Power Electronics
4. Thyristors Converters

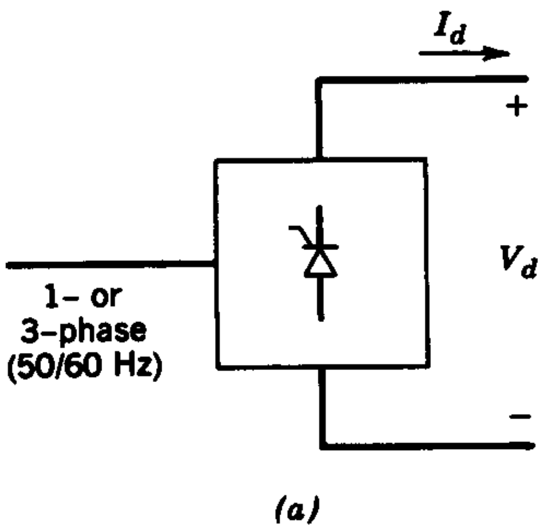
Dr inż. Dariusz Janiszewski

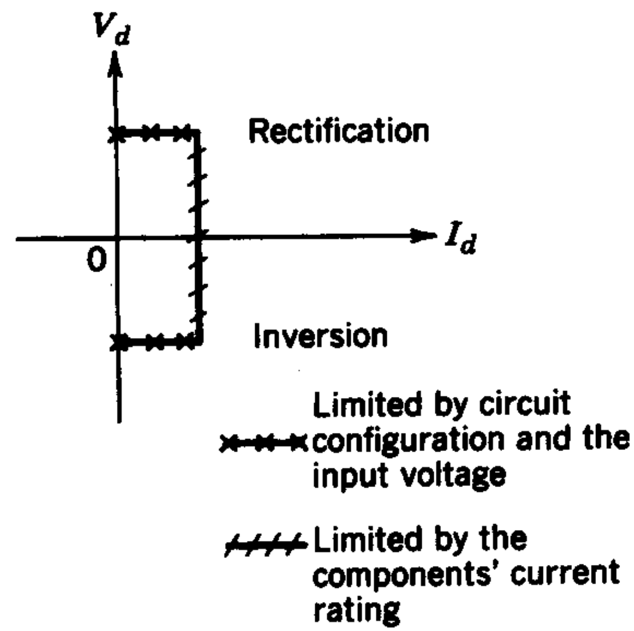
Prostowniki sterowalne (tyrystorowe)
Controlled conversion of AC into DC

- Wprowadzenie
- Obwody tyrystorowe i ich sterowanie
- Prostowniki jednofazowe
- Prostowniki trójfazowe
- Prostowniki wielofazowe

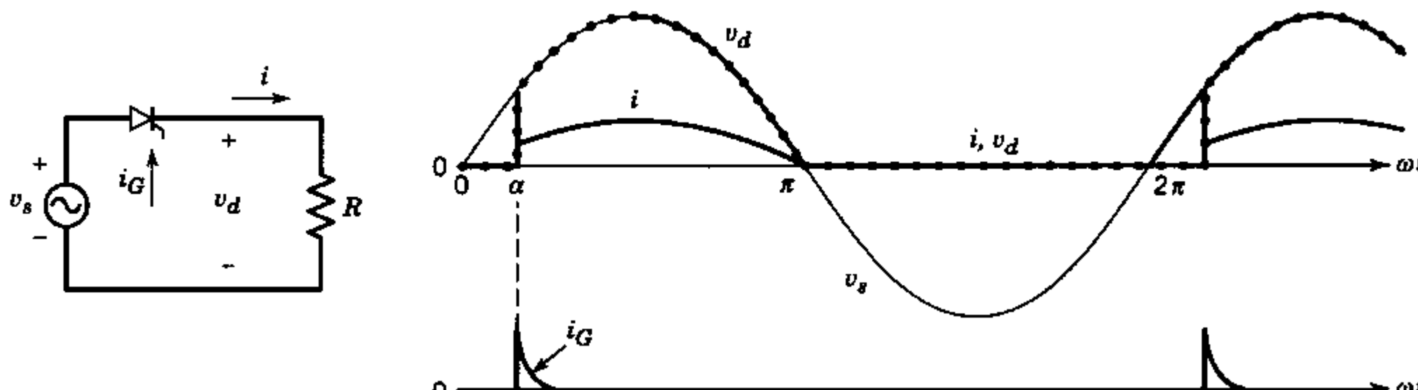
Thyristor Converters

- Two-quadrant conversion

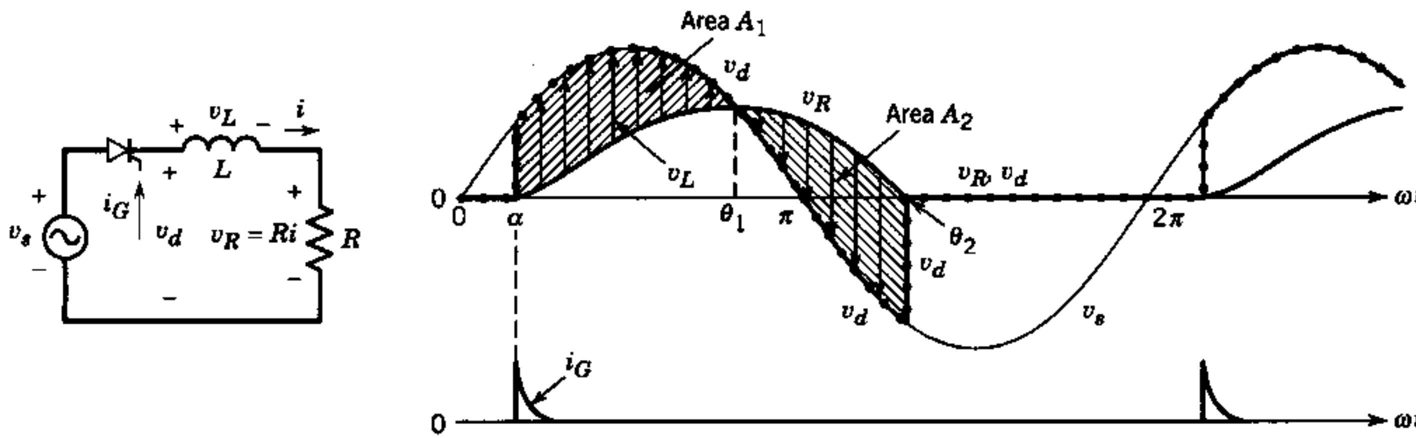




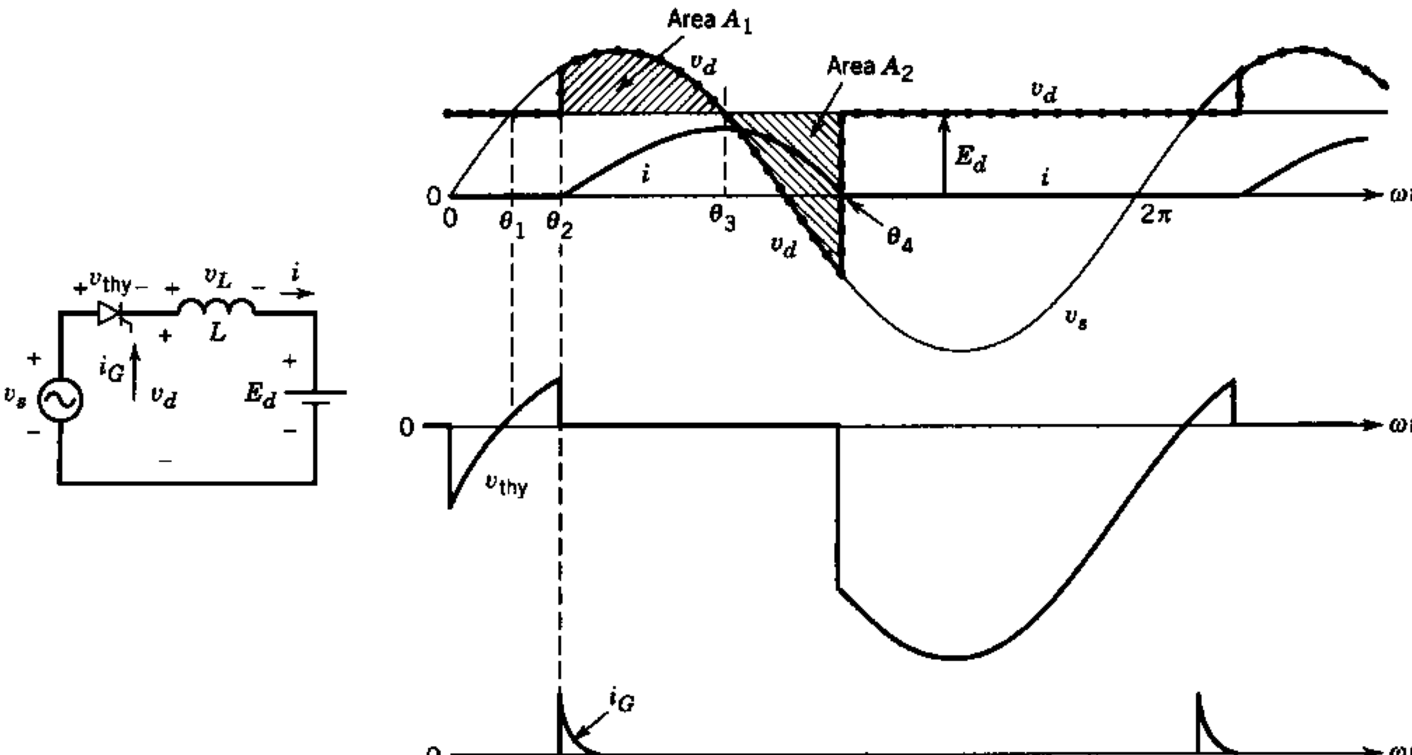
Primitive circuits with thyristors
R load



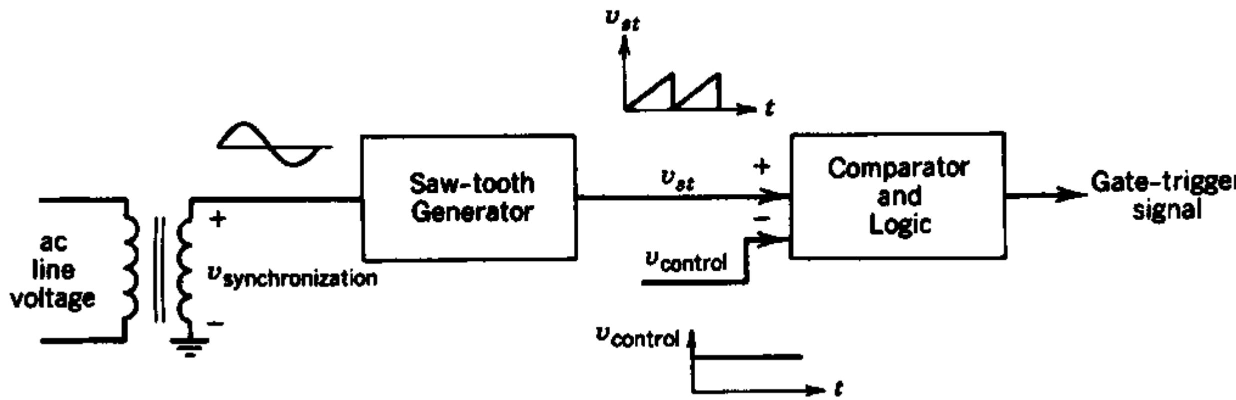
Primitive circuits with thyristors
RL load

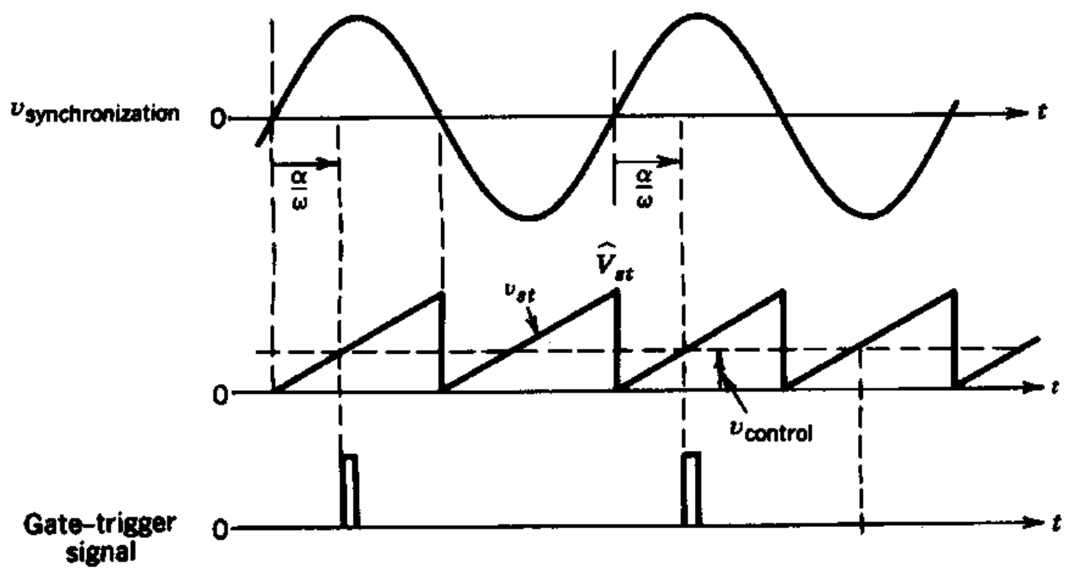


Primitive circuits with thyristors
RLE load



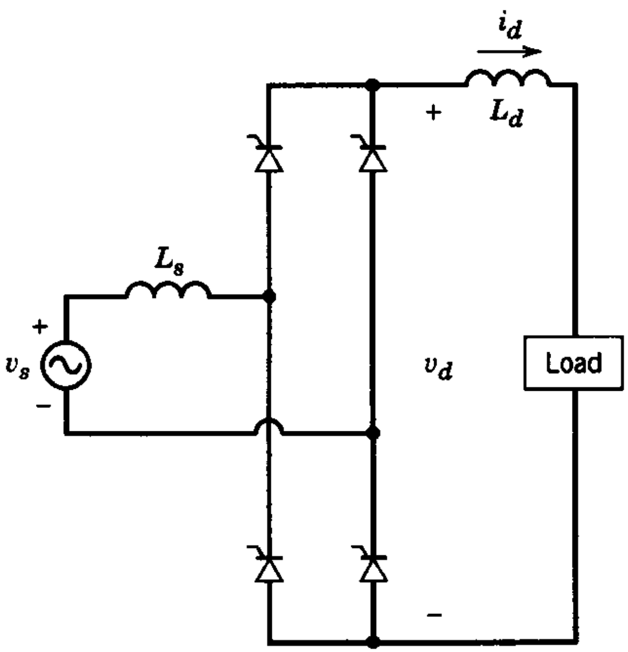
Thyristor Triggering

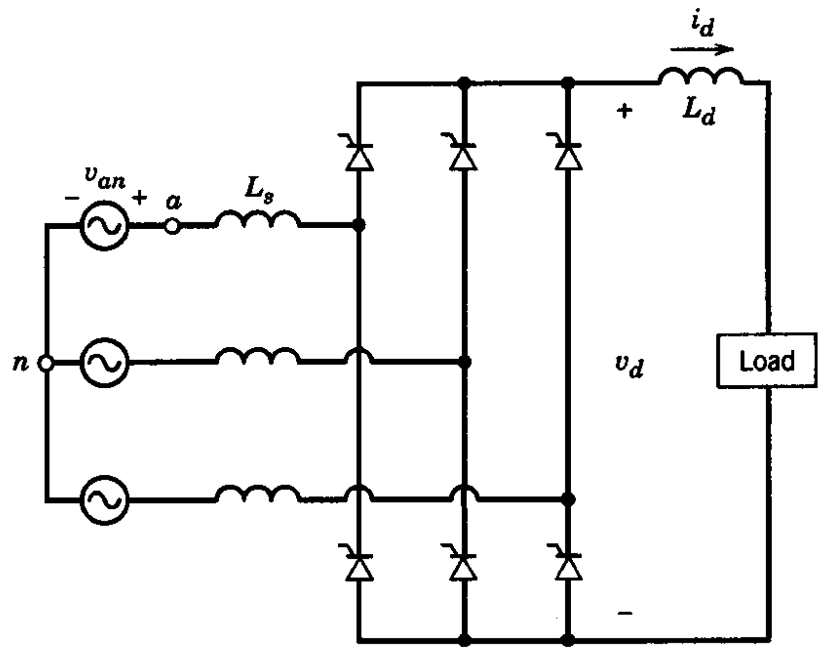




Full-Bridge Thyristor Converters

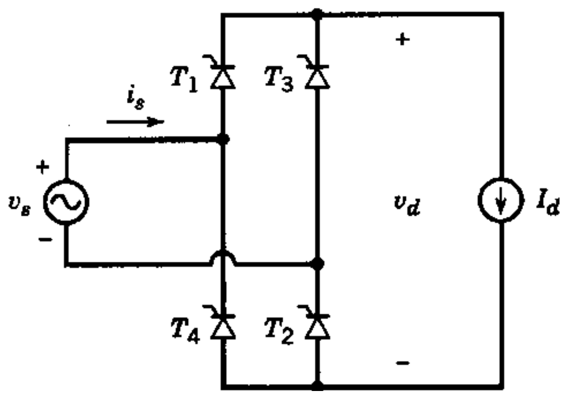
- Single-phase and three-phase

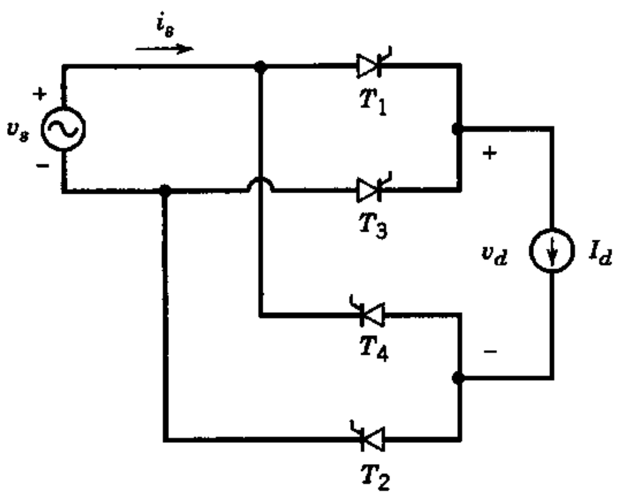


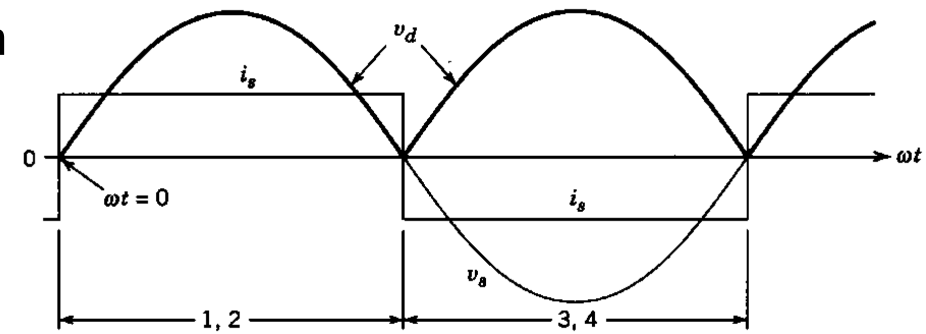


Single Phase Thyristor Converter Waveforms

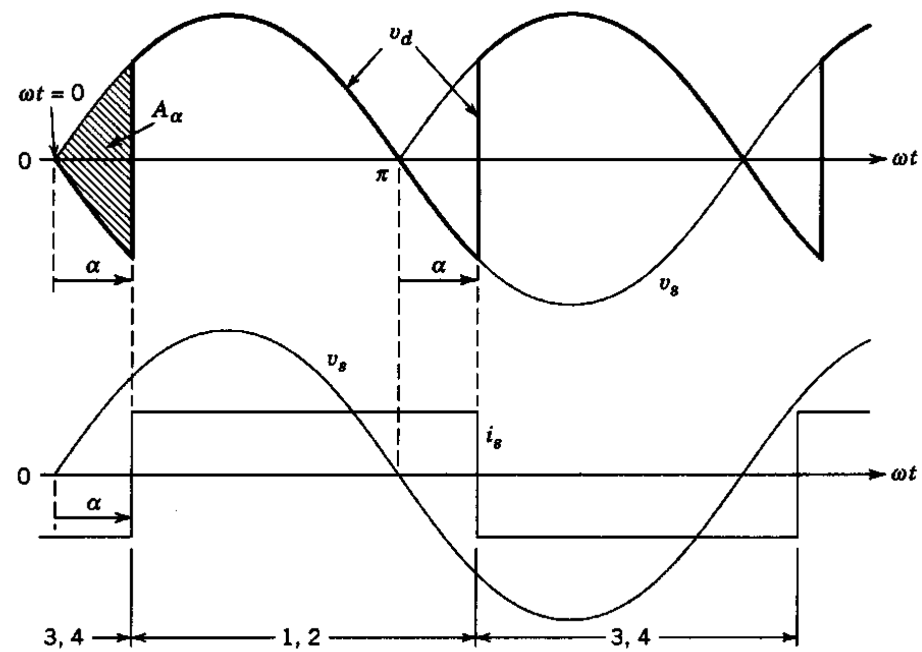
- Two groups with two thyristor each
- Assuming zero ac-side inductance





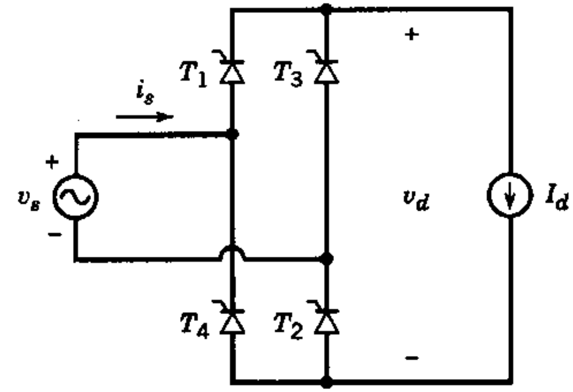


(a) $\alpha = 0$



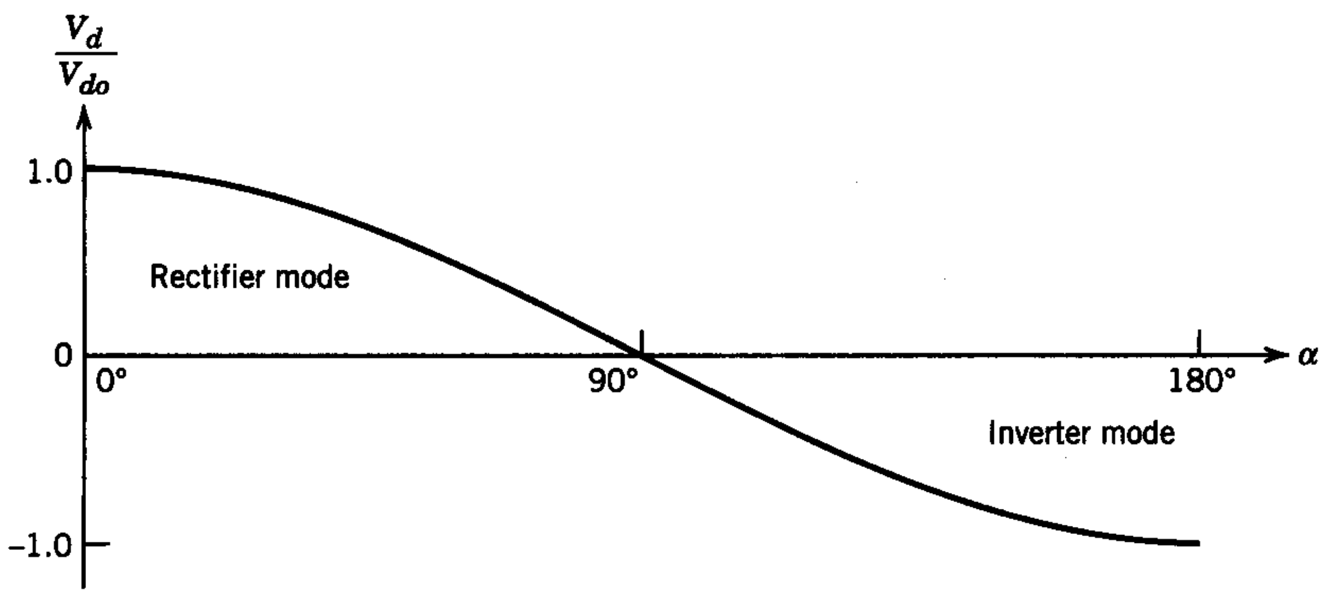
(b) α = finite

Average DC Output Voltage



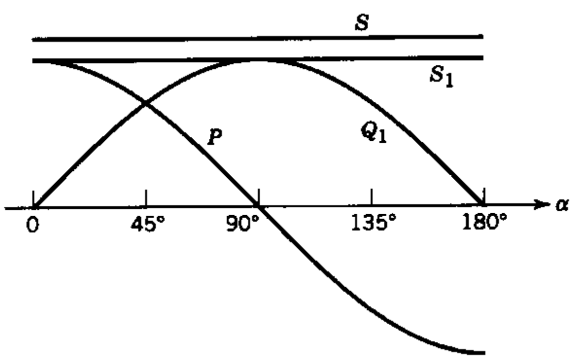
- Assuming zero ac-side inductance

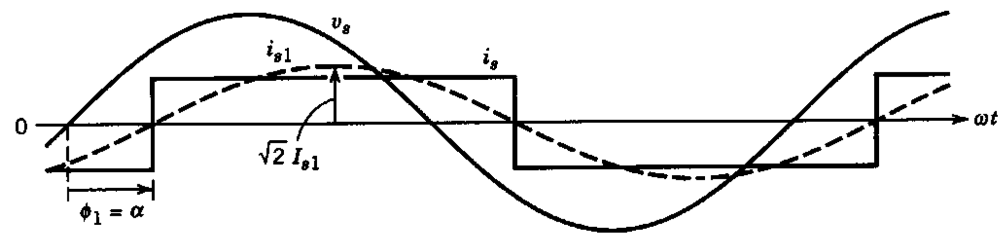
$$V_{d\alpha} = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} \sqrt{2}\,V_s \sin \omega t\, dt = \frac{2\sqrt{2}}{\pi} V_s \cos \alpha$$

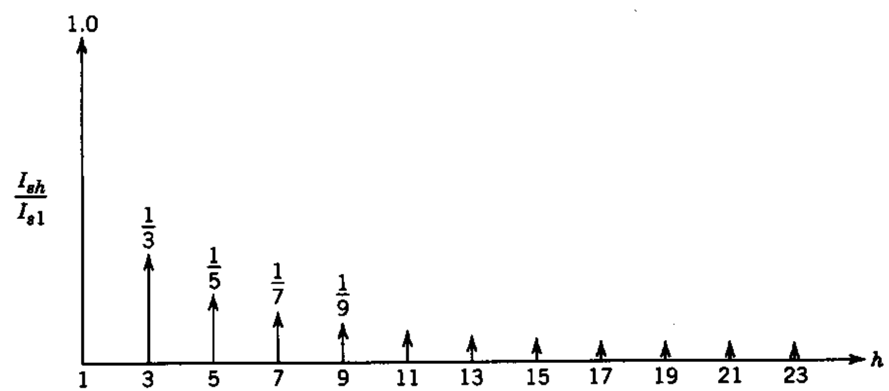


Input Line-Current Waveforms

- Harmonics, power and reactive power

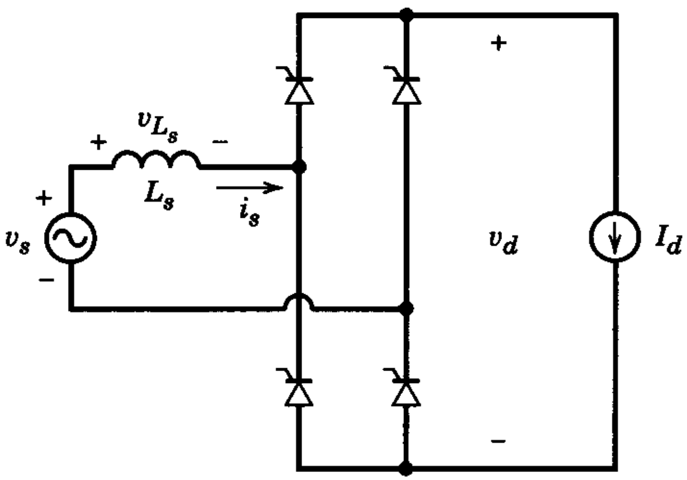


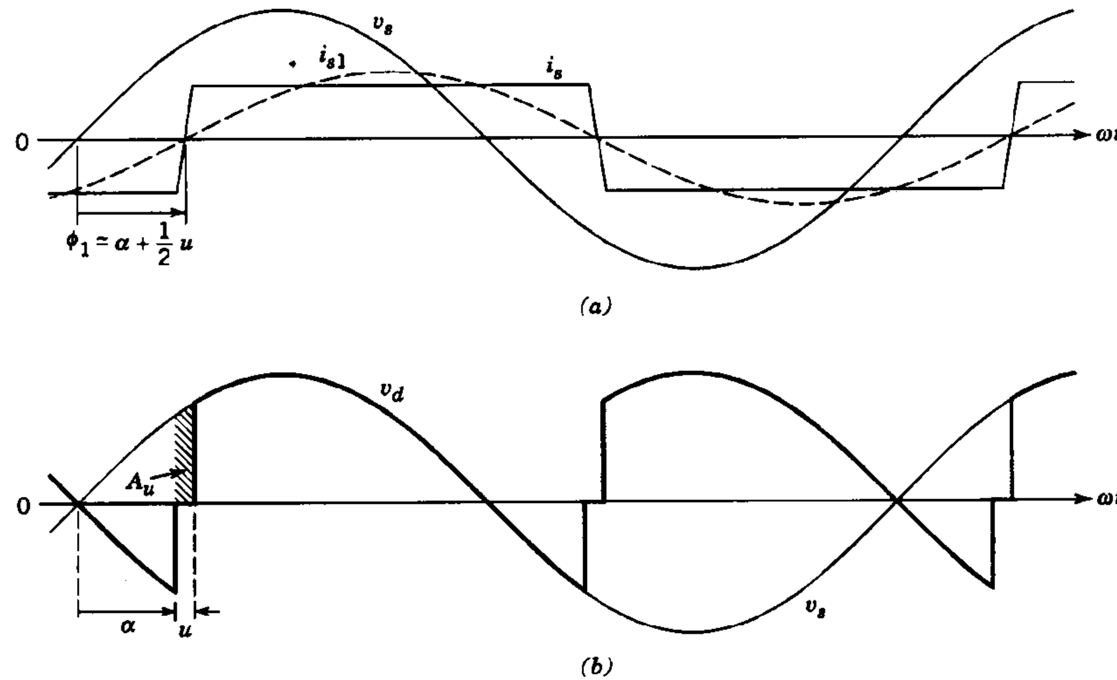




OnePhase Thyristor Converter Waveform

- Finite ac-side inductance; constant dc output current

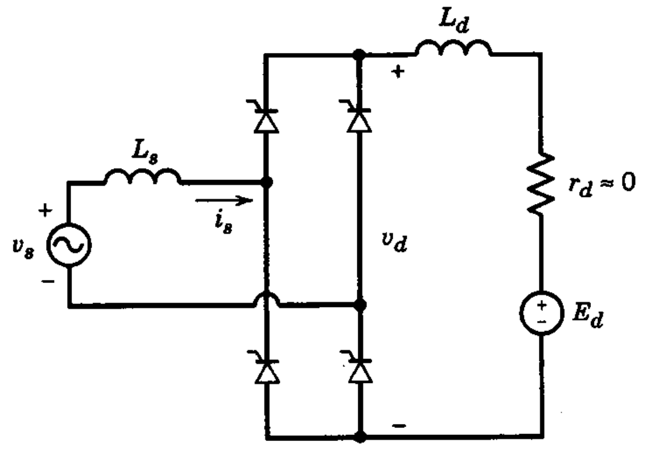


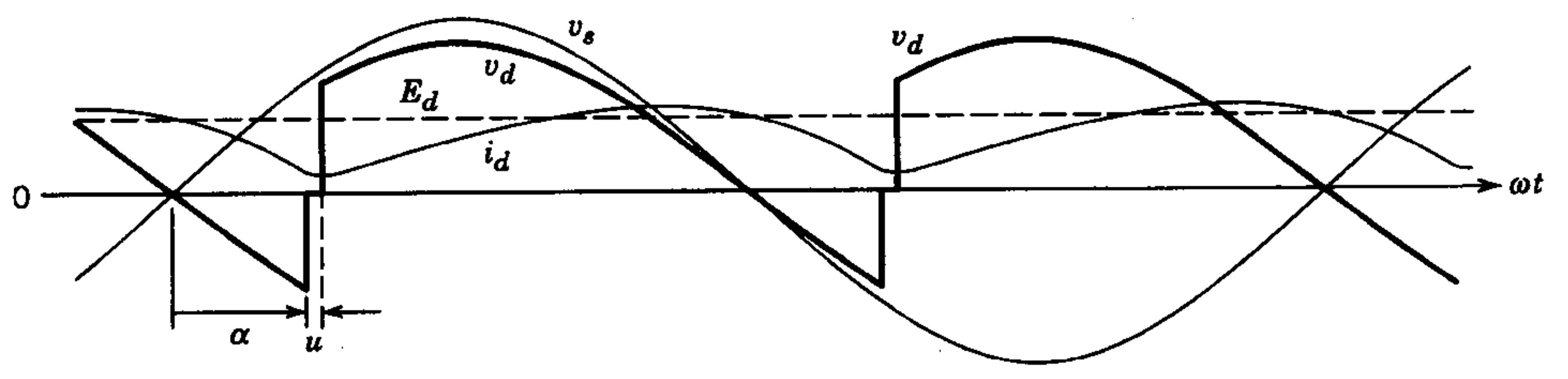


$$V_{d\alpha} = \frac{2\sqrt{2}}{\pi} V_s \cos\alpha - \frac{2}{\pi}\omega L_s I_d$$

Thyristor Converter: Discontinuous Mode

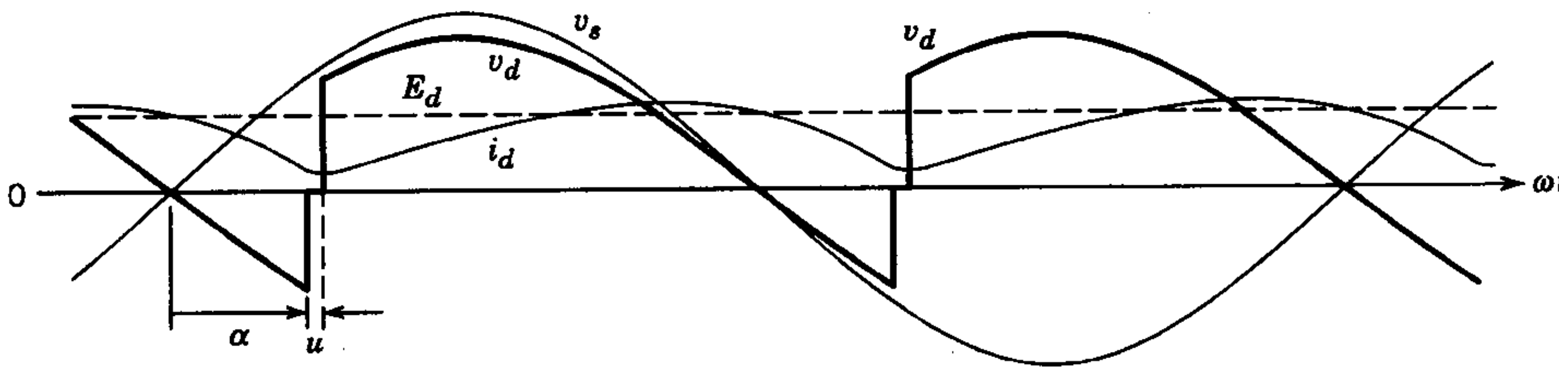
- This mode can occur in a dc-drive at light loads



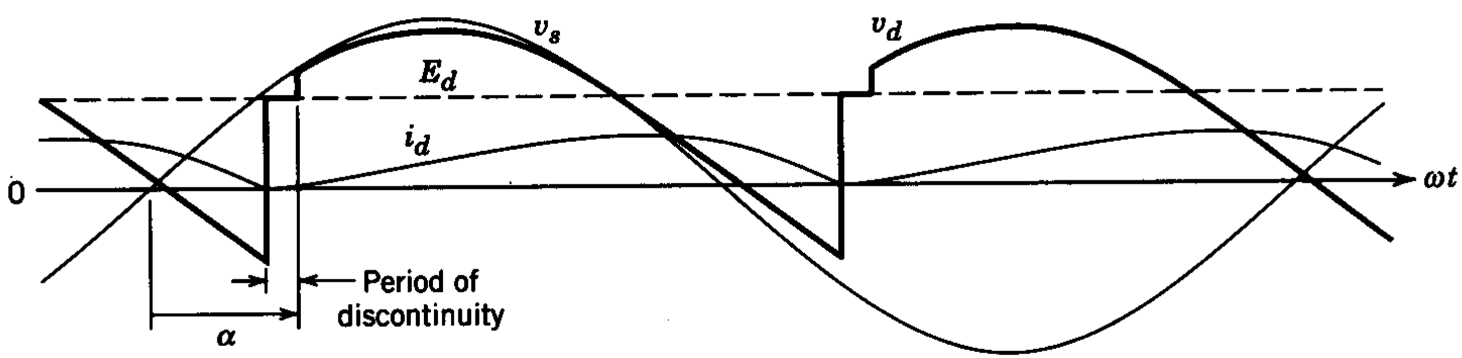


(b)

Thyristor Converter Waveforms: Discontinuous Conduction Mode

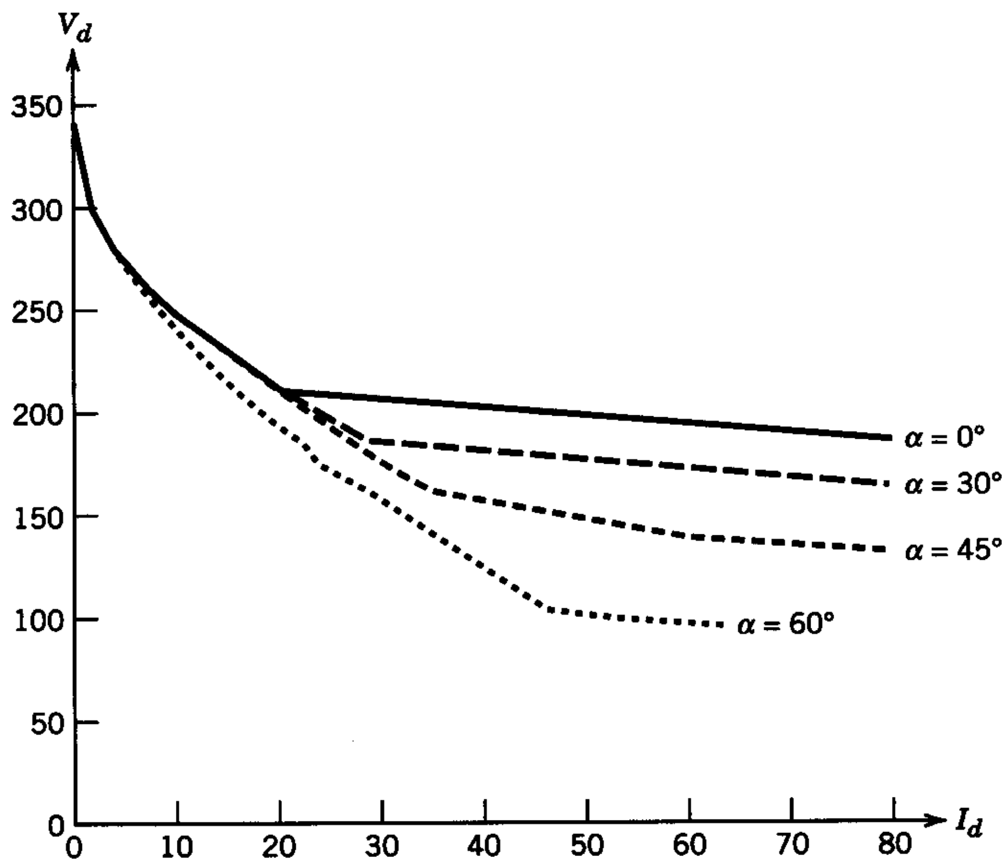


(b)



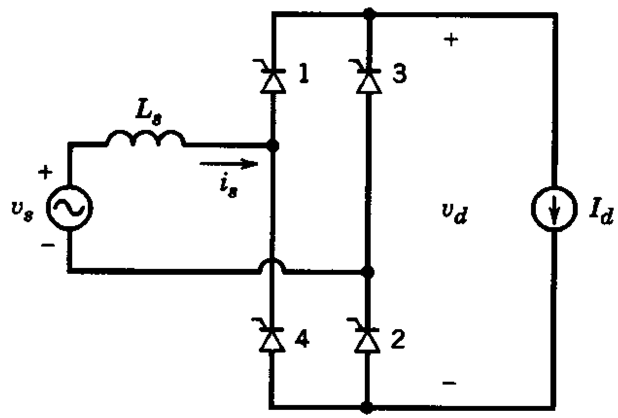
DC Voltage versus Load Current

- Various values of delay angle

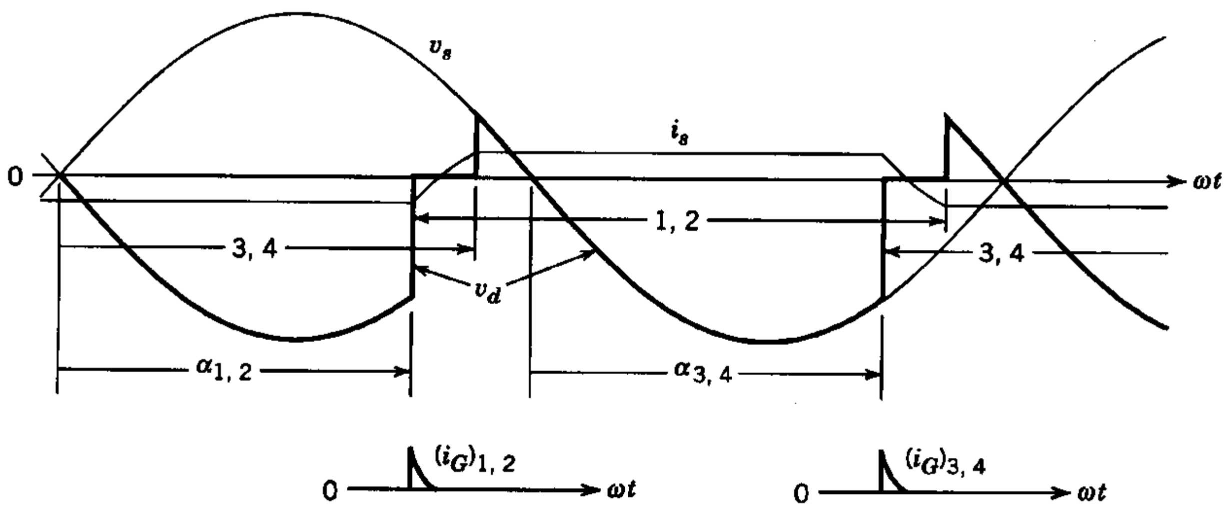


Thyristor Converters: Inverter Mode

- Assuming the ac-side inductance to be zero



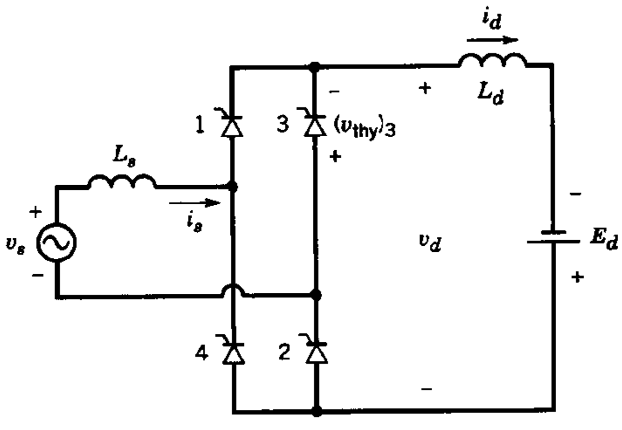
(a)



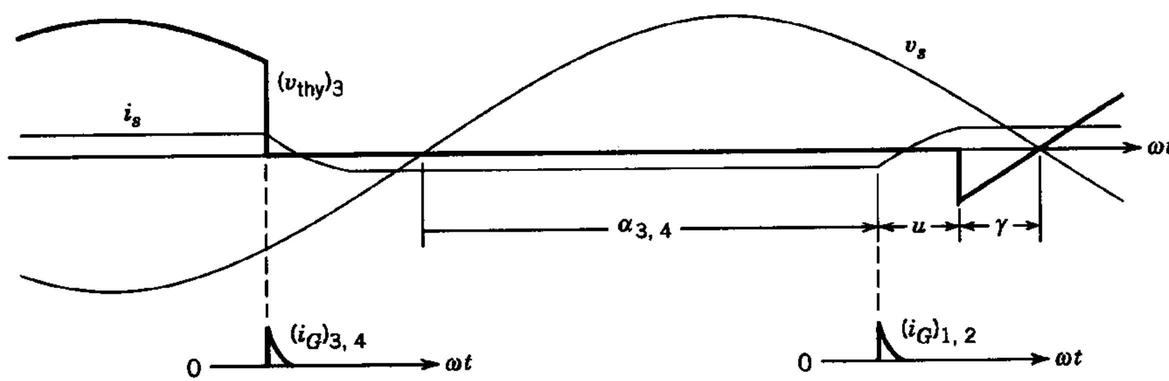
(b)

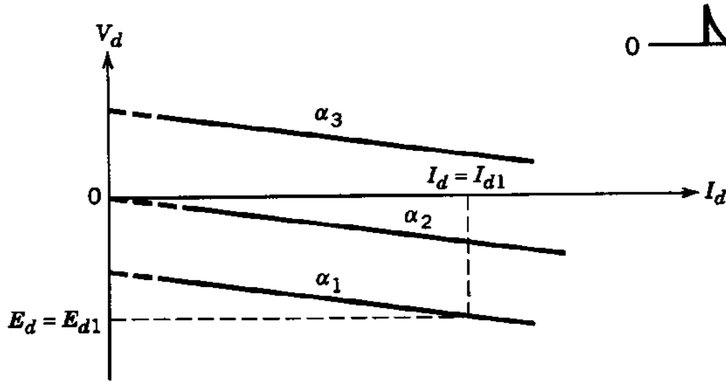
Thyristor Converters: Inverter Mode

- Family of curves at various values of delay angle
- Importance of extinction angle in inverter mode

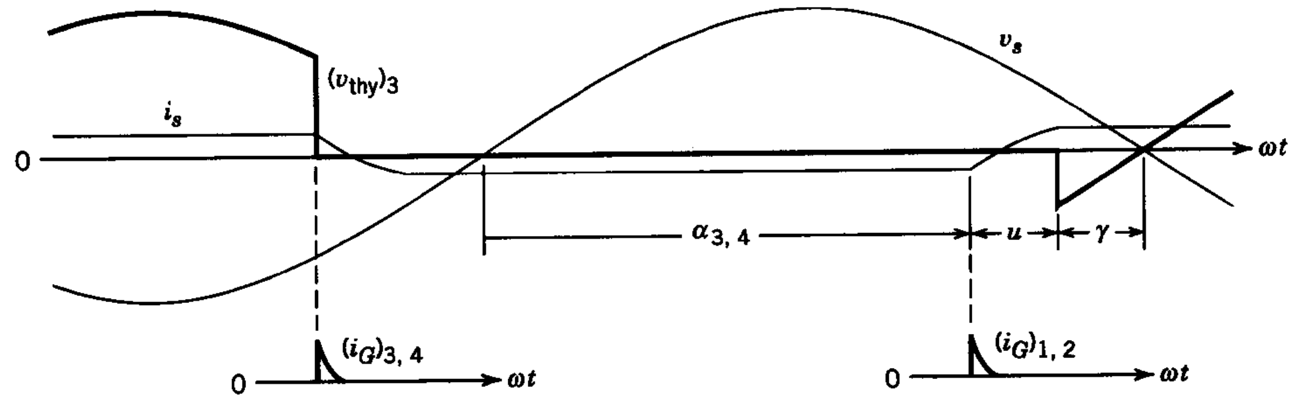


(a)

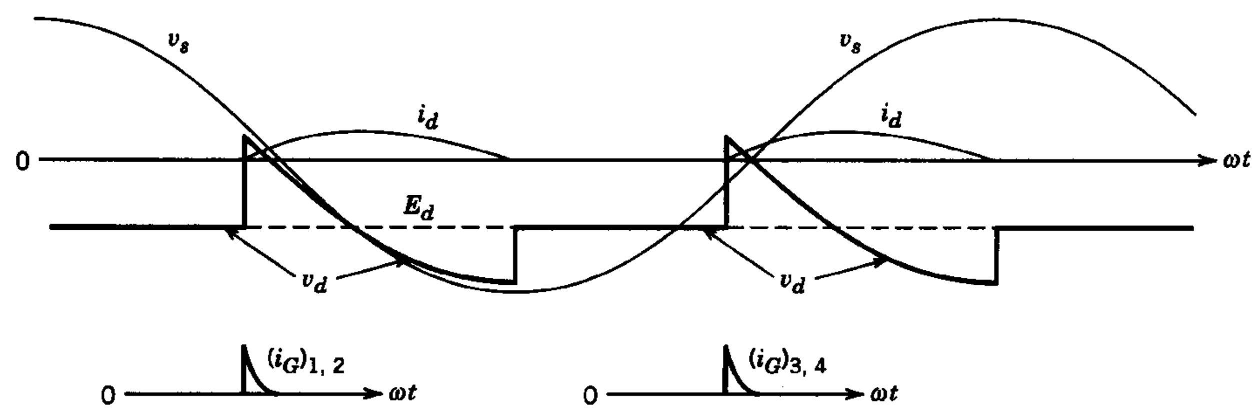




Thyristor Converters: Inverter Mode

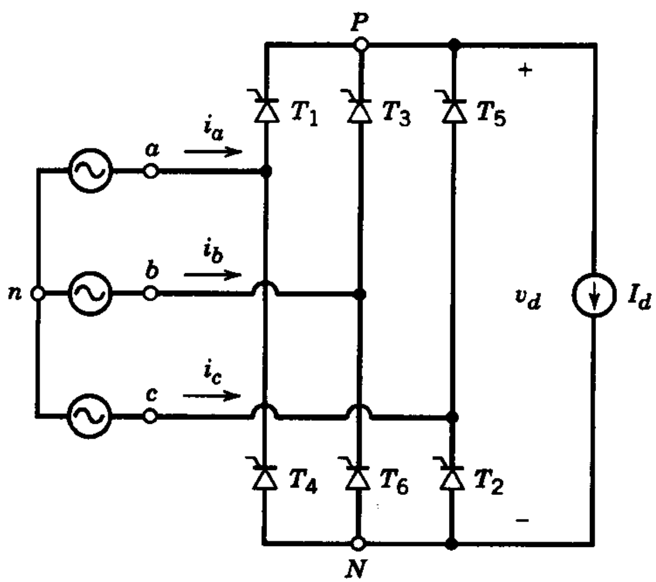


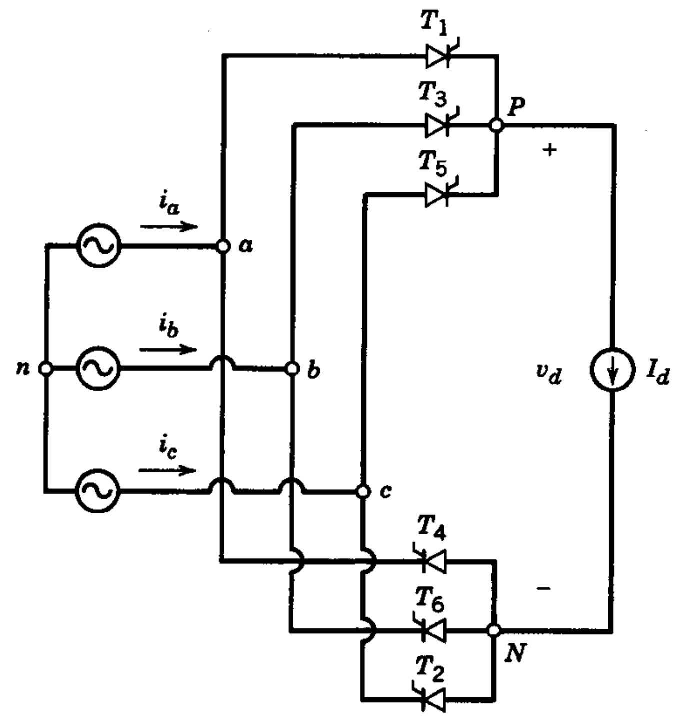
- Waveforms at start-up



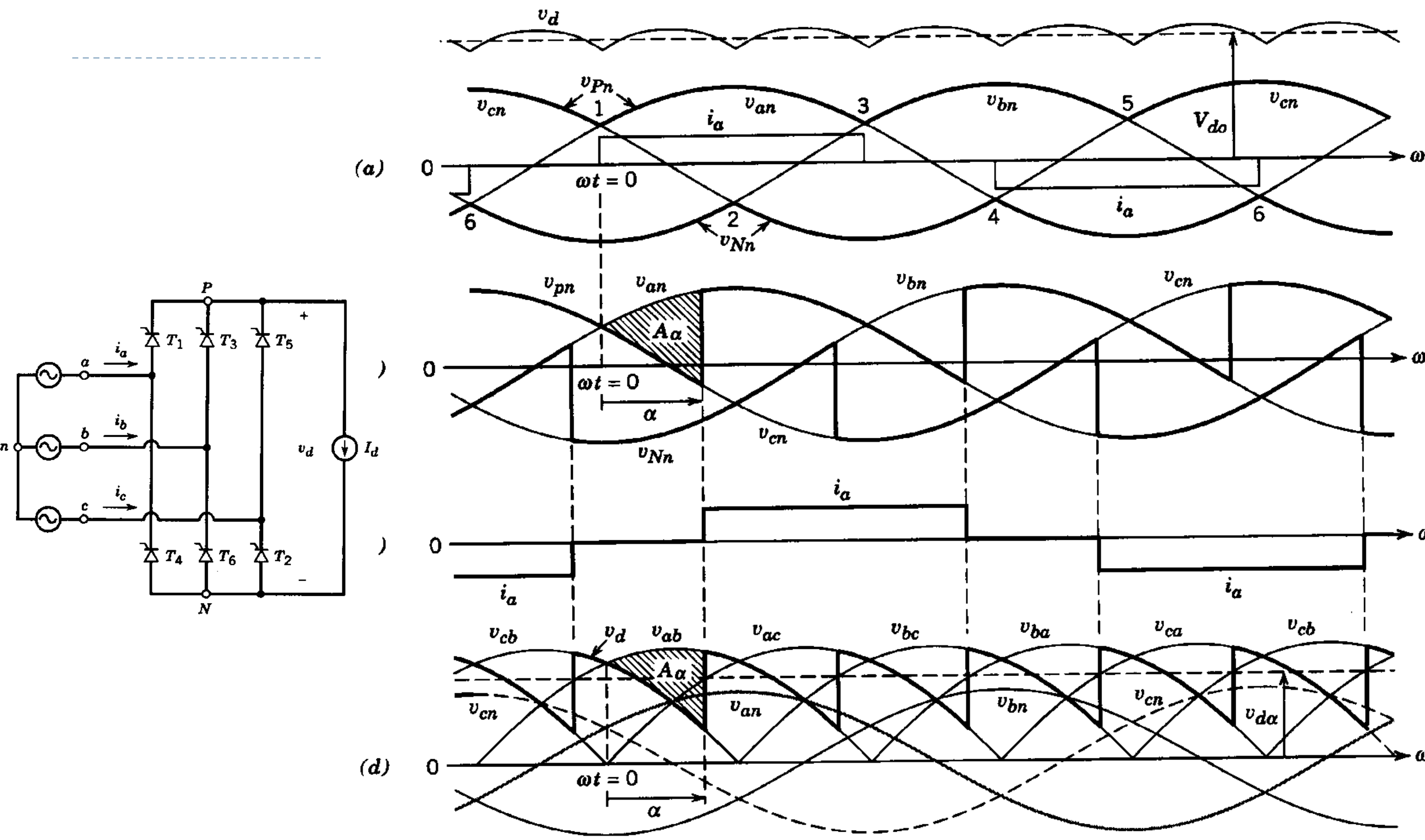
3-Phase Thyristor Converters

- Two groups of three thyristors each





3-Phase Thyristor Converter Waveforms

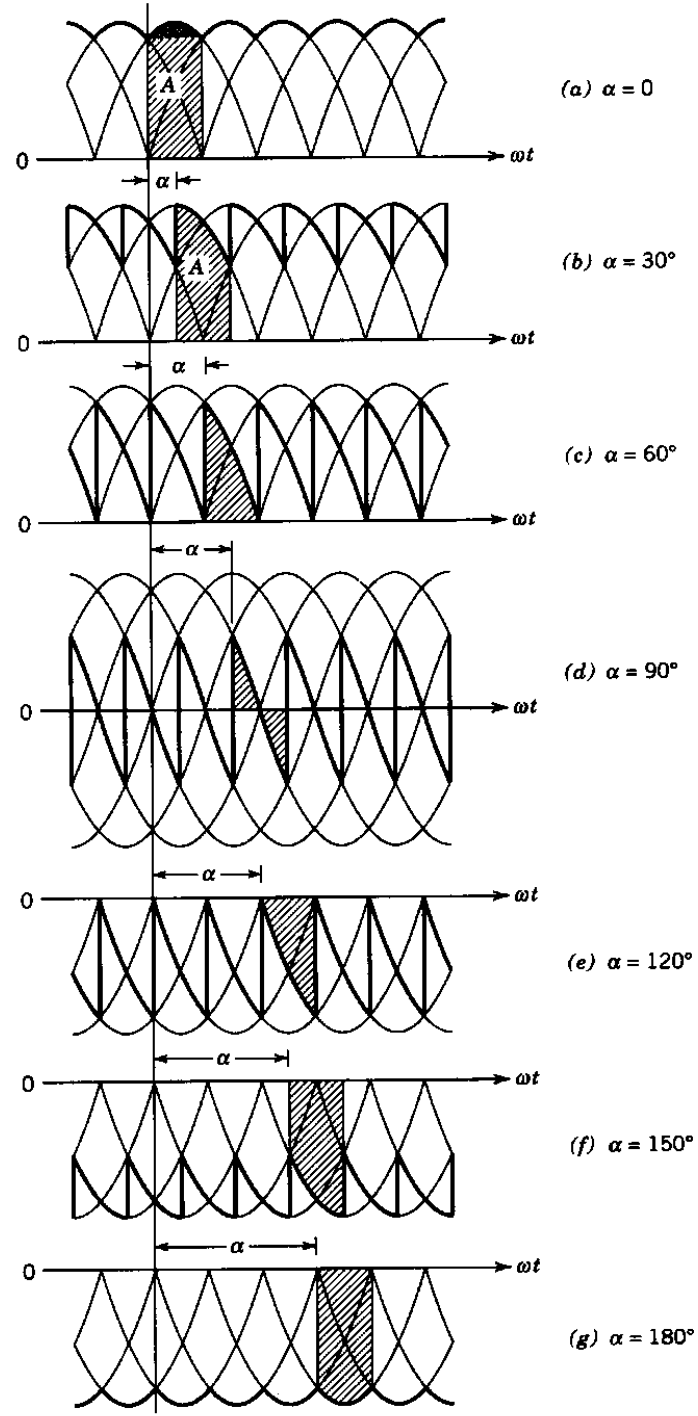


- Zero ac-side inductance; purely dc current

DC-side voltage waveforms

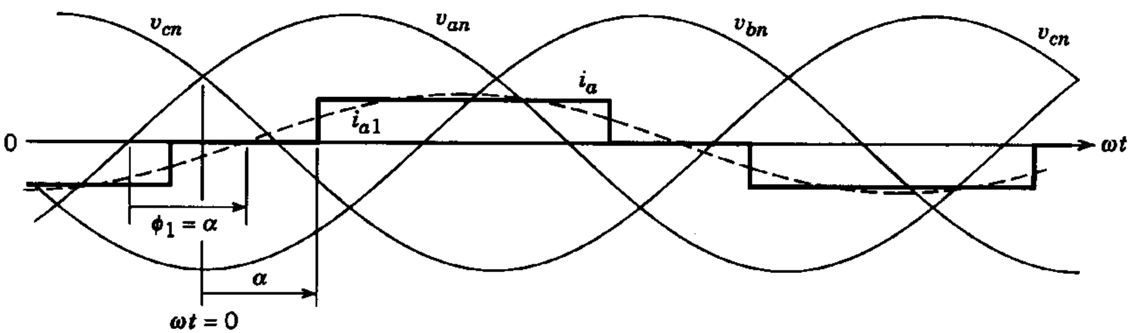
- assuming zero ac-side inductance

$$V_{d\alpha} = \frac{3\sqrt{2}}{\pi} V_{LL} \cos\alpha$$

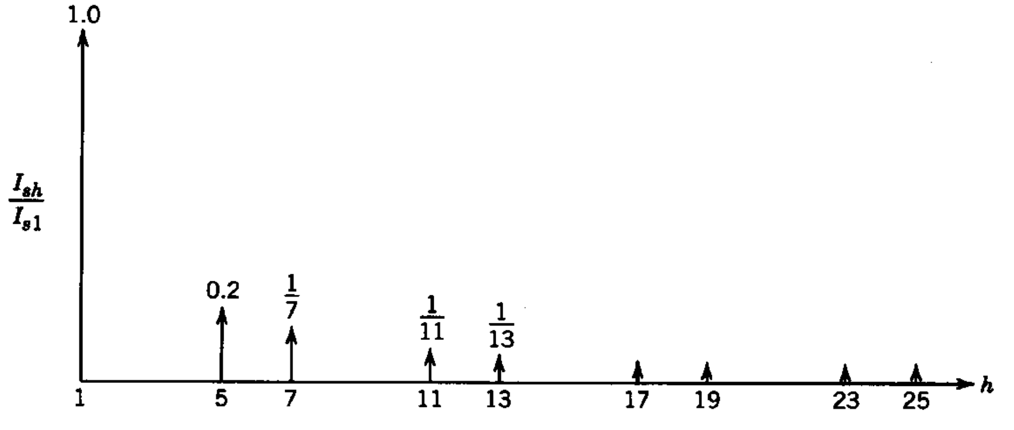


Input Line-Current Waveform

- Zero ac-side inductance

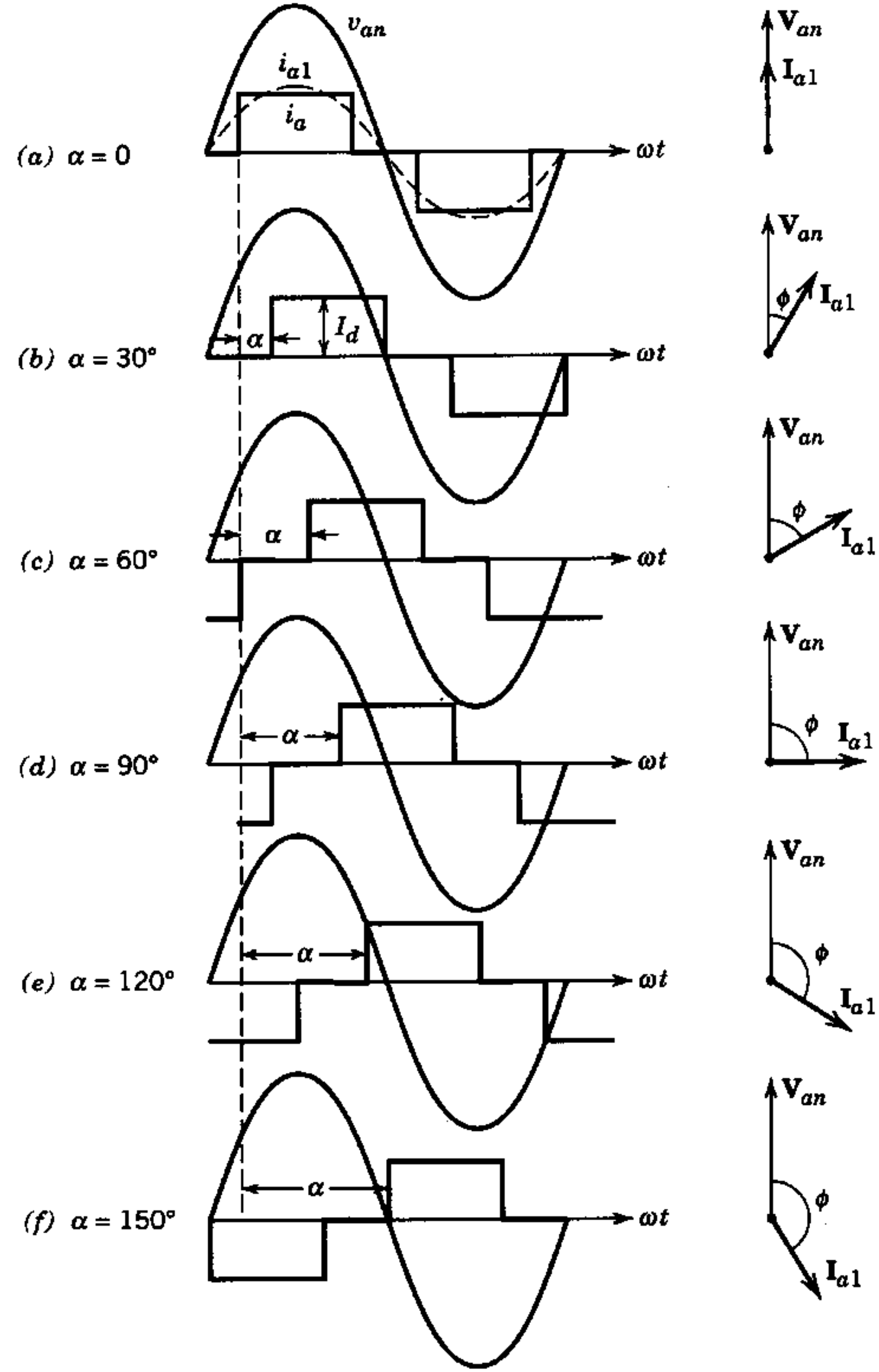


(a)

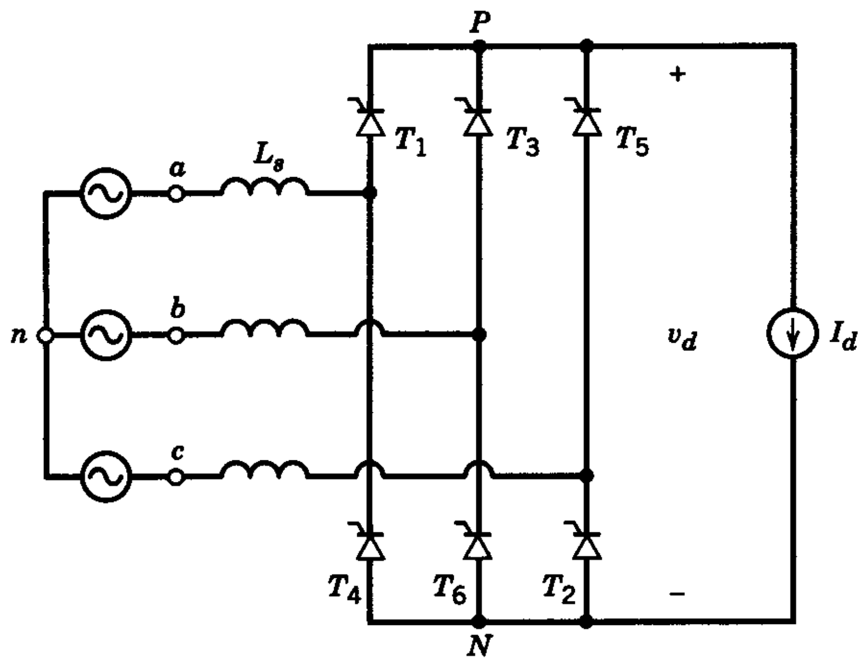


Input line-current waveform

- assuming zero ac-side inductance

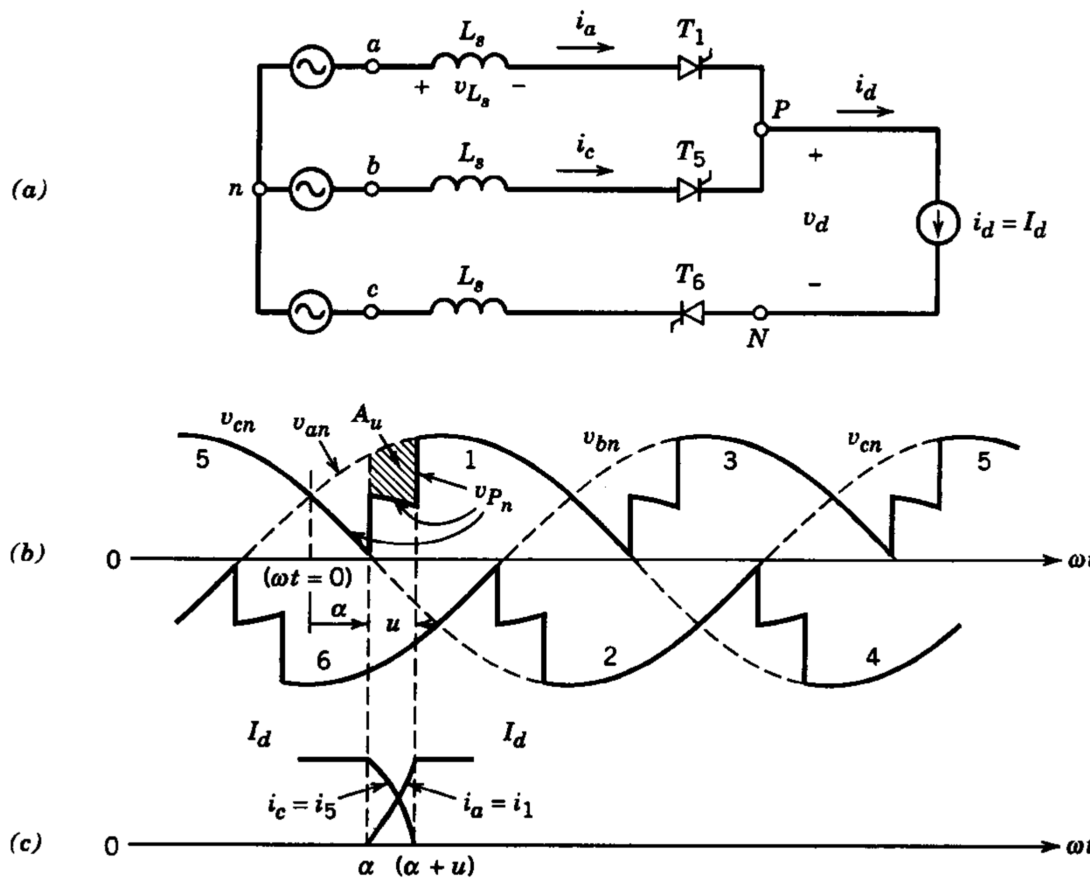


Three-Phase Thyristor Converter - AC-side inductance



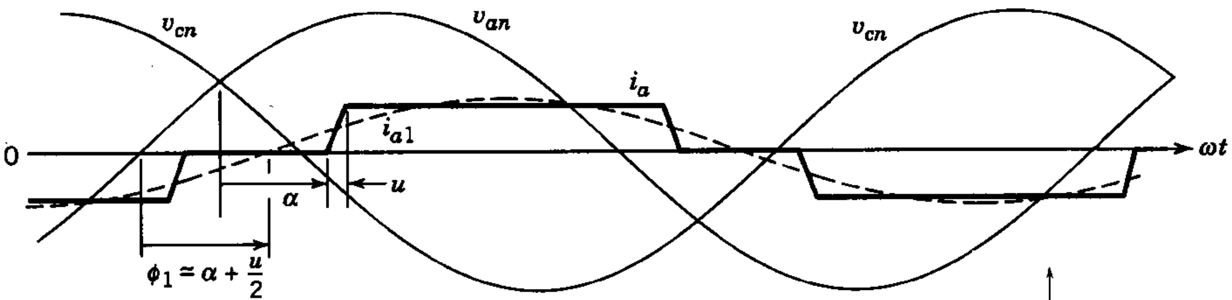
Current Commutation Waveforms

- Constant dc-side current



Input Line-Current Waveform

- Finite ac-side inductance



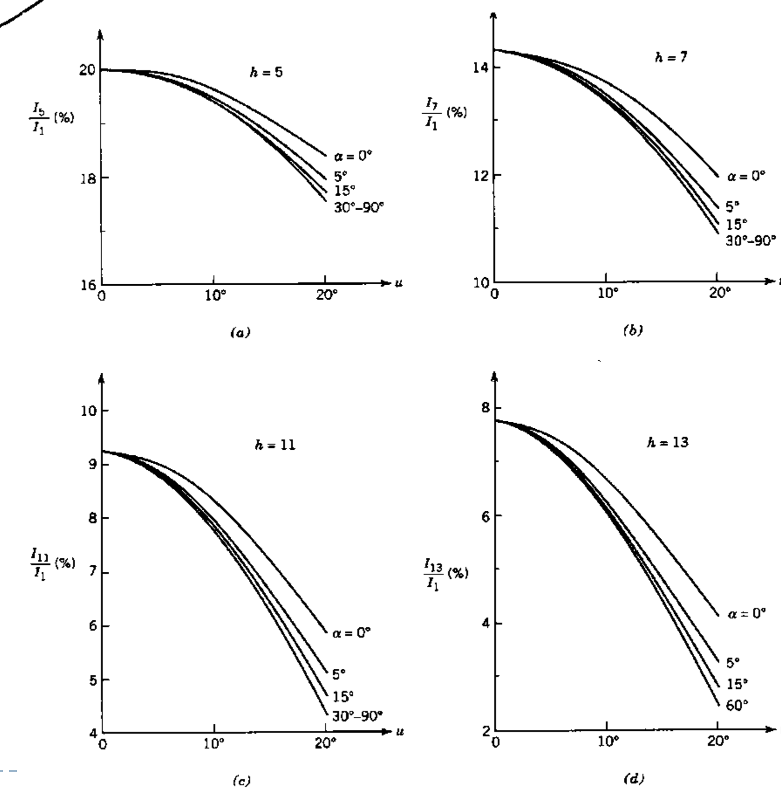
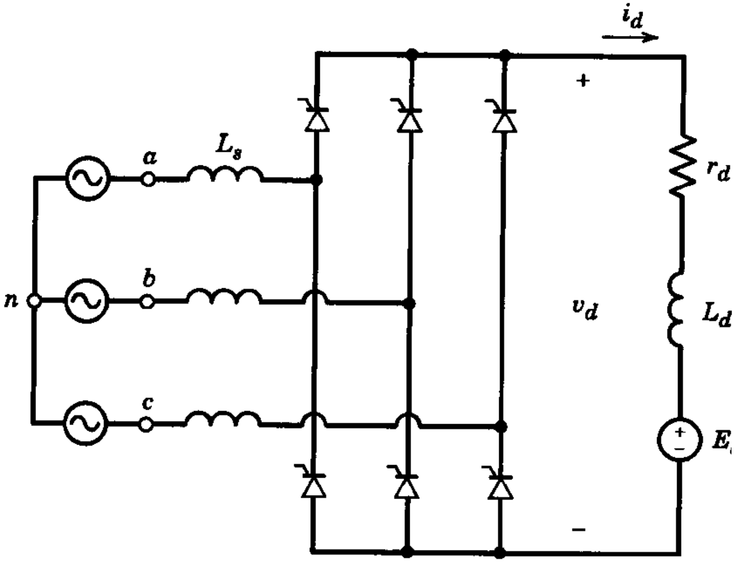
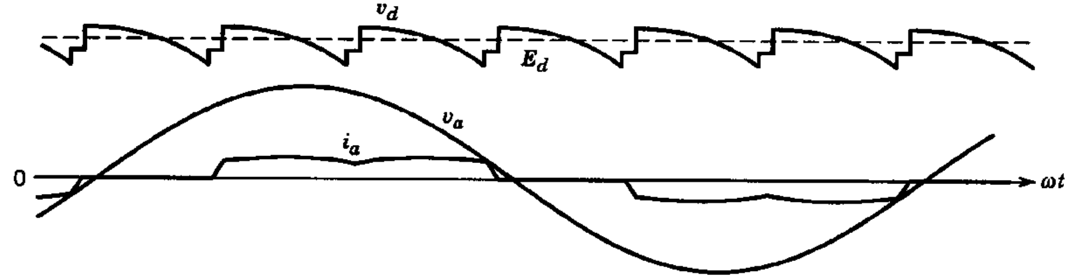


Figure 6-27 Normalized harmonic currents in the presence of L_s. (With permission from ref. 2).

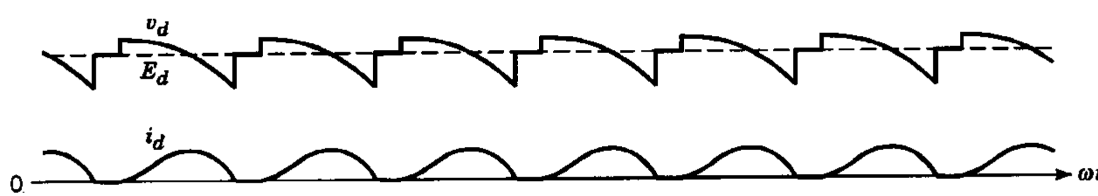
Three-Phase Thyristor Converter - realistic load



- Continous current

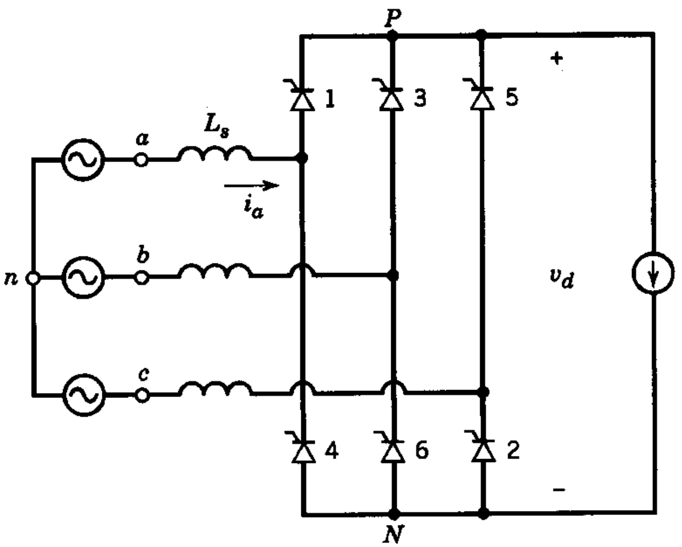


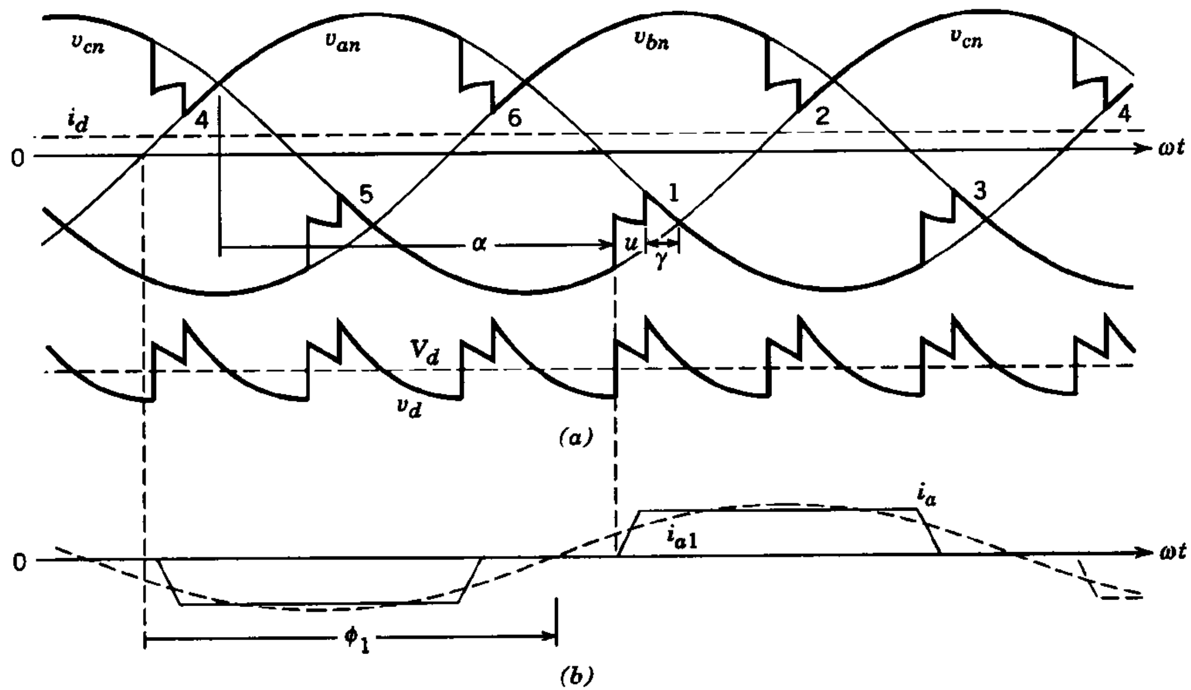
- Discontinous current



Thyristor Inverter

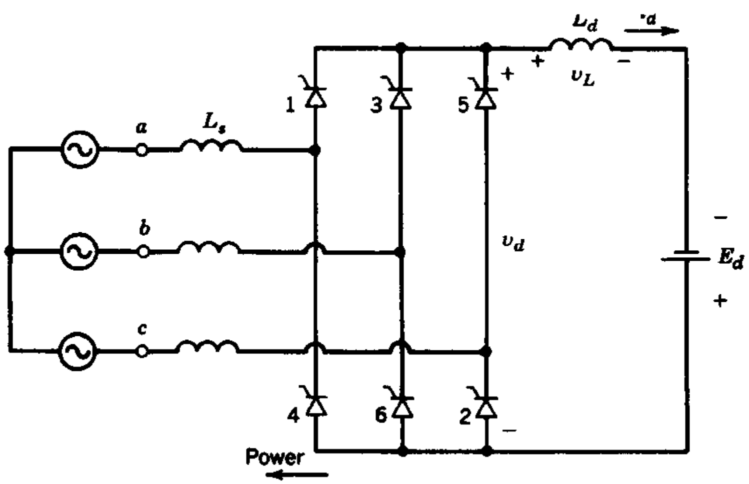
- Constant dc current

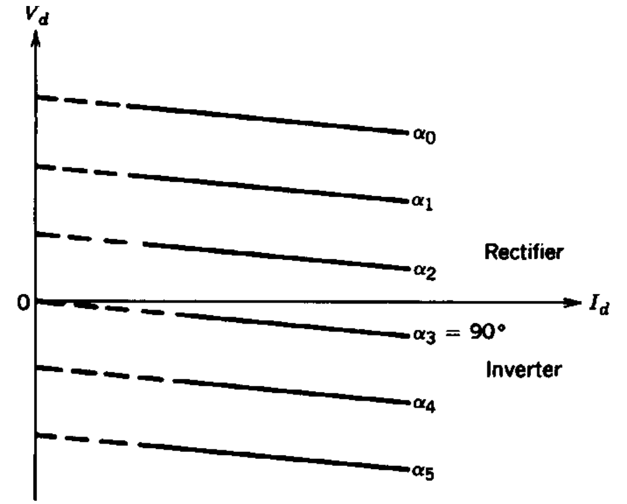




Thyristor Inverter – dc load

- Family of curves at various values of delay angle

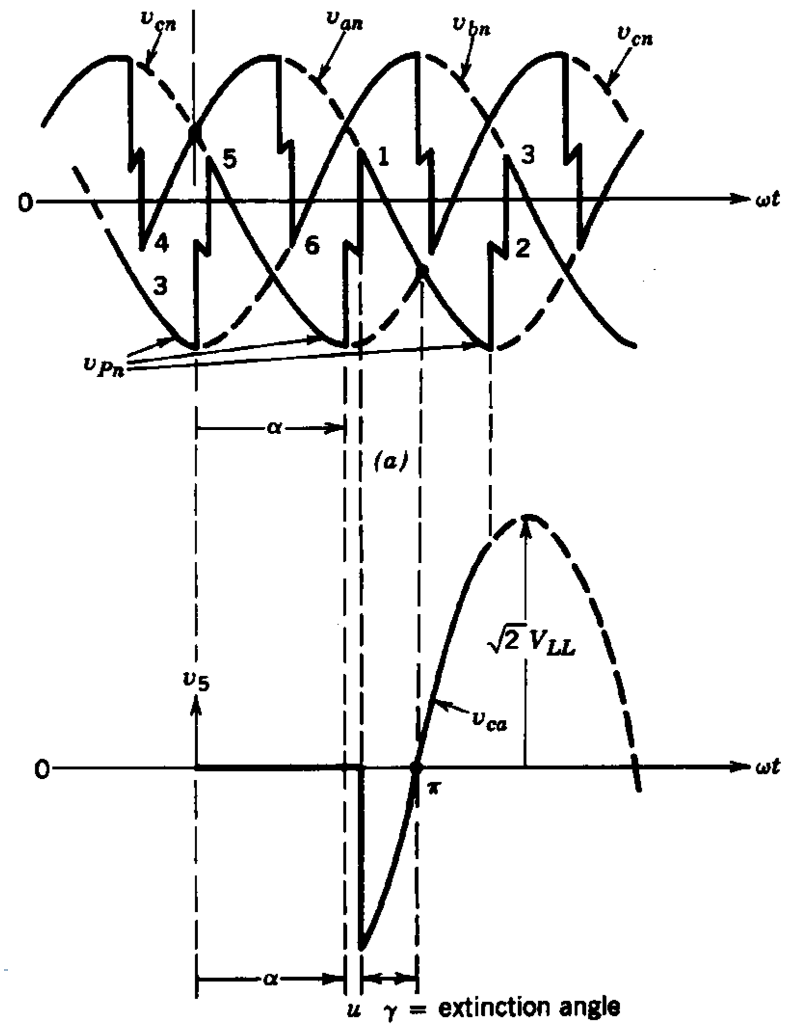




(b)

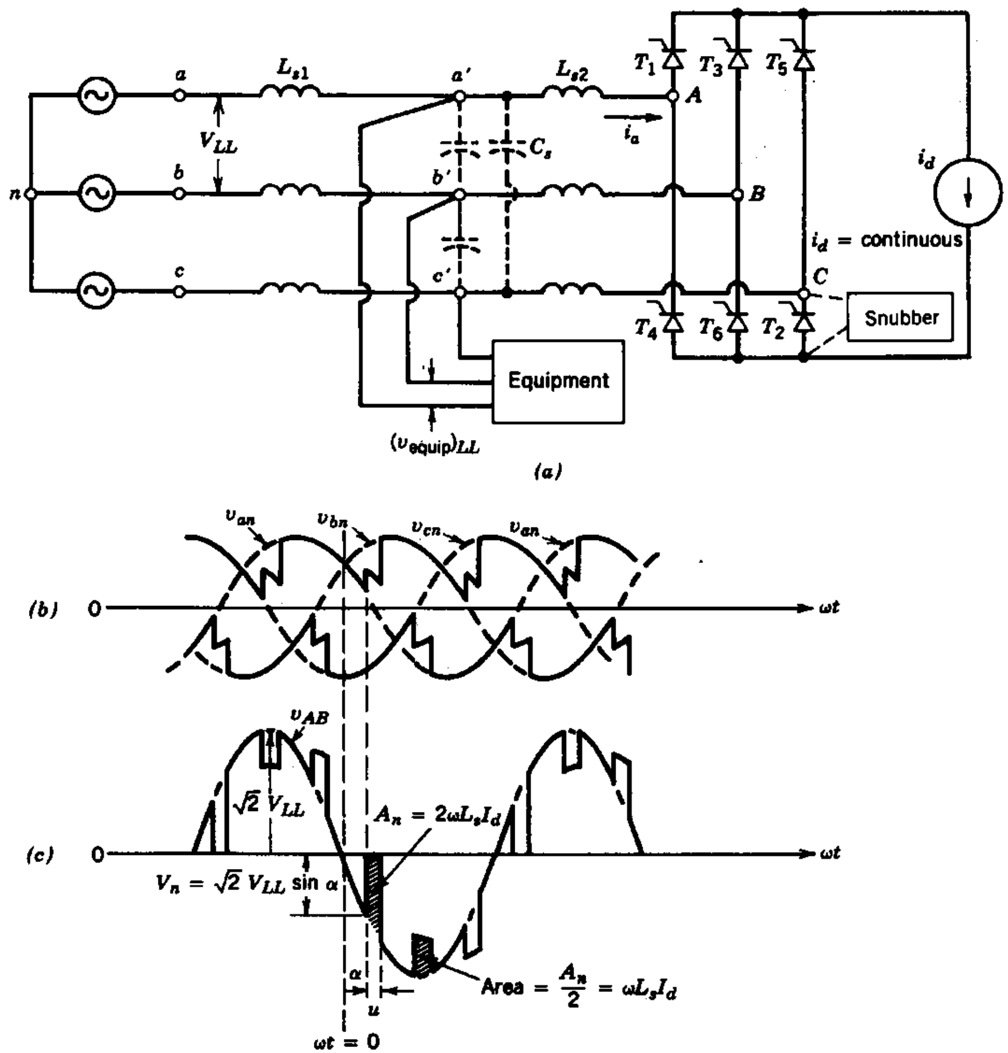
Thyristor Inverter Operation

- Importance of extinction angle



Thyristor Converters: Voltage Notching

- Importance of external ac-side inductance



Limits on Notching and Distortion

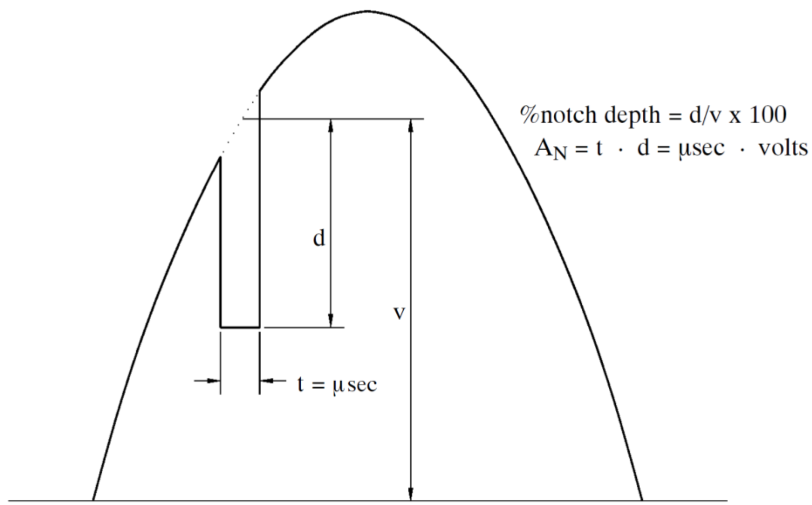
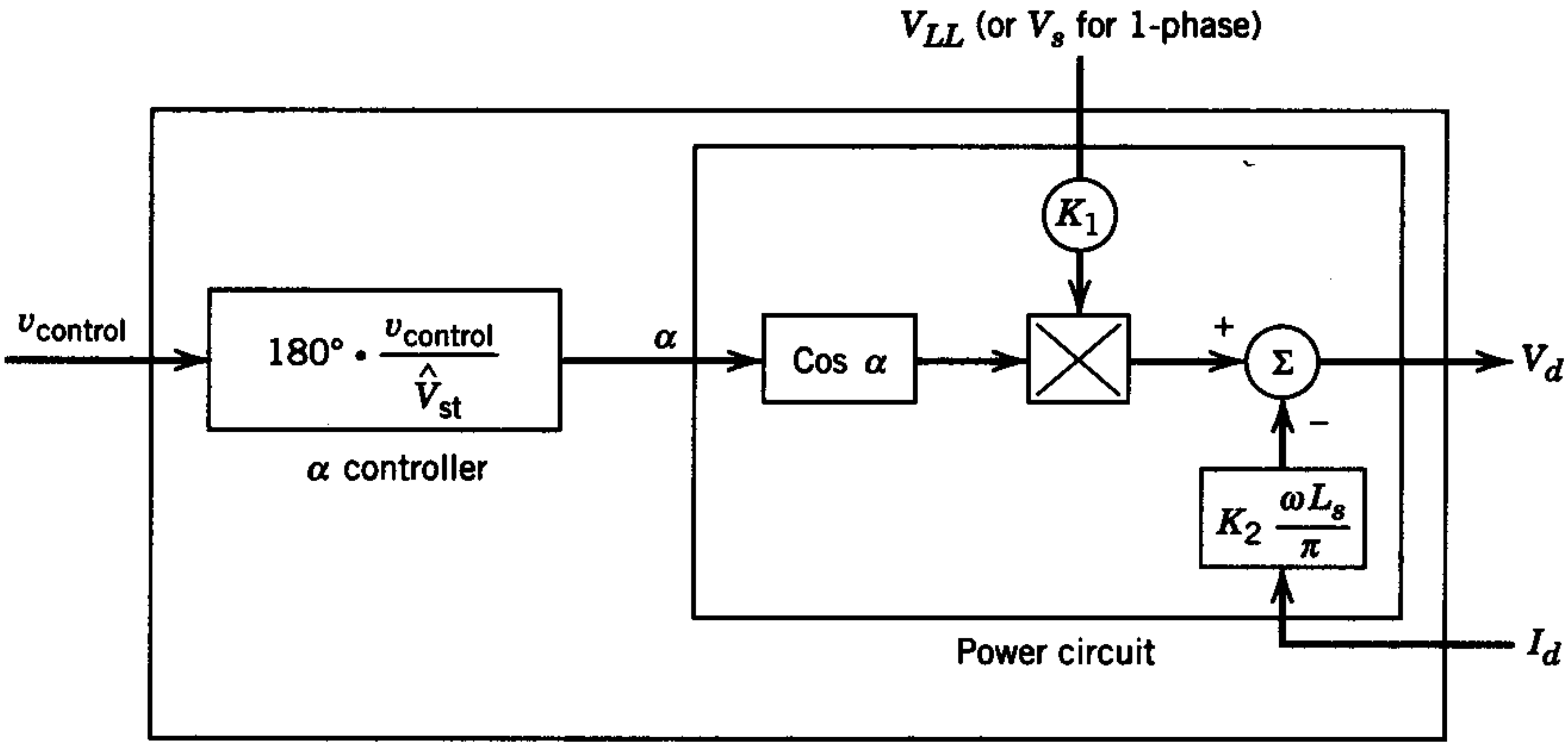


Table 6-2 Line Notching and Distortion Limits for 460-V Systems

Class	*Line Notch Depth* ρ(%)	*Line Notch Area* (V·μs)	*Voltage Total Harmonic Distortion* (%)
Special applications	10	16,400	3
General system	20	22,800	5
Dedicated system	50	36,500	10

Thyristor Converter Representation

- Functional block diagram



Single-phase full-bridge: $K_1 = 0.9$, $K_2 = 2$

Three-phase full-bridge: $K_1 = 1.35$, $K_2 = 3$

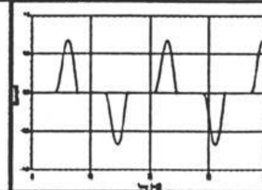
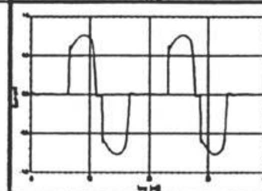
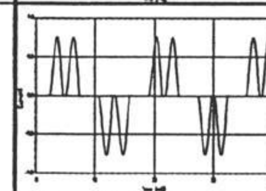
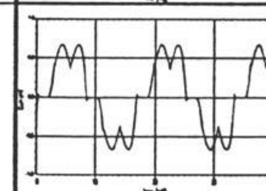
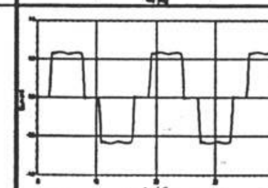
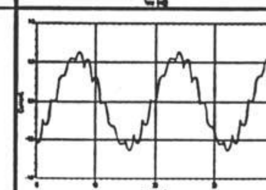
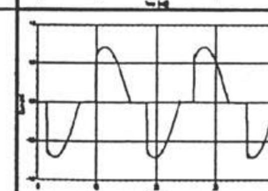
Typical Nonlinear Loads

Based on:

PacificCorp Engineering Handbook

- *Volume 1 - General*
- *Part C - Power Quality*
- *1C.4.1 - Harmonic Distortion*

PACIFIC POWER

Type of Load	Typical Waveform	Typical Current Distortion
Single Phase Power Supply		80% (high 3rd)
Semiconverter		high 2nd,3rd, 4th at partial loads
6 Pulse Converter, capacitive smoothing, no series inductance		80%
6 Pulse Converter, capacitive smoothing with series inductance > 3% or dc drive		40%
6 Pulse Converter with large inductor for current smoothing		28%
12 Pulse Converter		15%
ac Voltage Regulator		varies with firing angle

Homework