Power converters AC/DC and DC/AC - MM3

Single phase Thyristor converters

Content MM3

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2. Thyristor circuits and their control
3. Single phase converter ($L_s = 0$)
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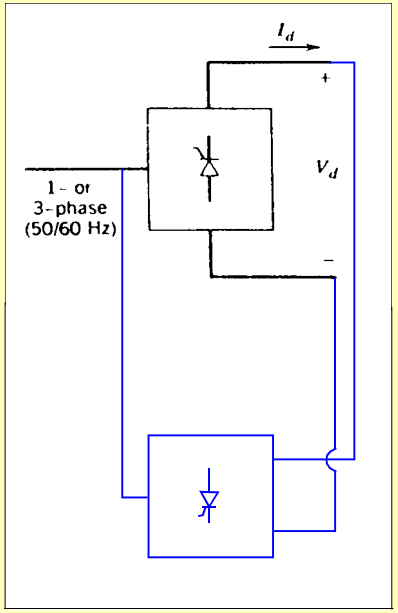
5. Practical circuits
6. Inverter mode
7. Exercises

2. Thyristor circuits and their control

- Diode rectifier
  - non-controllable DC-link-voltage
  - Large inrush currents

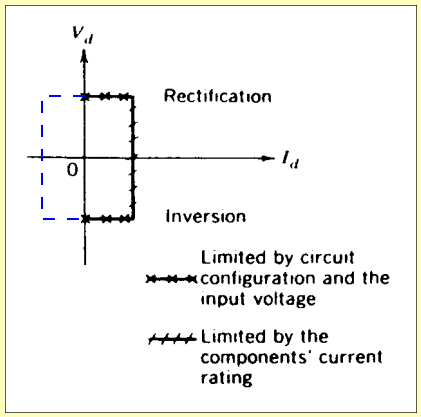
- Thyristor converter
  - Controllable DC-link-voltage
  - Controllable inrush currents

Principle rectifier/inverter



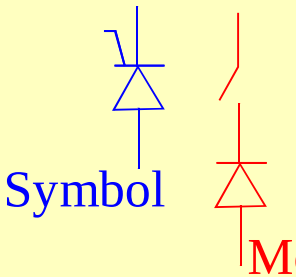
Battery chargers
DC-motor control (E = kω)

Operation area



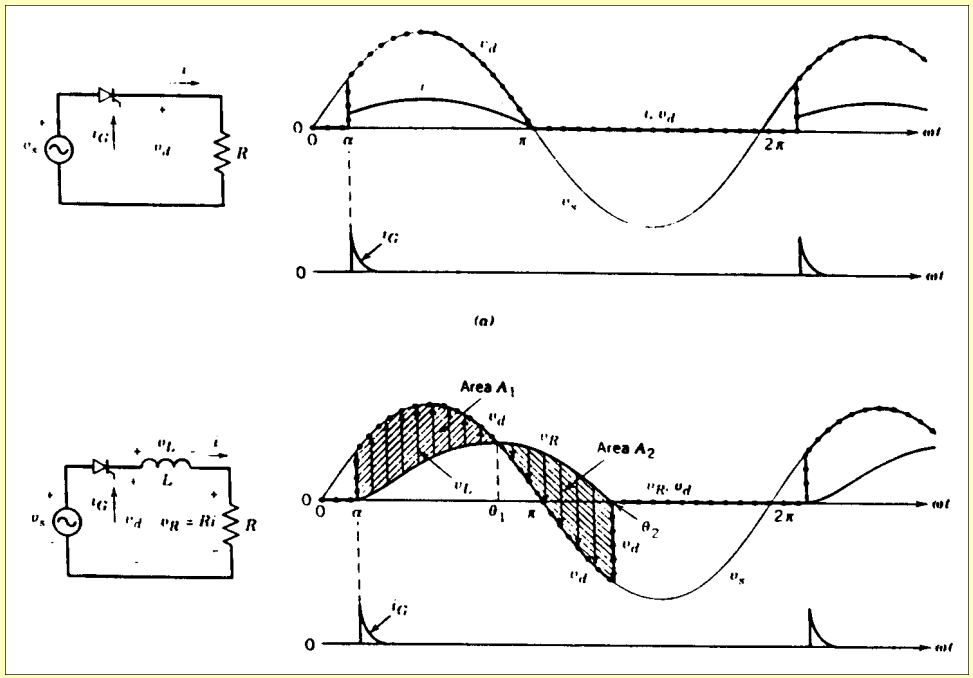
2. Thyristor circuits and their control

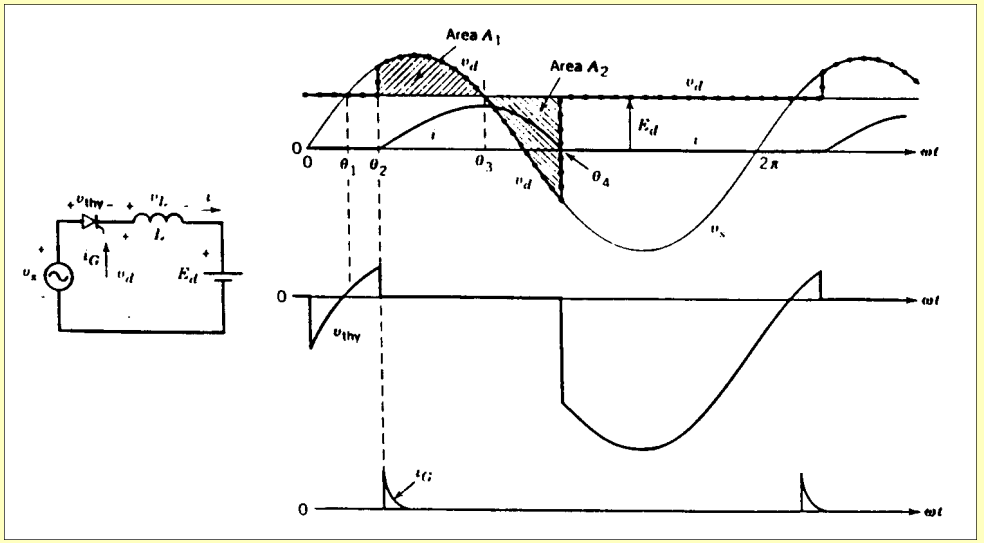
Thyristor



- Turned on with a gate trigger signal
- Closed only with a reversed biased voltage ☞ Line commutated
- 6 kV, 6kA (single Thyristor)
- Later more details about Thyristors

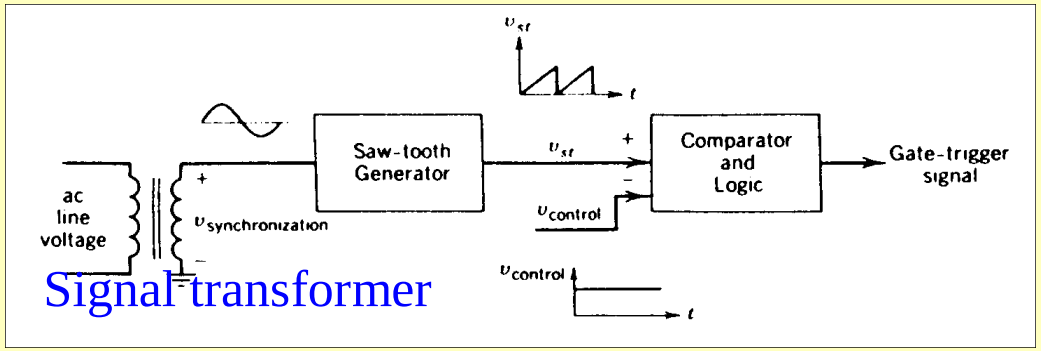
Principles





2. Thyristor circuits and their control

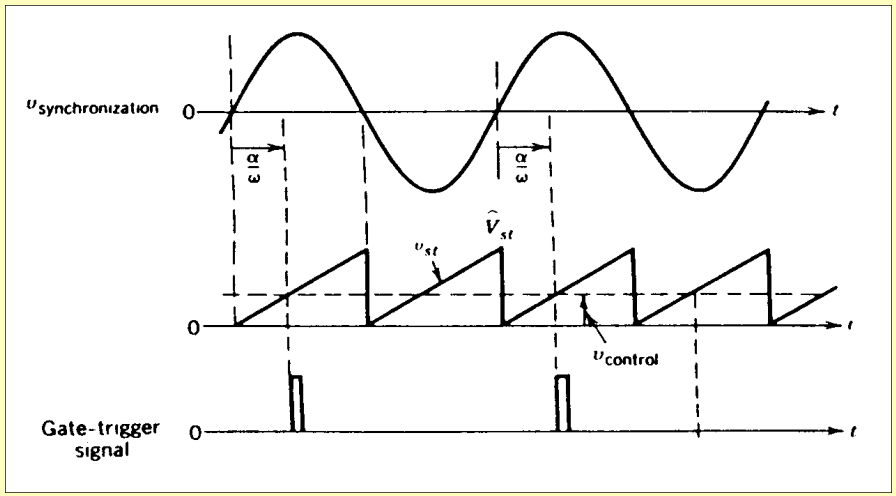
Gate trigger control circuit



Delay angle α

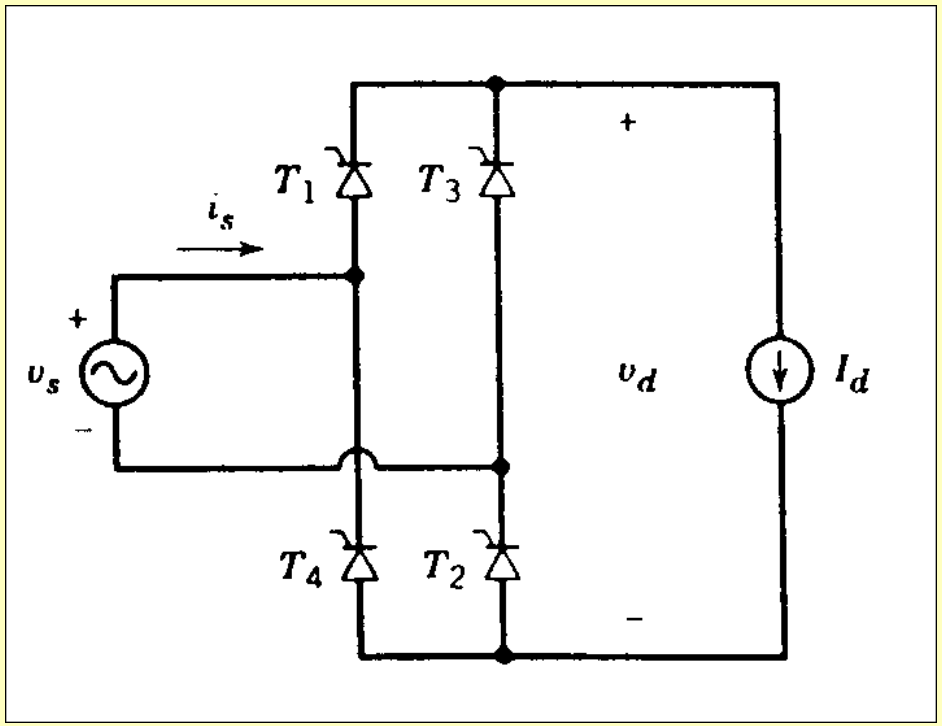
$$\alpha^{o} = 180^{o} \frac{v_{control}}{\hat{V}_{st}}$$

Delay angle α

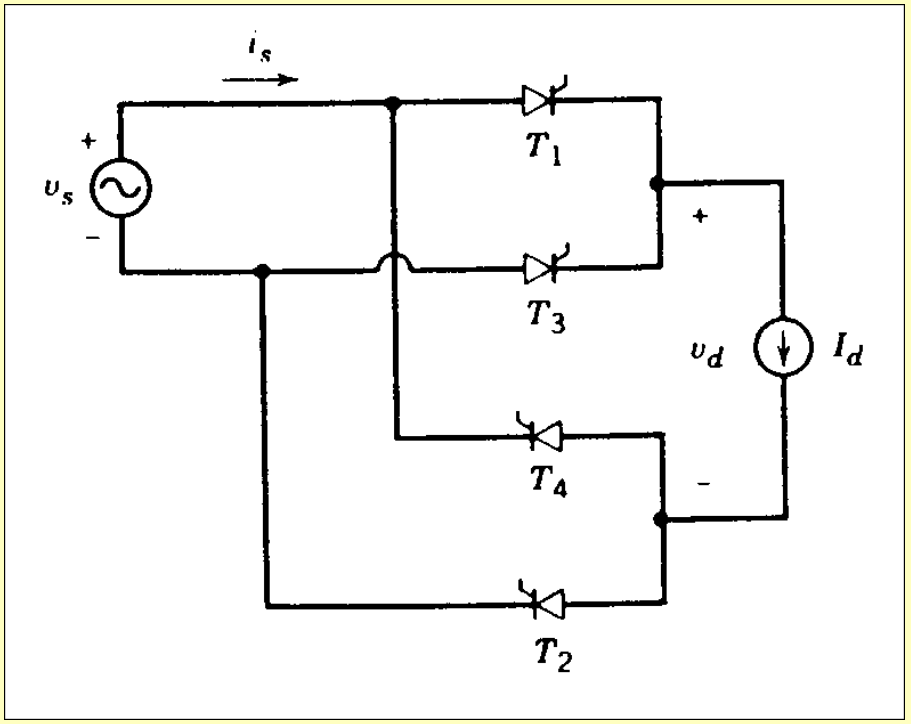


3. Single phase converter ($L_s = 0$)

Circuit (ideal)

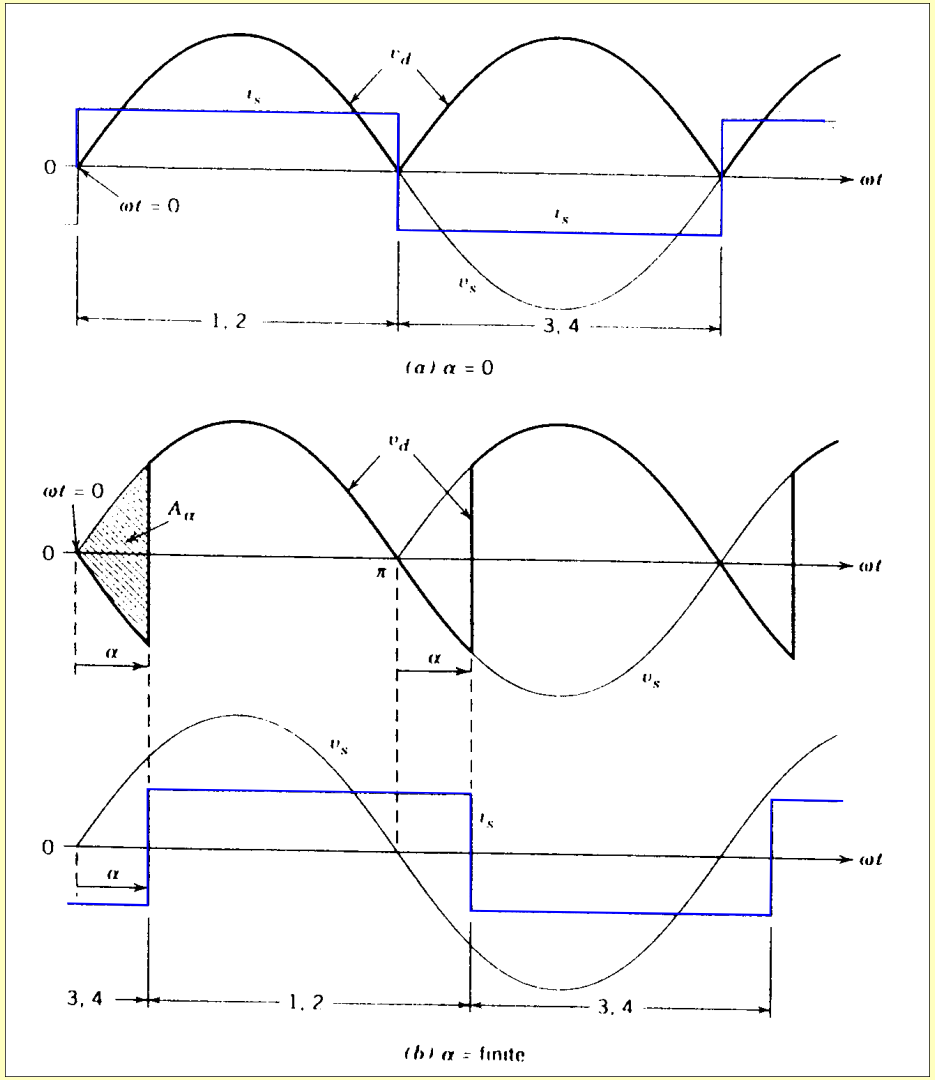


Reorganized



3. Single phase converter ($L_s = 0$)

Waveforms



Average voltage

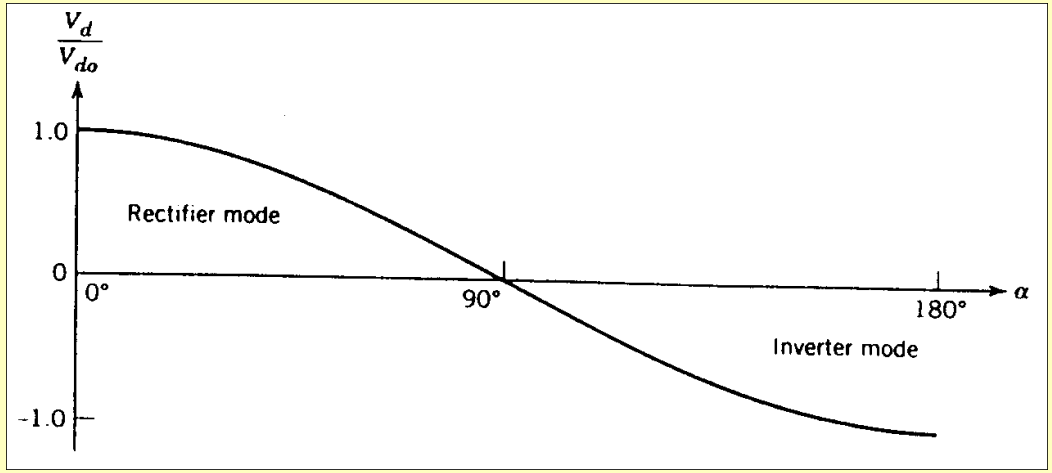
$$V_{d\alpha} = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} \sqrt{2}V_s \sin \omega t \, d(\omega t) = \frac{2\sqrt{2}}{\pi} V_s \cos \alpha = 0.9 V_s \cos \alpha$$

Power

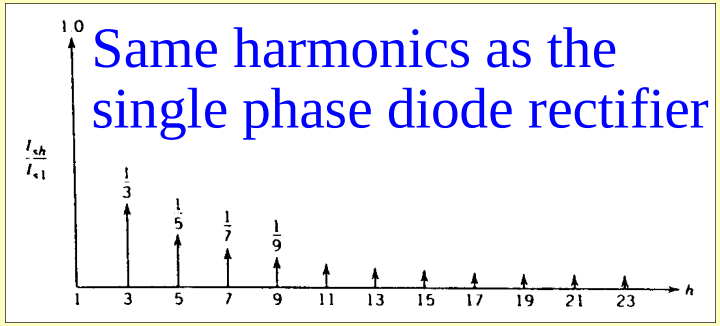
$$P = I_d\left(\frac{1}{T}\int_0^T v_d \, dt\right) = I_d V_d = 0.9 V_s I_d \cos \alpha$$

3. Single phase converter ($L_s = 0$)

Average voltage vs. delay angle

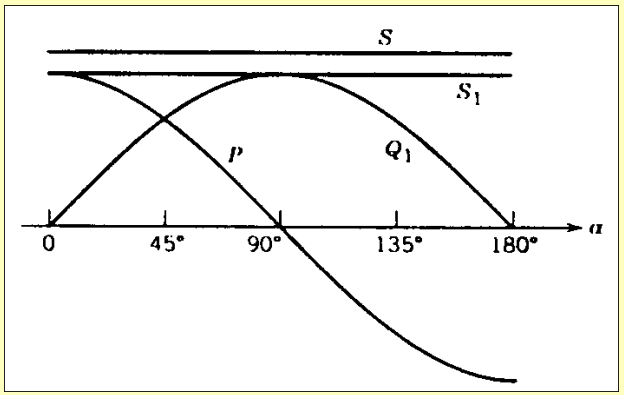


Harmonics



Same harmonics as the single phase diode rectifier

P, S, Q

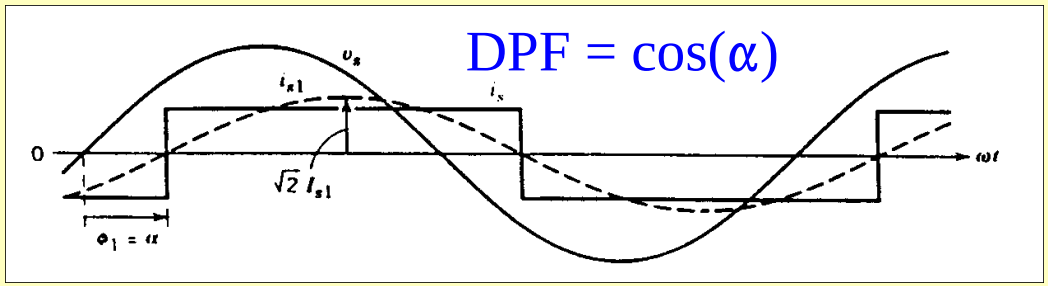


$$P_1 = V_s I_{s1} \cos(\phi_1)$$

$$Q_1 = V_s I_{s1} \sin(\phi_1)$$

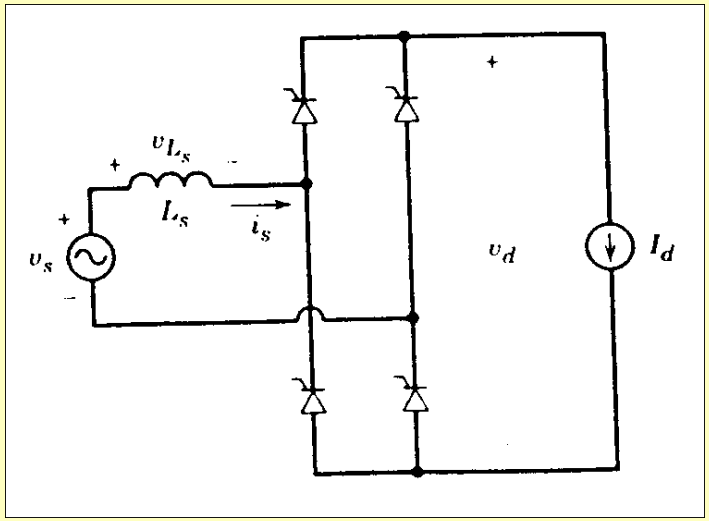
$$S_1 = \sqrt{P_1^2 + S_1^2}$$

Current

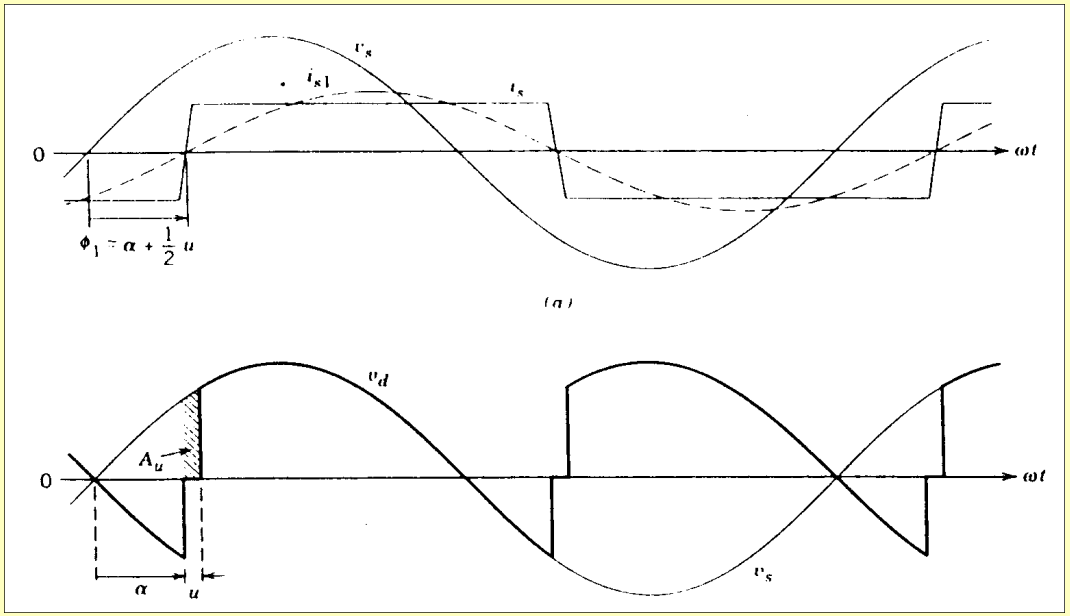


4. Single phase converter ($L_s \neq 0$)

Circuit



Waveforms



Voltage time integral

$$A_u = \sqrt{2}V_s[\cos\alpha - \cos(\alpha + u)] = 2\omega L_s I_d$$

Commutation interval

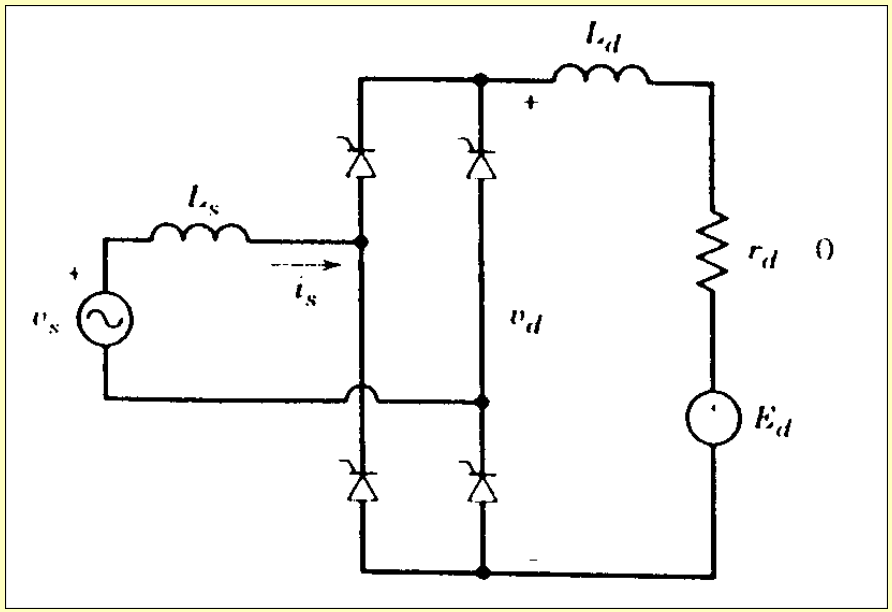
$$\cos(\alpha + u) = \cos\alpha - \frac{2\omega L_s I_d}{\sqrt{2}V_s}$$

Average voltage

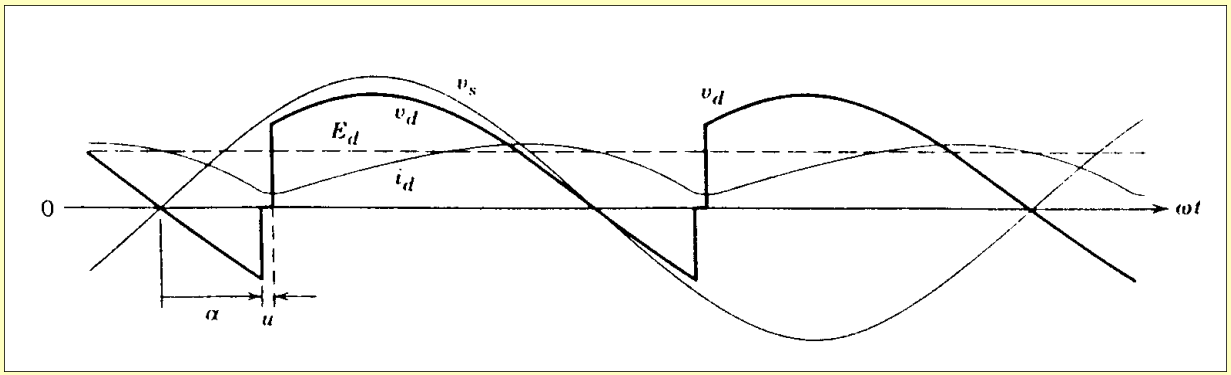
$$V_d = 0.9V_s\cos\alpha - \frac{2}{\pi}\omega L_s I_d$$

5. Practical circuits

DC-motor

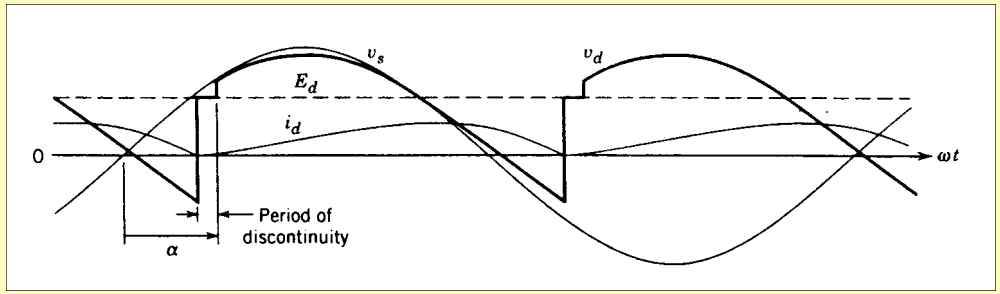


Waveforms

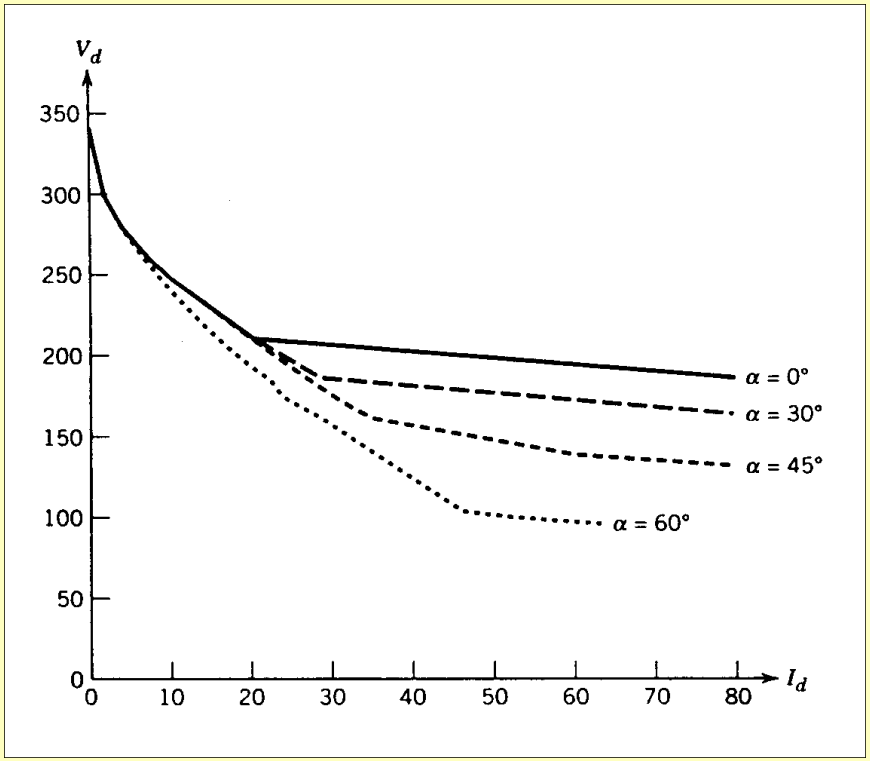


5. Practical circuits

Discontinues operation

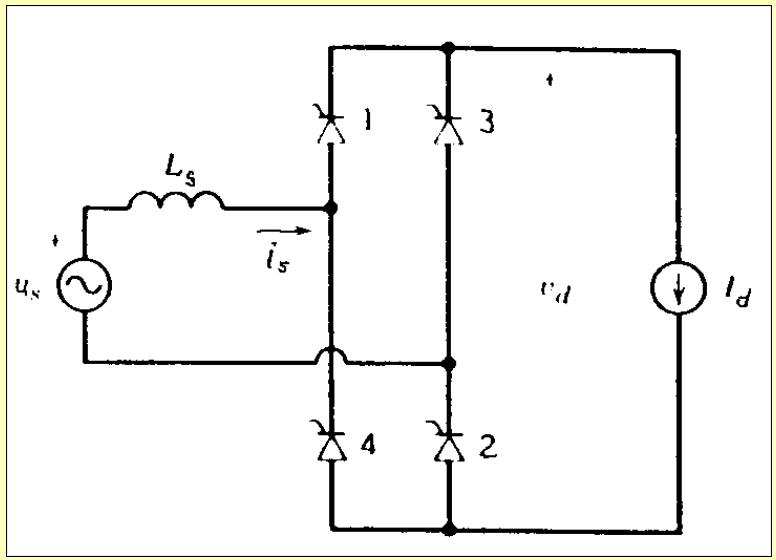


V_d versus I_d

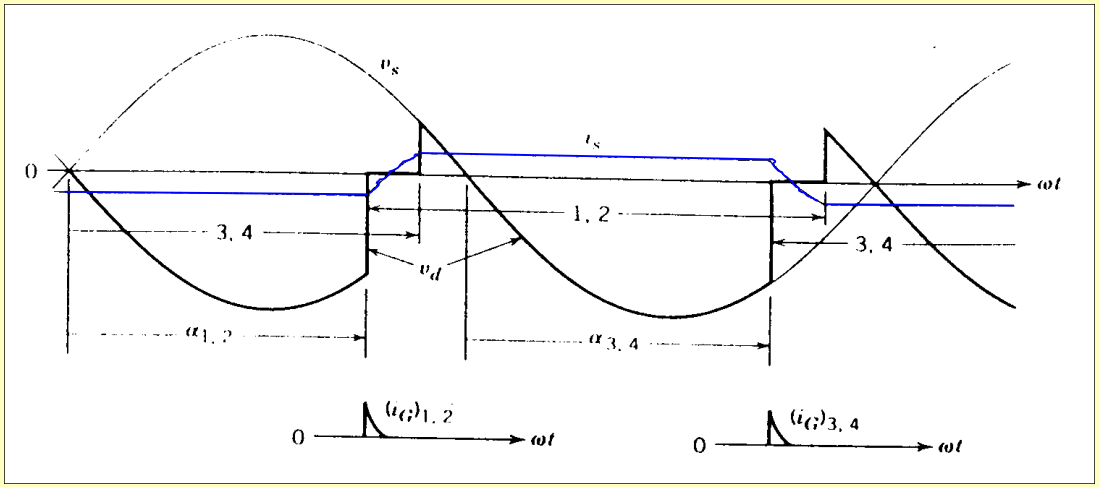


6. Inverter mode

Circuit (constant current)

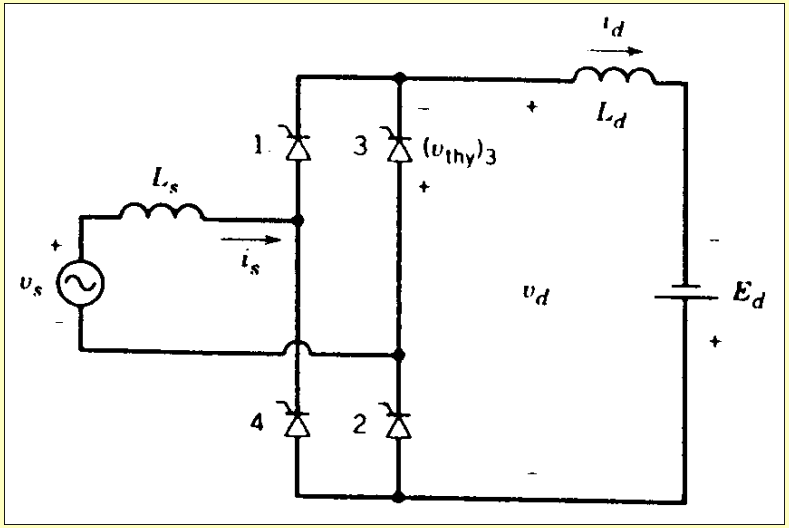


Waveforms ($\alpha > 90°$)

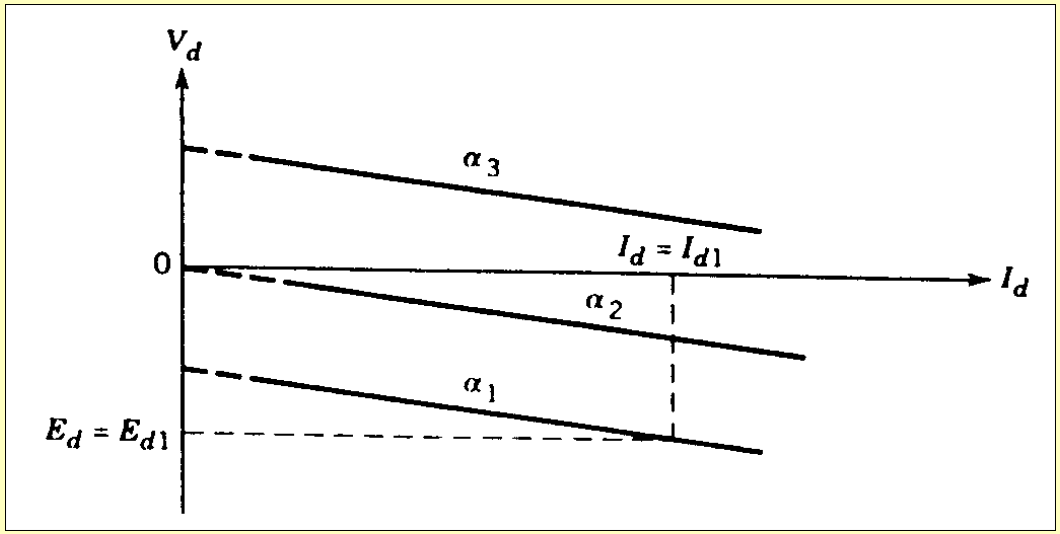


6. Inverter mode

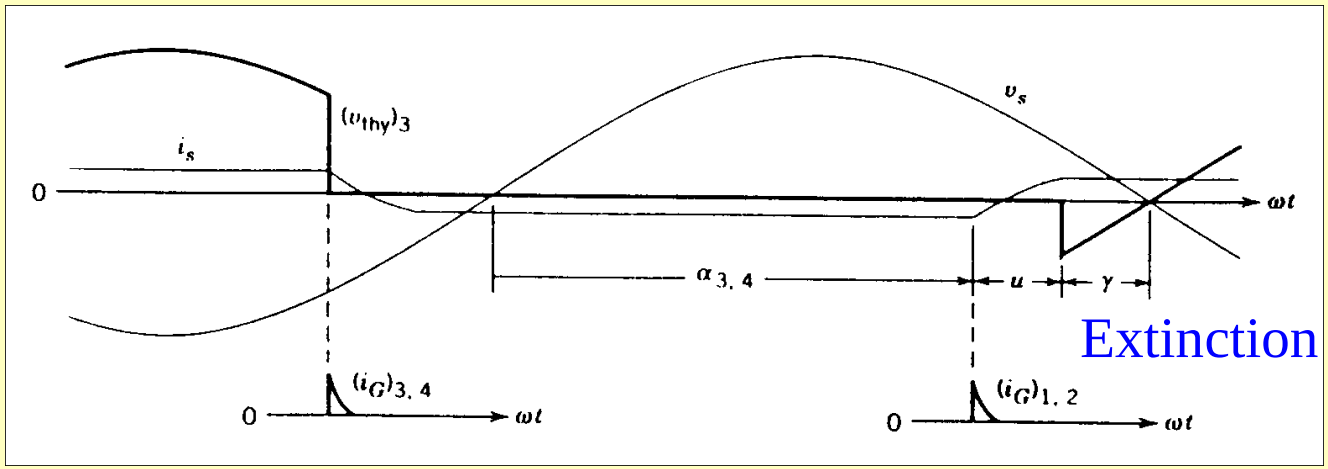
Circuit (Constant voltage)



Characteristics



Waveform



Extinction angle

7. Exercises

Exercise 6.3 + Exercise 6.5 in Mohan