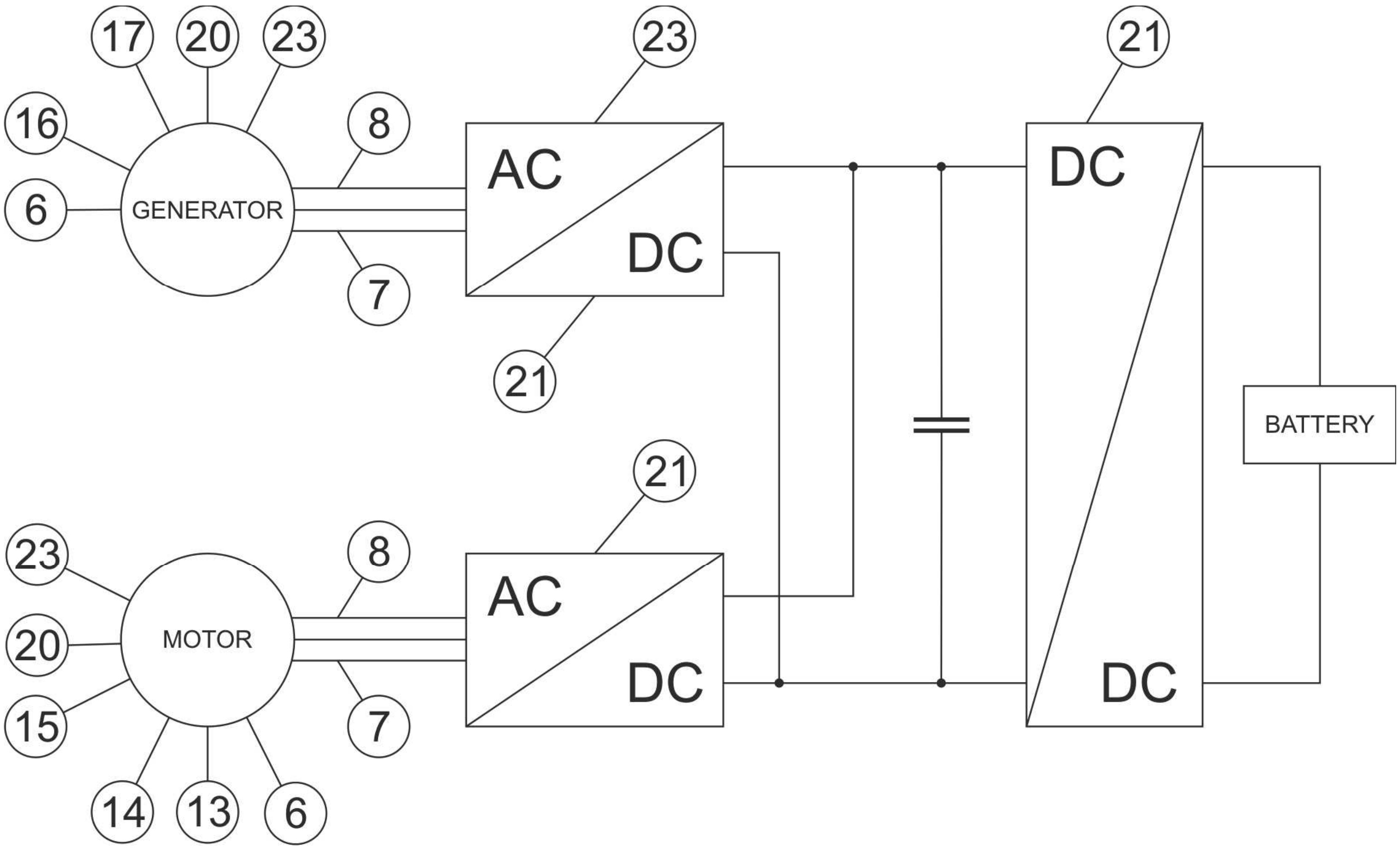
Elektrische Aandrijvingen

WTB

Lokatie/evenement

P.BAUER

Delft University of Technology


17
20
23
16
6
GENERATOR
8
7
AC
DC
23
21
21
DC
DC
BATTERY
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15
MOTOR
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13
6
8
7
AC
DC

Fundamental Elements of Power Electronics

Figure 21.1 **Potential level method of representing voltages.**

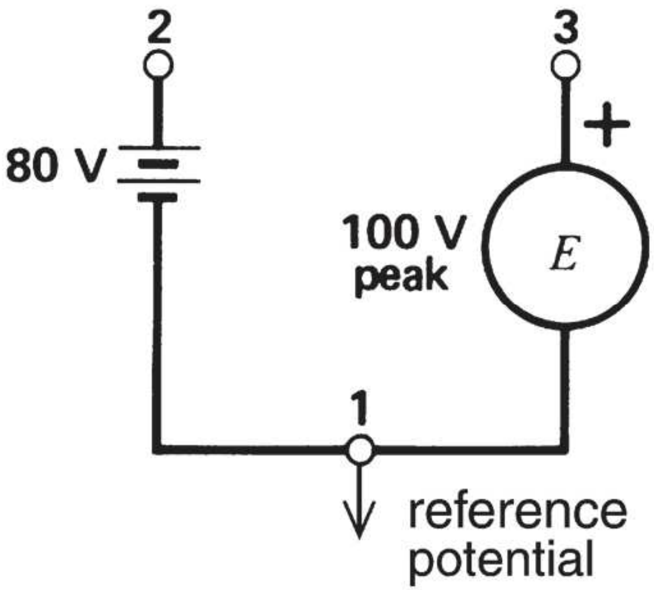


Figure 21.2 **Potential levels of terminals 1, 2, and 3.**

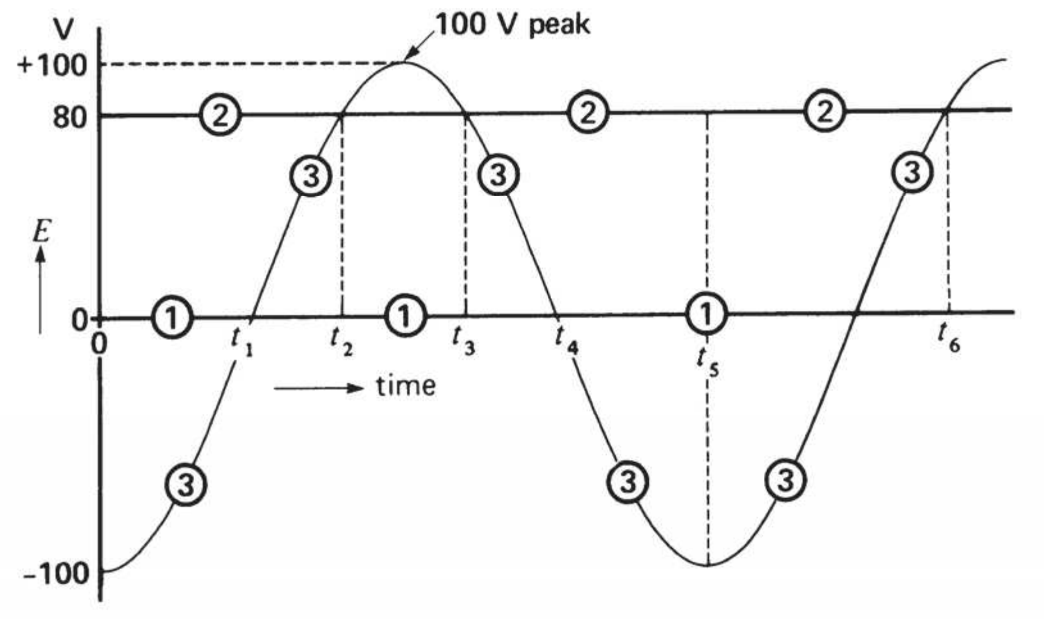


Figure 21.3 **Changing the reference terminal.**

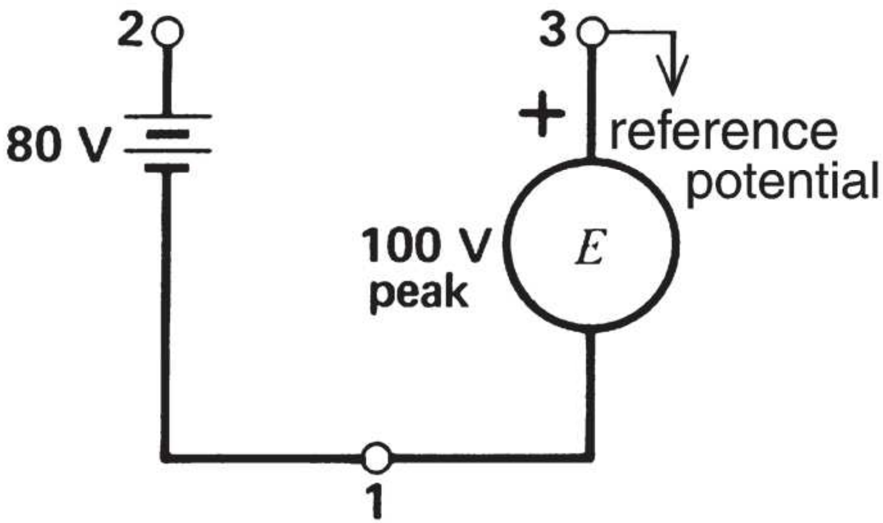
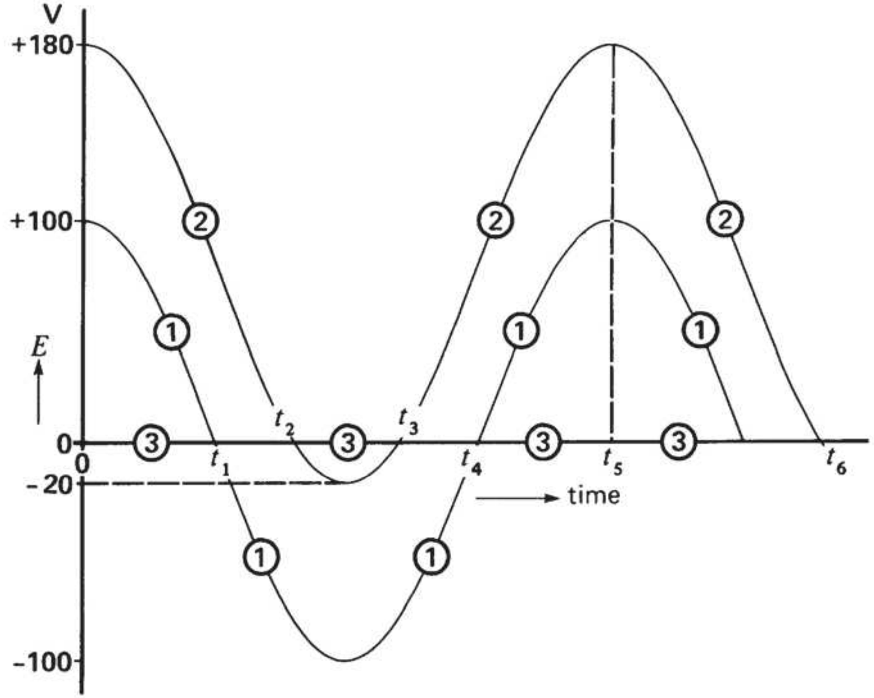


Figure 21.4 **The relative potential levels are the same as in Fig. 21.2.**



Voltage across some circuit elements

Figure 21.5 **Potential across a switch.**

Figure 21.6 **Potential across a resistor.**

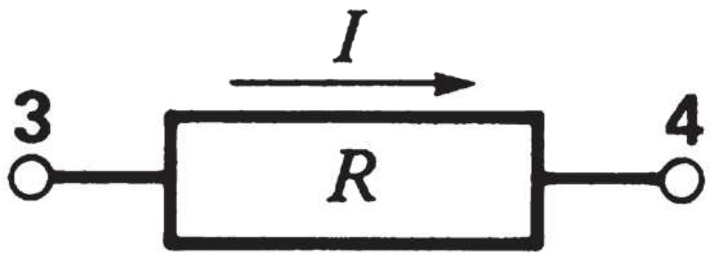


Figure 21.7 **Potential across an inductor.**

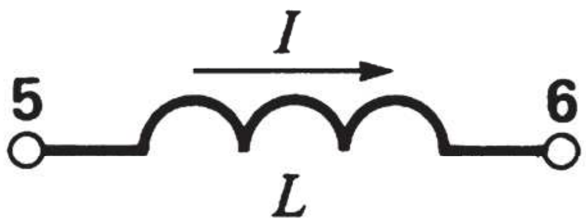
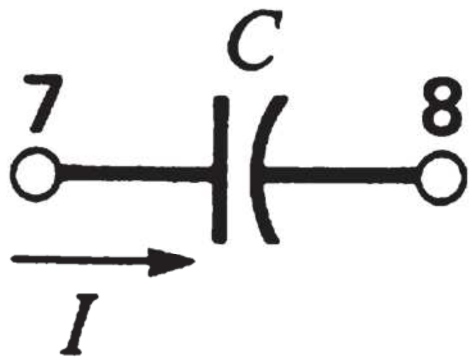


Figure 21.8 **Potential across a capacitor.**



Diode

Figure 21.9 **Basic rules governing diode behavior.**

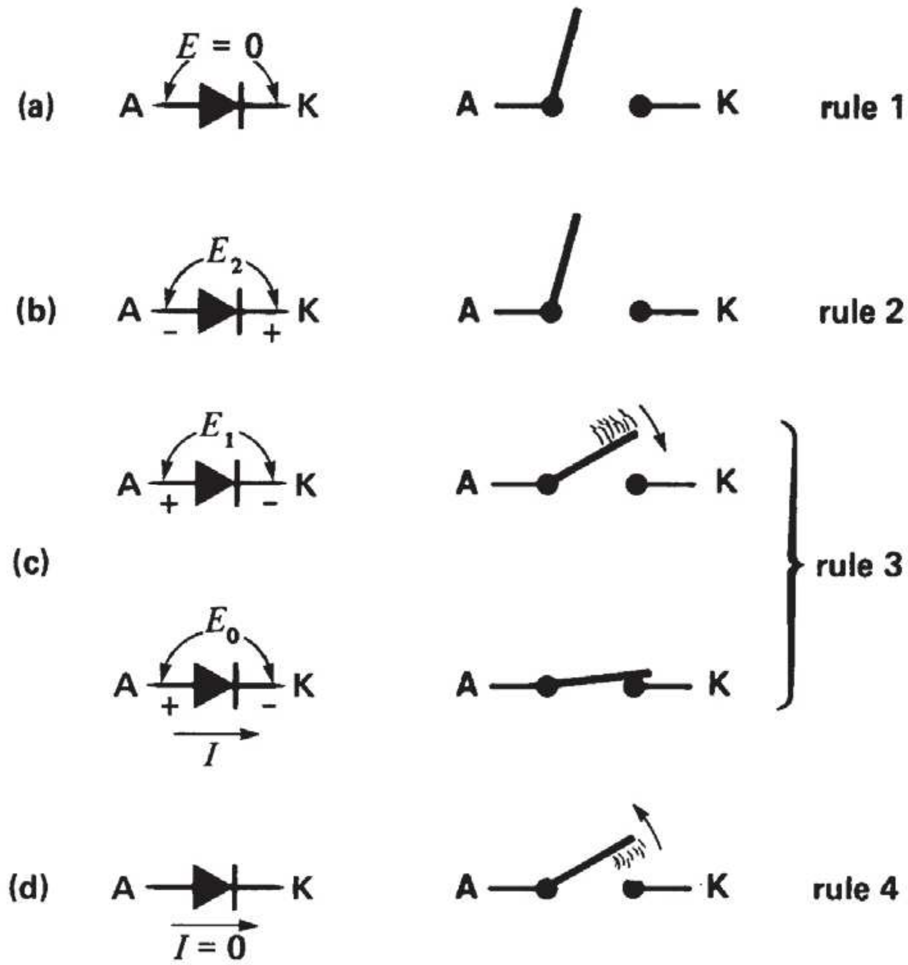


Figure 21.10 (continued) **a. Average current: 4 A; PIV: 400 V; body length: 10 mm; diameter: 5.6 mm. b. Average current: 15 A; PIV: 500 V; stud type; length less thread: 25 mm; diameter: 17 mm. c. Average current: 500 A; PIV: 2000 V; length less thread: 244 mm; diameter: 40 mm. d. Average current: 2600 A; PIV: 2500 V; Hockey Puk; distance between pole-faces: 35 mm; diameter: 98 mm.** ***(Photos courtesy of International Rectifier)***

Figure 21.10 **a. Average current: 4 A; PIV: 400 V; body length: 10 mm; diameter: 5.6 mm. b. Average current: 15 A; PIV: 500 V; stud type; length less thread: 25 mm; diameter: 17 mm. c. Average current: 500 A; PIV: 2000 V; length less thread: 244 mm; diameter: 40 mm. d. Average current: 2600 A; PIV: 2500 V; Hockey Puk; distance between pole-faces: 35 mm; diameter: 98 mm.** ***(Photos courtesy of International Rectifier)***

Figure 21.10 (continued) **a. Average current: 4 A; PIV: 400 V; body length: 10 mm; diameter: 5.6 mm. b. Average current: 15 A; PIV: 500 V; stu type; length less thread: 25 mm; diameter: 17 mm. c. Average current: 500 A; PIV: 2000 V; length less thread: 244 mm; diameter: 40 mm. d. Average current: 2600 A; PIV: 2500 V; Hockey Puk; distance between pole-faces: 35 mm; diameter: 98 mm.** ***(Photos courtesy of Internationa Rectifier)***

Figure 21.10 (continued) **a. Average current: 4 A; PIV: 400 V; body length: 10 mm; diameter: 5.6 mm. b. Average current: 15 A; PIV: 500 V; stud type; length less thread: 25 mm; diameter: 17 mm. c. Average current: 500 A; PIV: 2000 V; lengt h less thread: 244 mm; diameter: 40 mm. d. Average current: 2600 A; PIV: 2500 V; Hockey Puk; distance between pole-faces: 35 mm; diameter: 98 mm.** ***(Photos courtesy of International Rectifier)***

Battery charger with resistor

Figure 21.11 **a. Simple battery charger circuit. b. Corresponding voltage and current waveforms.**

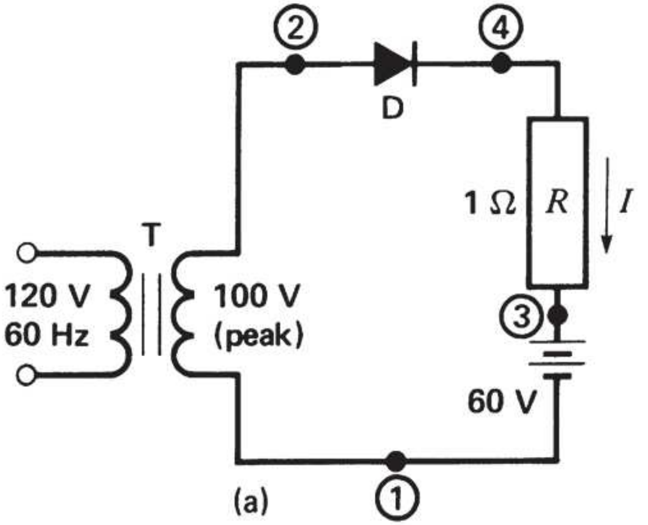
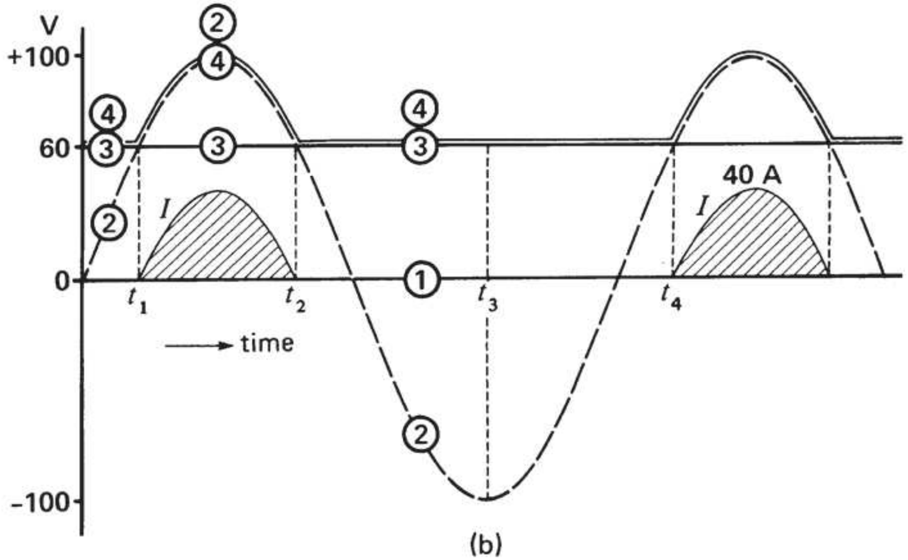


Figure 21.11 (continued) **a. Simple battery charger circuit. b. Corresponding voltage and current waveforms.**



Battery charger with inductor

Figure 21.12 **a. Battery charger using a series inductor. b. Corresponding voltage and current waveforms.**

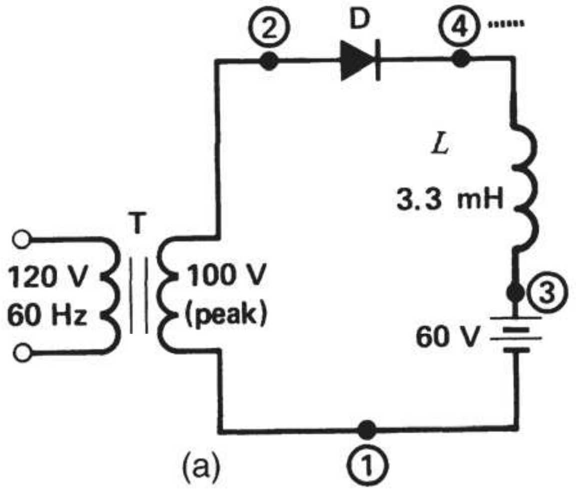
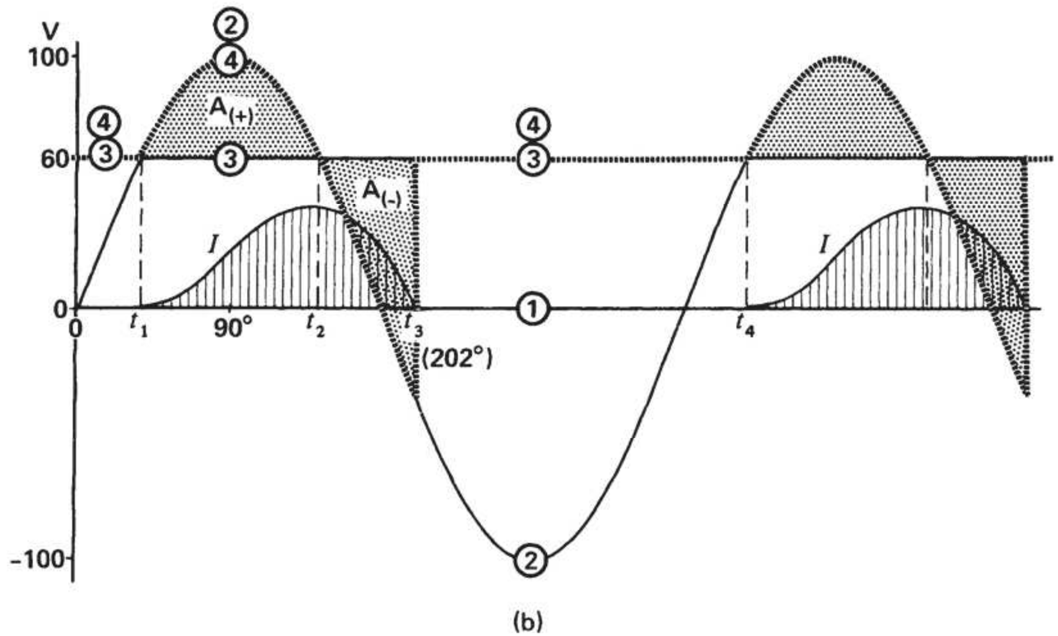
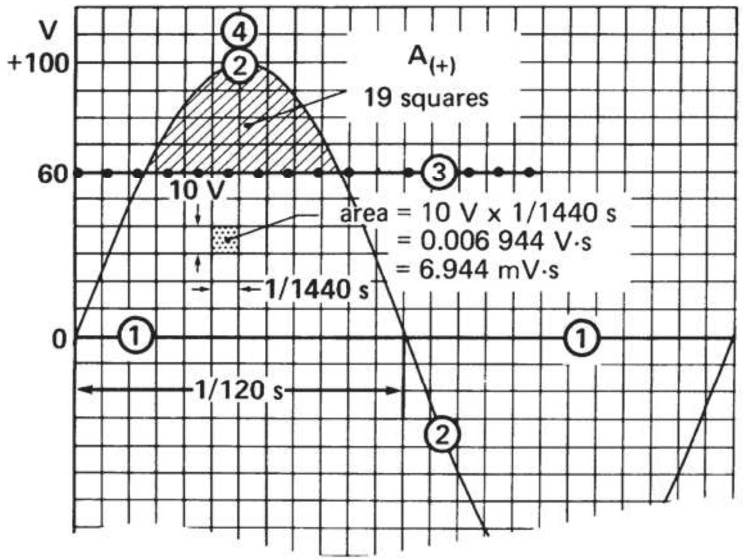


Figure 21.12 (continued) **a. Battery charger using a series inductor. B Corresponding voltage and current waveforms.**



Example 21.1

Figure 21.12c **See Example 21-1.**



Single bridge diode rectifier

Figure 21.13a **a. Single-phase bridge rectifier. b. Voltage levels.**

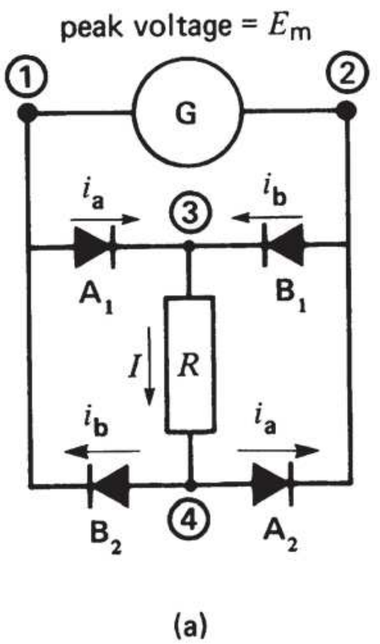


Figure 21.13b **a. Single-phase bridge rectifier. b. Voltage levels.**

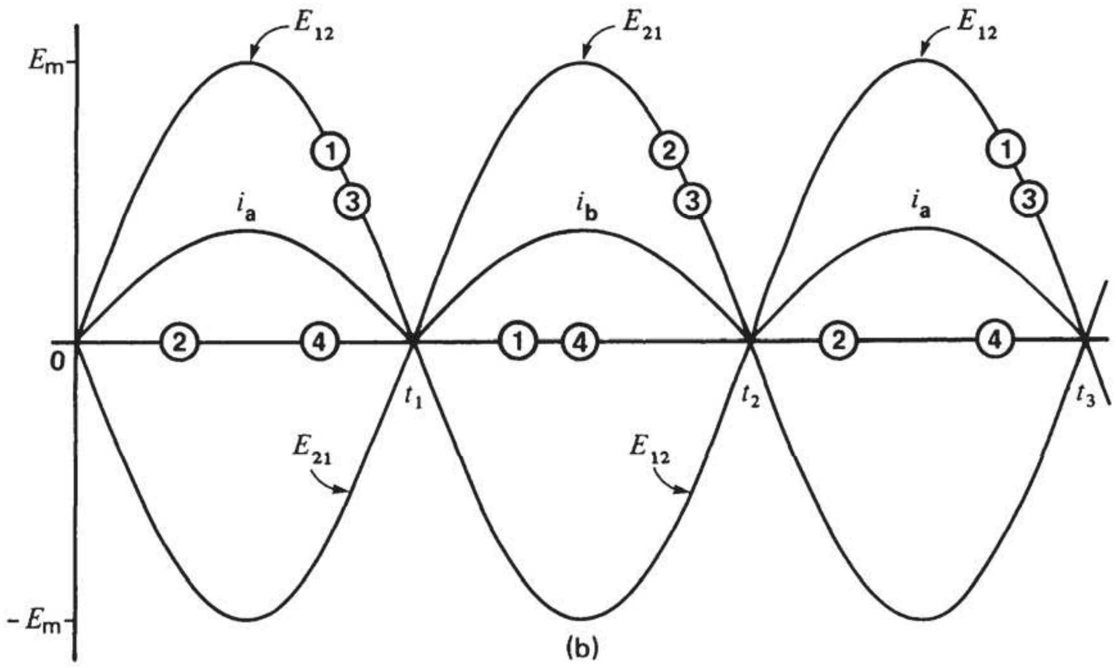


Figure 21.13c **Voltage and current waveforms in load *R*.**

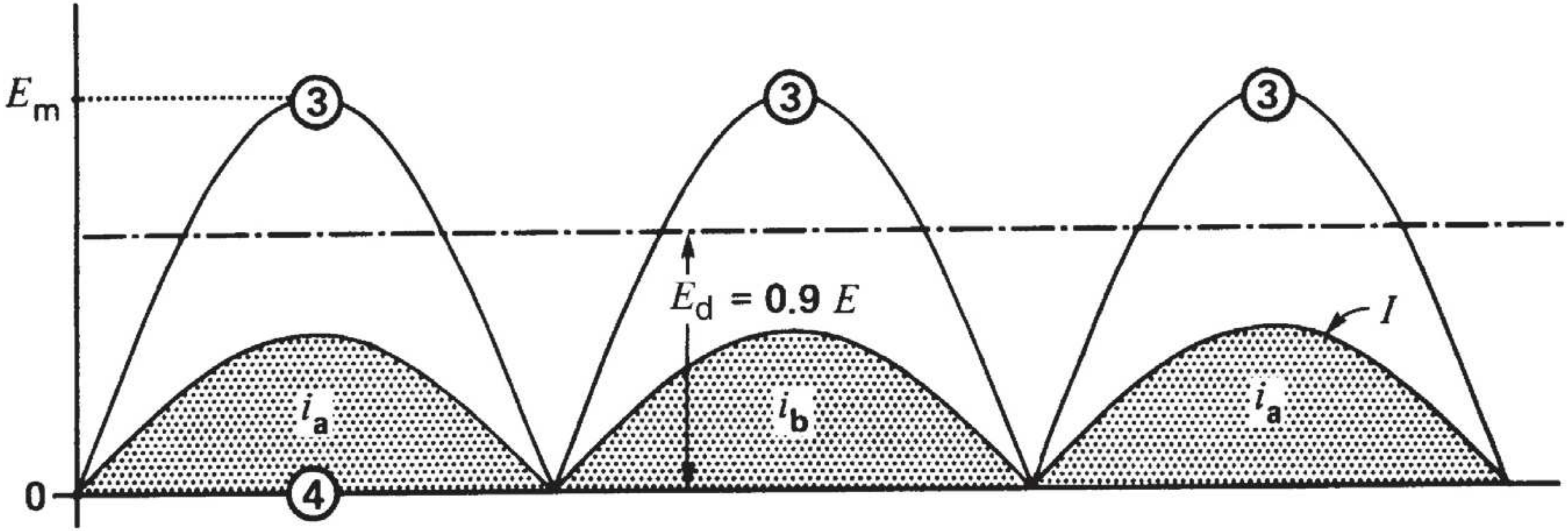


Figure 21.14 **a. Rectifier with inductive filter. b. Rectifier with capacitive filter.**

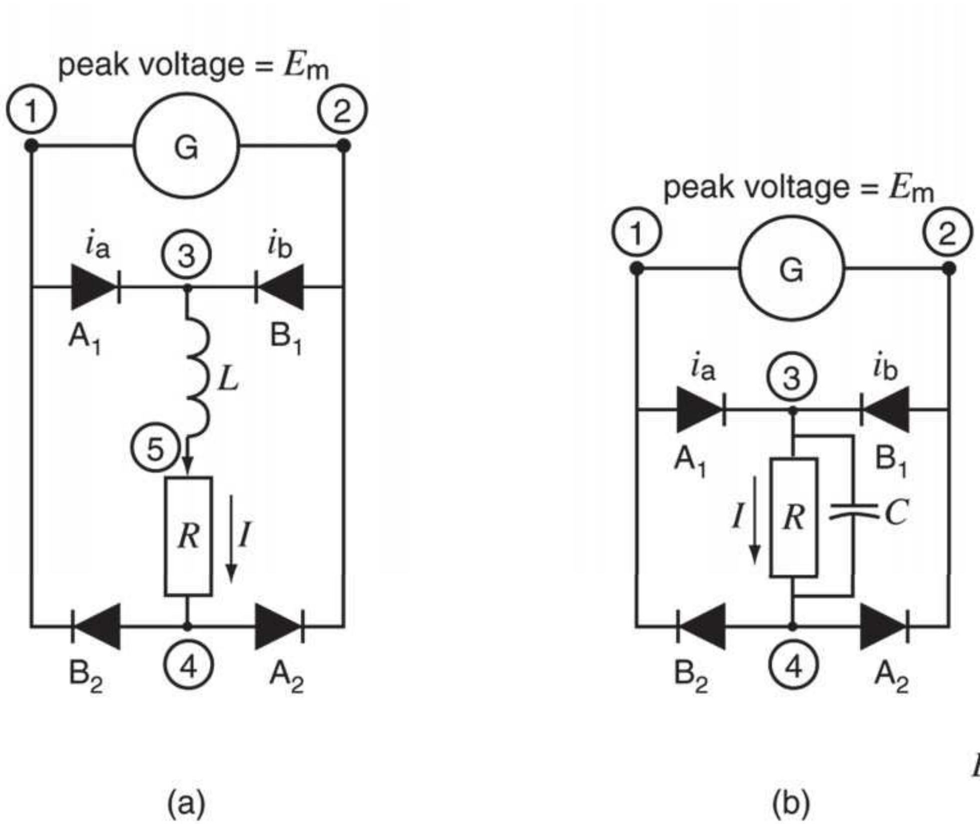


Figure 21.15 **Current and voltage waveforms with inductive filter.**

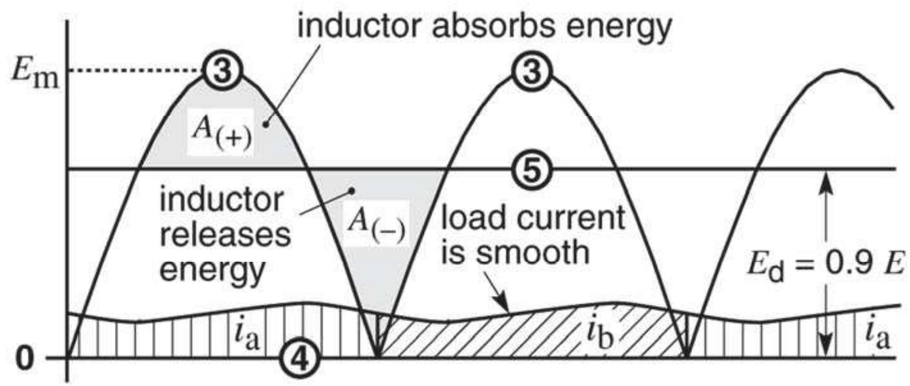
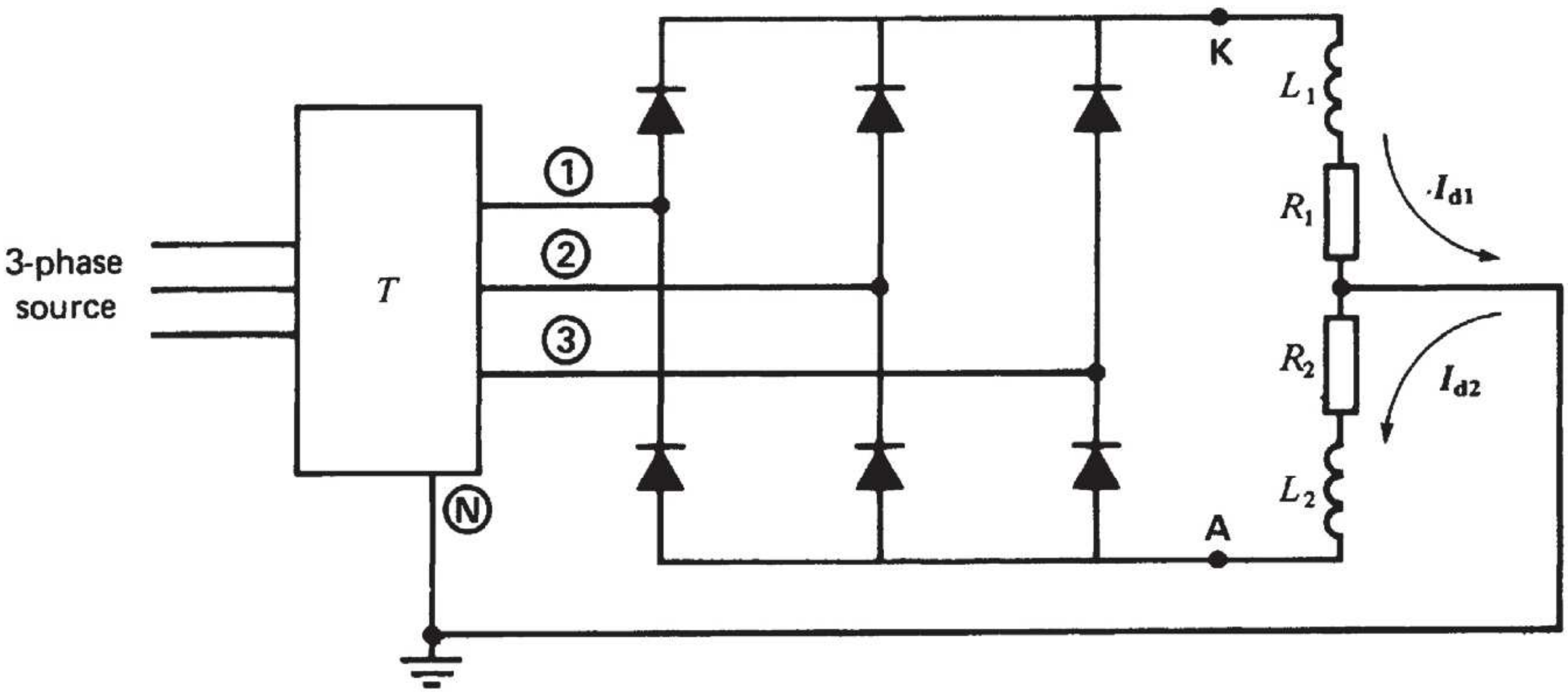


Figure 21.18 **Dual 3-phase, 3-pulse rectifier.**



Three-phase 6 pulse rectifier

Figure 21.20 **Voltage and current waveforms in Fig. 21.19.**

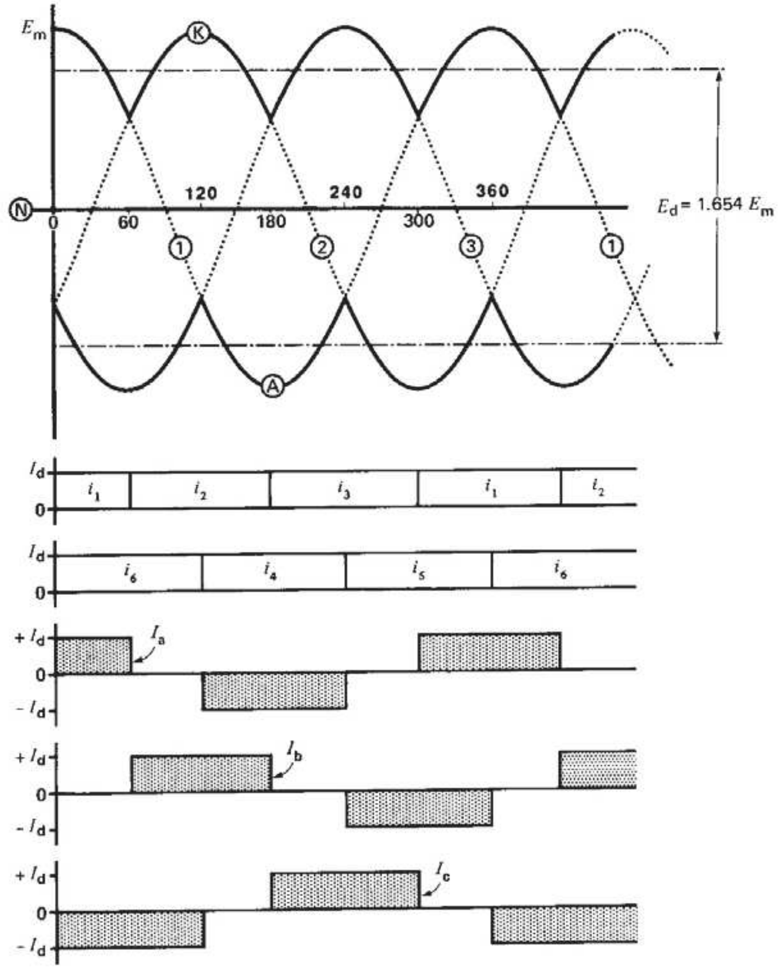


Figure 21.19 **Three-phase, 6-pulse rectifier with inductive filter.**

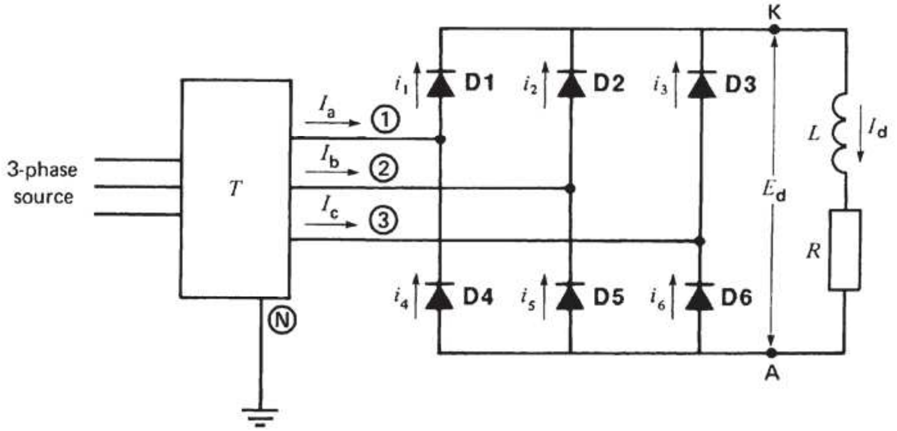


Figure 21.21 **Another way of showing EKA using line voltage potentials. Note also the position of E2N with respect to the line voltages.**

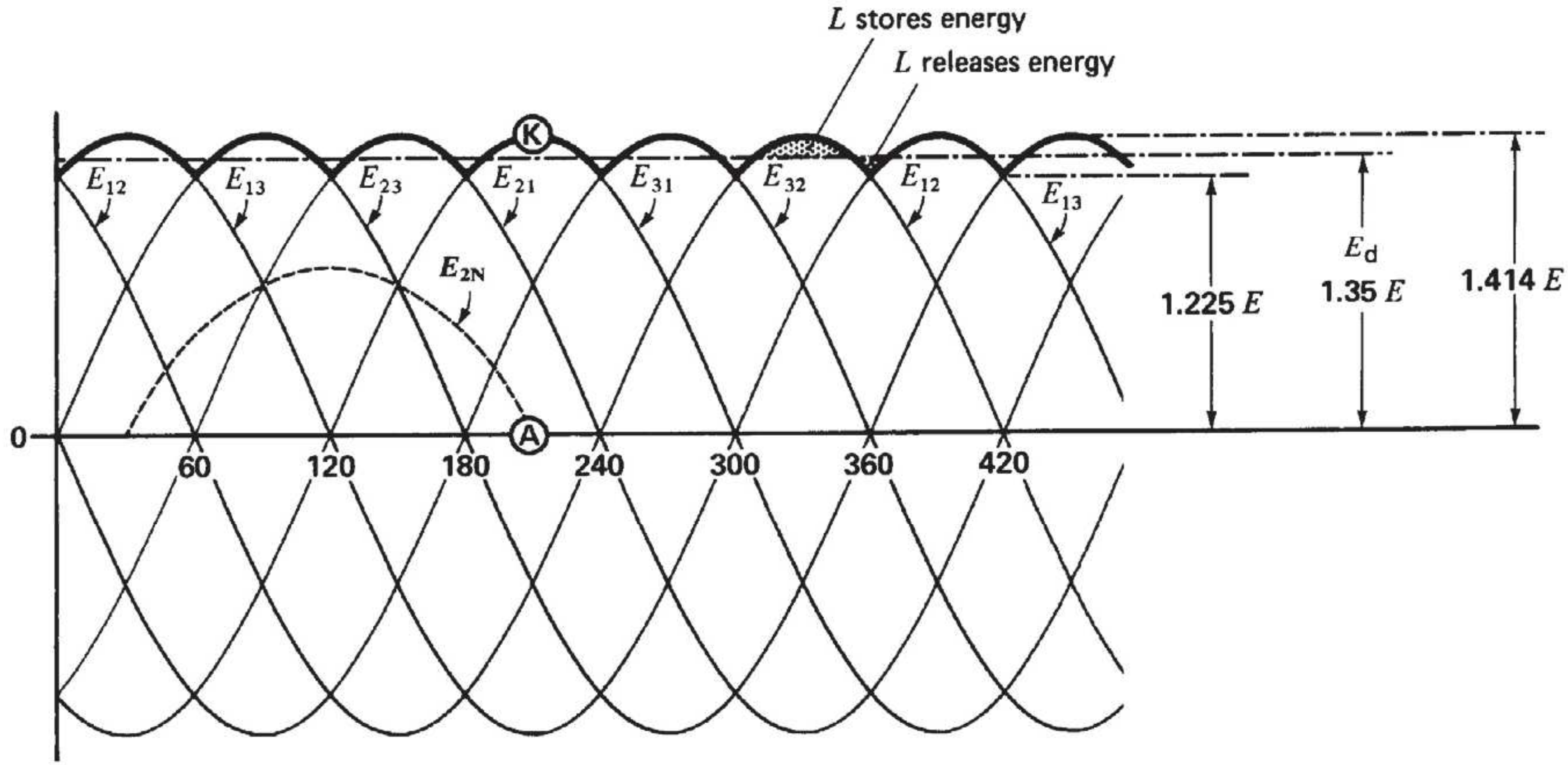
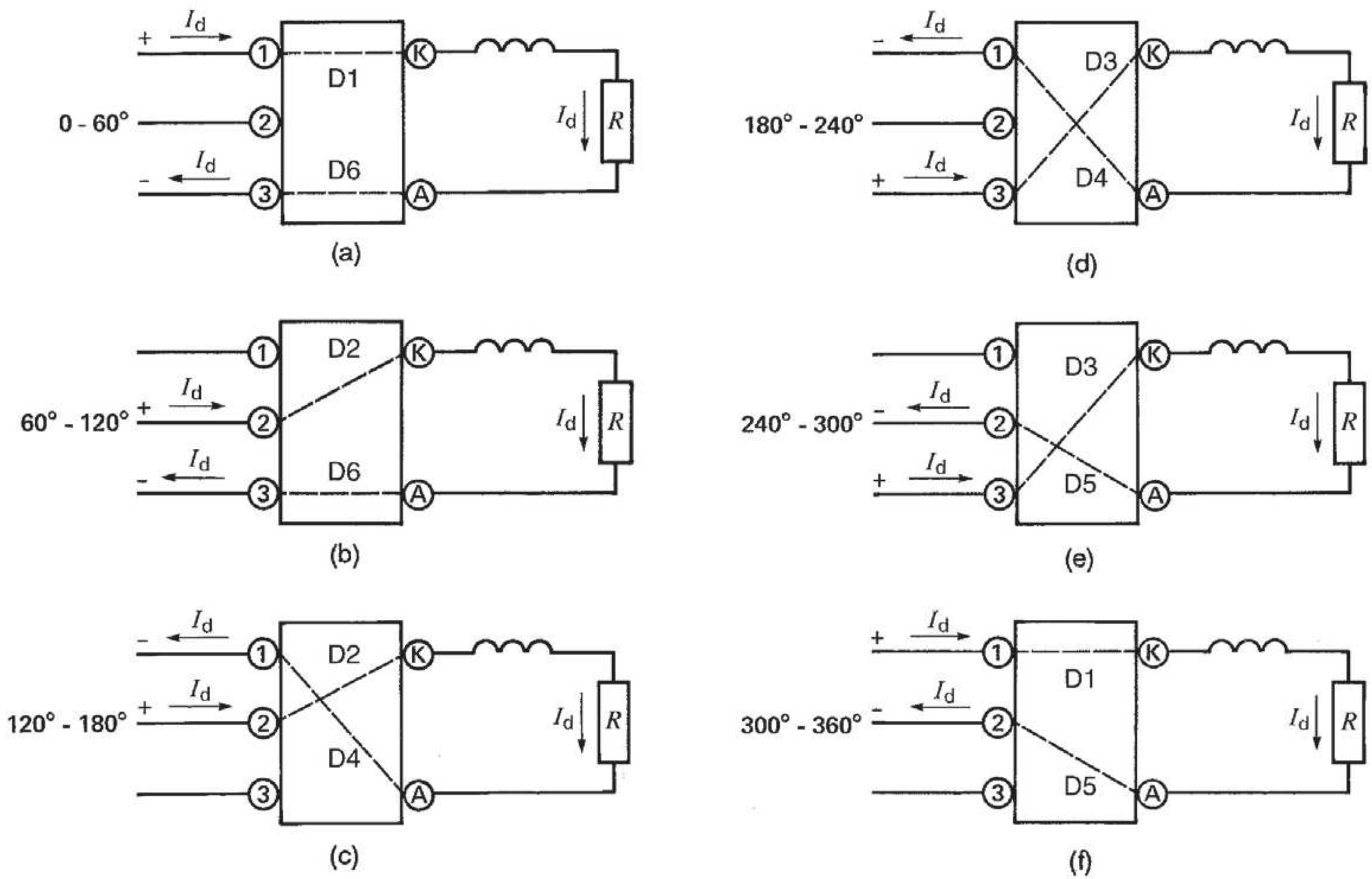
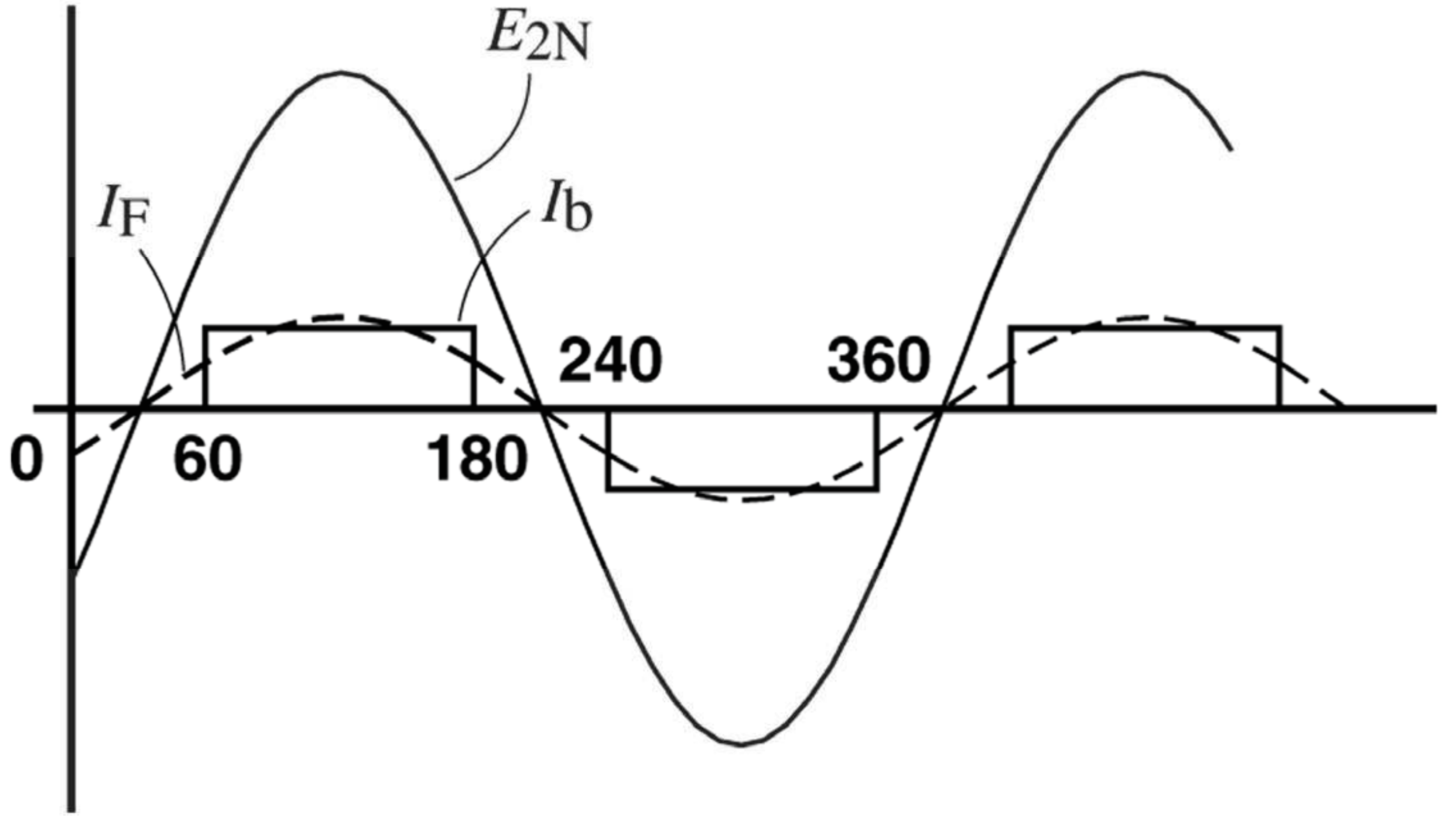


Figure 21.22 **Successive diode connections between the 3-phase input and dc output terminals of a 3-phase, 6-pulse rectifier.**



Effective, fundamental line current

Figure 21.23 **Line-to-neutral voltage and line current in phase 2 of Fig. 21.20.**



The thyristor

Figure 21.24 **Symbol of a thyristor, or SCR.**

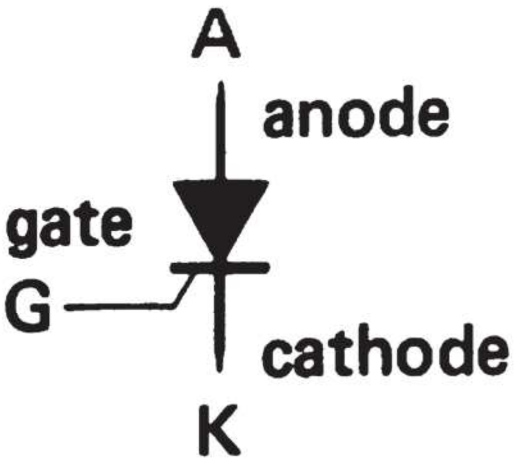


Figure 21.25 **a. A thyristor does not conduct when the gate is connected to the cathode. b. A thyristor conducts when the anode is positive and a current pulse is injected into the gate.**

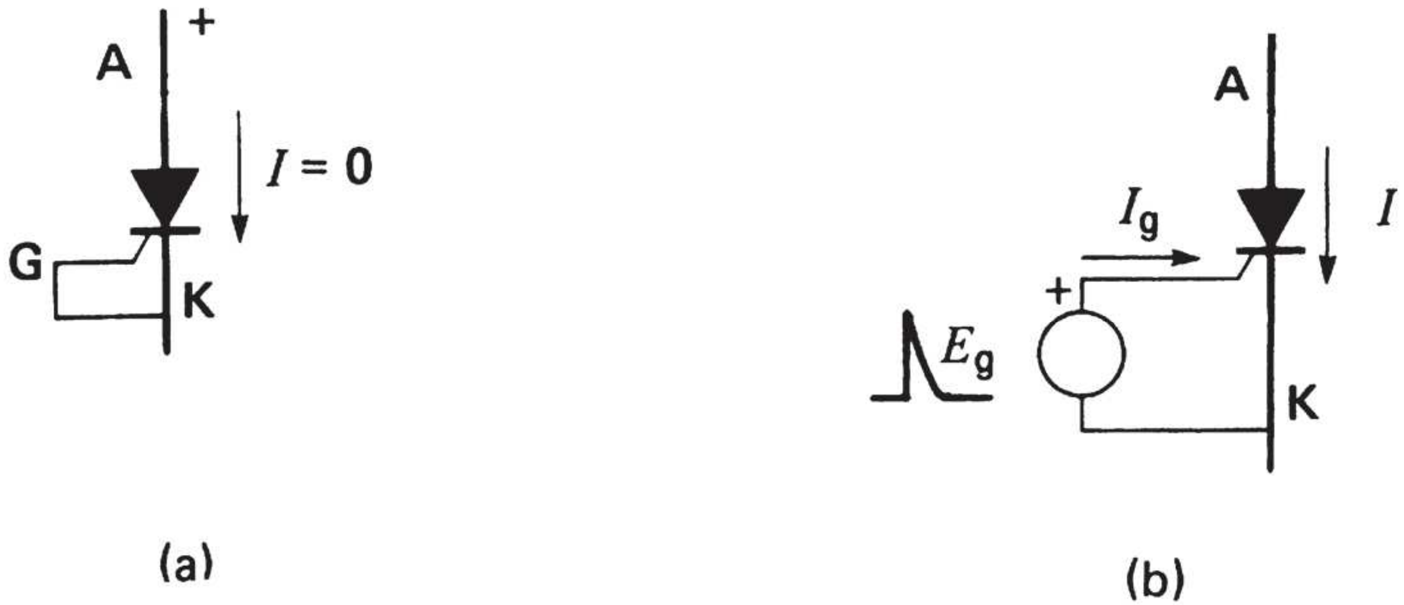


Figure 21.26 **Range of SCRs from medium to very high power capacity.**

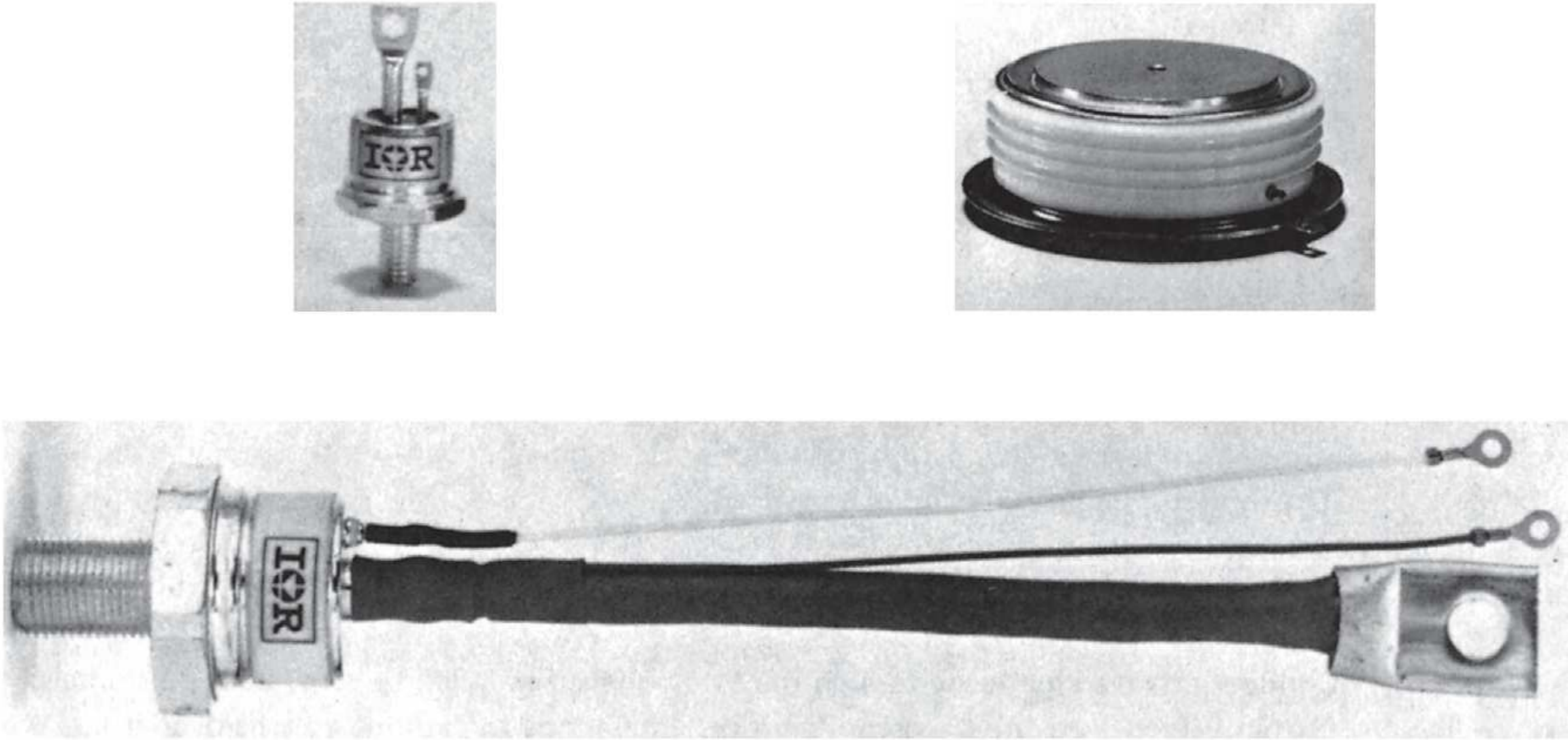


Figure 21.27 **a. Thyristor and resistor connected to an ac source. B . Thyristor behavior depends on the timing of the gate pulses.**

Figure 21.27 (continued) **a. Thyristor and resistor connected to an ac source . b. Thyristor behavior depends on the timing of the gate pulses.**

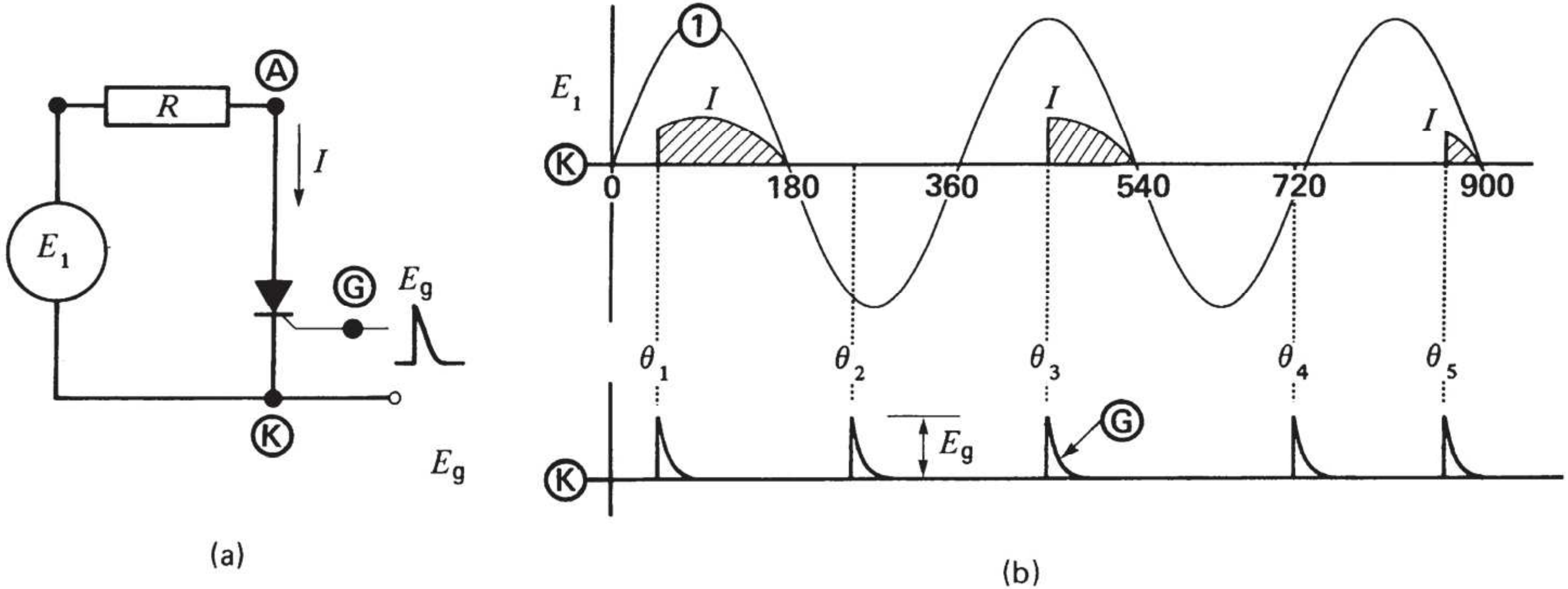


Figure 21.28 **a. Thyristor connected to a dc source. b. Forced commutation.**

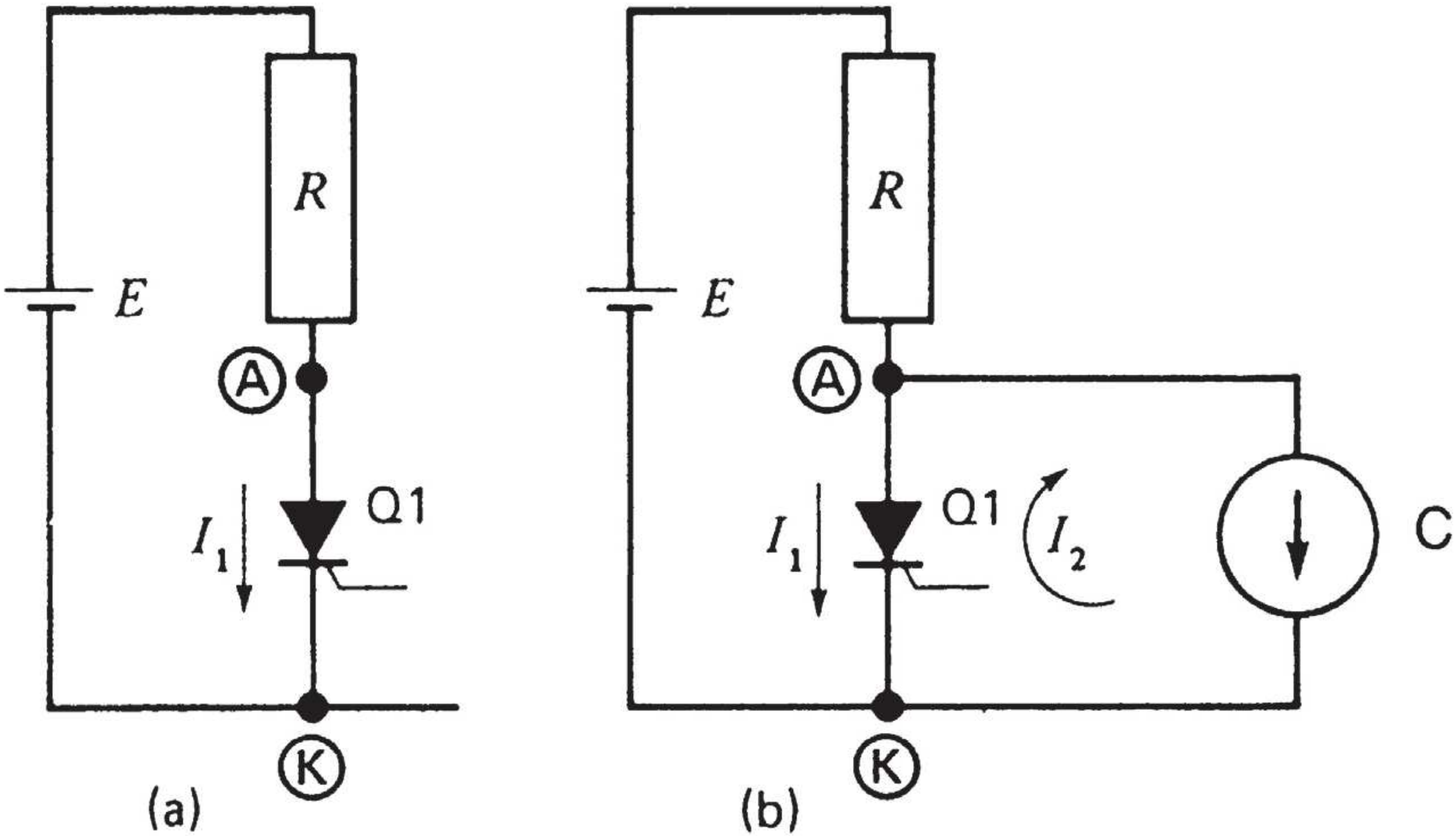


Figure 21.29 **A discharging capacitor C and an auxiliary thyristor Q2 can force-commutate the main thyristor Q1. Thus, the current in load *R* can be switched on and off by triggering Q1 and Q2 in succession.**

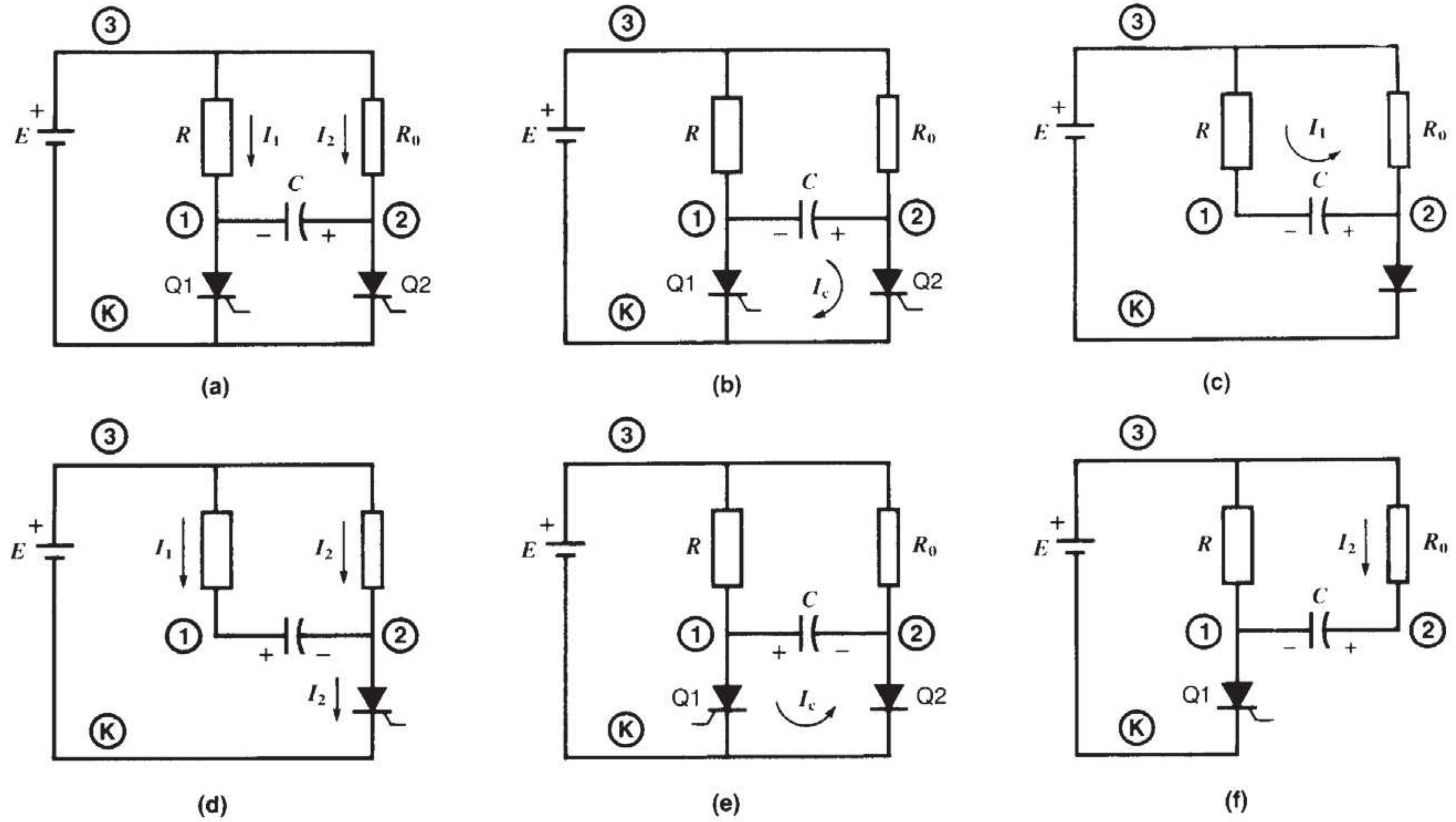


Figure 21.30 **a. SCR supplying a passive load. b. Voltage and current waveforms.**

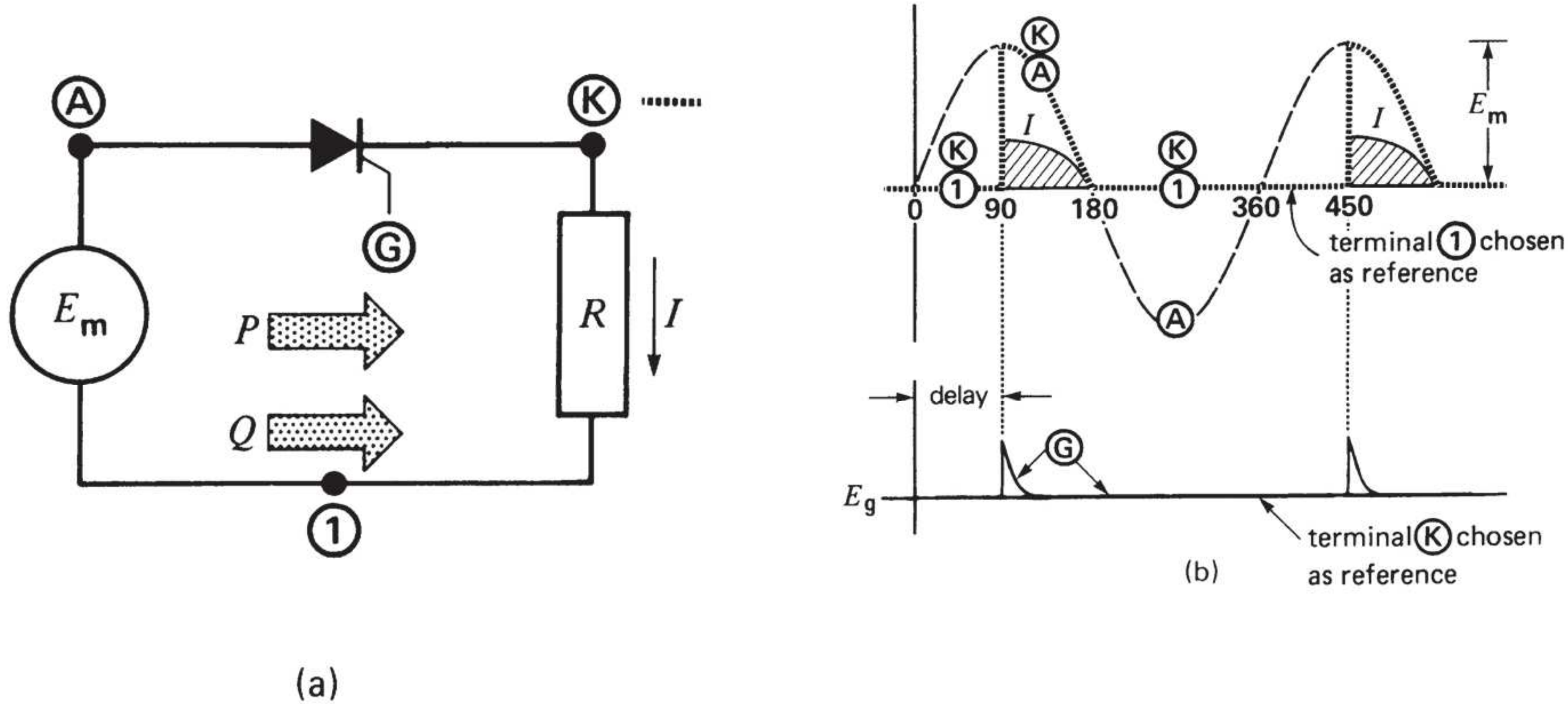
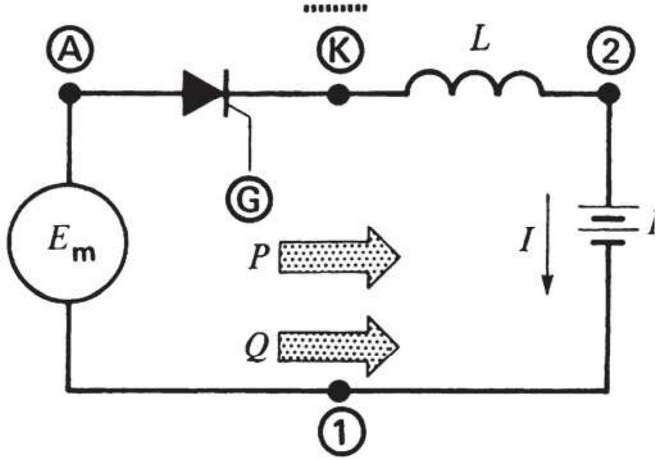
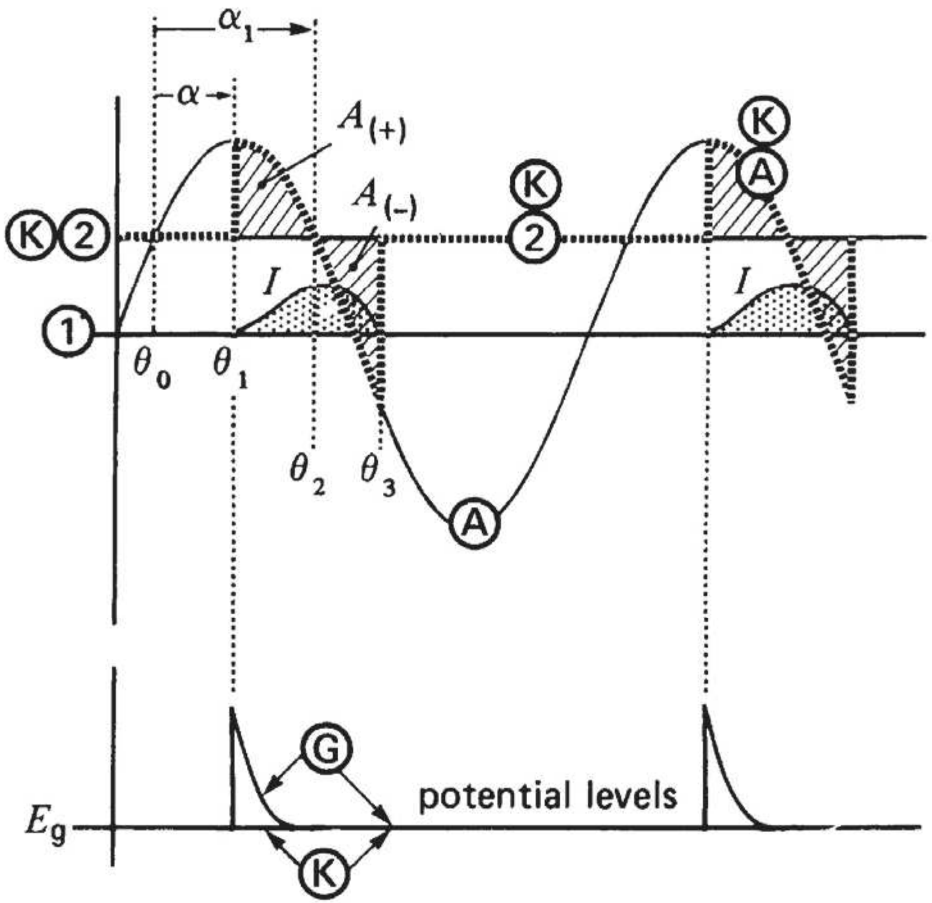


Figure 21.31 **a. SCR supplying an active load. b. Voltage and current waveforms.**

(a)



(b)



Line commutated inverter

Figure 21.32 **a. Line-commutated inverter. b. Voltage and current waveforms**

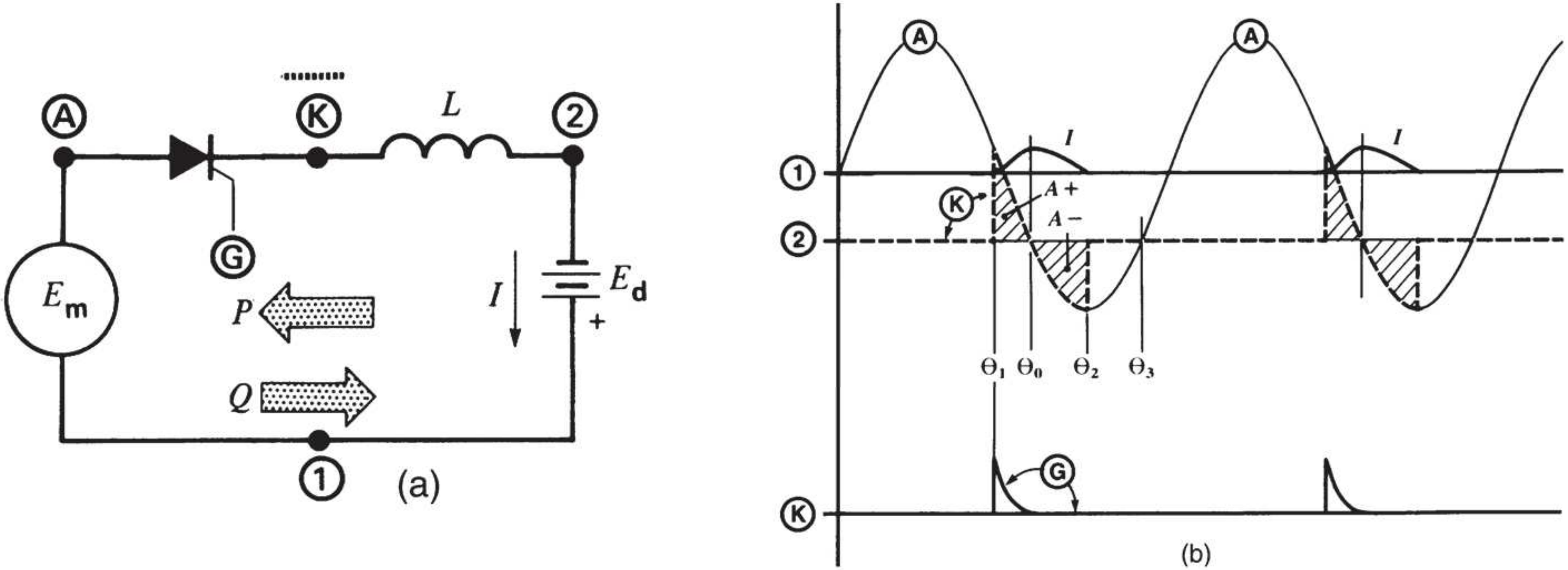
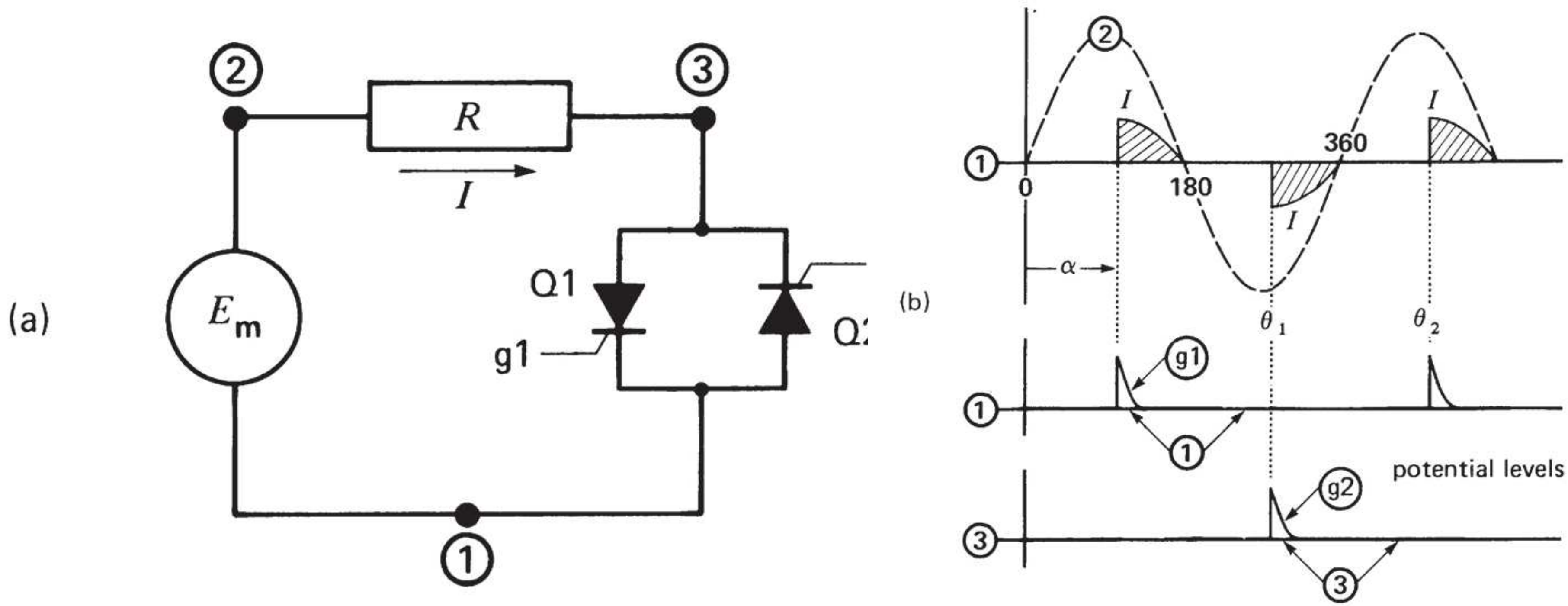


Figure 21.33 **a. Electronic contactor. b. Waveforms with a resistive load.**



Cycloconverter

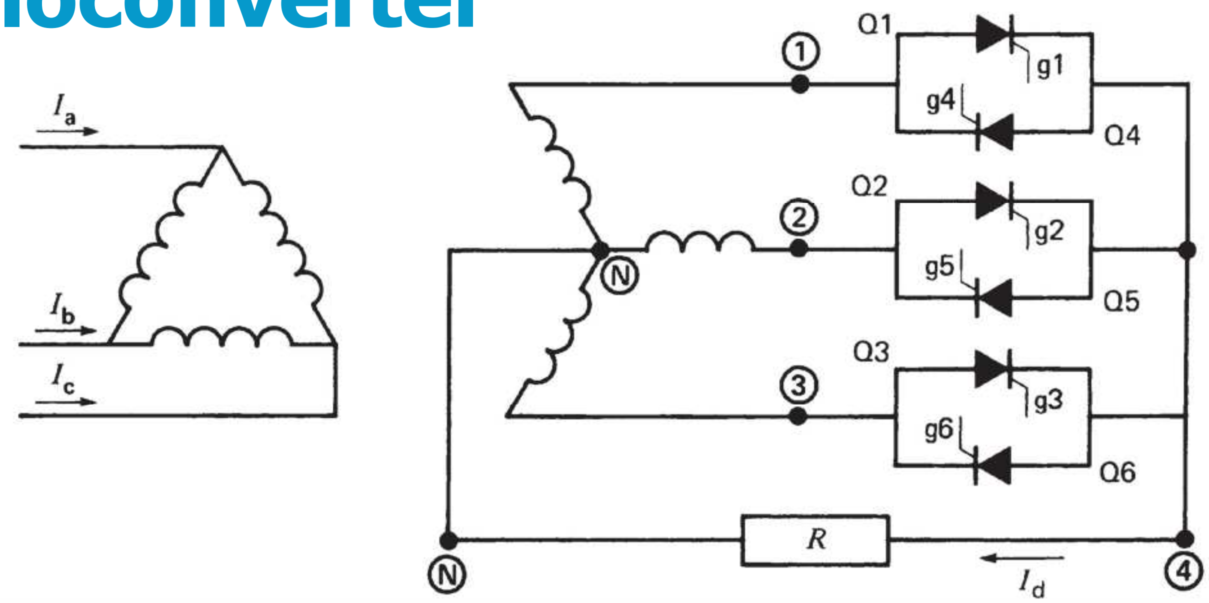


Figure 21.34 **Elementary cycloconverter.**

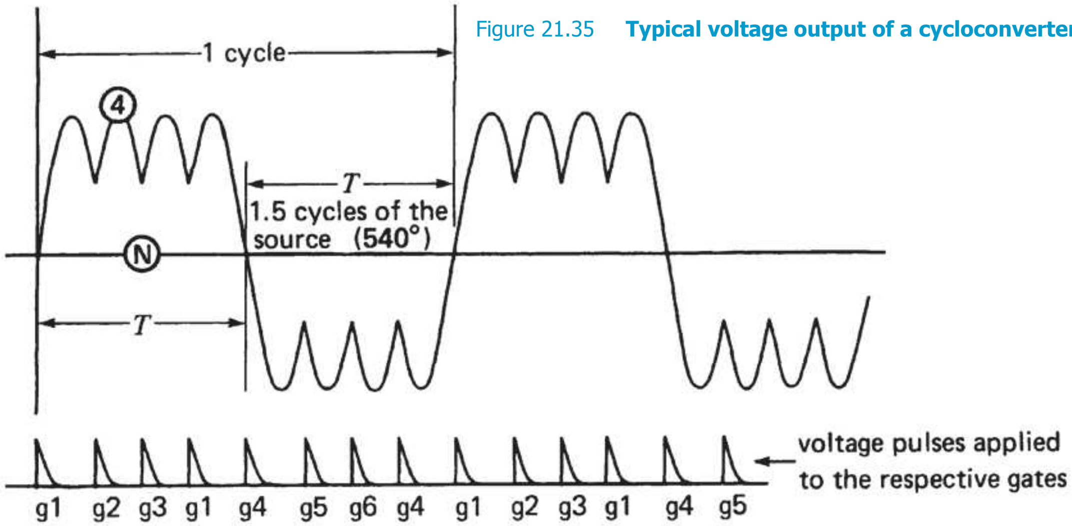
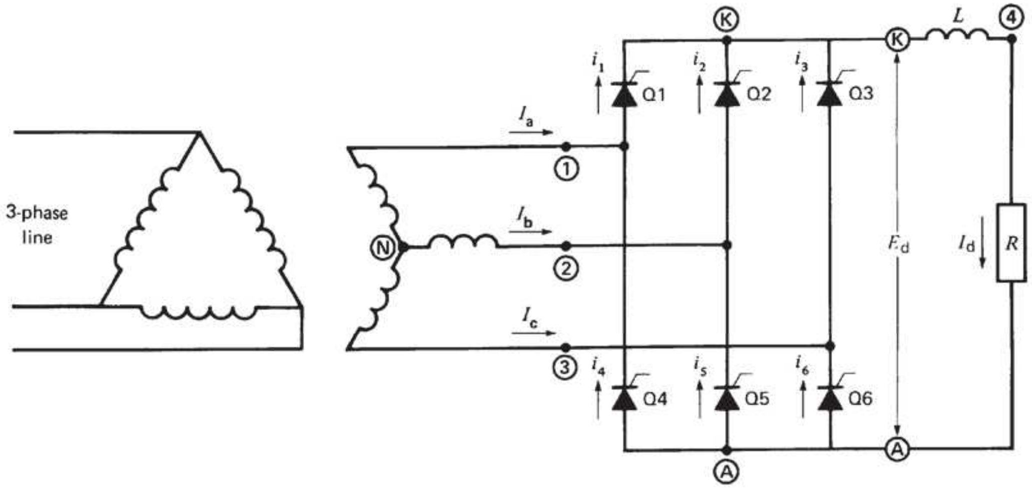


Figure 21.35 **Typical voltage output of a cycloconverter.**

3 phase 6 pulse contr. converter

Figure 21.36 **Three-phase, 6-pulse thyristor converter.**



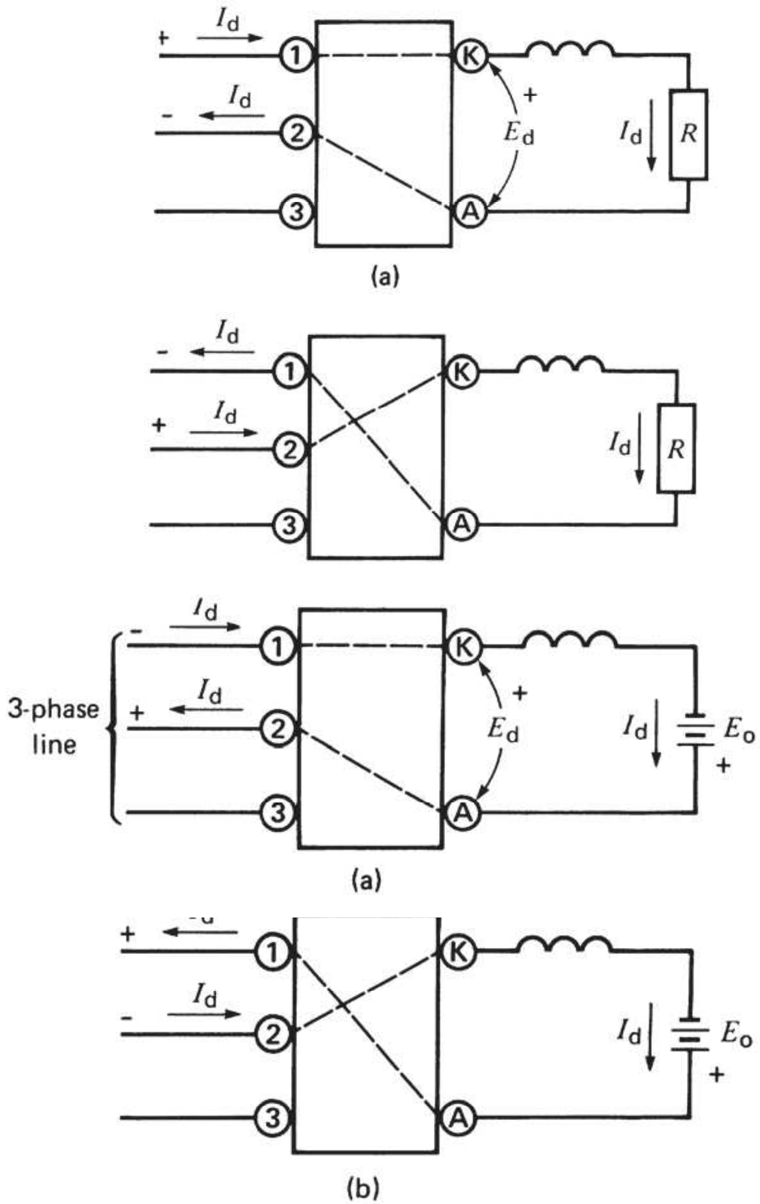


Figure 21.40a **Delay angle: zero.**

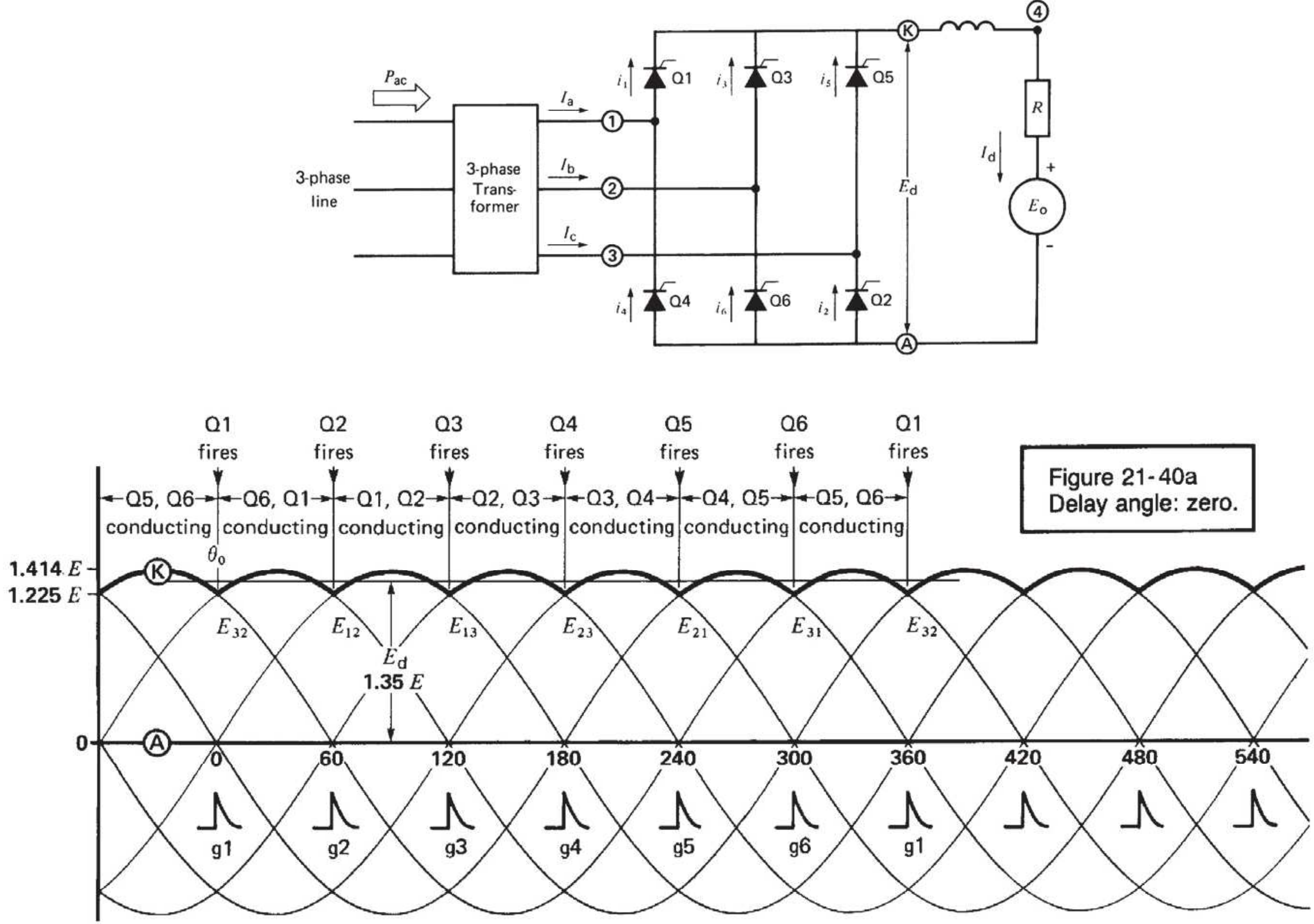


Figure 21.40b **Delay angle: 15°.**

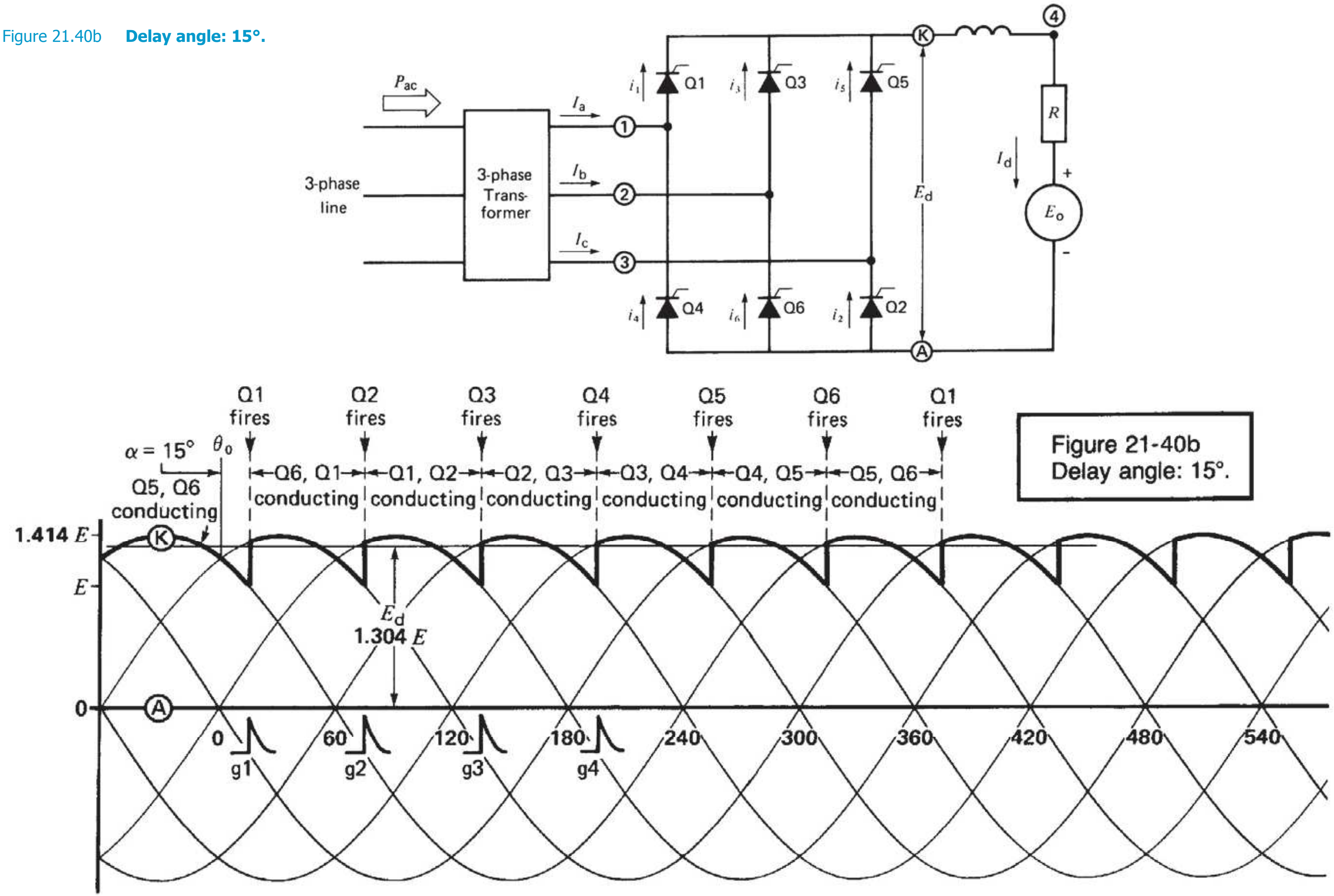


Figure 21-40b
Delay angle: 15°.

Figure 21.40c **Delay angle: 45°.**

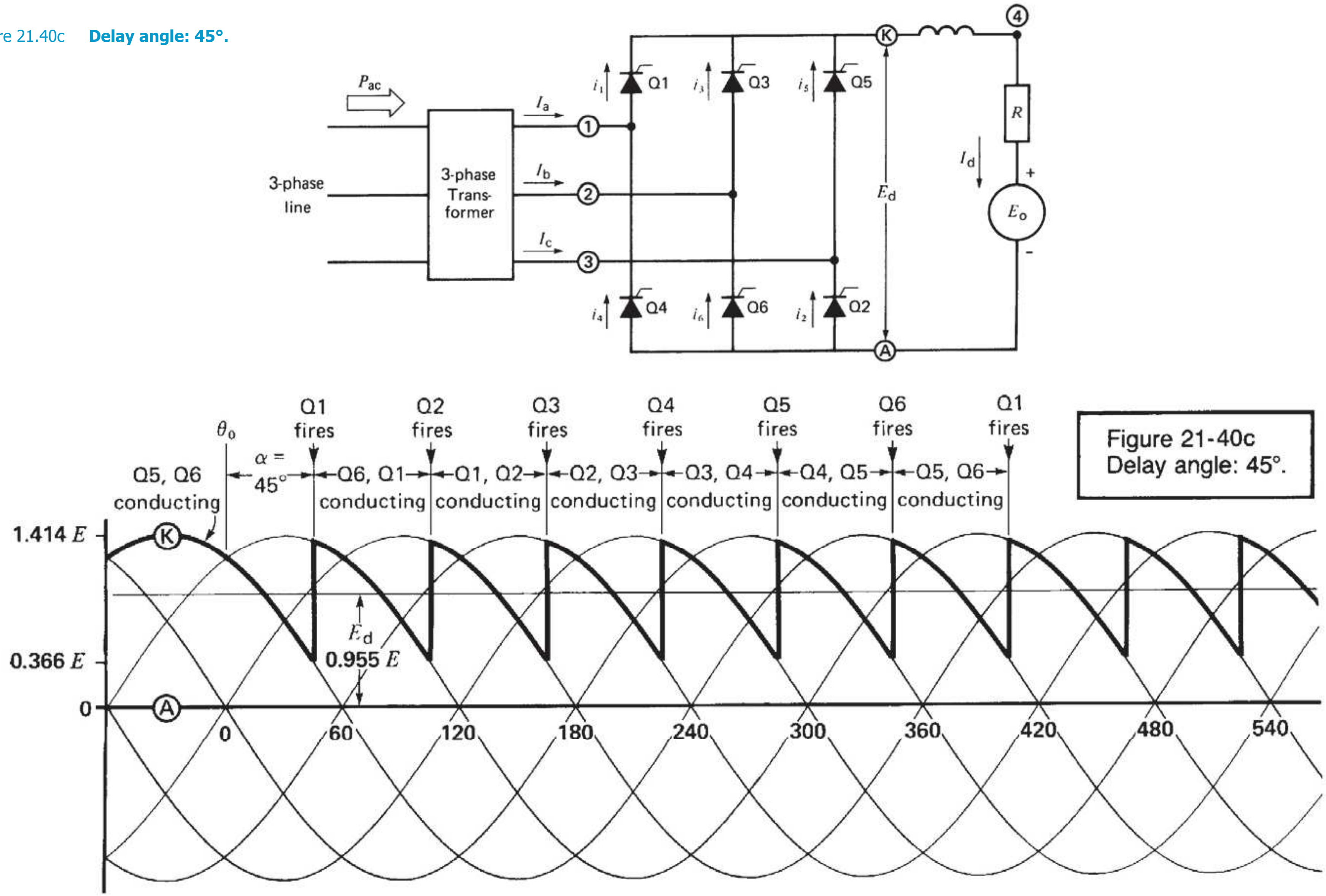
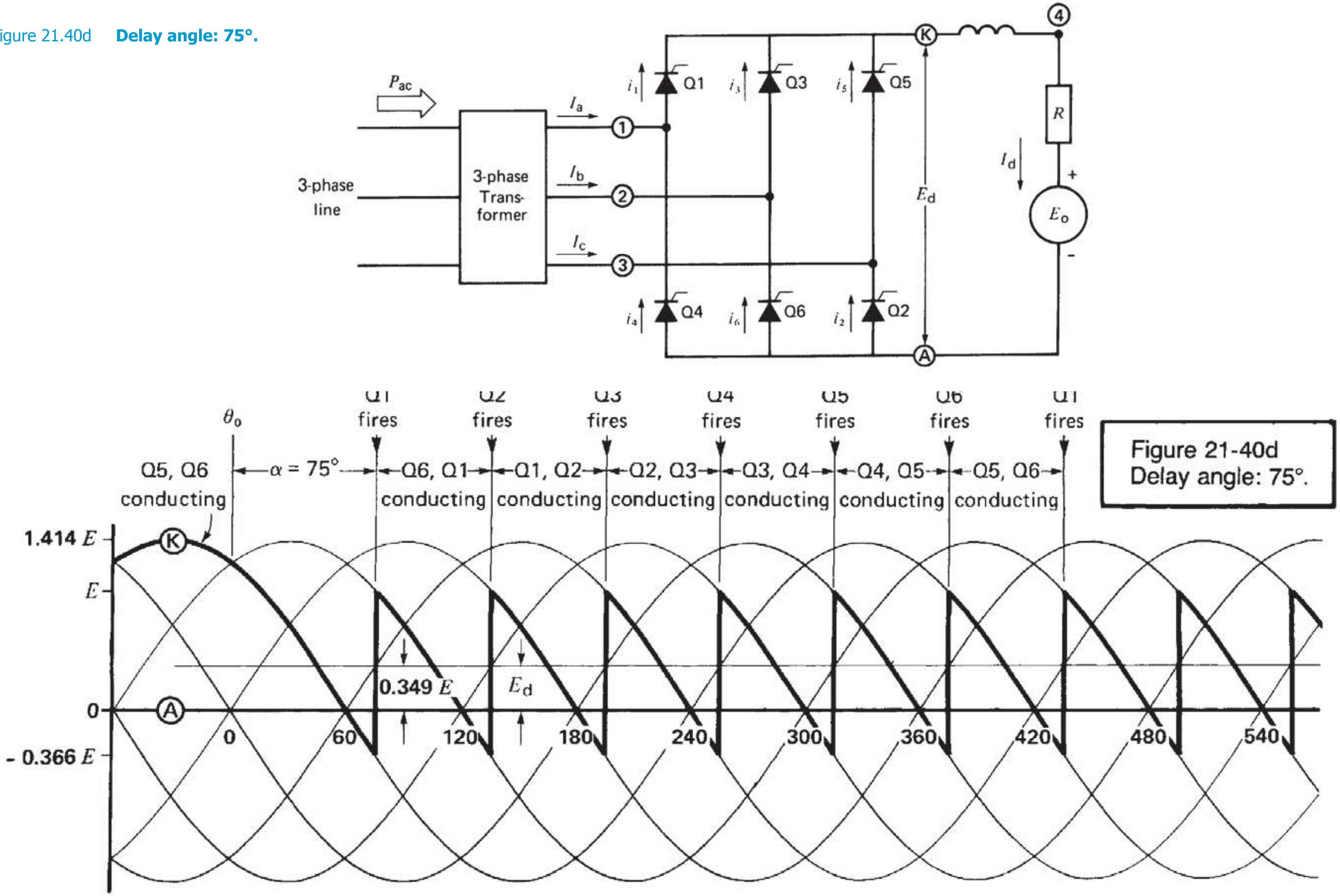
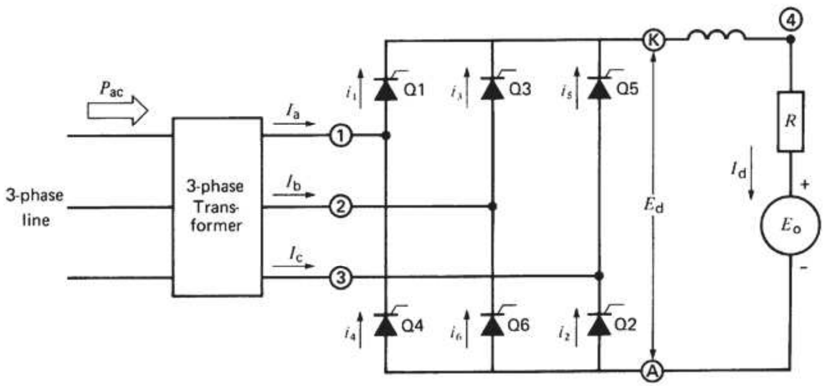


Figure 21.40d **Delay angle: 75°.**



Example 21.17

- The 3 phase converter is connected to 3 phase 480 V 60 Hz source, Load 500 V dc resistance 2 ohm. Calculate the power supplied to the load for delays of 15 and 75.



- $E_d = 1{,}35\ E \cos ά$

voltage drop on R

- $E = E_d - E_o$
- $I_d = E/R$
- $P = E_d I_d$

Figure 21.41 **Three-phase, 6-pulse converter in the inverter mode.**

Inverter mode

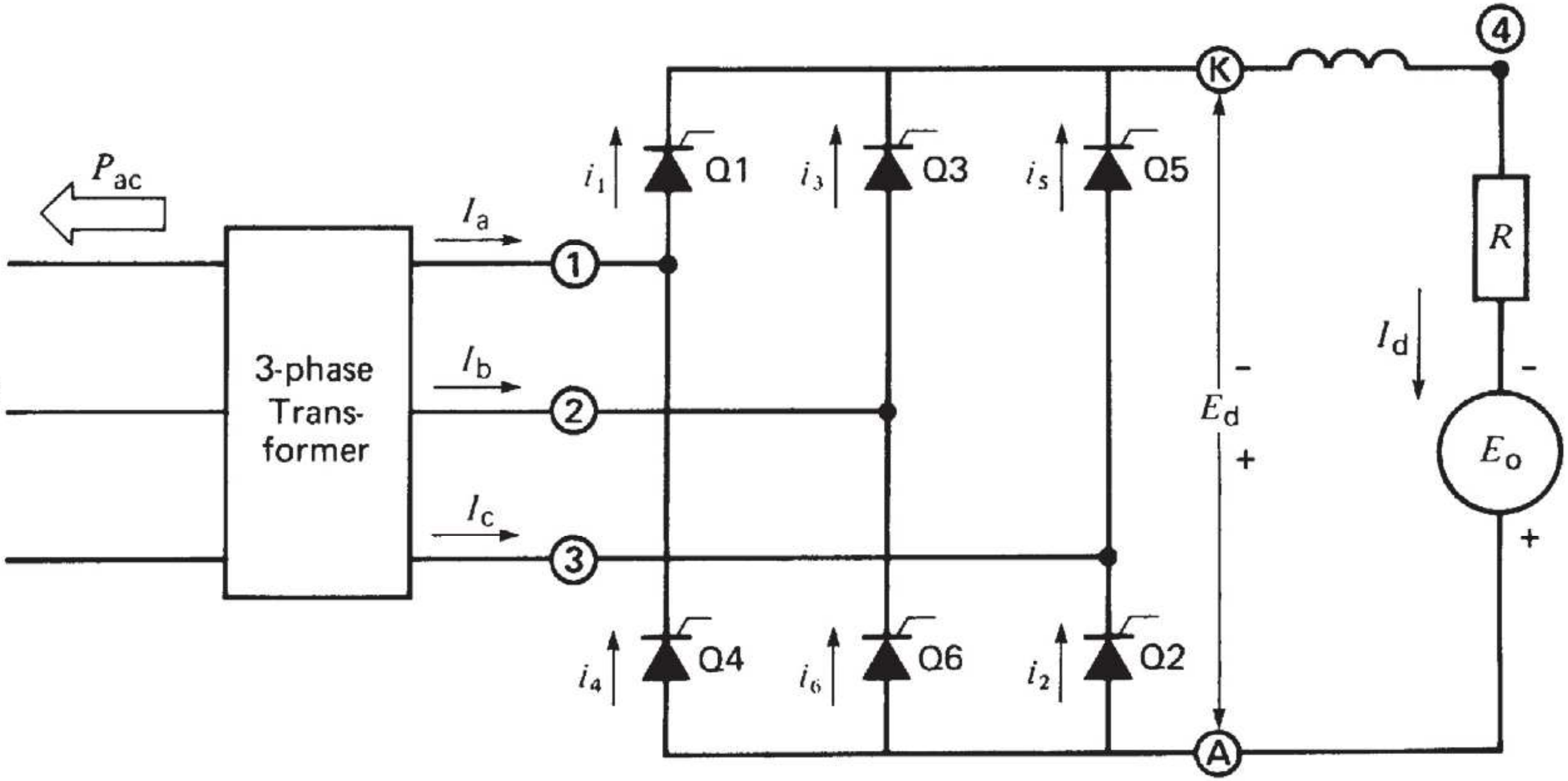


Figure 21.42a **Triggering sequence and waveforms with a delay angle of 105°.**

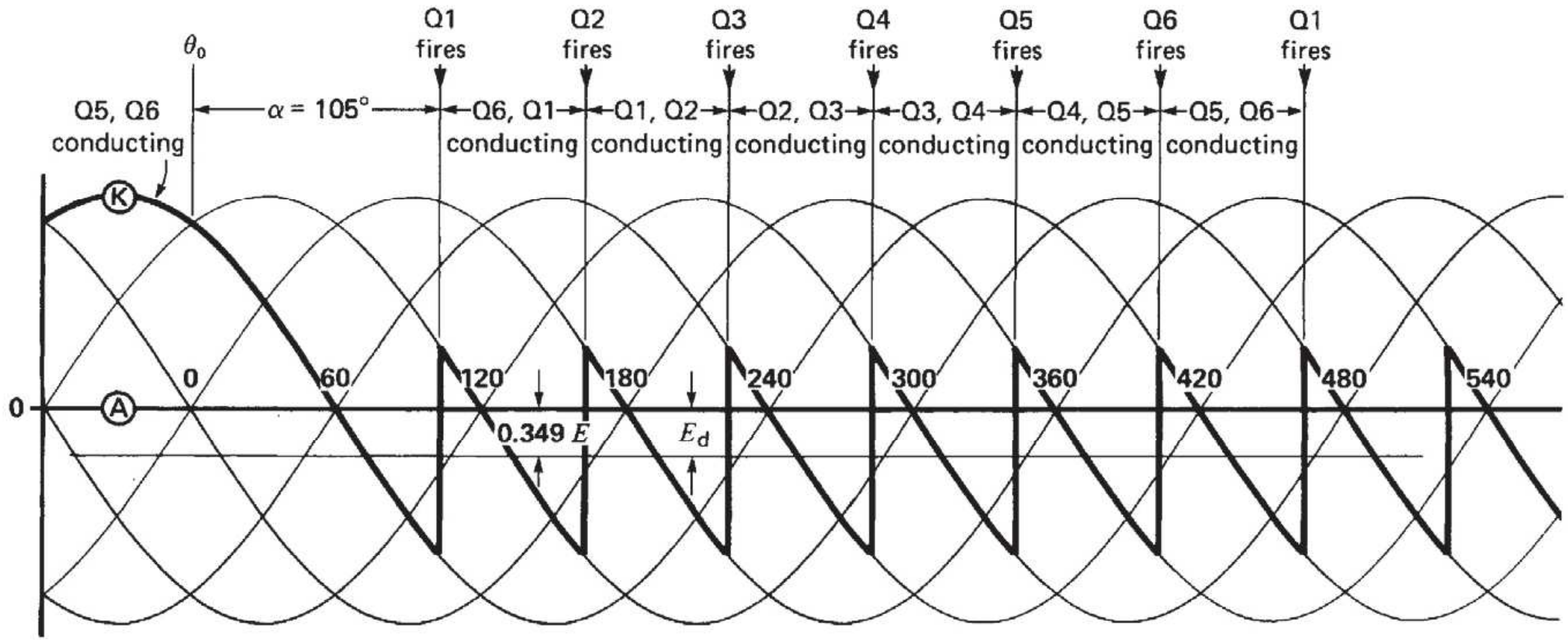


Figure 21.42b **Triggering sequence and waveforms with a delay angle of 135°.**

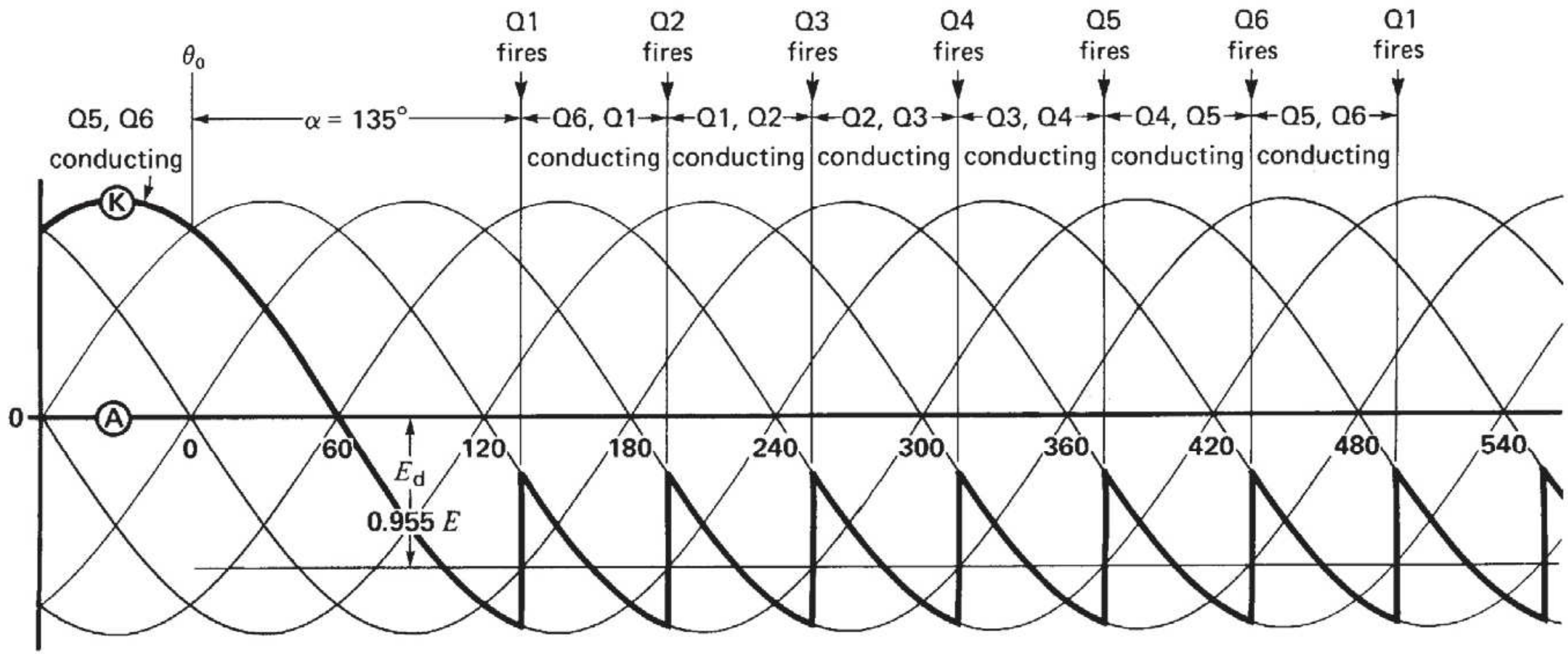


Figure 21.42c **Triggering sequence and waveforms with a delay angle of 165°.**

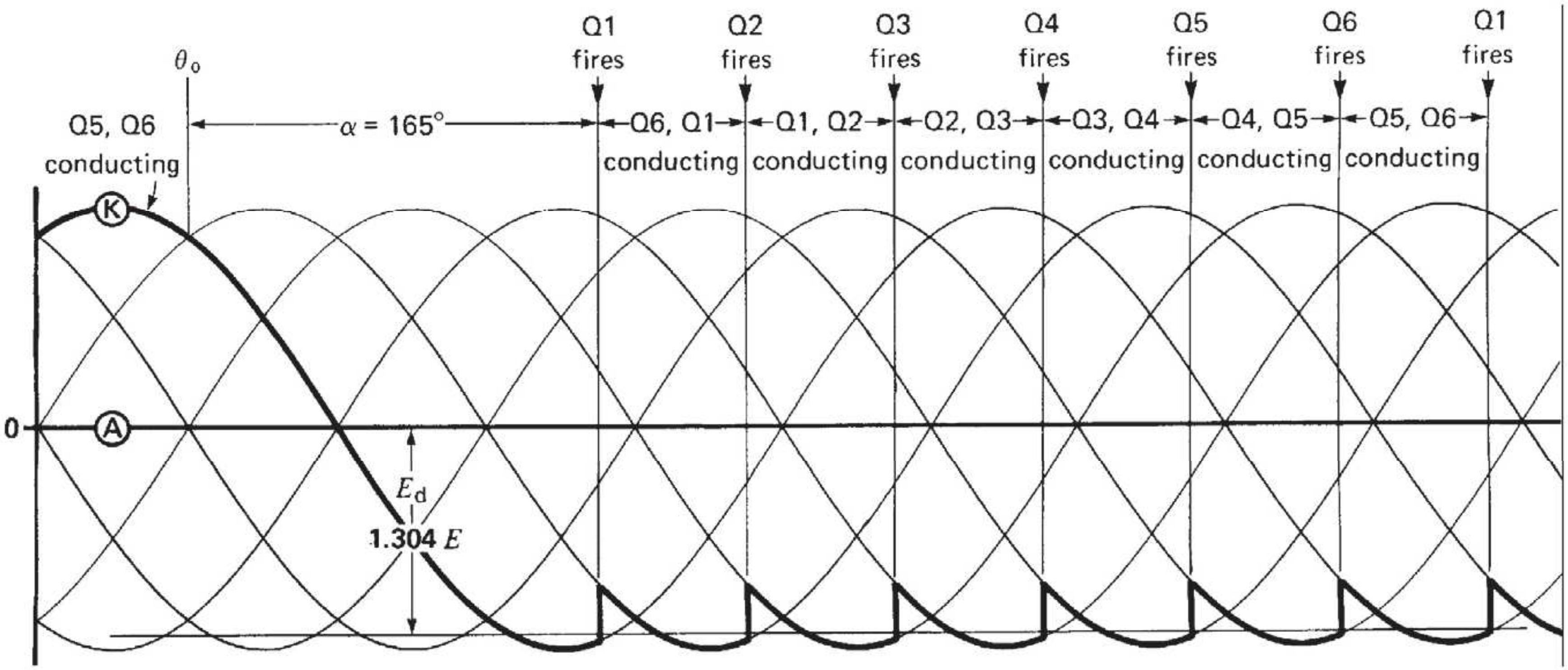


Figure 21.43 **Permitted gate firing zones for thyristor Q1.**

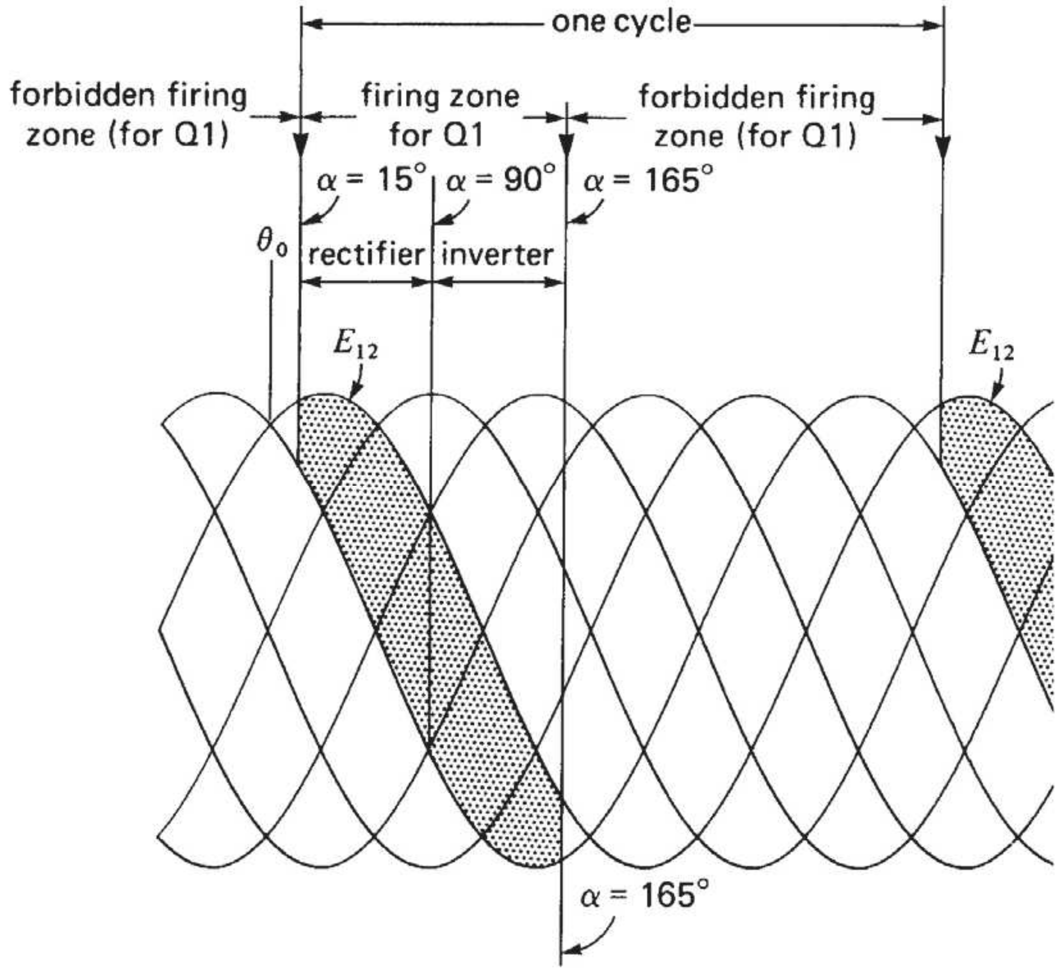


Figure 21.44 **Equivalent circuit of a thyristor converter.**

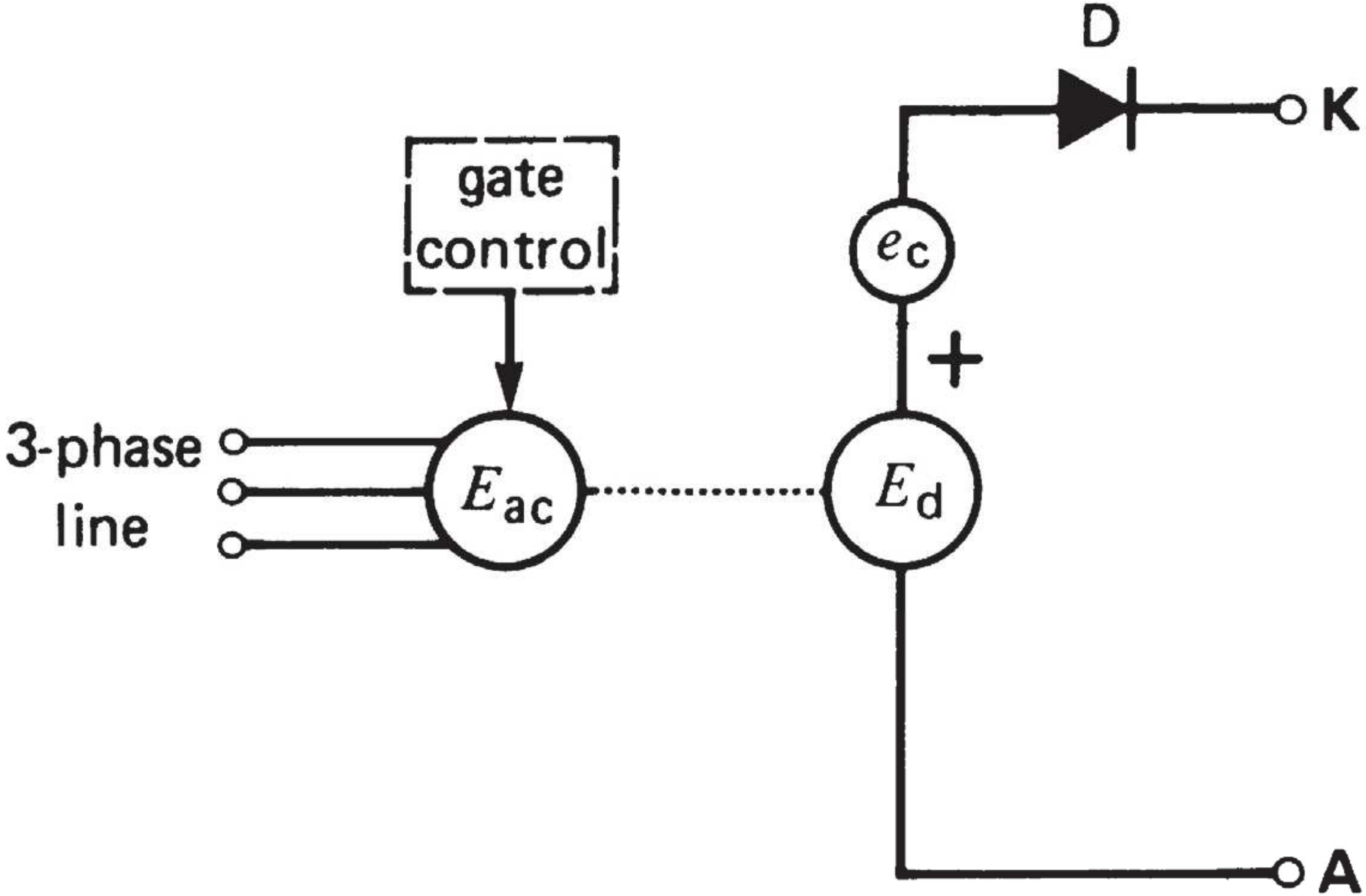


Figure 21.45 **Equivalent circuit of a 3-phase converter in the rectifier mode.**

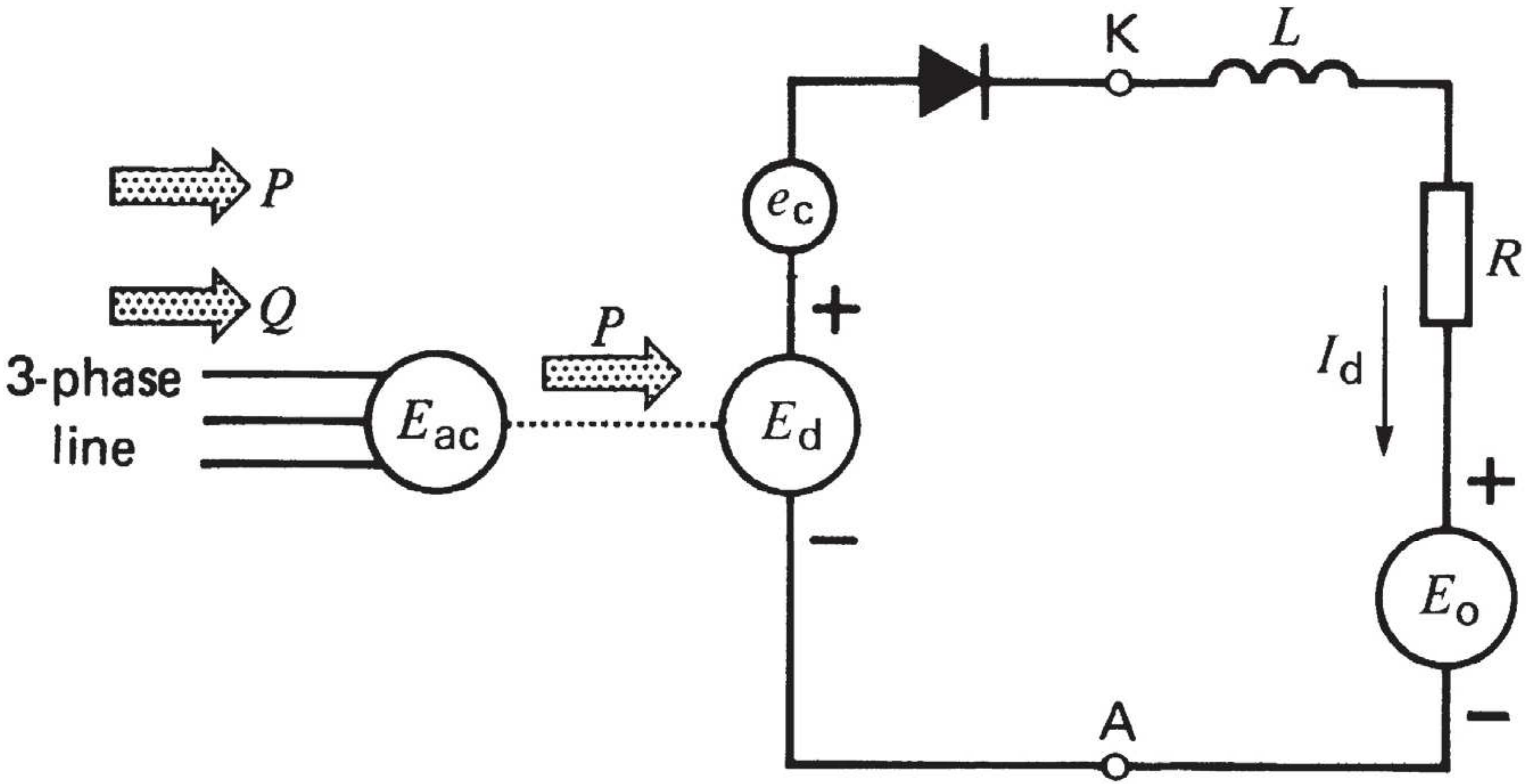


Figure 21.46 **Equivalent circuit of a 3-phase thyristor converter in the inverter mode.**

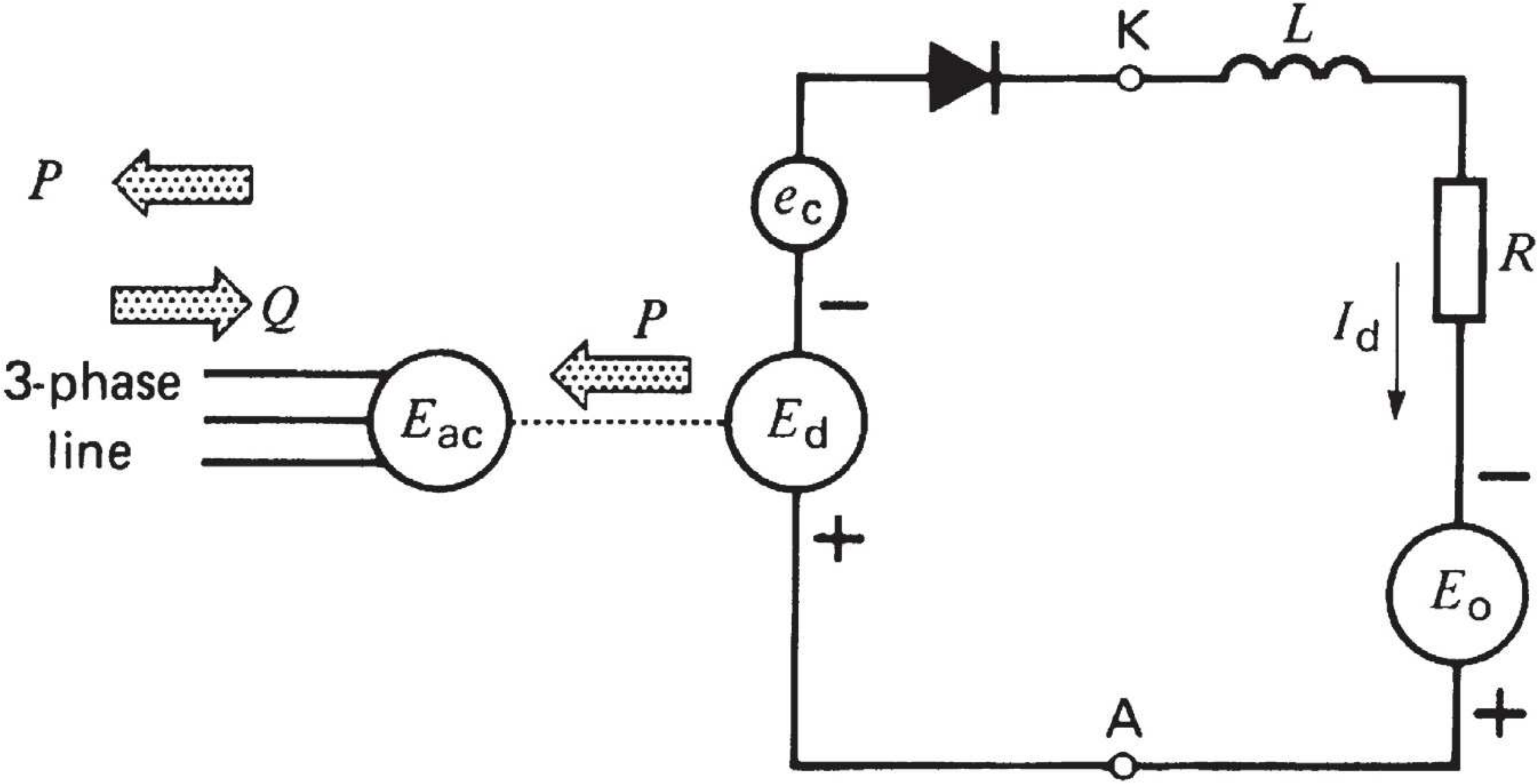


Figure 21.47 **Voltage and current waveforms in the thyristor converter of Fig. 21.39 with a delay angle of 45°.**

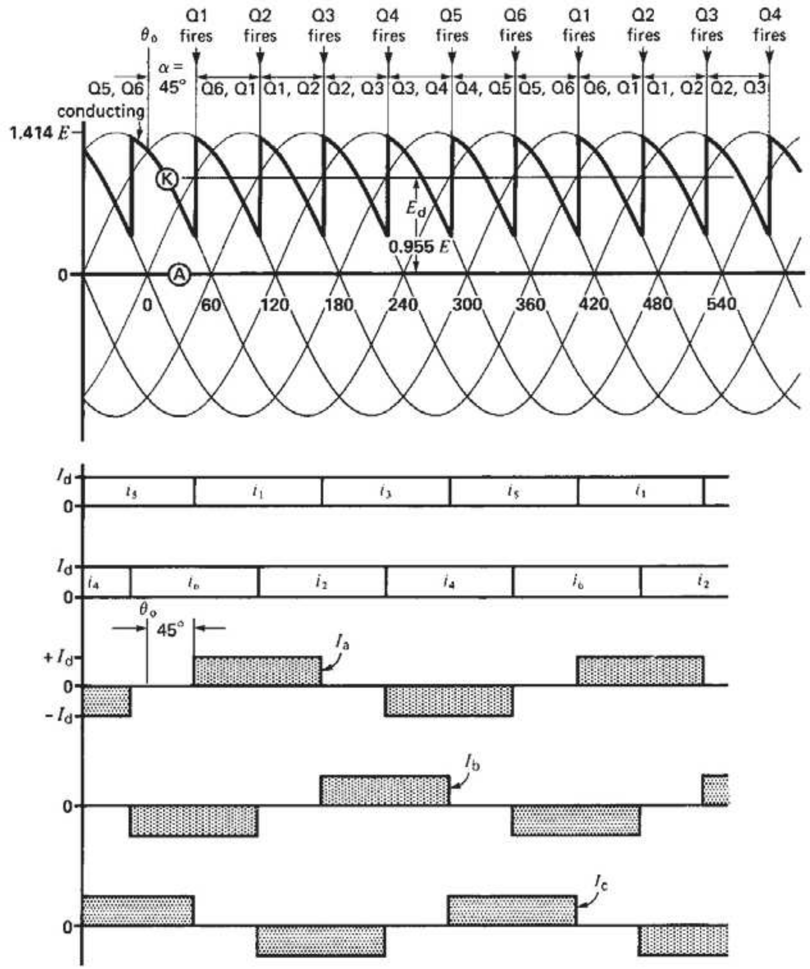


Figure 21.48 **See Example 21-11.**

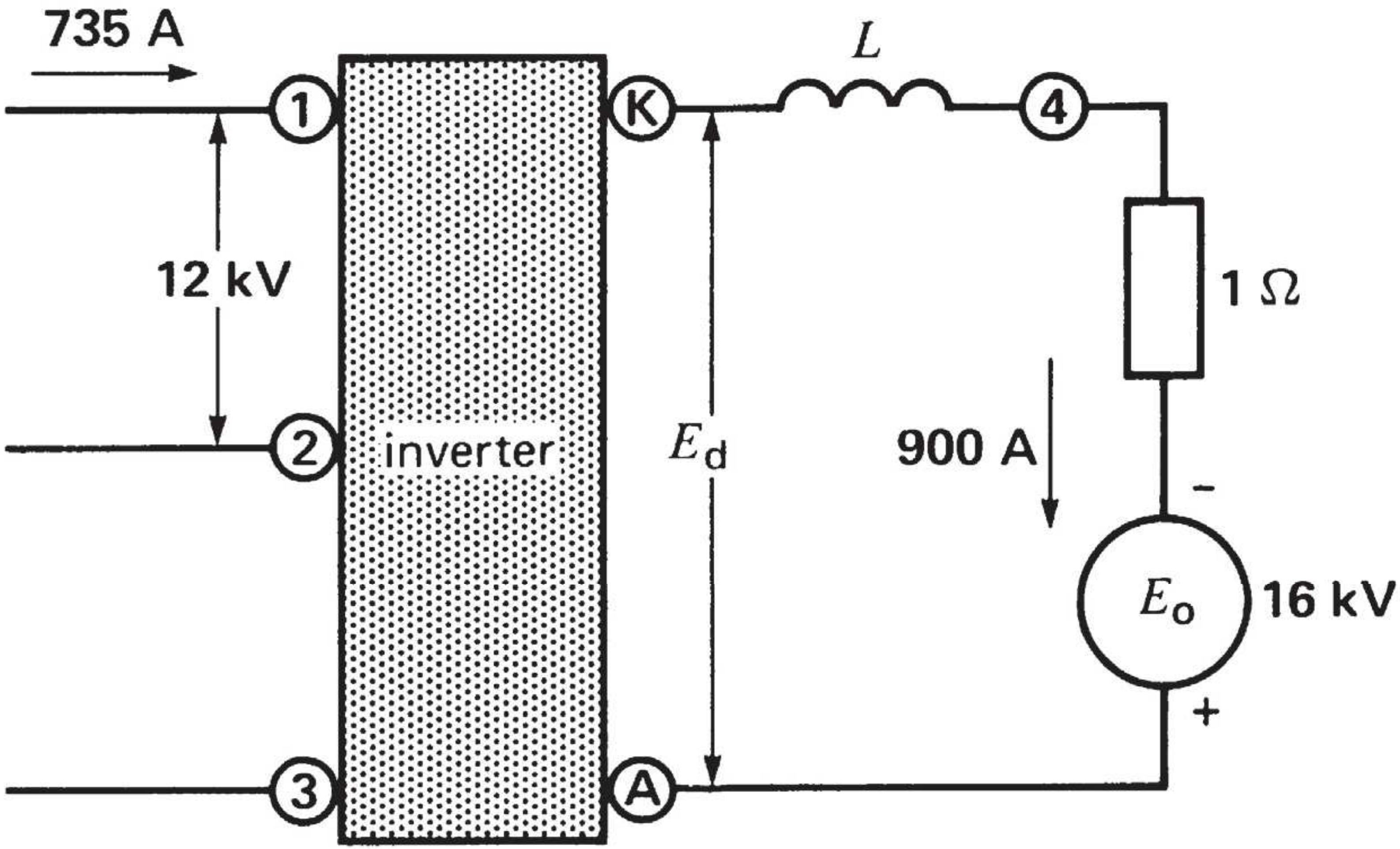


Figure 21.49 **a. Instantaneous commutation in a rectifier when ∝ = 45° (see Fig. 21.58). b. Same conditions with commutation overlap of 30°, showing current waveshapes in Q1, Q3, Q5.**

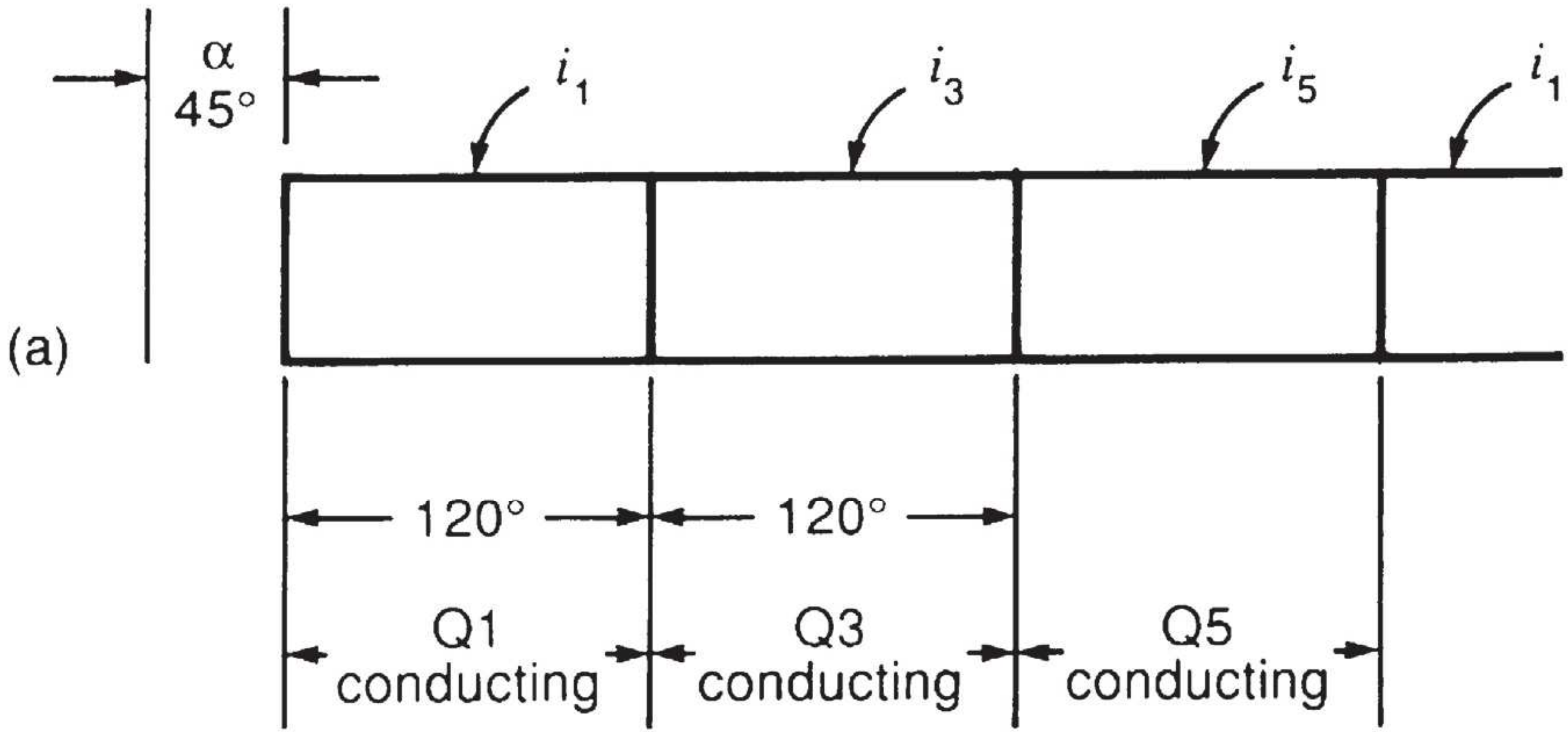


Figure 21.49 (continued) **a. Instantaneous commutation in a rectifier when ∝ = 45° (see Fig. 21.58). b. Same conditions with commutation overlap of 30°, showing current waveshapes in Q1, Q3, Q5.**

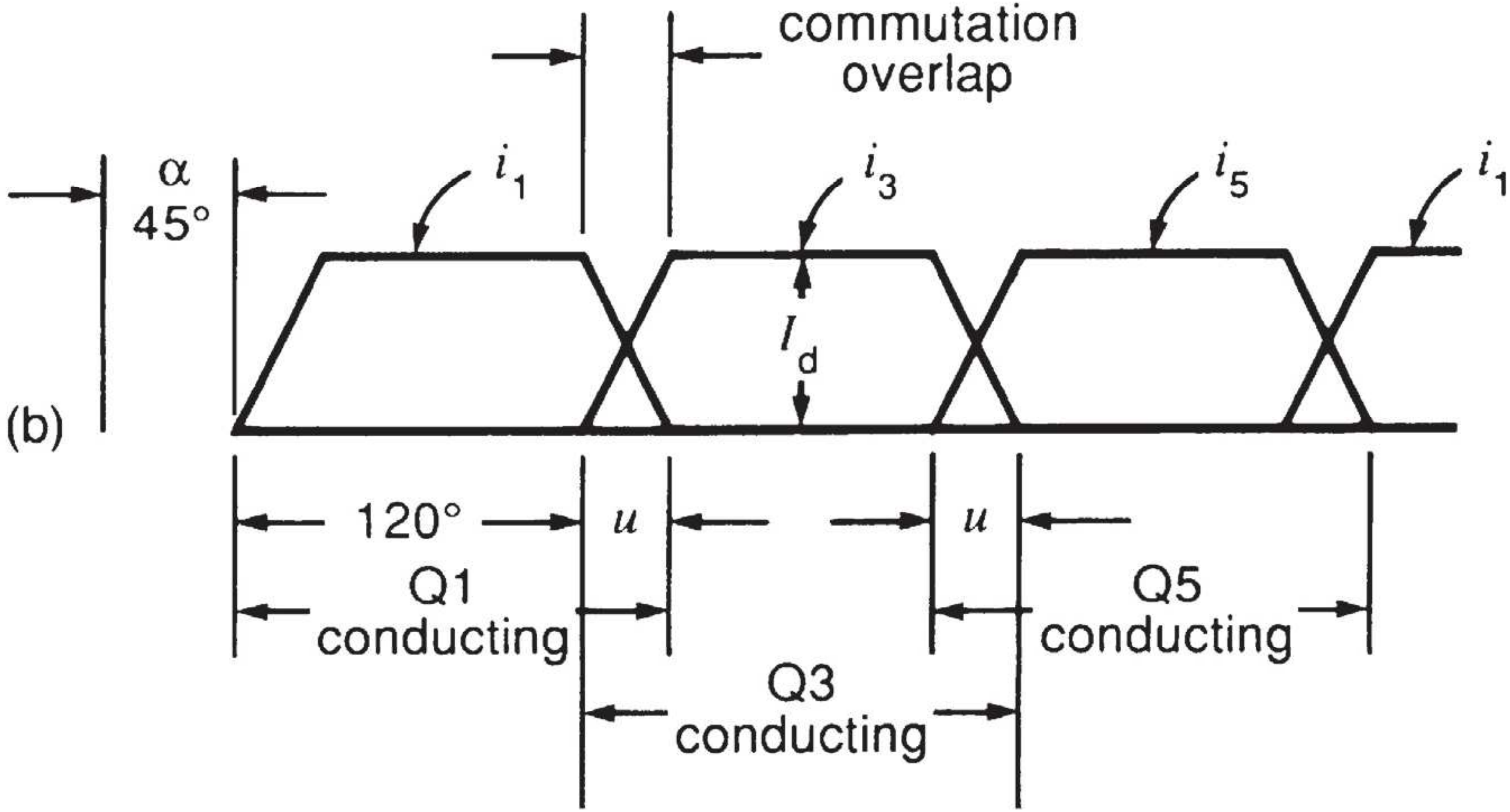


Figure 21.50 **Waveshape of i_1 in thyristor Q1 for a delay angle ∝. The extinction angle γ permits Q1 to establish its blocking ability before the critical angle of 300° is reached. At 300° the anode of Q1 becomes positive with respect to its cathode. The figure also shows the relationship between angles ∝, β, γ, and *u*.**

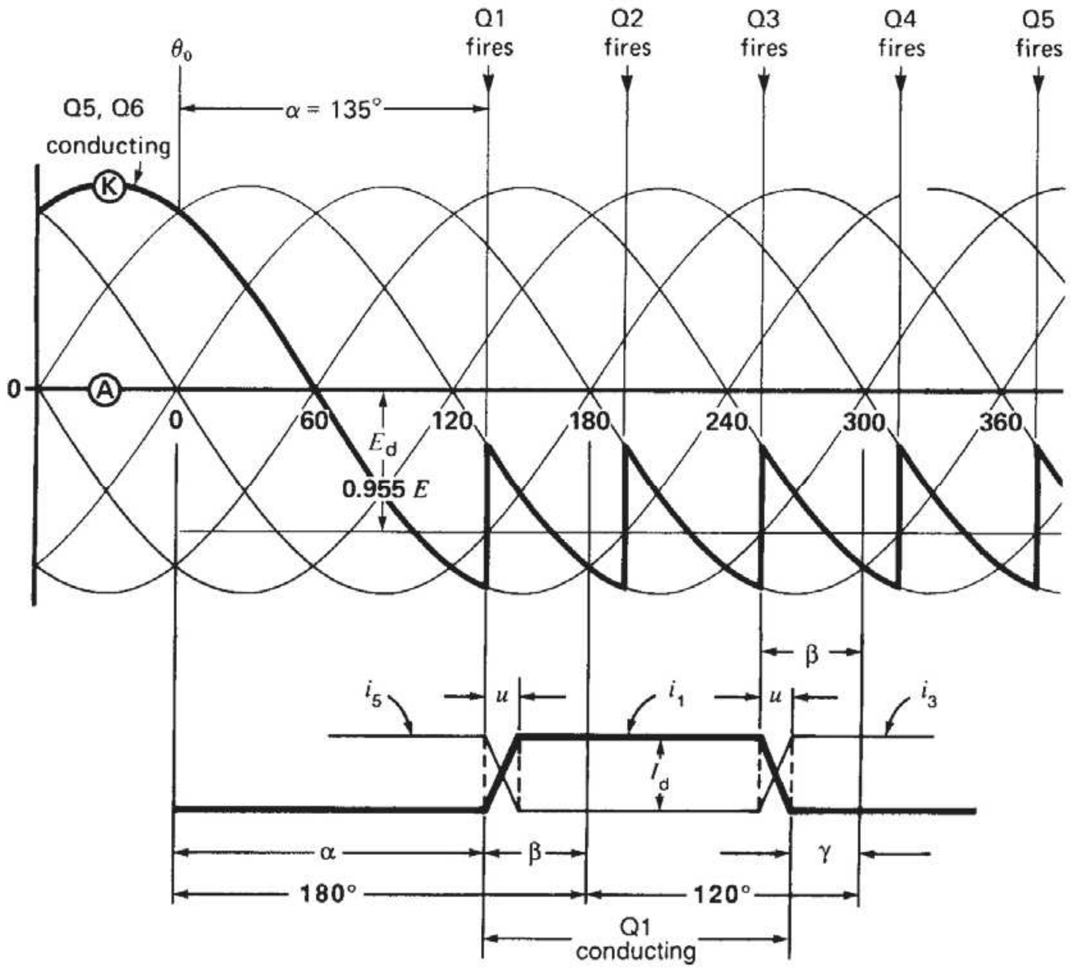


Figure 21.51 **Typical properties and approximate limits of GTOs and thyristors in the on and off states.**

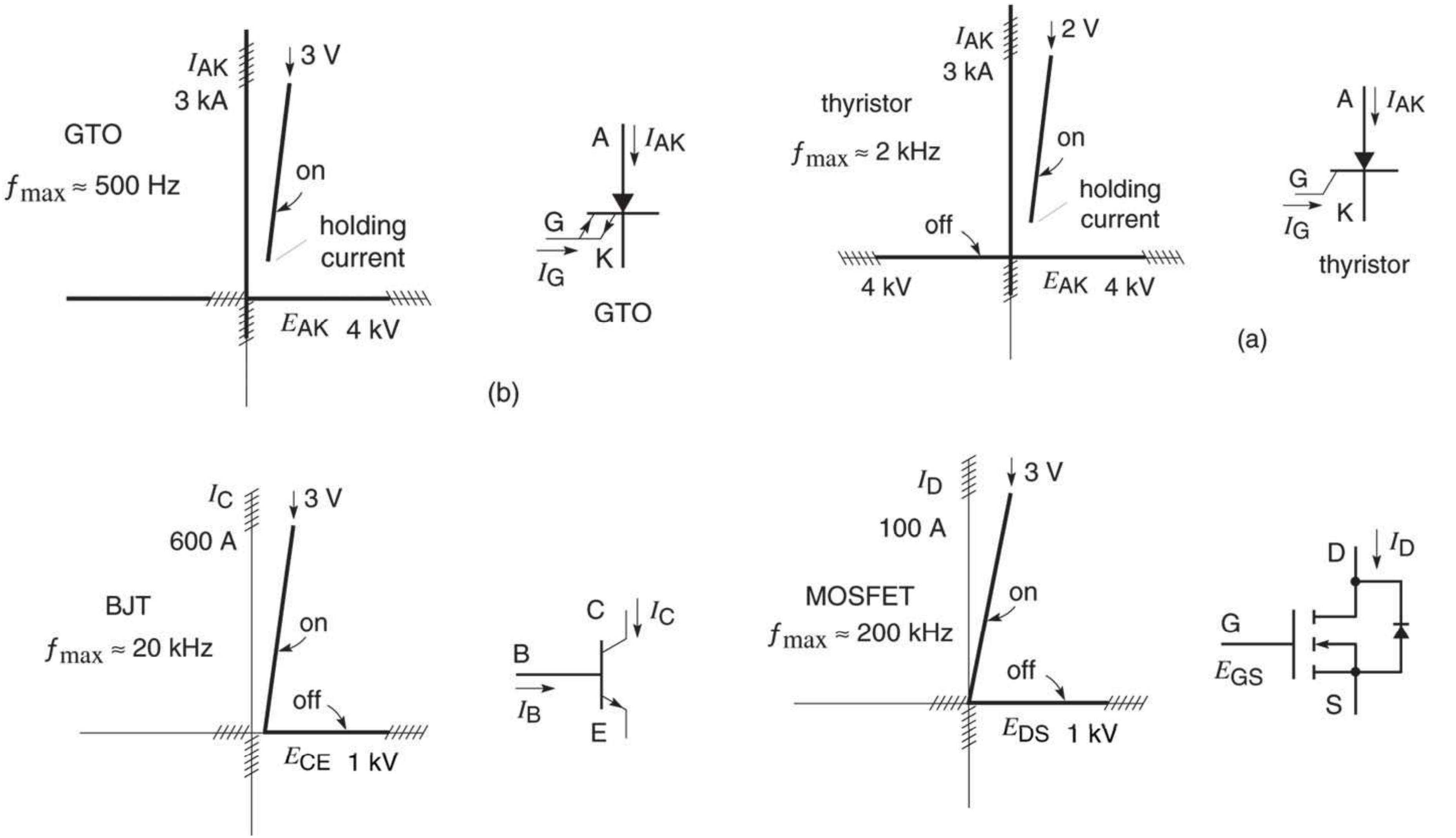
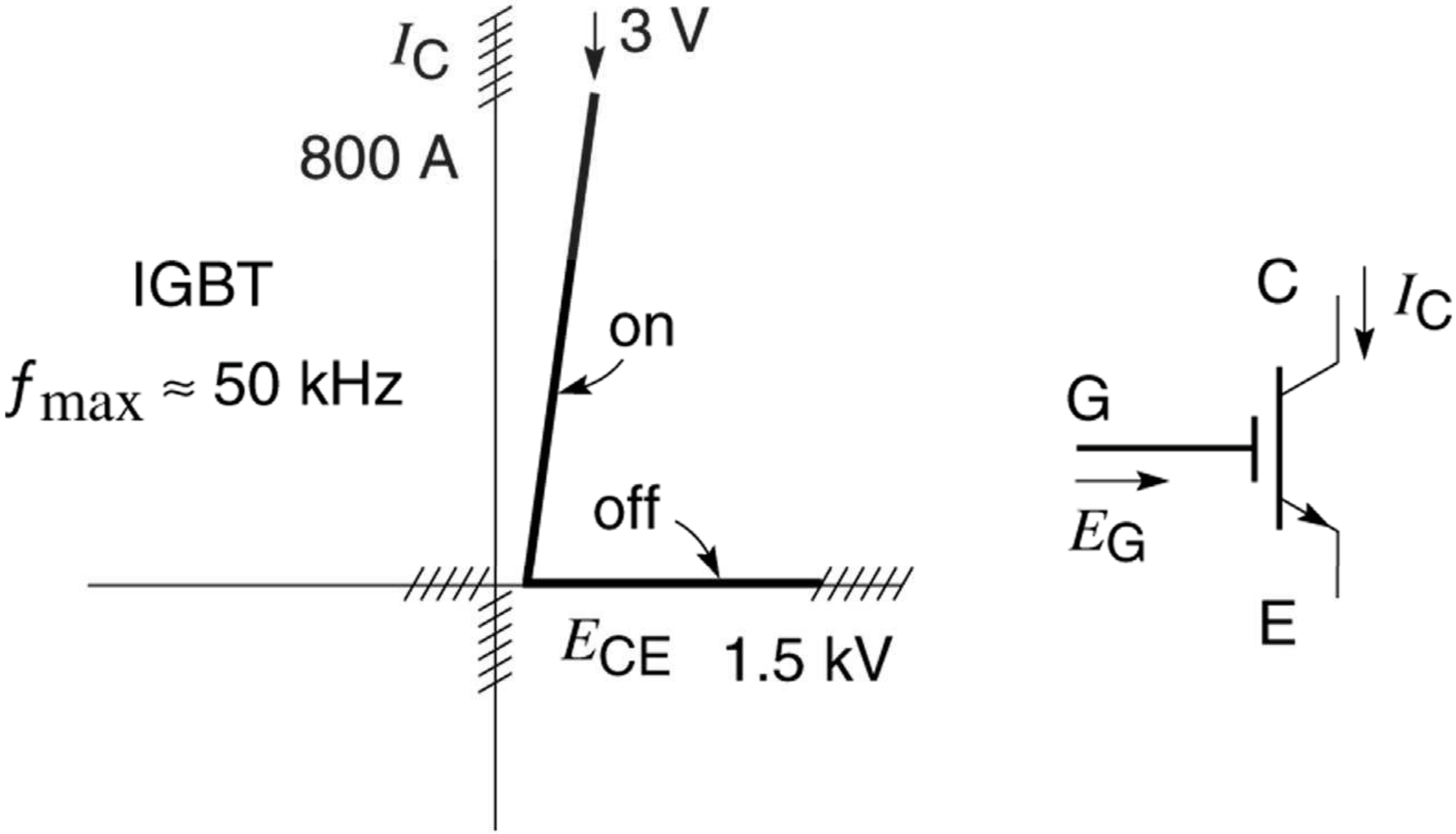
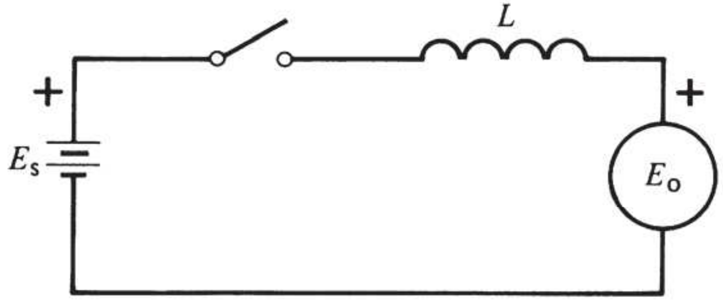
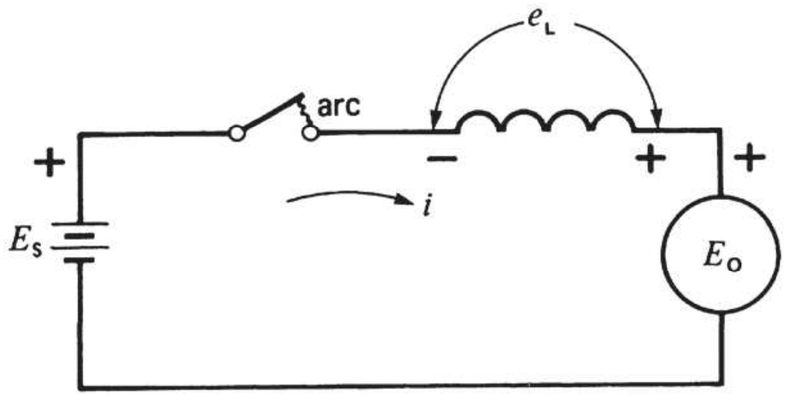
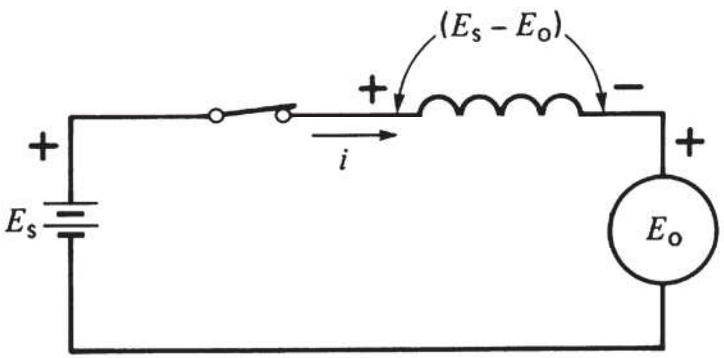


Figure 21.54 **Typical properties and approximate limits of IGBTs.**




L
+
+
Es
Eo


eL
arc
−
+
+
+
i
Es
Eo


(Es − Eo)
+
−
+
+
i
Es
Eo

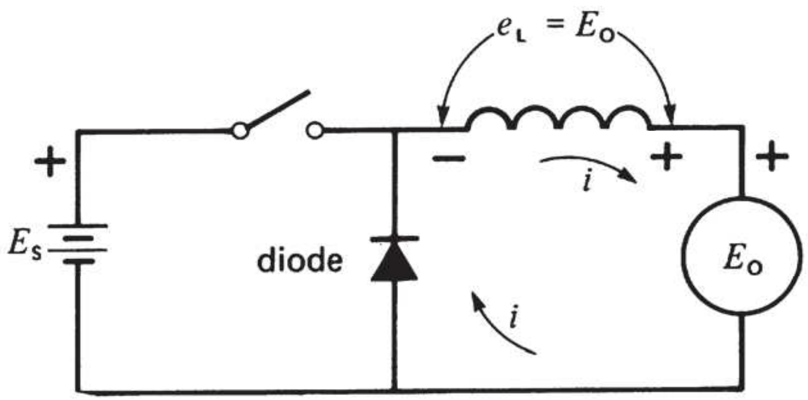
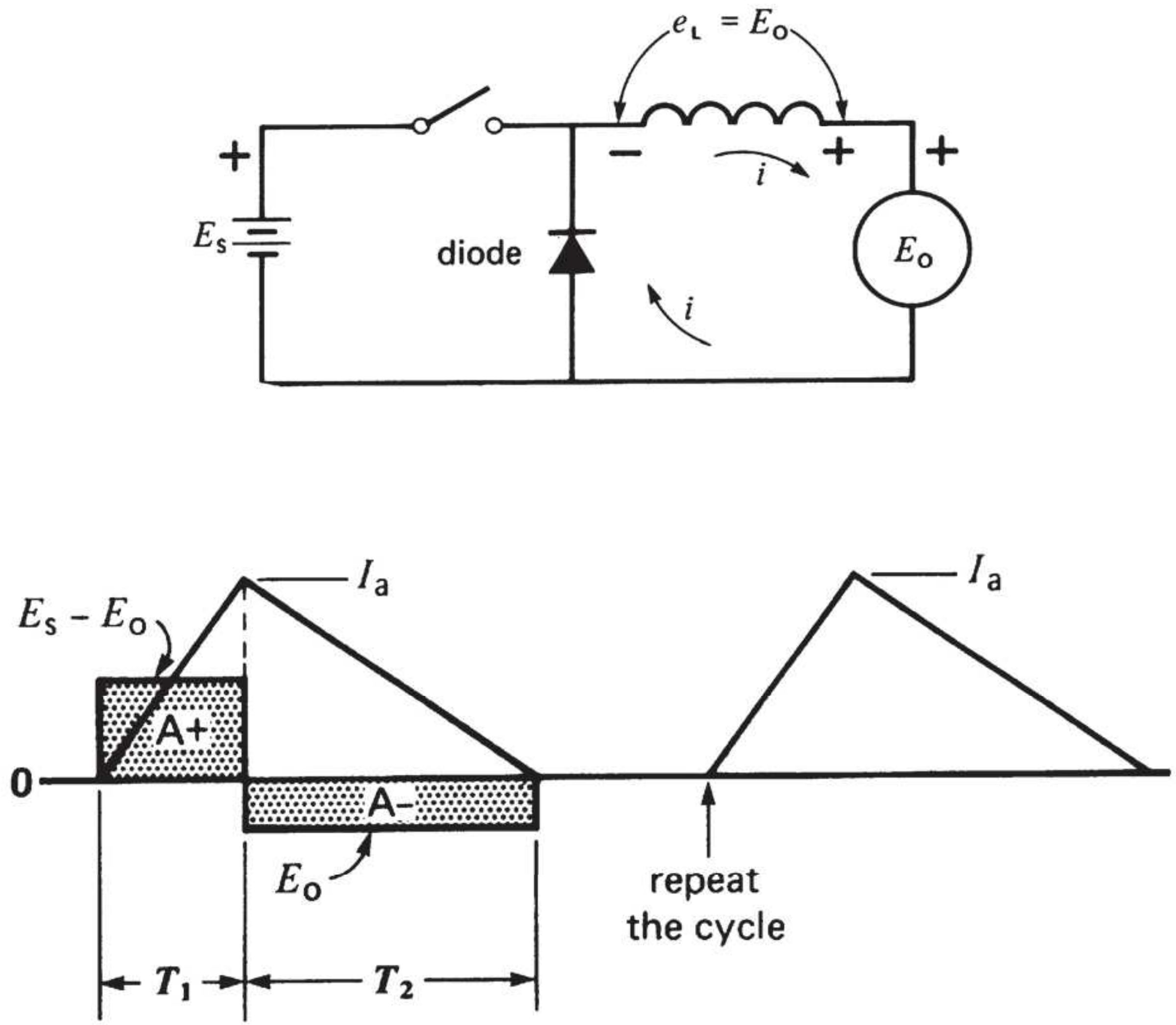
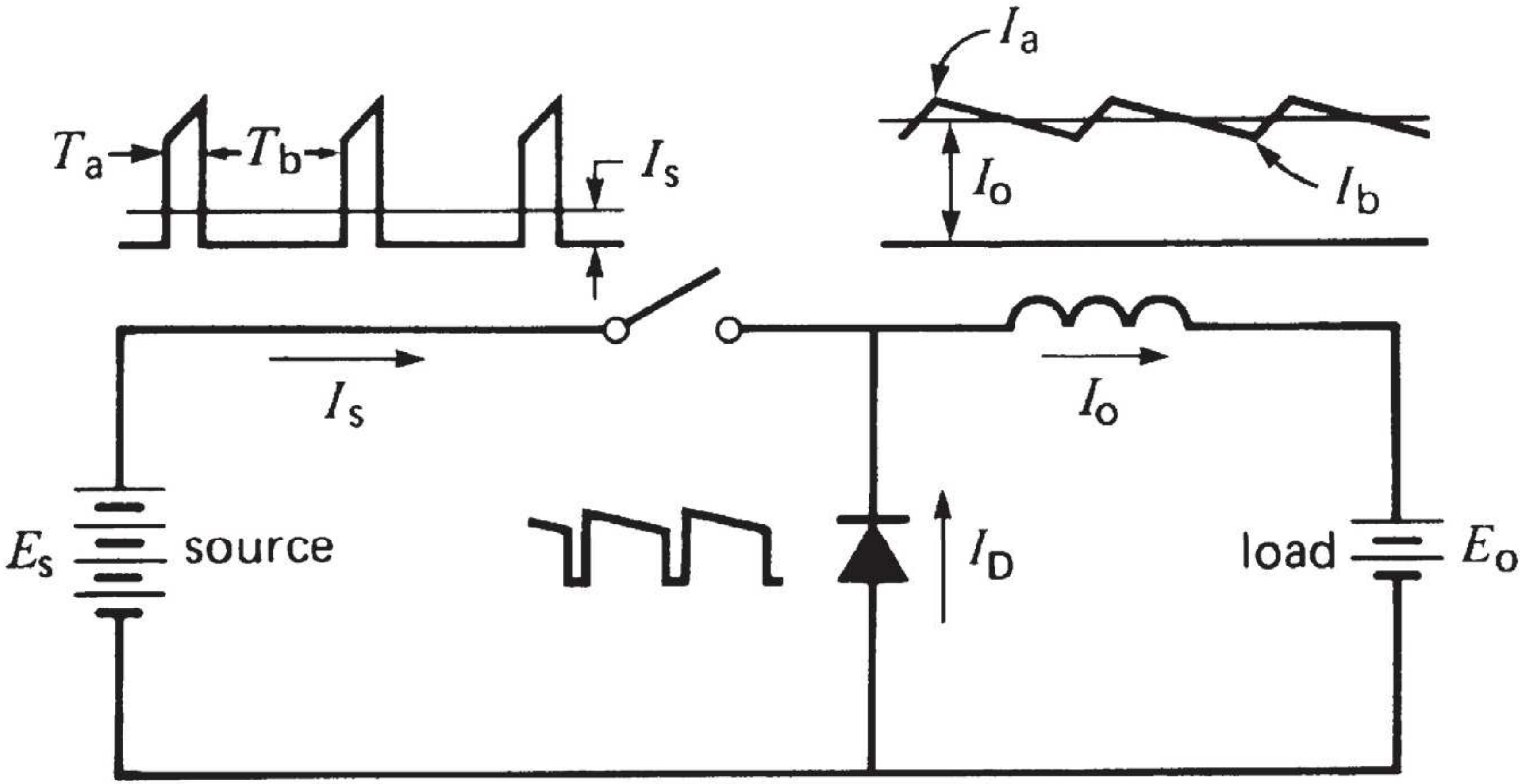

eL = Eo
−
+
+
+
i
Es
diode
i
Eo

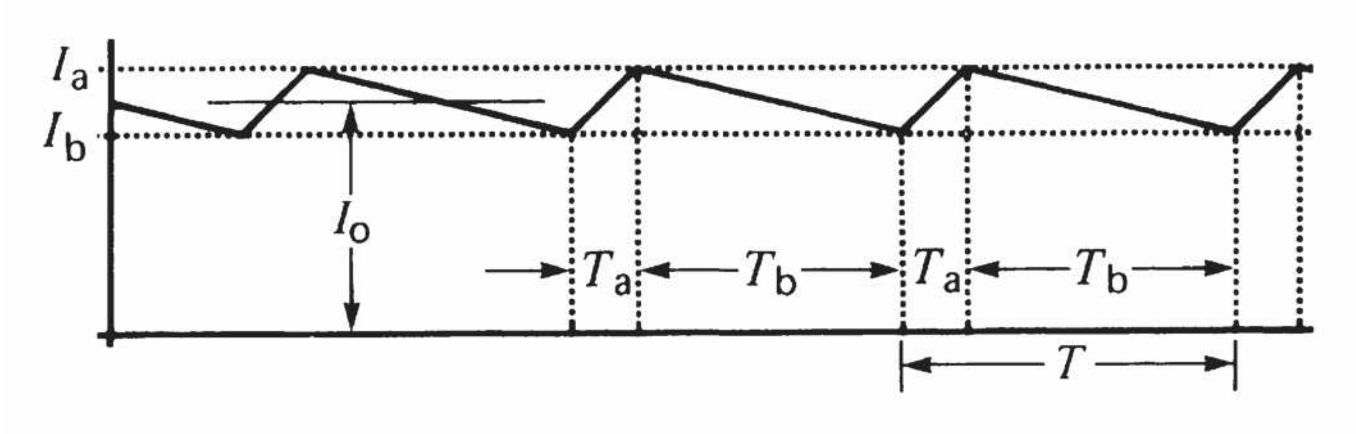
Figure 21.59 ***E* and *I* in the inductor of Fig. 21.58.**

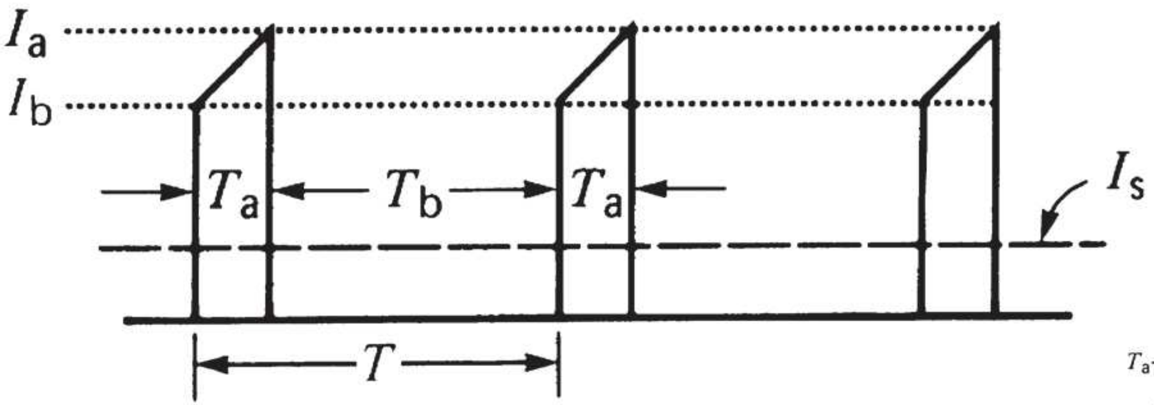




- $I_o = (I_a + I_b)/2$
- $I_S = I_o\,(T_a/T)$
- $I_S = I_o\,D$

Figure 21.60b Current in the load





- $E_s I_s = E_o I_o$
- $E_o = E_s I_s / I_o$
- $E_o = D\ E_s$

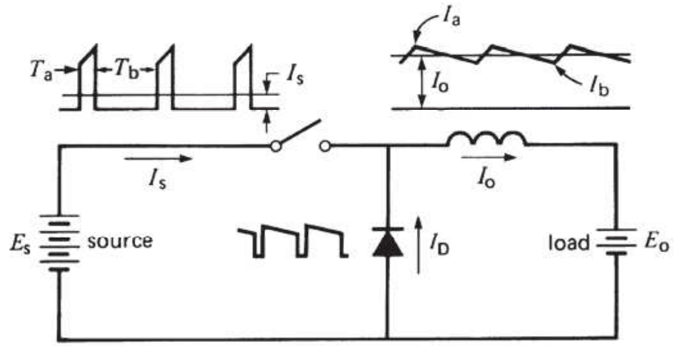
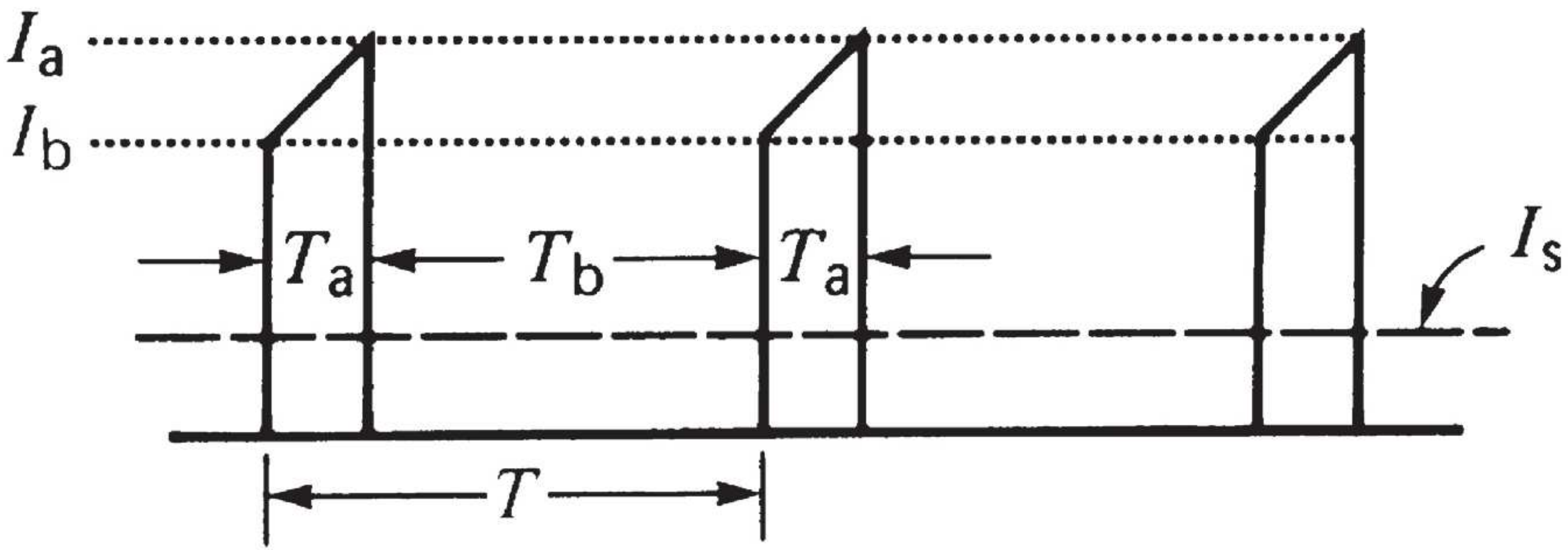


Figure 21.60c **Current pulses provided by the source.**

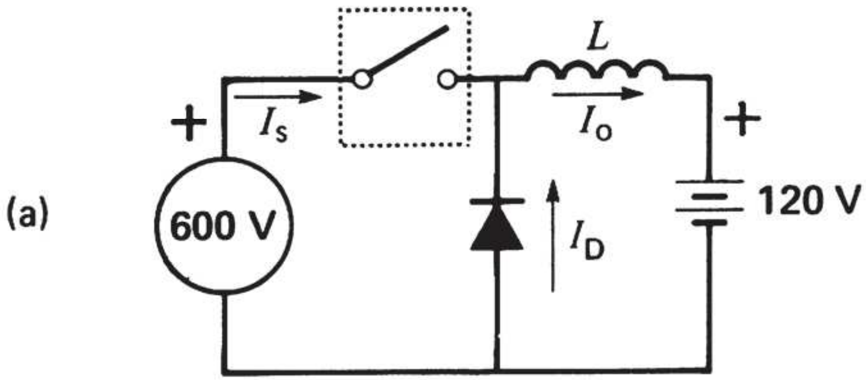


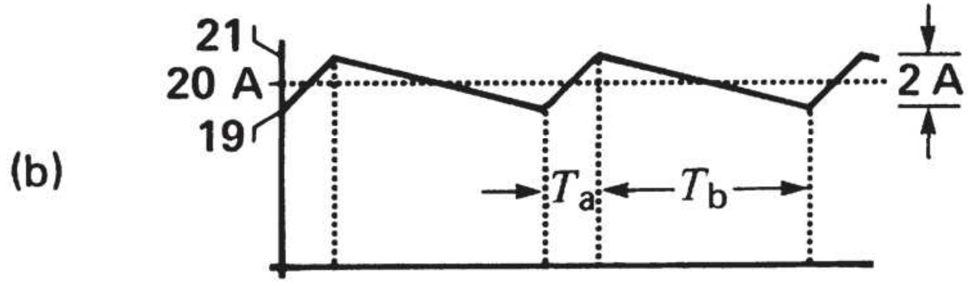
Example 21-11

Charge 120 V battery from 600 V dc source using a dc chopper, average current 20 App ripple 2 A, f =200Hz

- dc current from the source
- dc current in the diode
- the duty cycle
- inductance of the inductor

- $P = E_o I_o$
- $I_s = P/ E_s$





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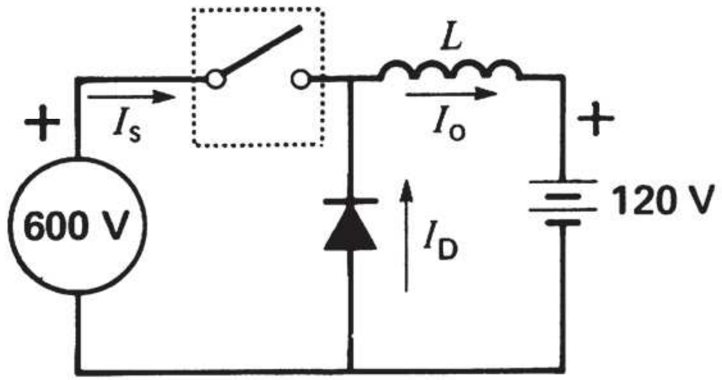
Example 21-11

Charge 120 V battery from 600 V dc source using a dc chopper, average current 20 App ripple 2 A, f =200Hz

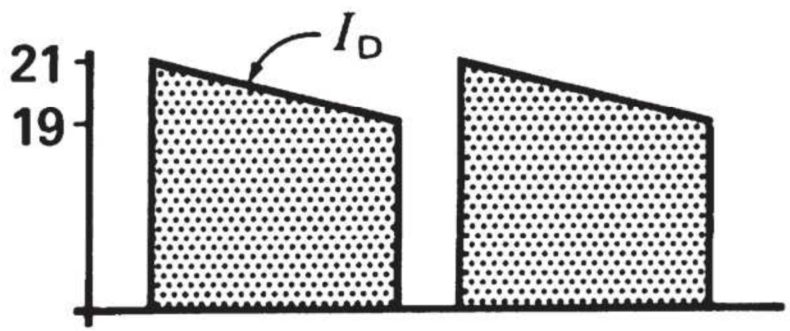
- dc current from the source
- dc current in the diode
- the duty cycle
- inductance of the inductor

- $I_D = I_o - I_s$
- $D = E_o / E_s$

(a)



(d)



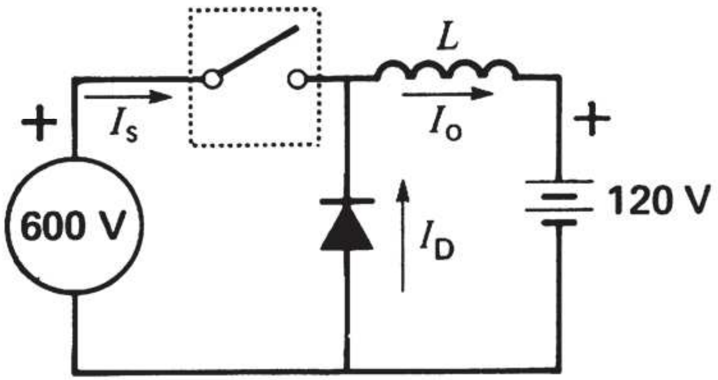
Example 21-11

Charge 120 V battery from 600 V dc source using a dc chopper, average current 20 App ripple 2 A, f =200Hz

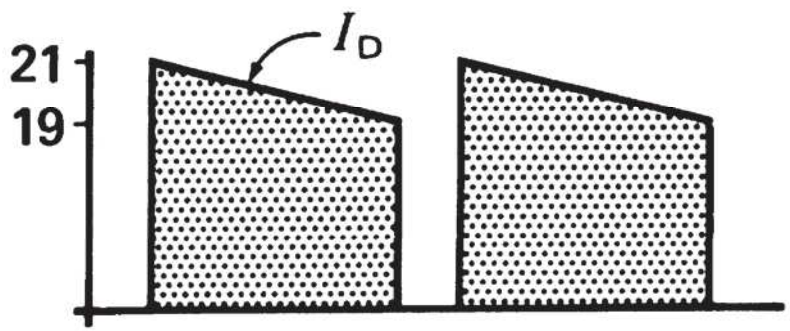
- dc current from the source
- dc current in the diode
- the duty cycle
- inductance of the inductor

- $I_D = I_o - I_s$
- $D = E_o / E_s$

(a)



(d)



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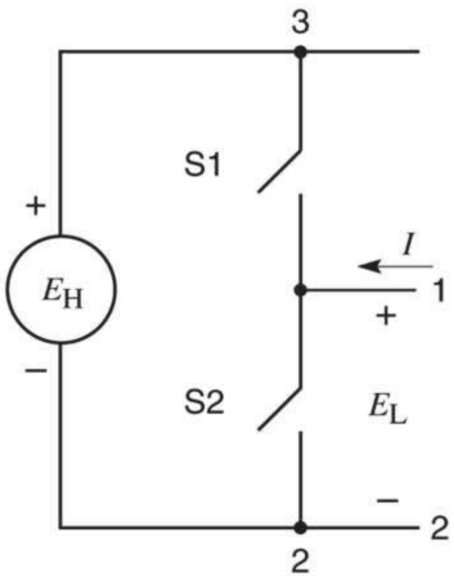
2 quadrant DC-DC converter

- $E_L = D\ E_H$



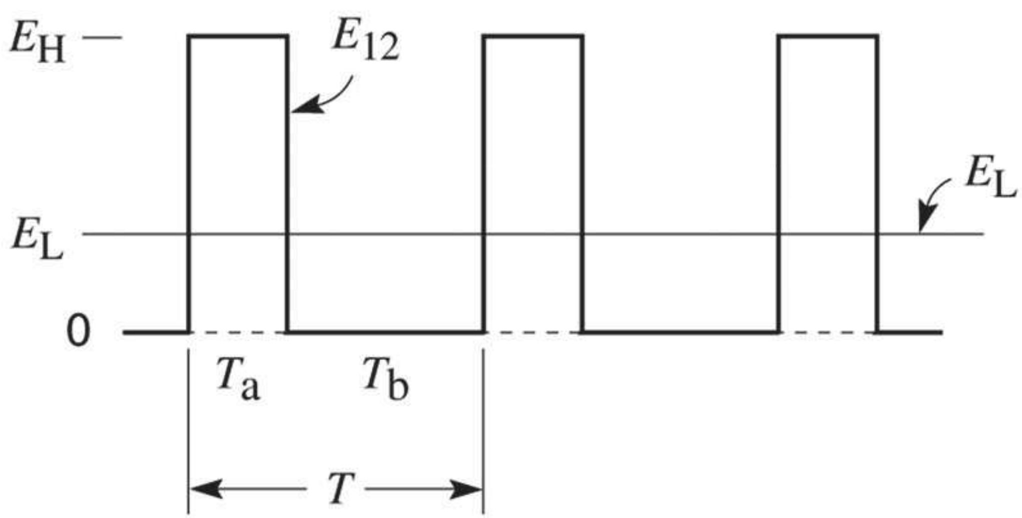
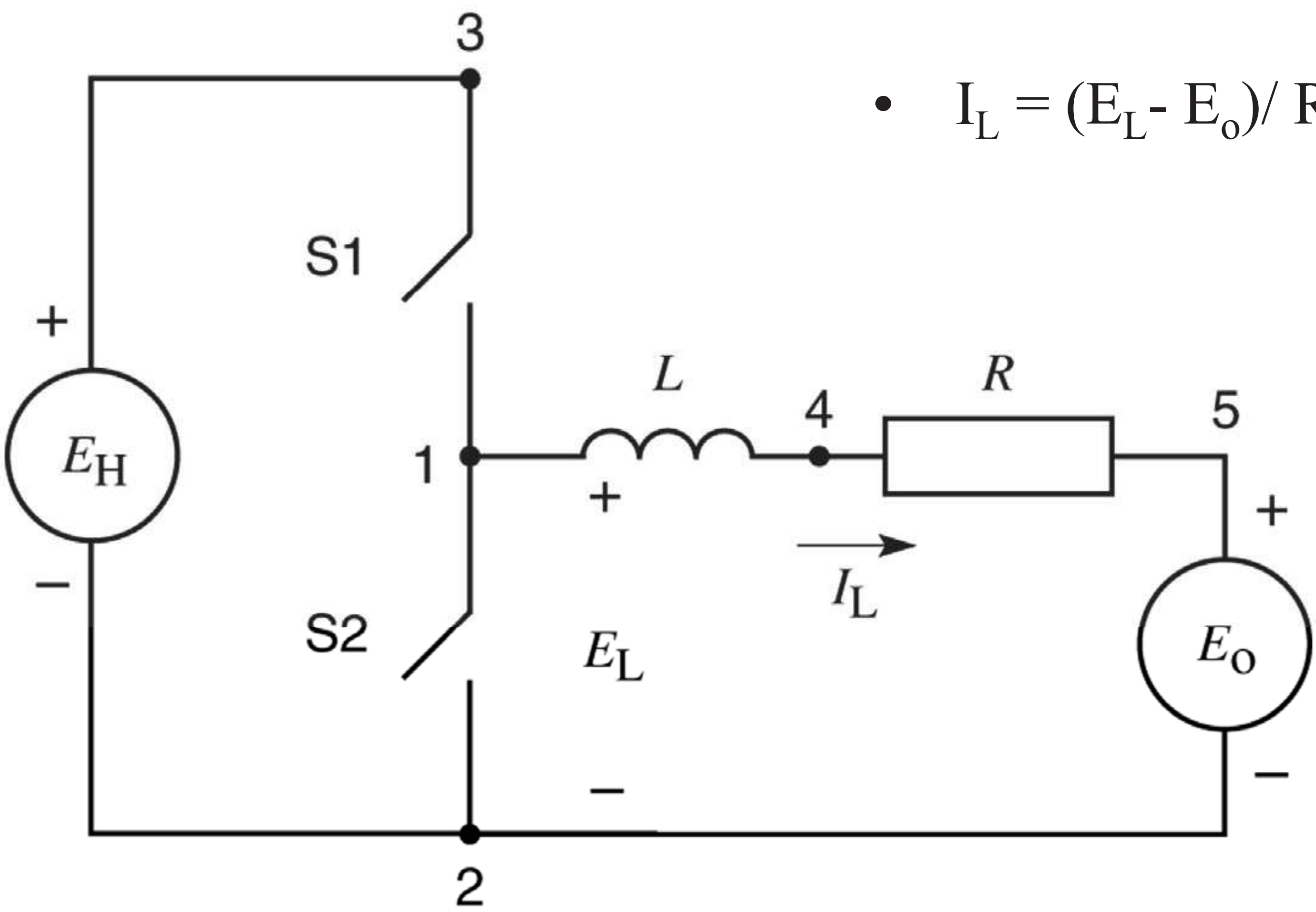


Figure 21.64 **Power can flow from E_H to E_o and vice versa.**

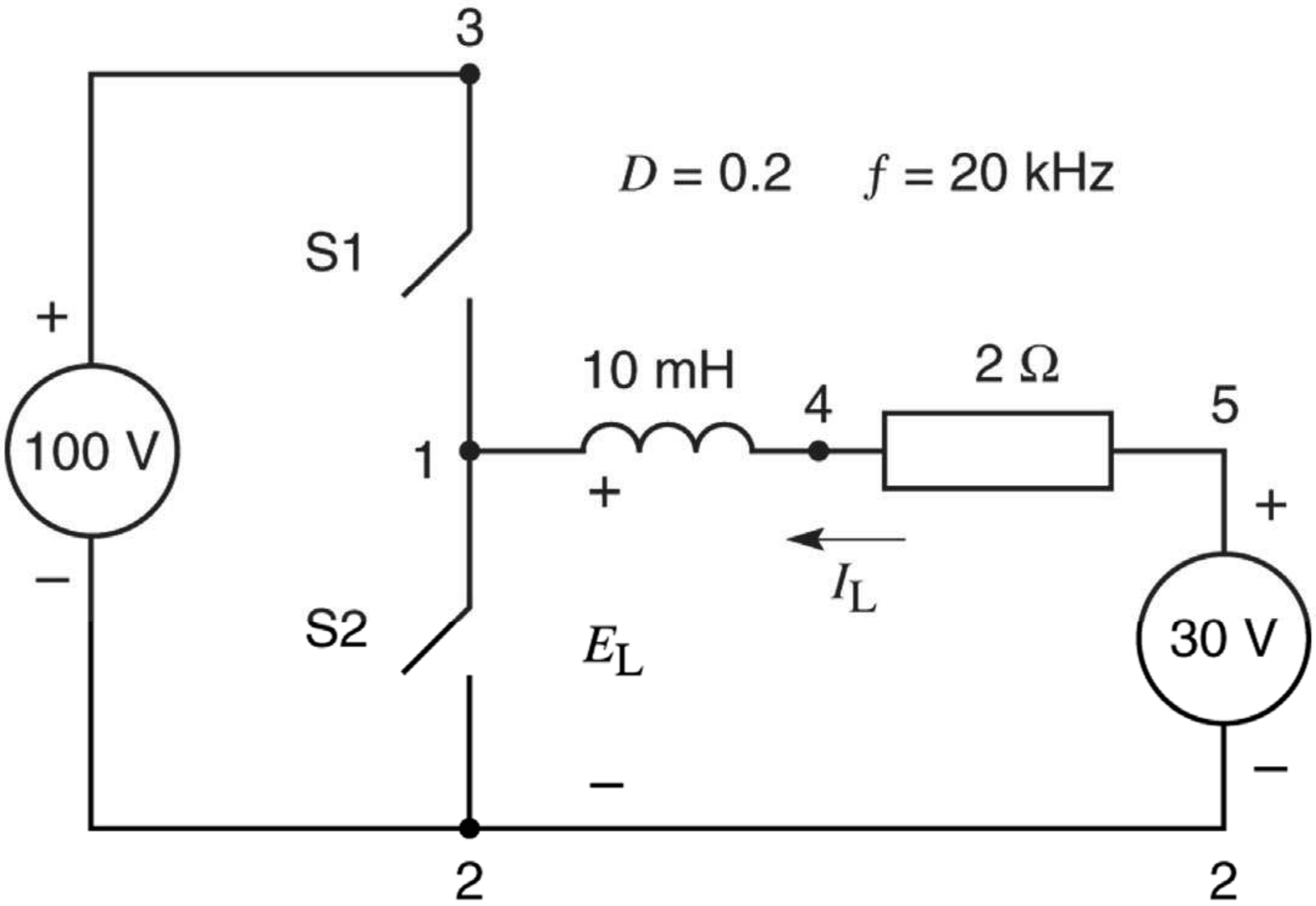
$E_L > E_o$



- $I_L = (E_L - E_o)/ R$

Figure 21.65 **Circuit of Example 21-13.**

$E_L < E_o$

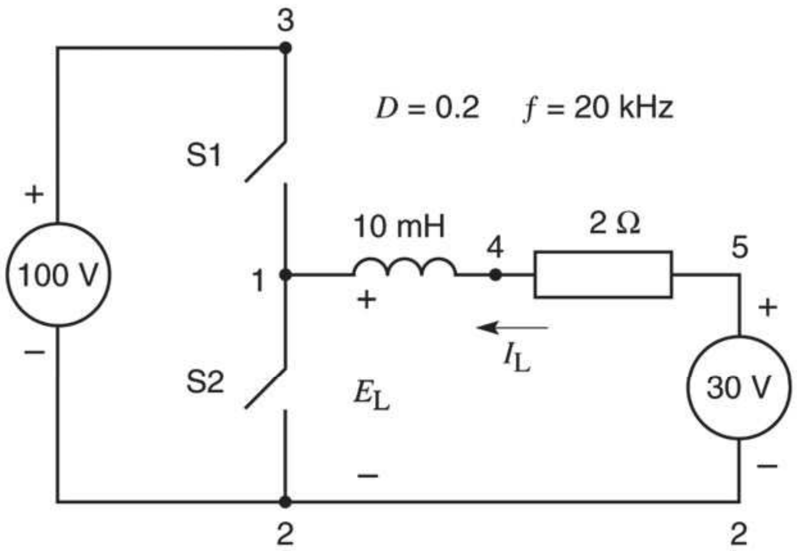


Example 21-13.

100 V, 30 V, S ohm, 10 mH, 20 kHz, D=0,2

Value and direction of IL

Pp ripple



- $E_L = D\ E_H = 20V$
- $I_L = (E_o - E_L) / R$
- $T = 1/f$

Figure 21.66 **See Example 21-13.**

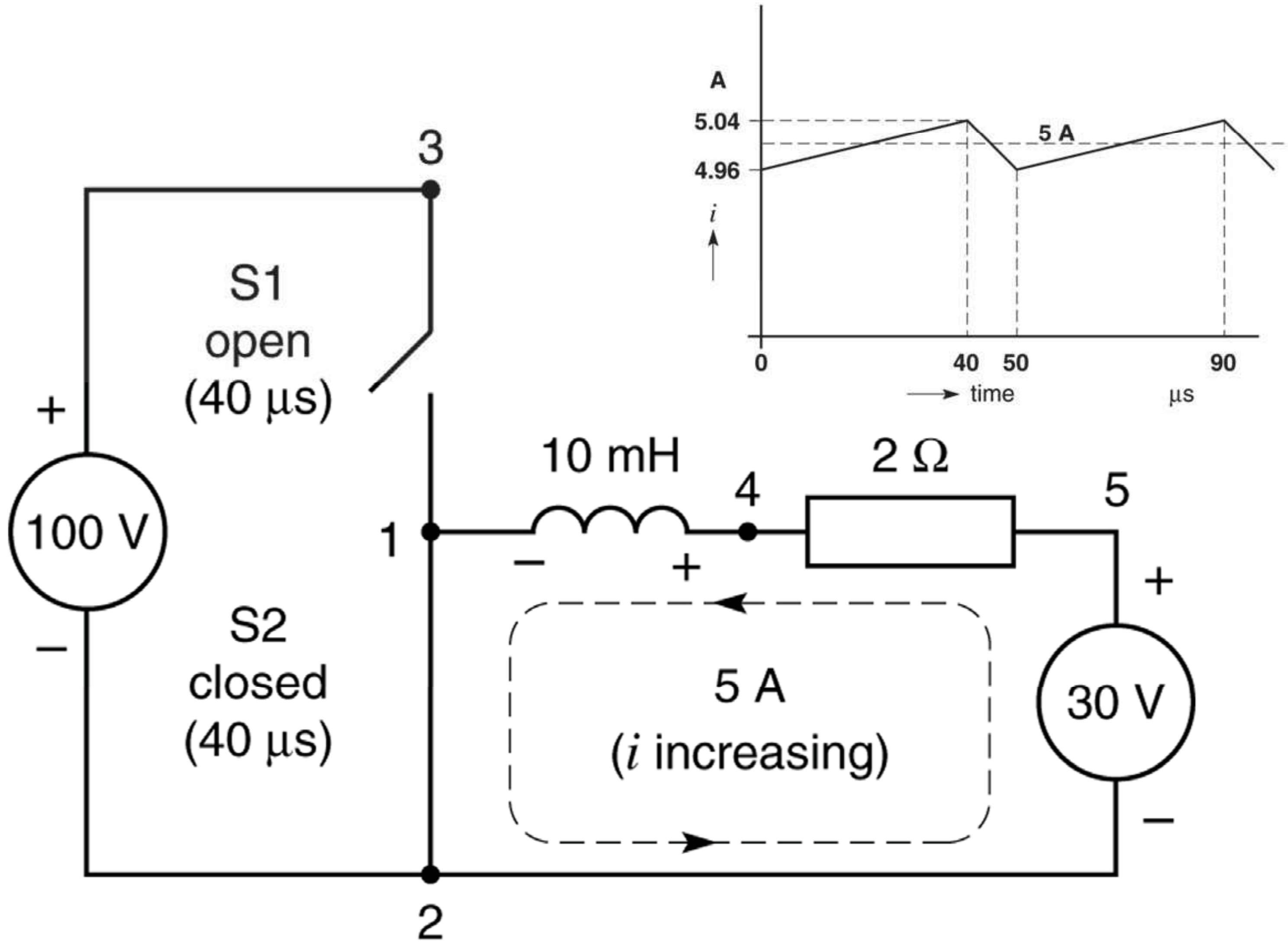


Figure 21.67 **See Example 21-13.**

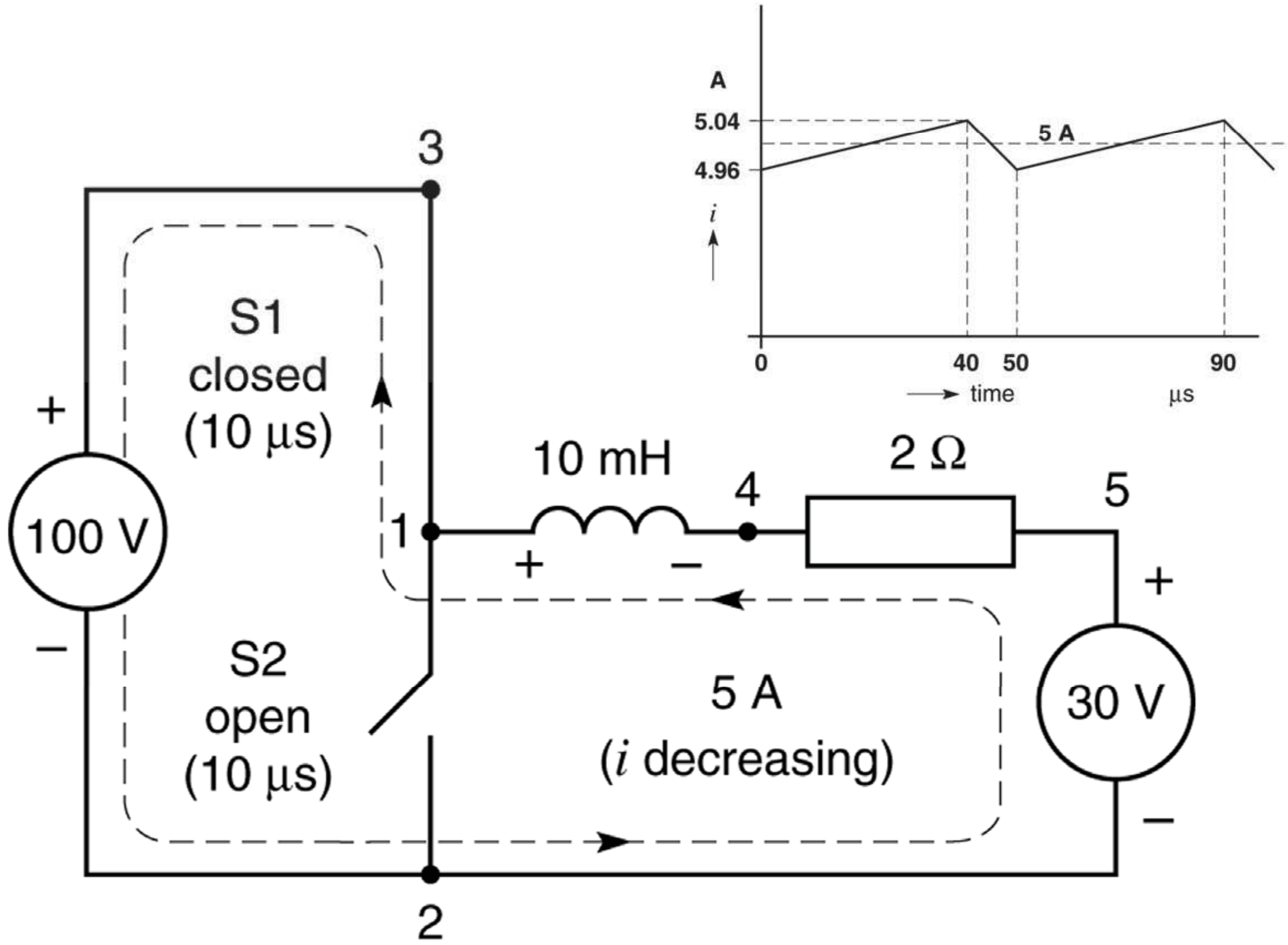


Figure 21.69 **Two-quadrant electronic converter.**

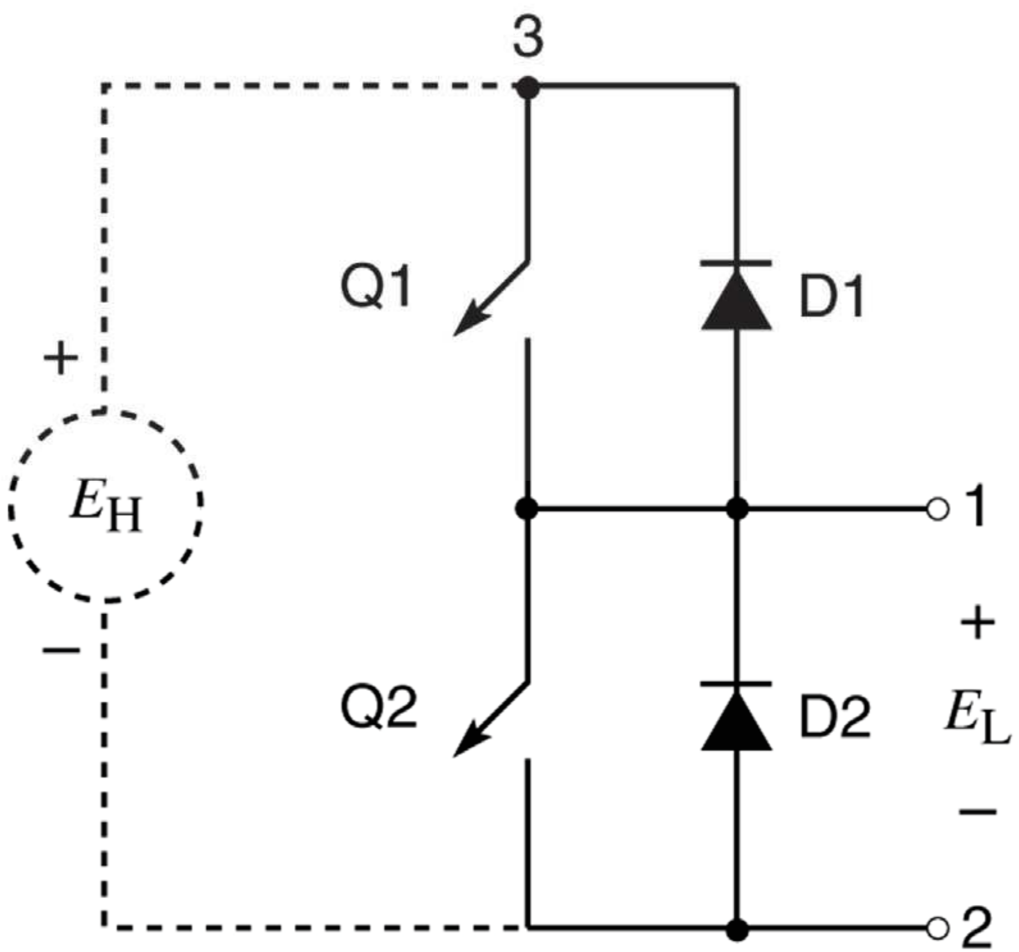
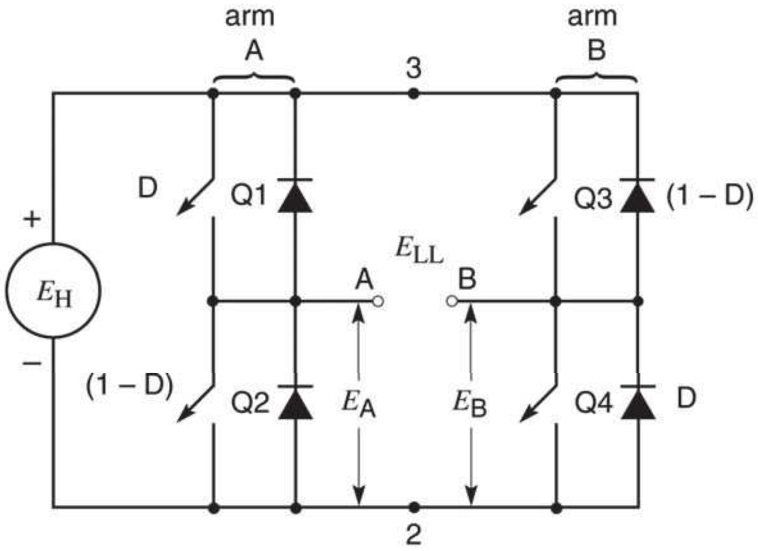


Figure 21.70 **Four-quadrant dc-to-dc converter.**

- $E_L = D\,E_H = 20V$



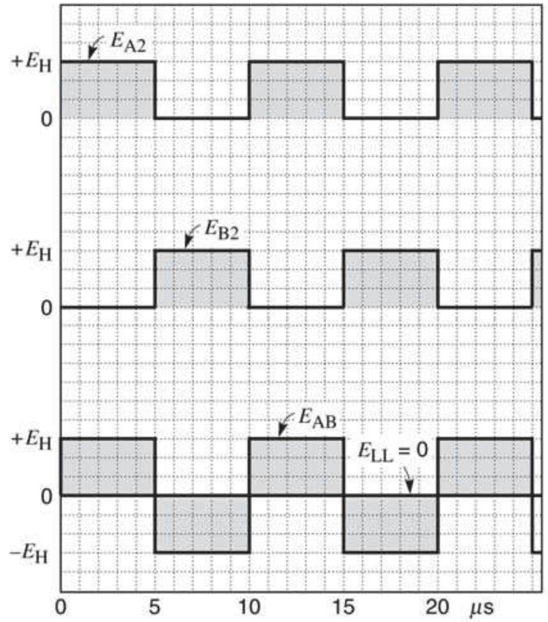
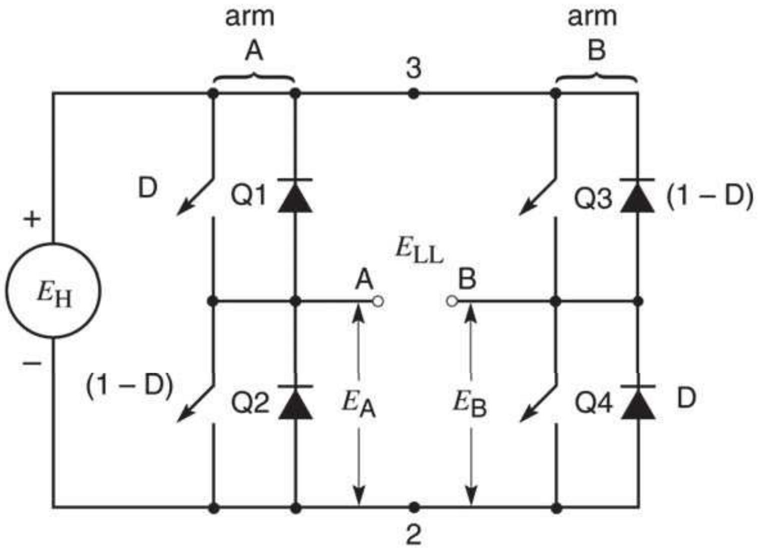


Figure 21.70 **Four-quadrant dc-to-dc converter.**

- $E_{LL} = E_H (2D-1)$



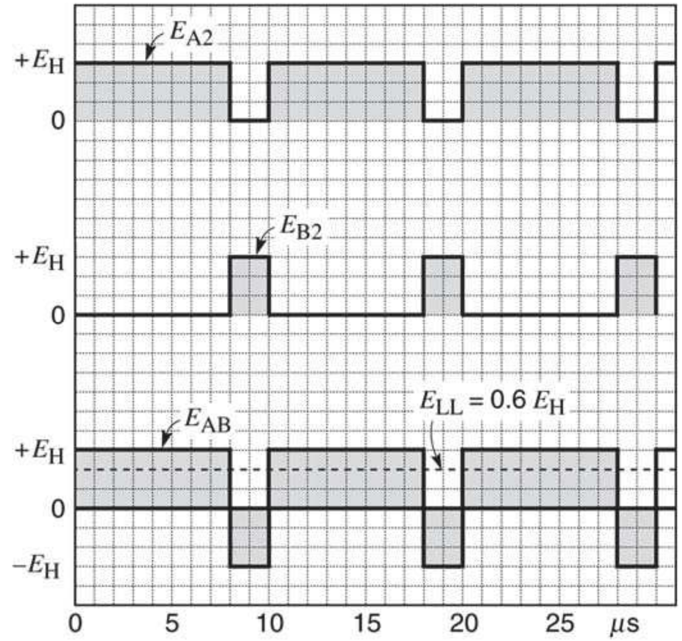


Figure 21.73 **Four-quadrant dc-to-dc converter feeding a passive dc load *R*.**

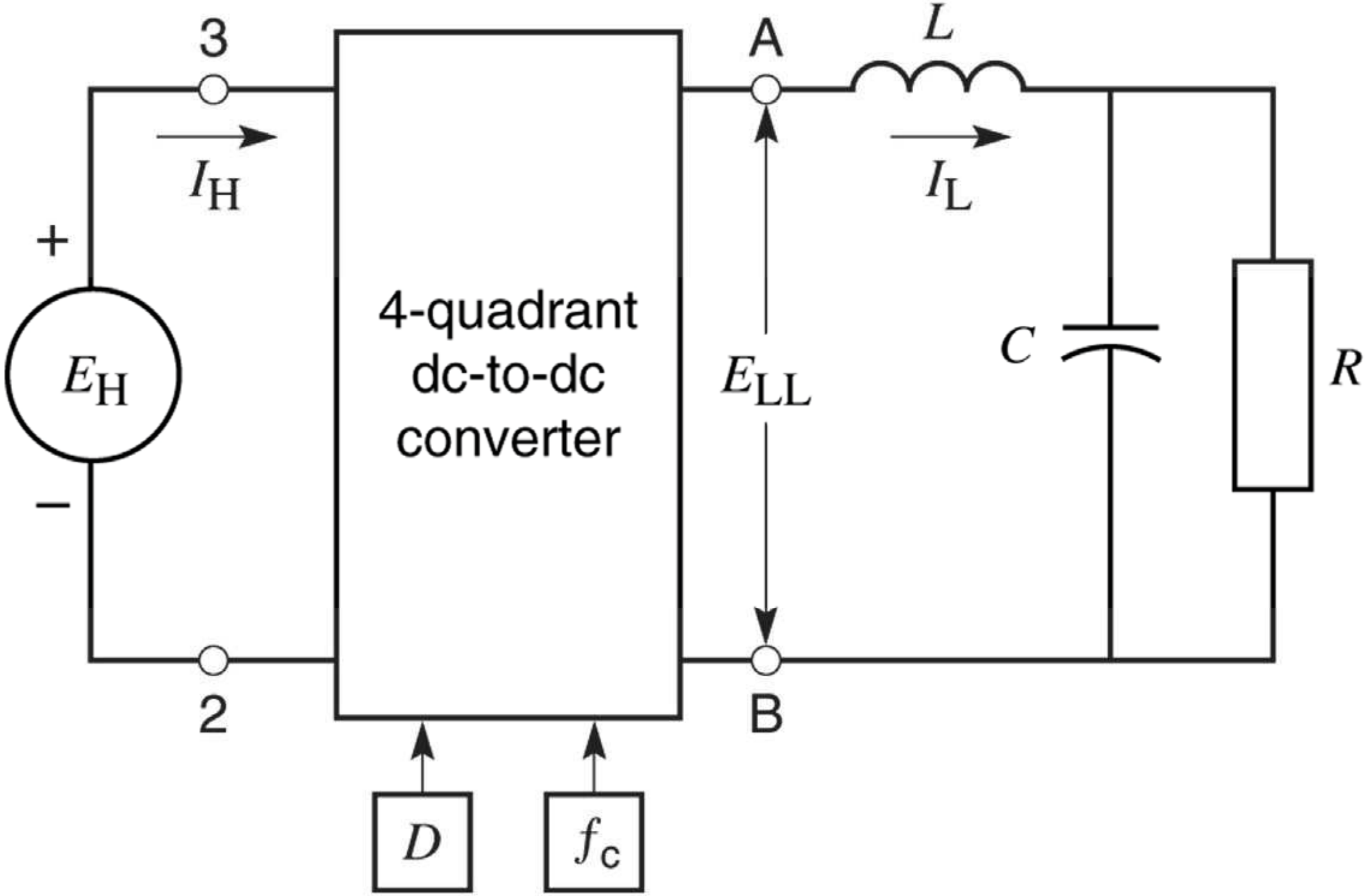


Figure 21.74 **Four-quadrant dc-to-dc converter feeding an active dc source/sink E_o.**

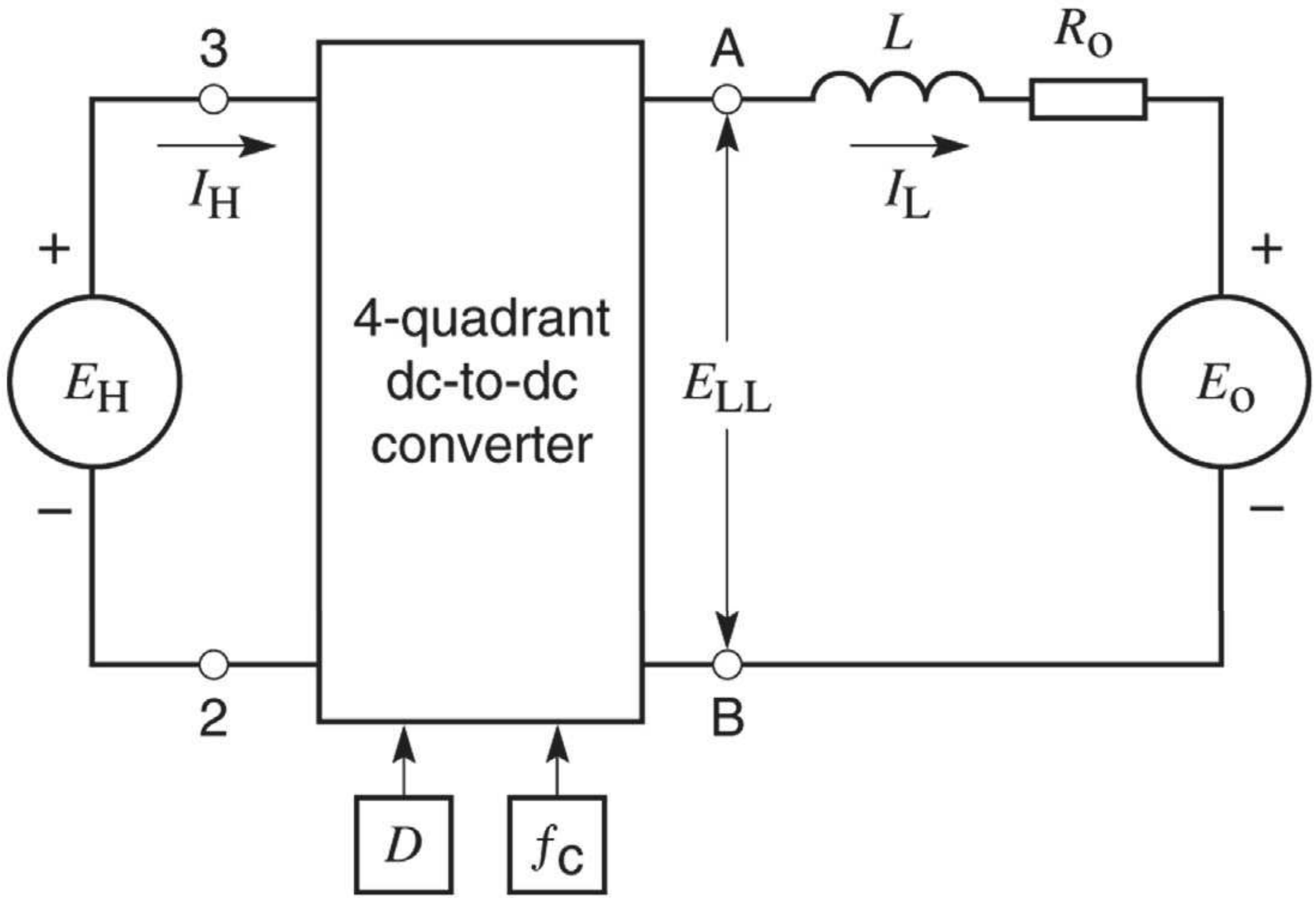


Figure 21.75a **Switching semiconductor and snubber.**

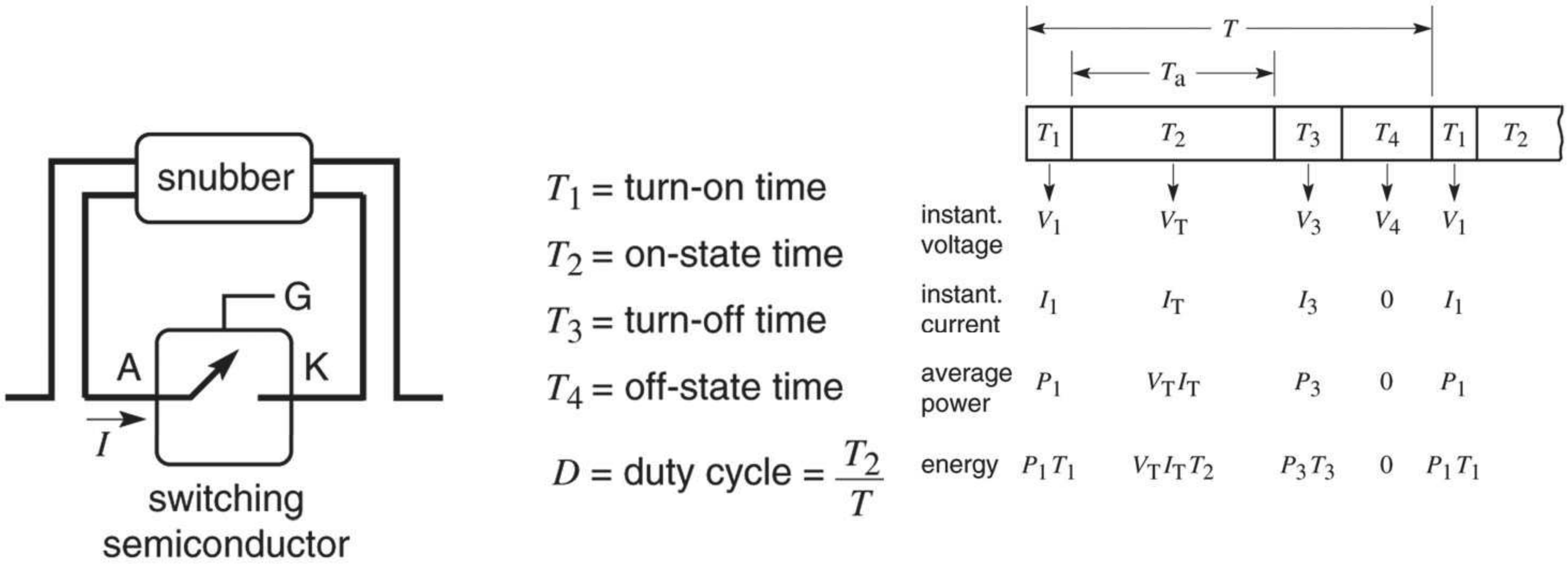


Figure 21.76a **The square wave contains a fundamental sinusiodal component.**

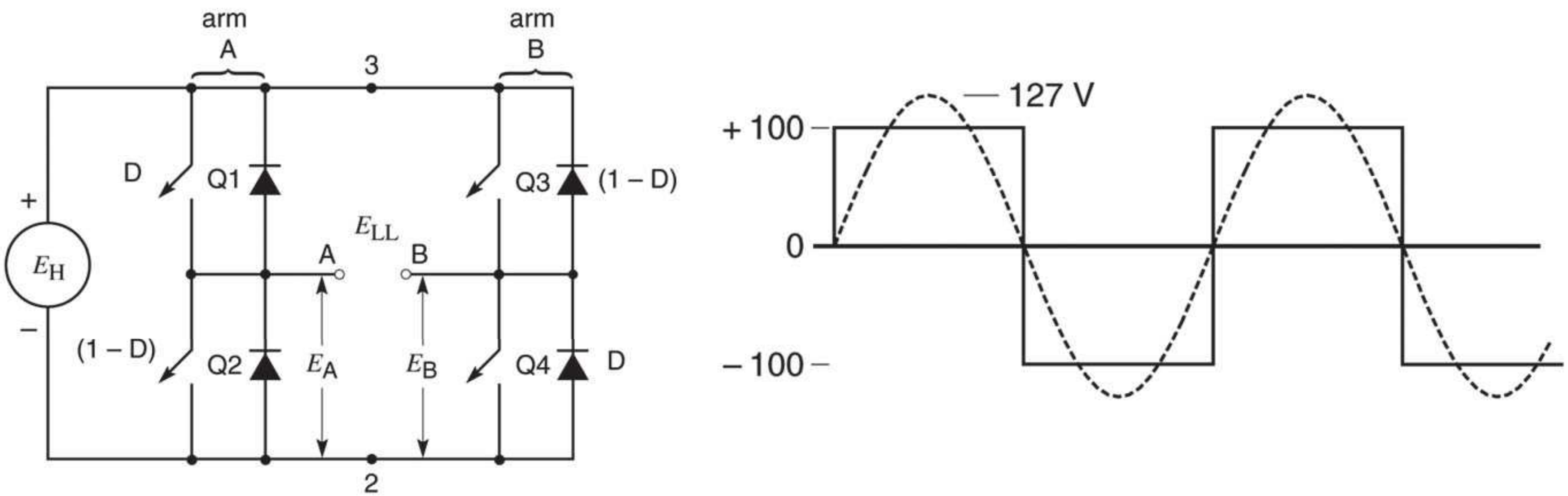


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Figure 21.76b **Single-phase dc-to-ac switching converter in which D = 0.5 and *f* can be varied.**

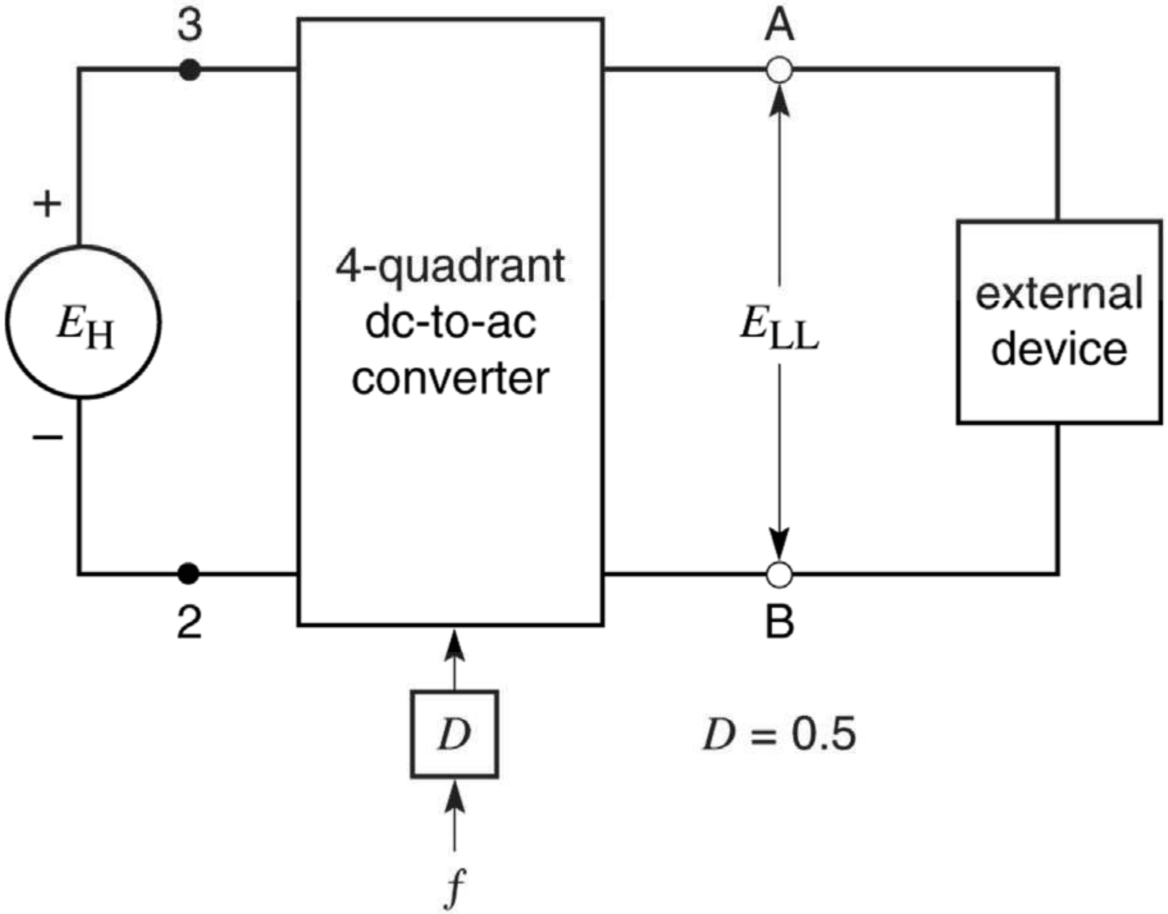
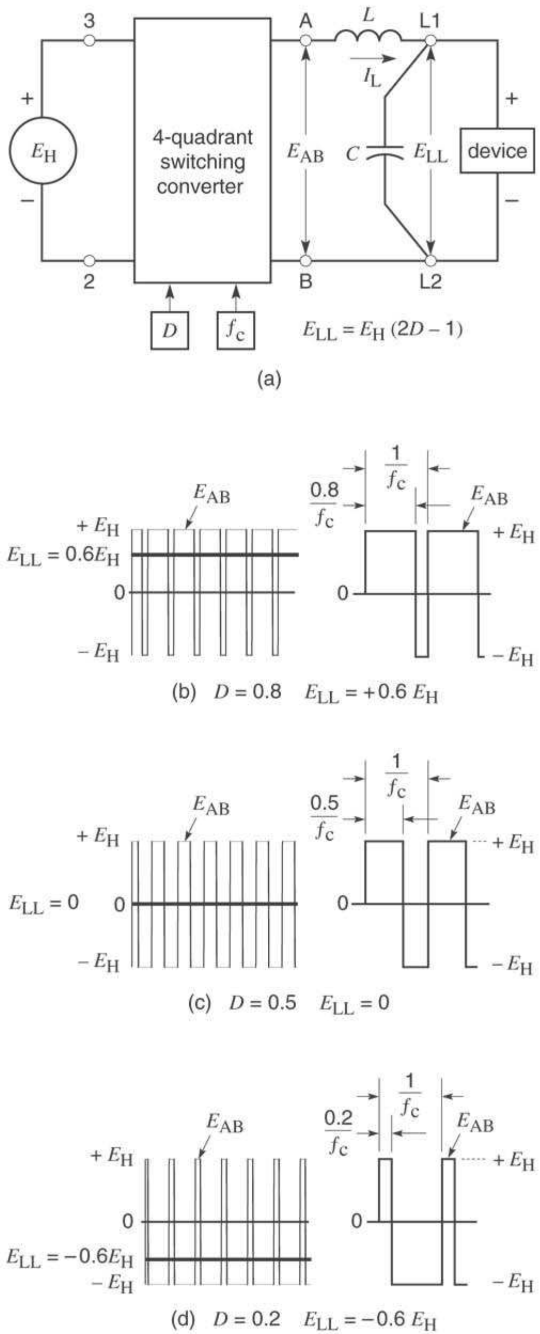


Figure 21.77 **Four-quadrant dc-to-ac switching c**



- $E_{LL} = E_H(2D-1)$

Figure 21.78 **Frequency and amplitude control by varying *D*.**

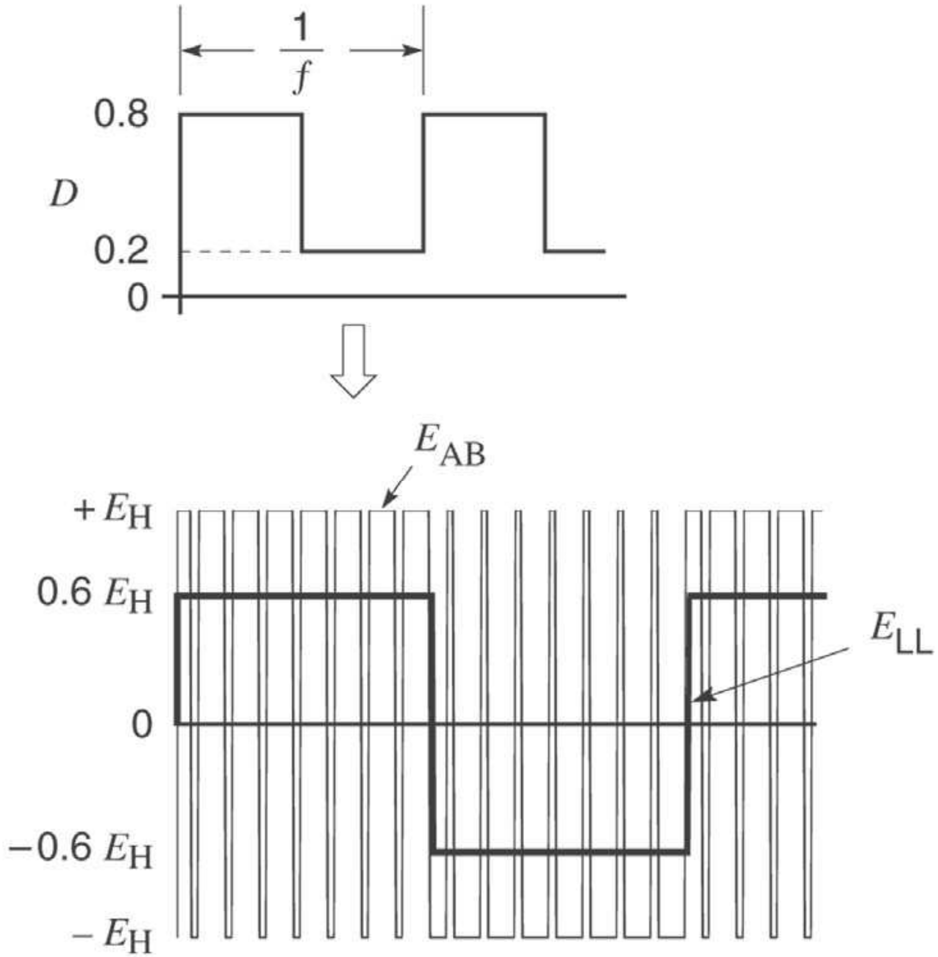


Figure 21.79 **Frequency, amplitude, and phase control by varying *D*.**

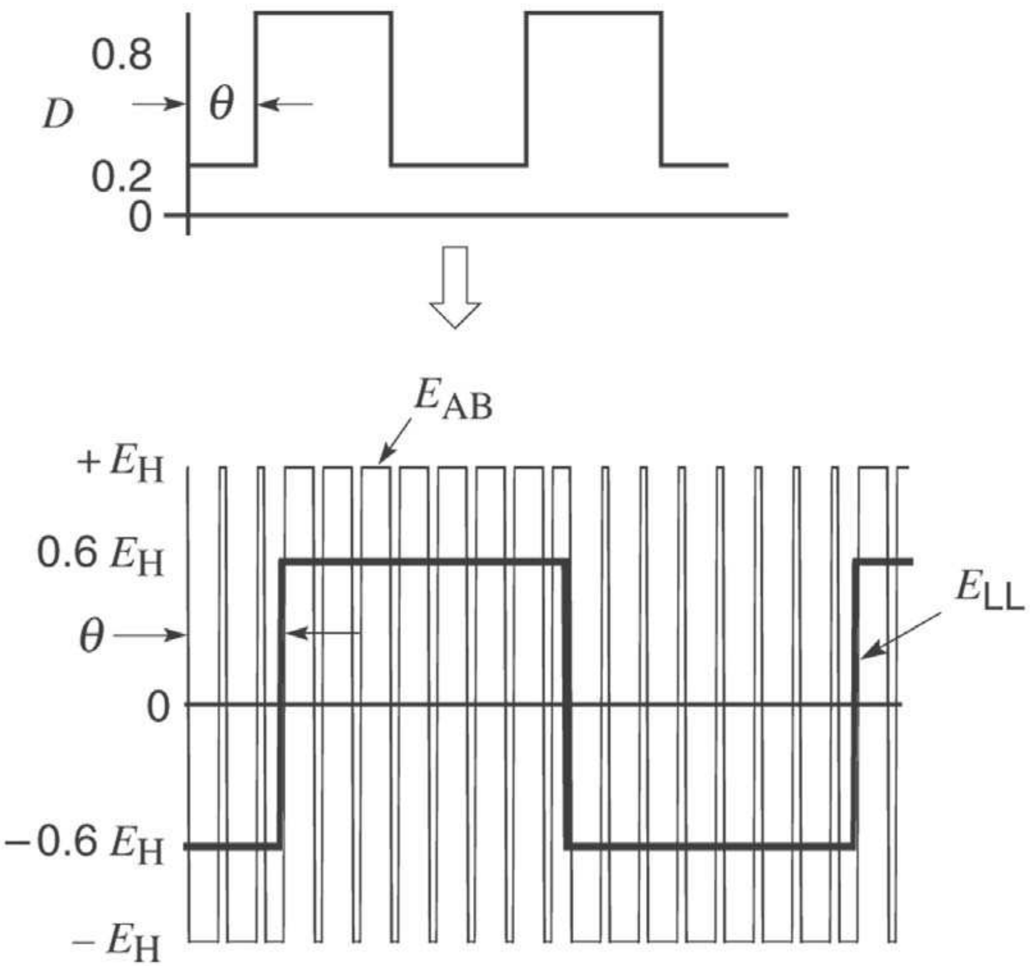


Figure 21.80 **Waveshape control by varying *D*.**