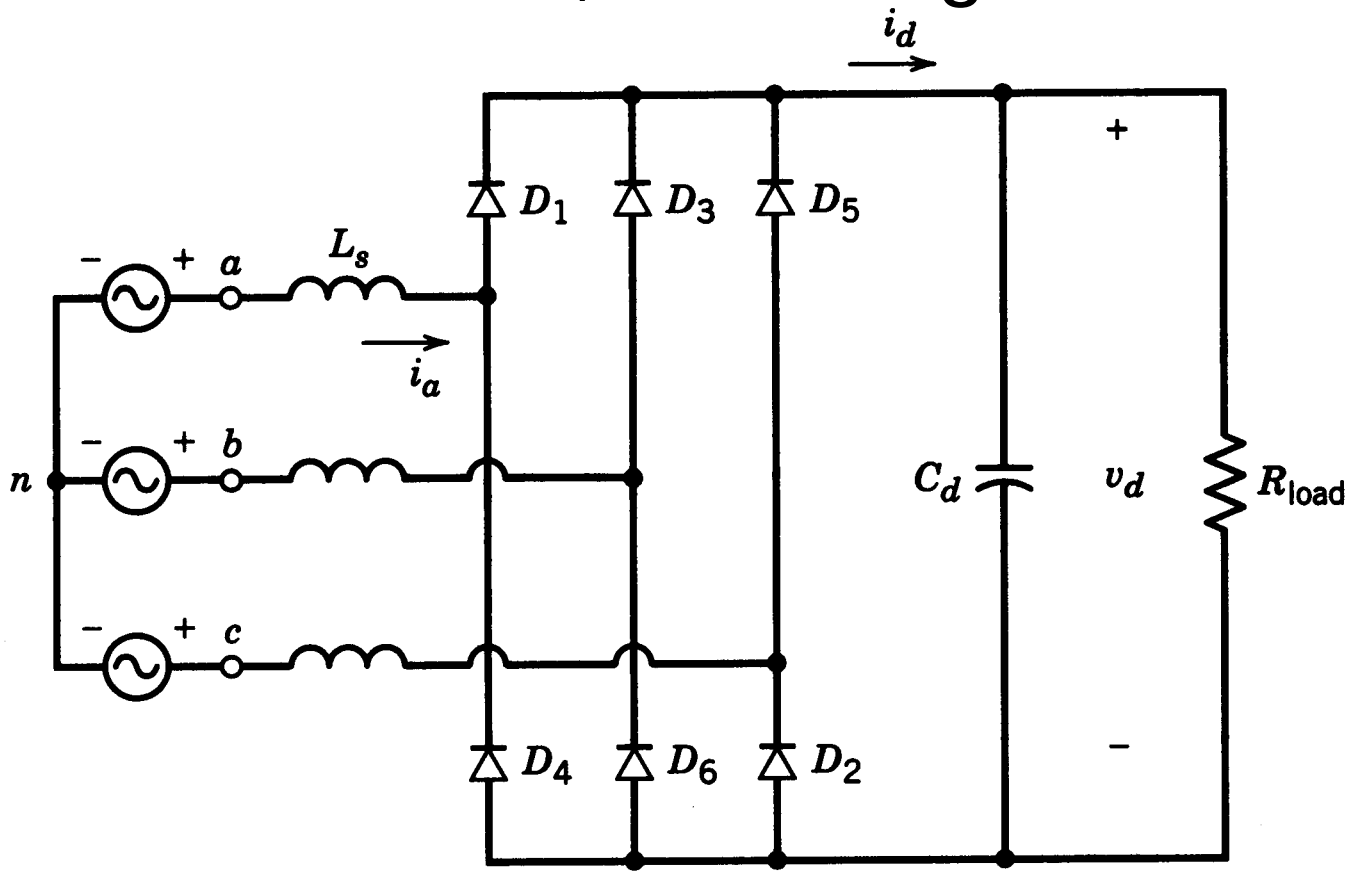


Figure 5-30 Three-phase, full-bridge rectifier.

- Commonly used

Three-Phase, Full-Bridge Rectifier: Redrawn

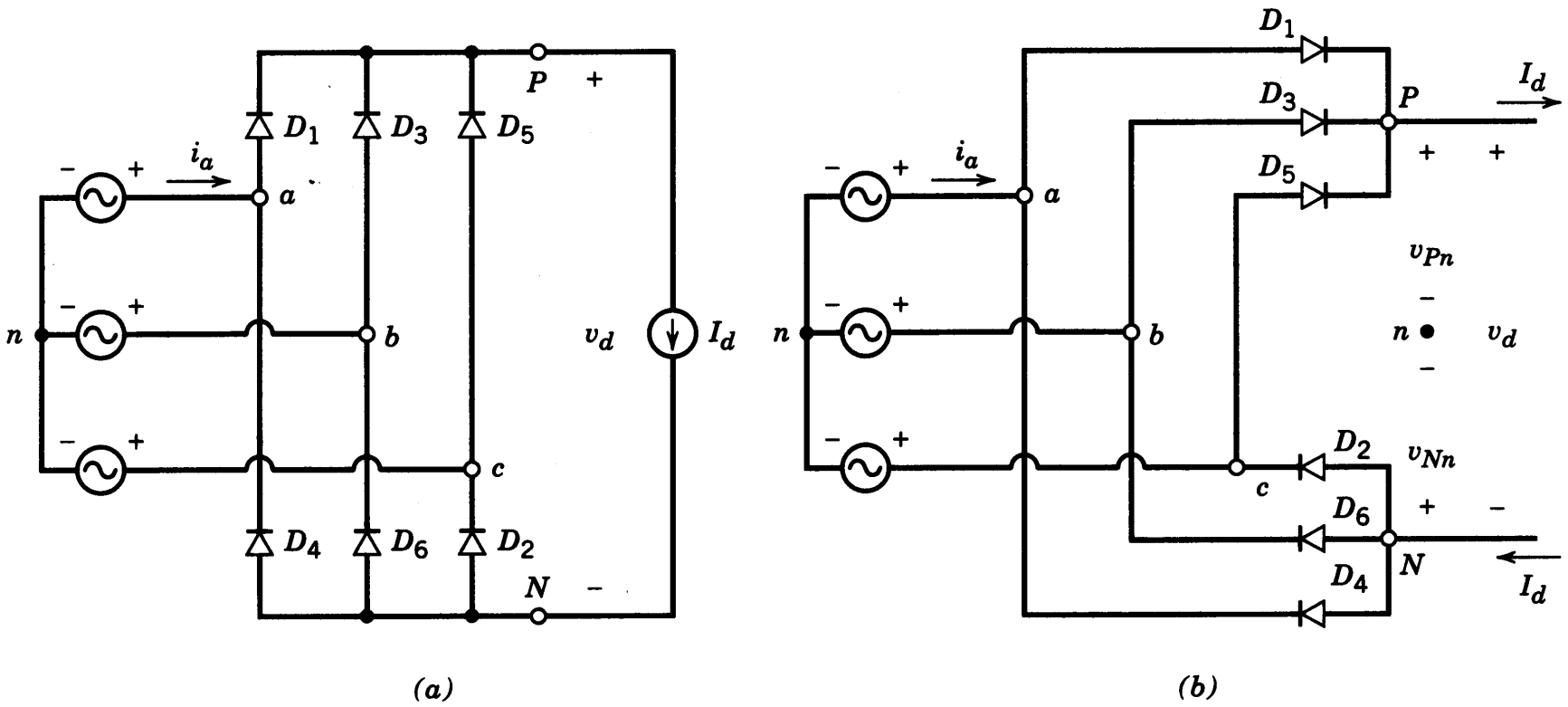


Figure 5-31 Three-phase rectifier with a constant dc current.

- Two groups with three diodes each

Three-Phase, Full-Bridge Rectifier Waveforms

- Output current is assumed to be dc

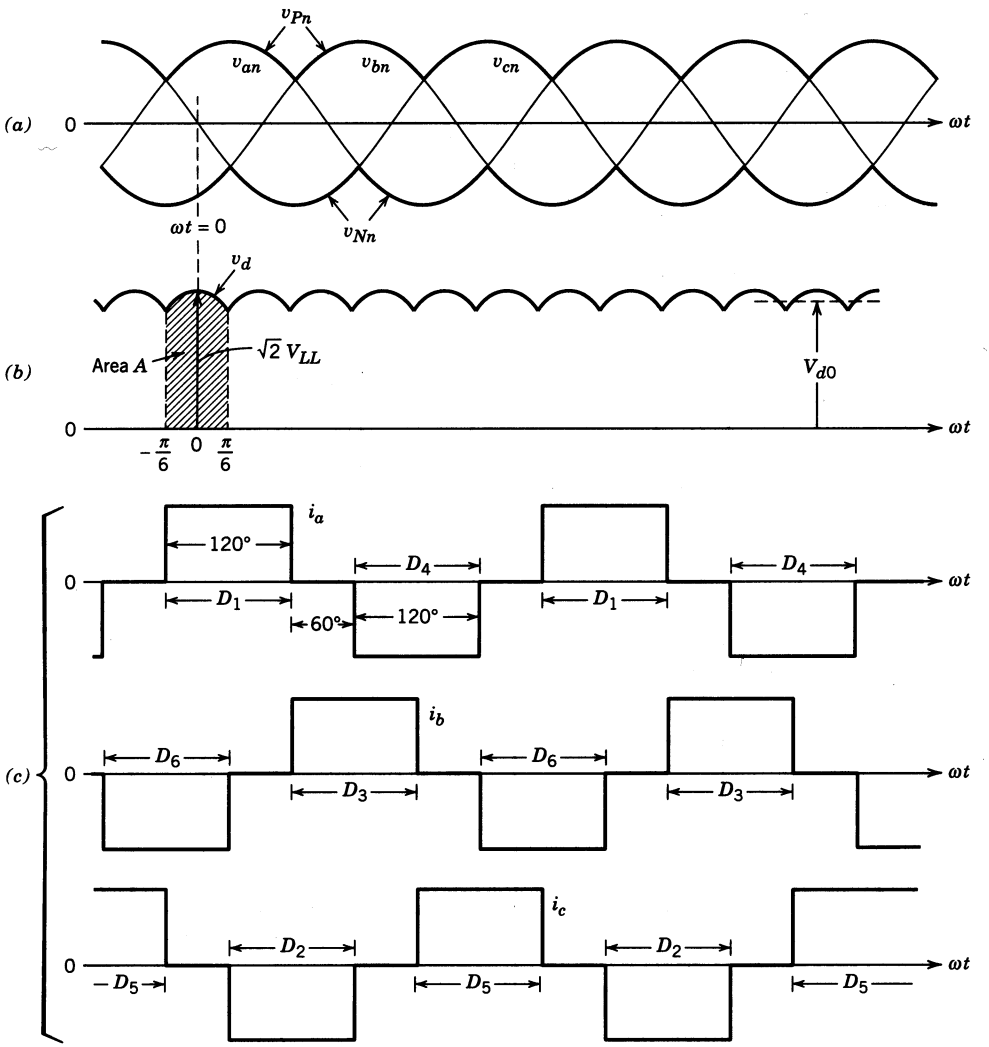


Figure 5-32 Waveforms in the circuit of Fig. 5-31.

Three-Phase, Full-Bridge Rectifier: Input Line-Current

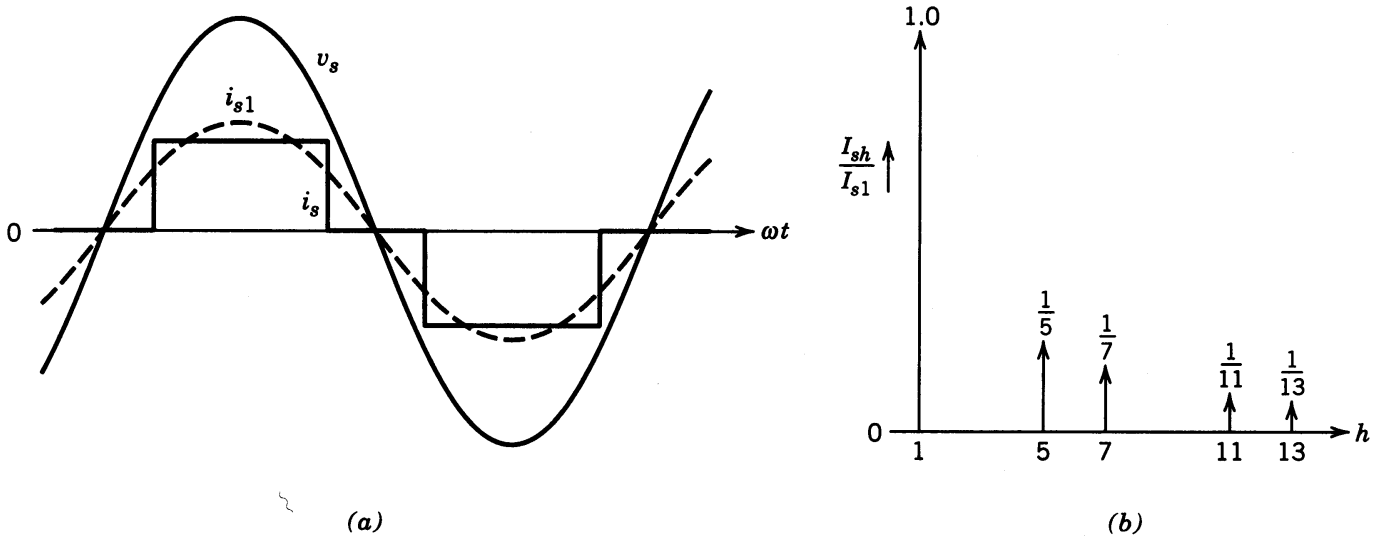


Figure 5-33 Line current in a three-phase rectifier in the idealized case with $L_s = 0$ and a constant dc current.

- Assuming output current to be purely dc and zero ac-side inductance

Three-Phase, Full-Bridge Rectifier

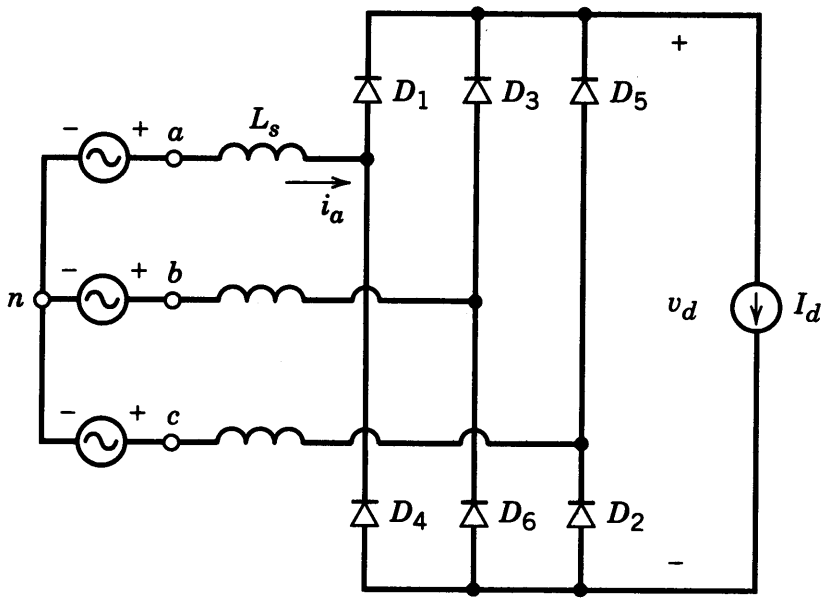


Figure 5-34 Three-phase rectifier with a finite L_s and a constant dc current.

- Including the ac-side inductance

3-Phase Rectifier: Current Commutation

- output current is assumed to be purely dc

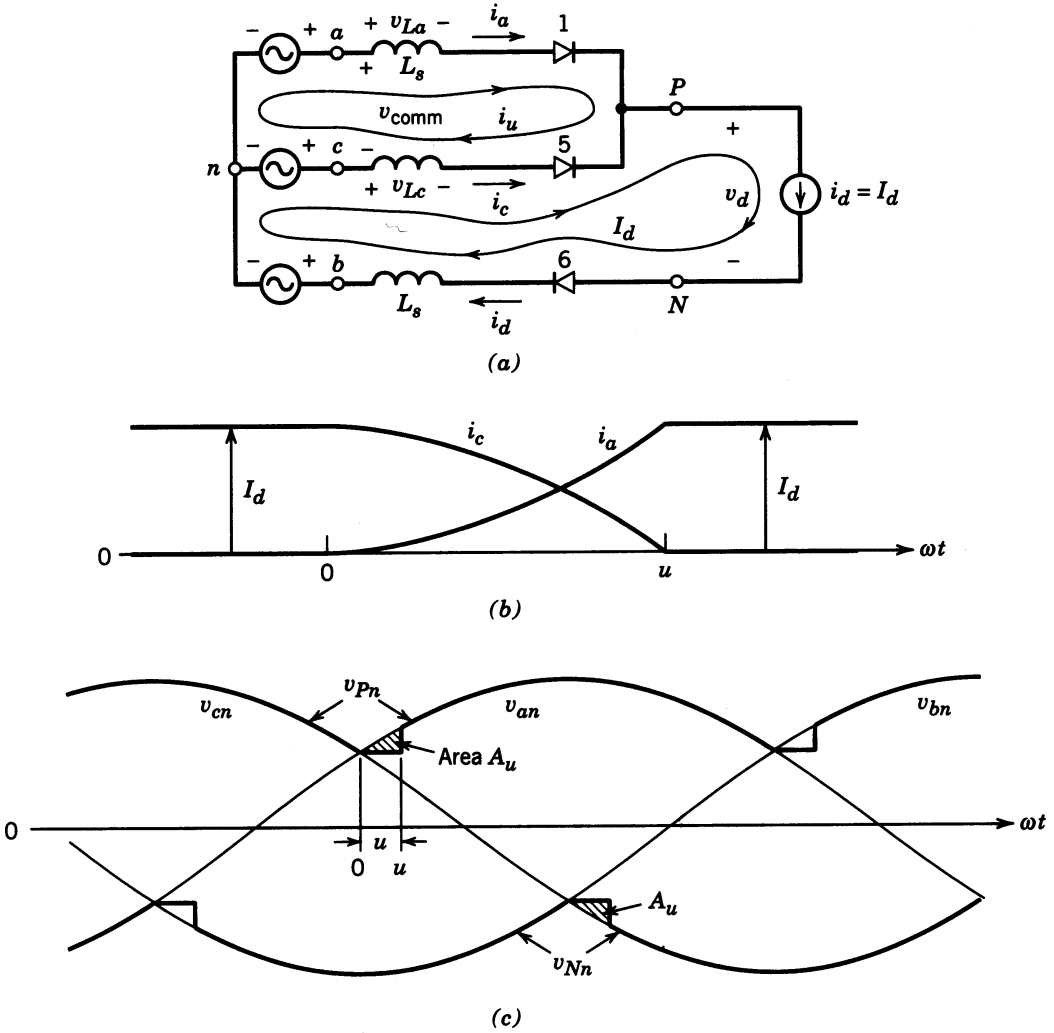


Figure 5-35 Current commutation process.

Rectifier with a Large Filter Capacitor

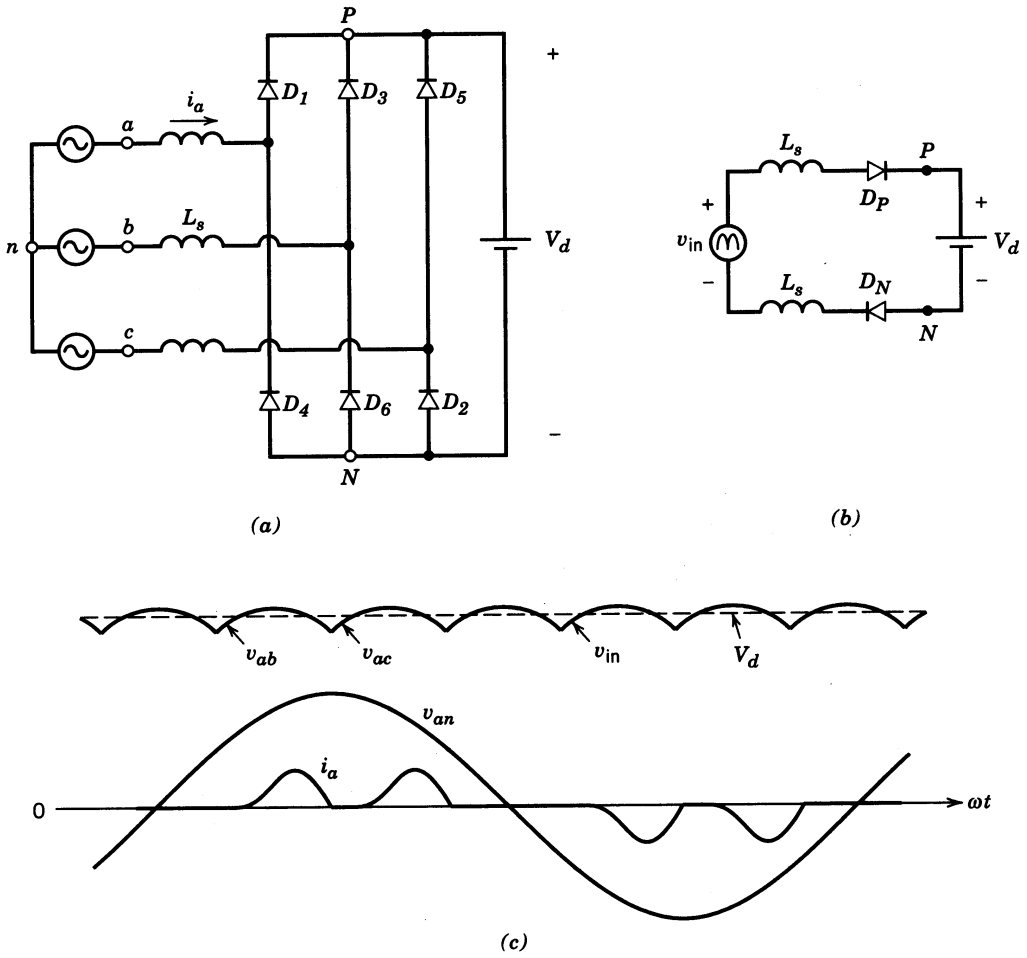


Figure 5-36 (*a*) Three-phase rectifier with a finite L_s and a constant dc voltage. (*b*) Equivalent circuit. (*c*) Waveforms.

- Output voltage is assumed to be purely dc

Three-Phase, Full-Bridge Rectifier

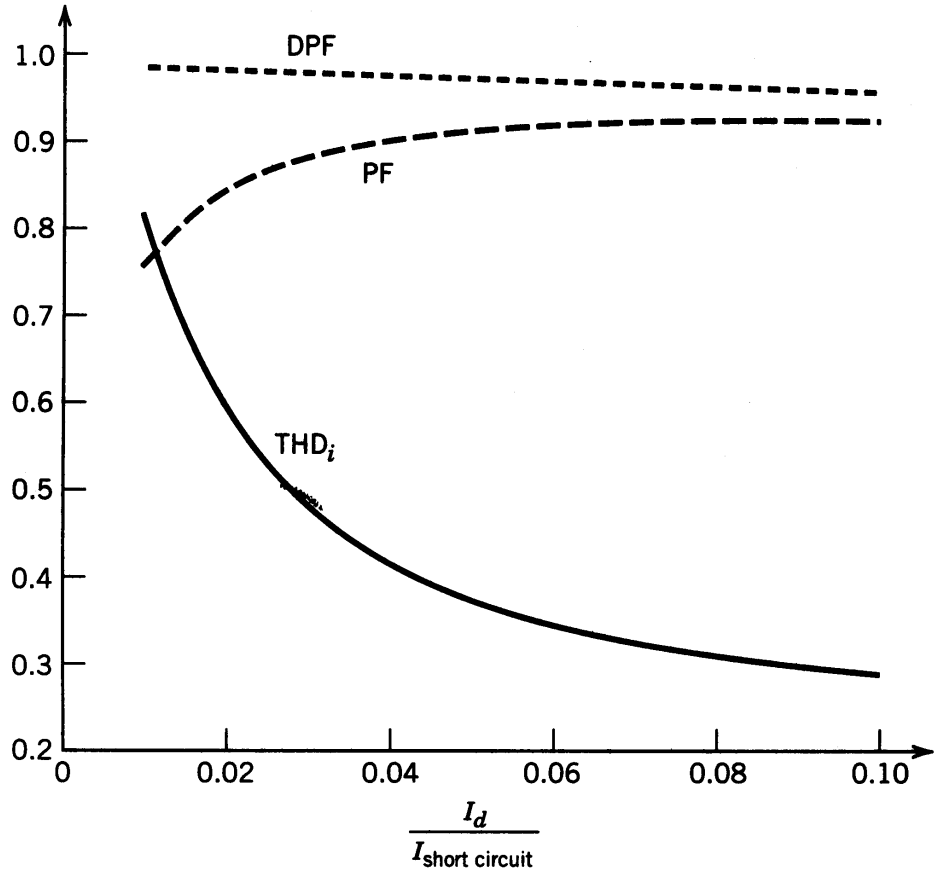


Figure 5-37 Total harmonic distortion, DPF, and PF in the rectifier of Fig. 5-36 with a constant dc voltage.

- THD, PF and DPF as functions of load current

Crest Factor versus the Current Loading

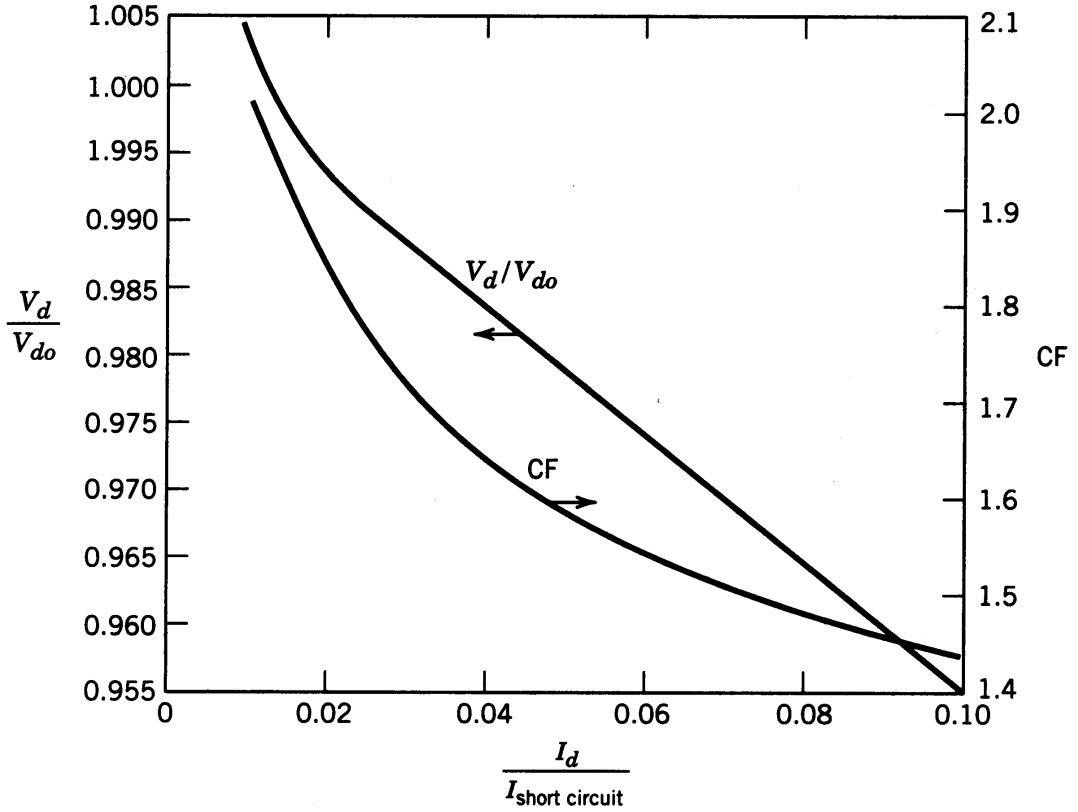


Figure 5-38 Normalized V_d and crest factor in the rectifier of Fig. 5-36 with a constant dc voltage.

- The Crest Factor is very high at low values of current

Three-Phase Rectifier Waveforms

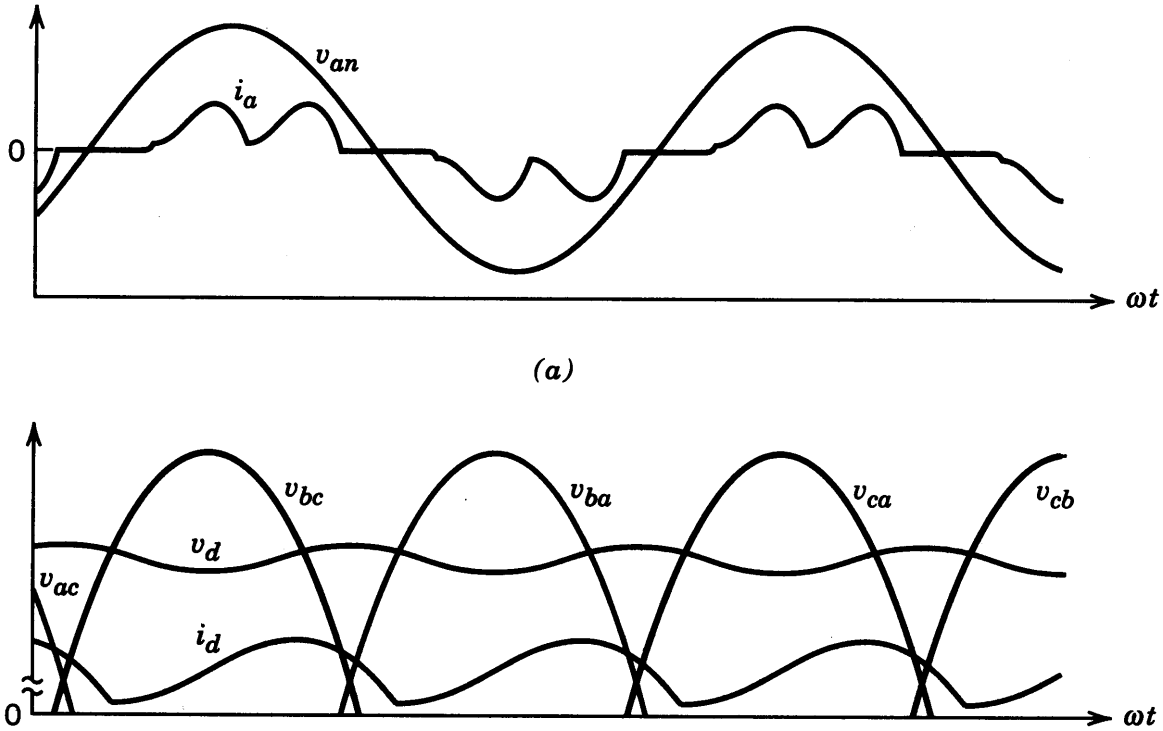


Figure 5-39 Waveforms in the rectifier of Fig. 5-30, obtained in Example 5-7.

- PSpice-based analysis