EE-463 STATIC POWER CONVERSION-I

3-Phase Controlled Rectifiers

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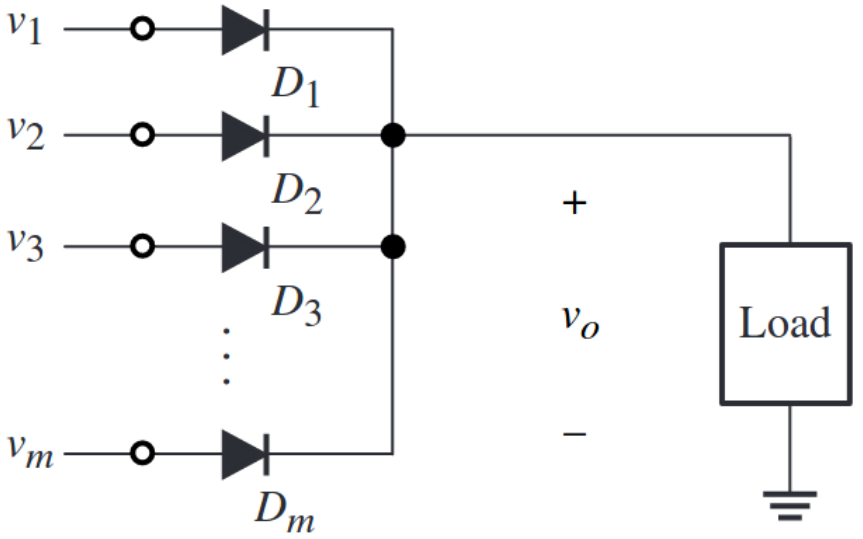
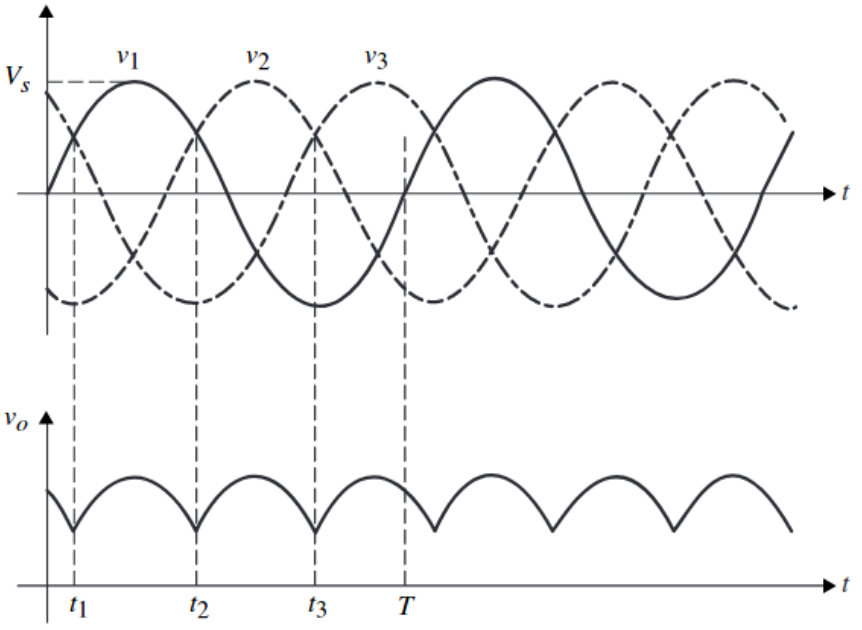
Review

N-Phase Half Wave Rectifier



Review

3-Phase Half Wave Diode Rectifier



Review

3-Phase Half Wave Diode Rectifier Average Voltage?

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3-Phase Half Wave Diode Rectifier Average Voltage?

$$V_{dc} = \frac{3\sqrt{6}}{2\pi} V_{ph,rms}$$

or

$$V_{dc} = \frac{3\sqrt{2}}{2\pi} V_{ll,rms}$$

Half-bridge Thyristor Rectifier

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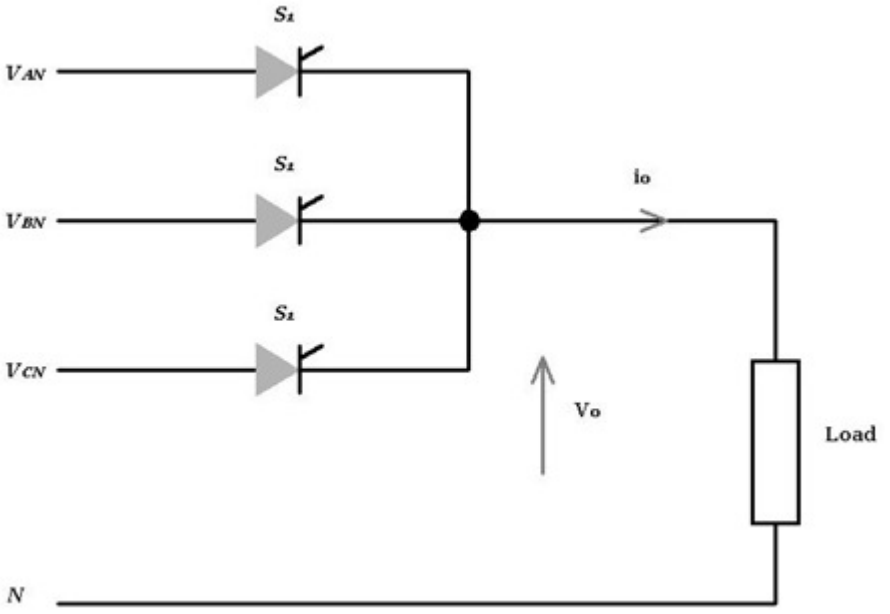


Half-bridge Thyristor Rectifier

Average Voltage?

Half-bridge Thyristor Rectifier

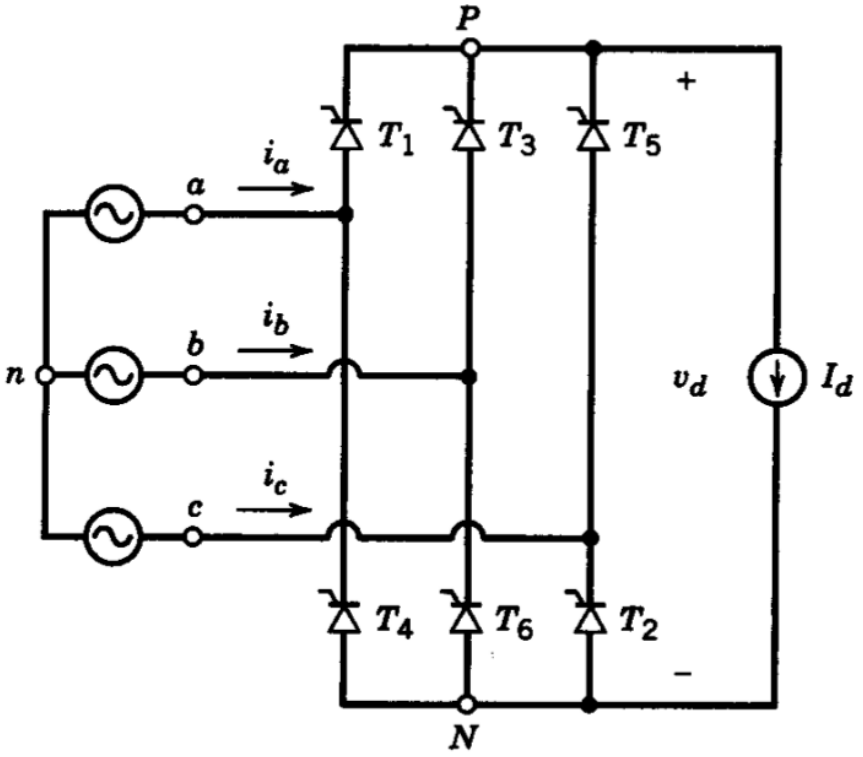
Average Voltage?

$$V_{dc(\alpha)} = \frac{3\sqrt{6}}{2\pi} V_{ph,rms} cos(\alpha)$$

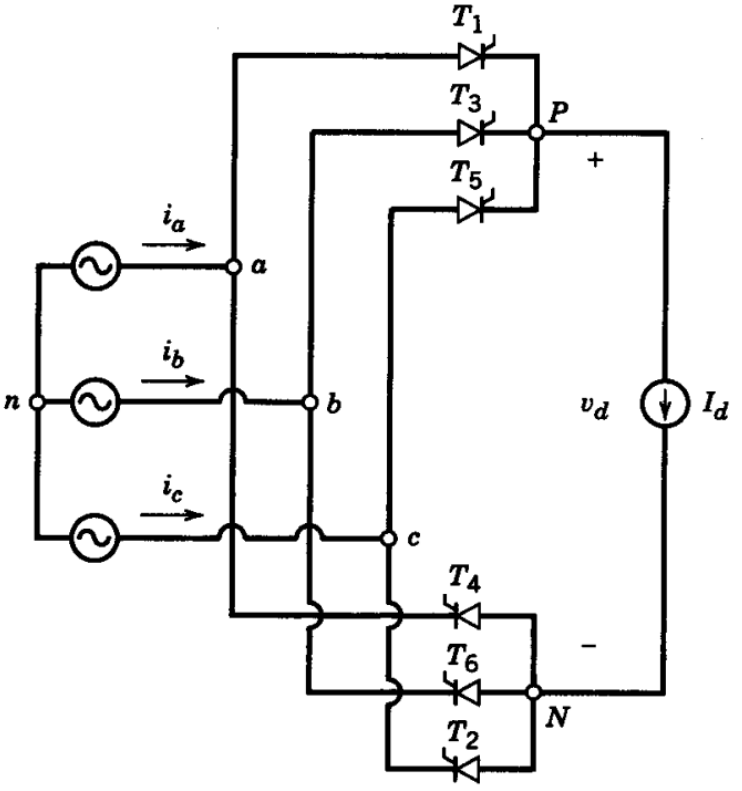
or

$$V_{dc(\alpha)} = \frac{3\sqrt{2}}{2\pi} V_{ll,rms} cos(\alpha)$$

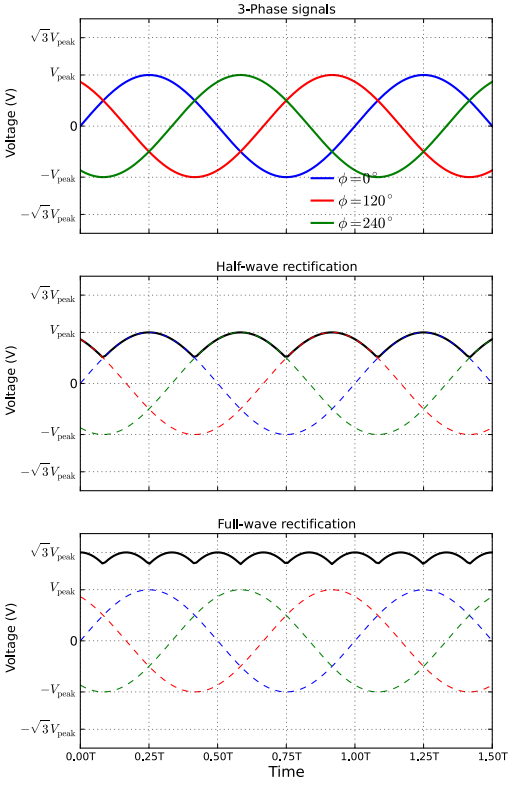
Full-bridge Thyristor Rectifier



Full-bridge Thyristor Rectifier

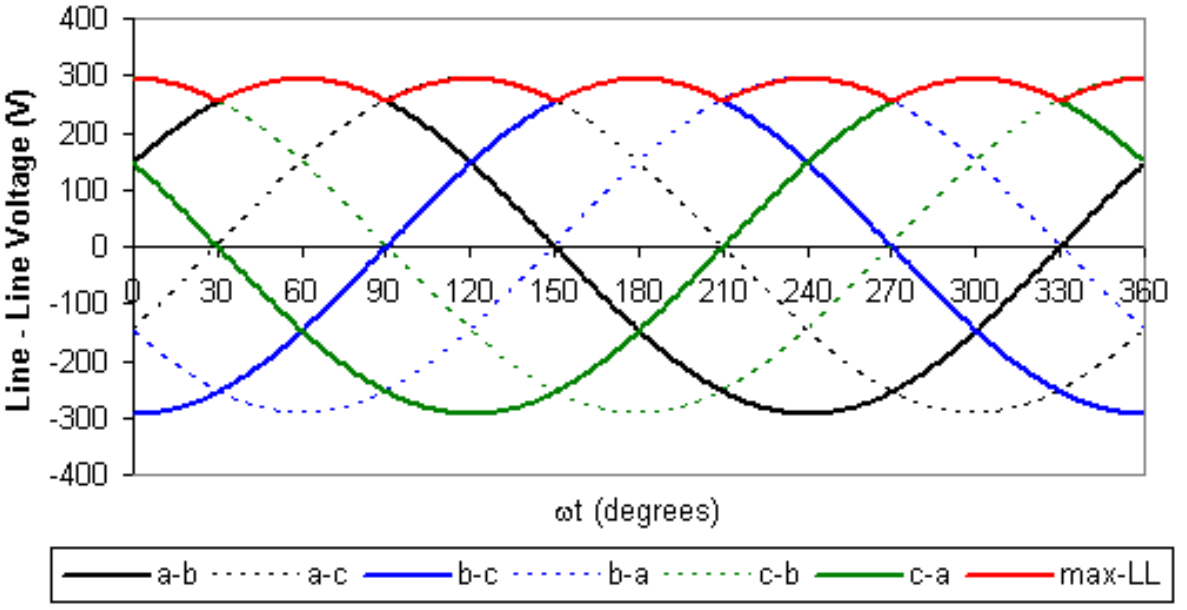


Diode Rectifier (or $\alpha = 0$)



Full-bridge Thyristor Rectifier

Remember output voltage follows line to line voltages!



Full-bridge Thyristor Rectifier

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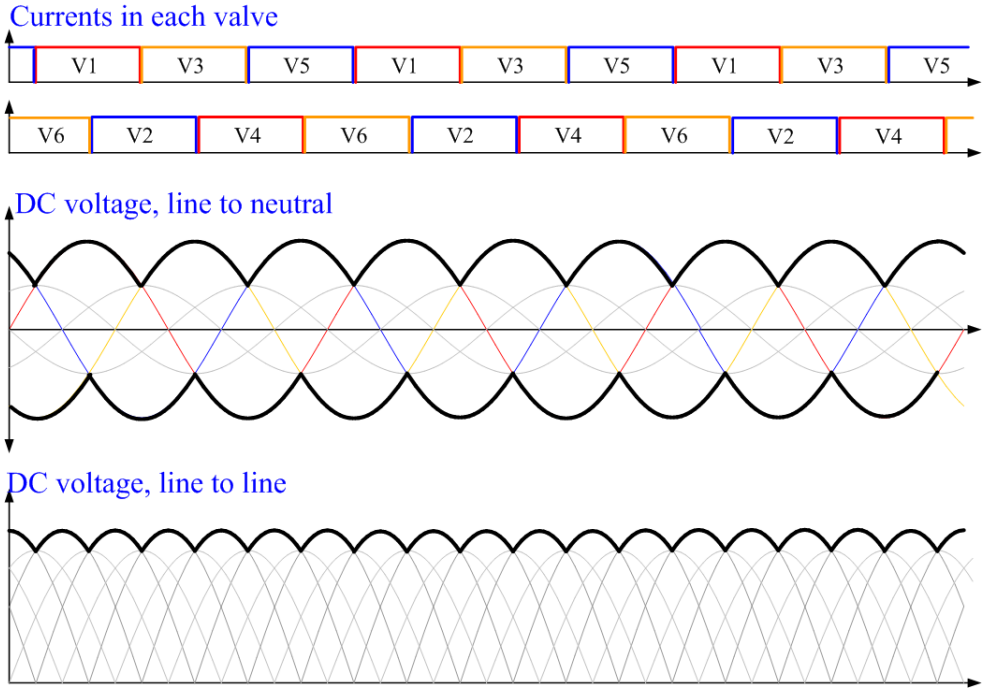

Full-bridge Thyristor Rectifier

Non-zero firing angle

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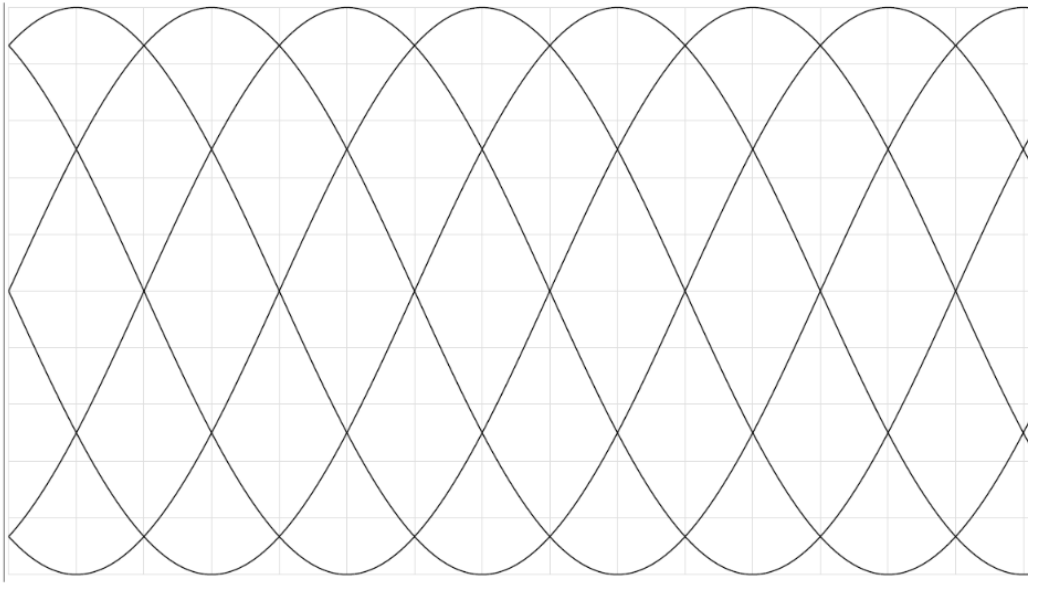
Non-zero firing angle



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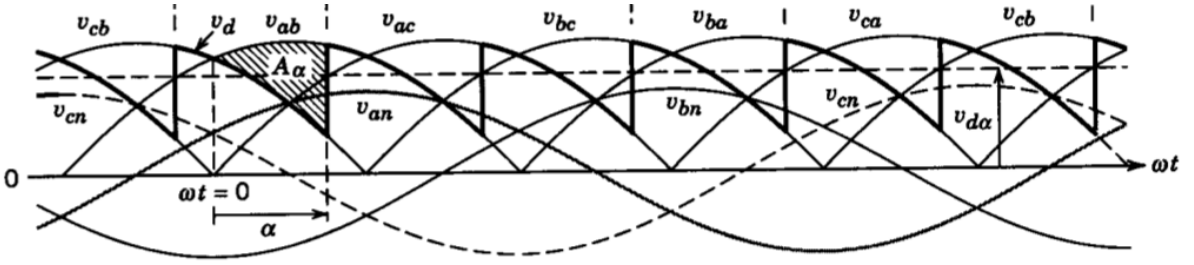

Output Voltage vs. Firing Angle

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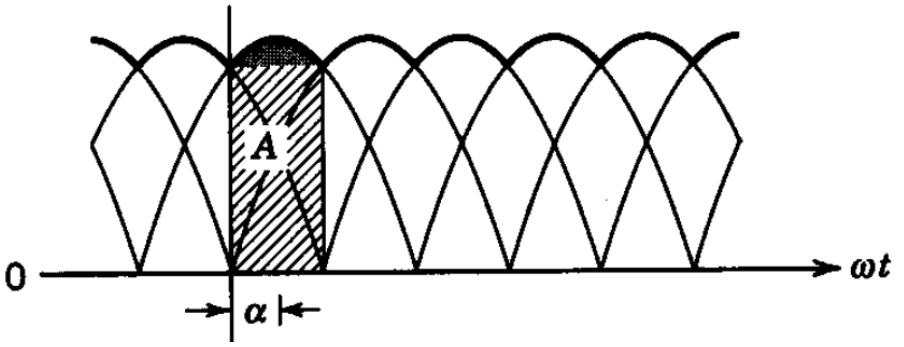
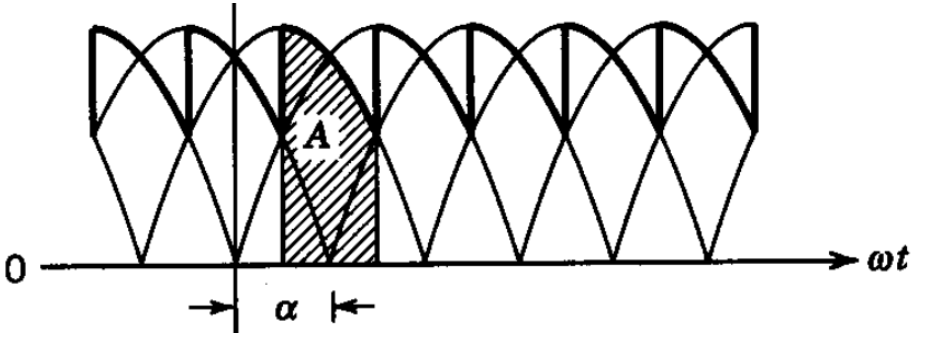


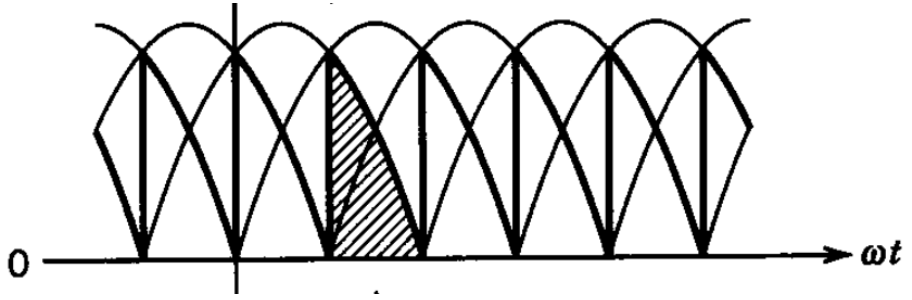
(a) $\alpha = 0$

Output Voltage vs. Firing Angle



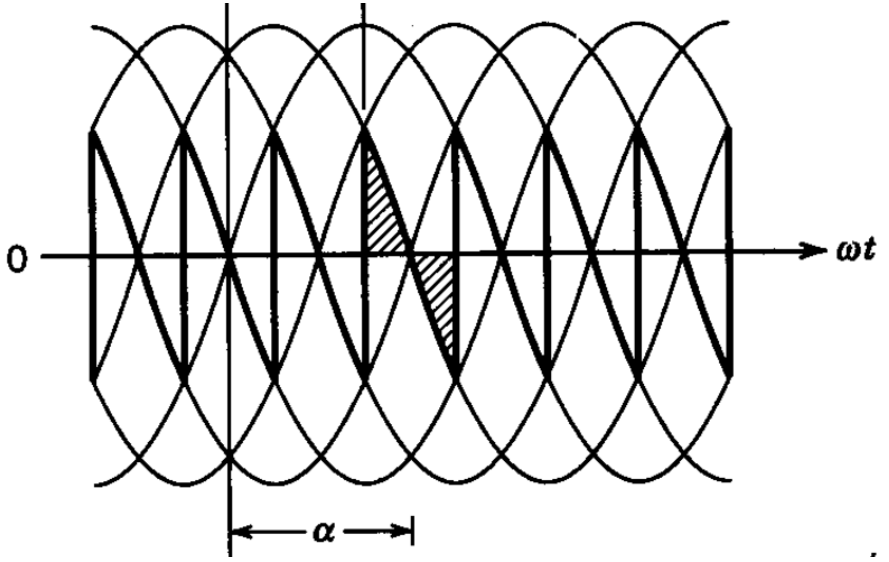
(b) $\alpha = 30°$

Output Voltage vs. Firing Angle



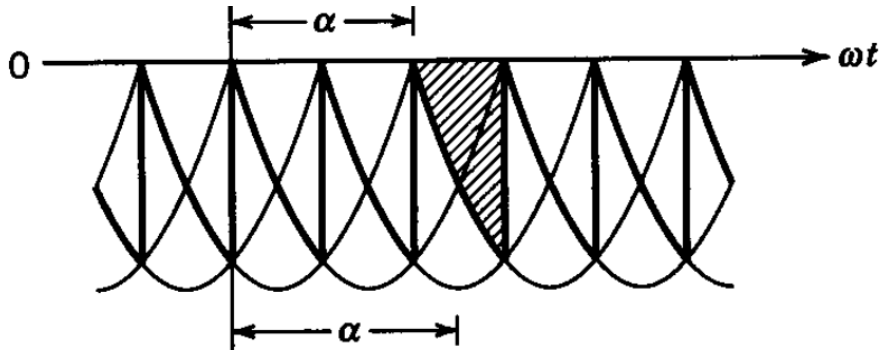
(c) $\alpha = 60°$

Output Voltage vs. Firing Angle



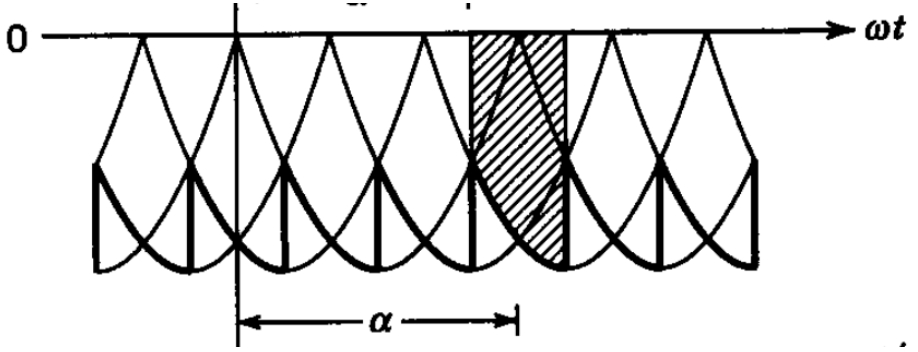
(d) $\alpha = 90°$

Output Voltage vs. Firing Angle



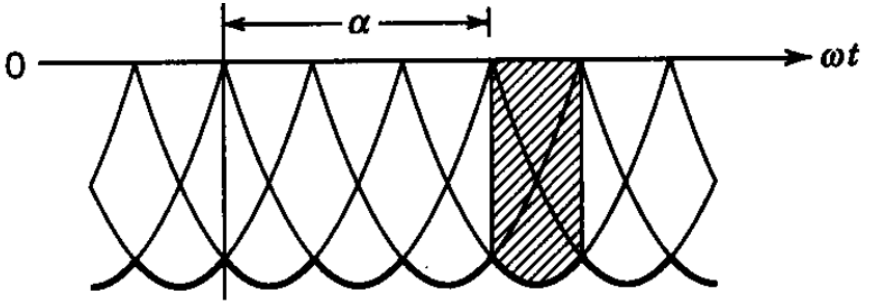
(e) $\alpha = 120°$

Output Voltage vs. Firing Angle



(f) $\alpha = 150°$

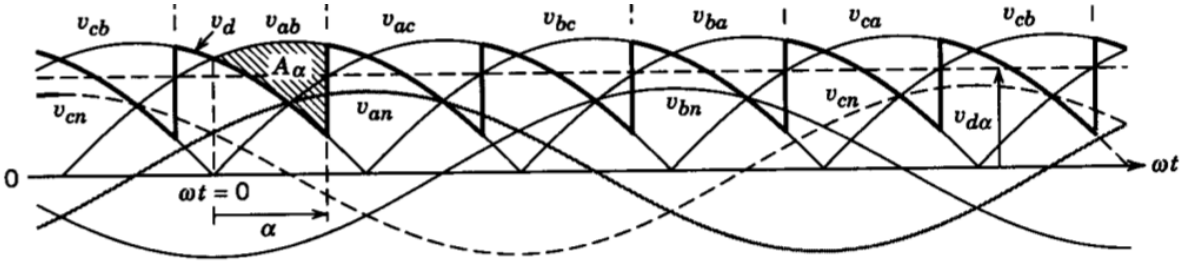
Output Voltage vs. Firing Angle



(g) $\alpha = 180°$

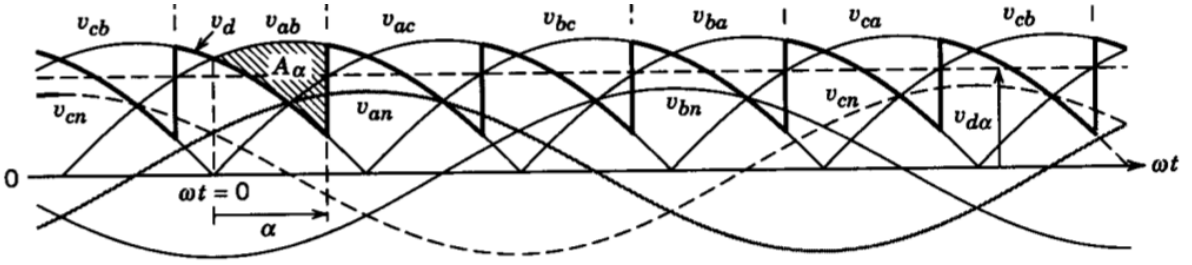
Full-bridge Thyristor Rectifier

Average output voltage?



Full-bridge Thyristor Rectifier

Average output voltage?



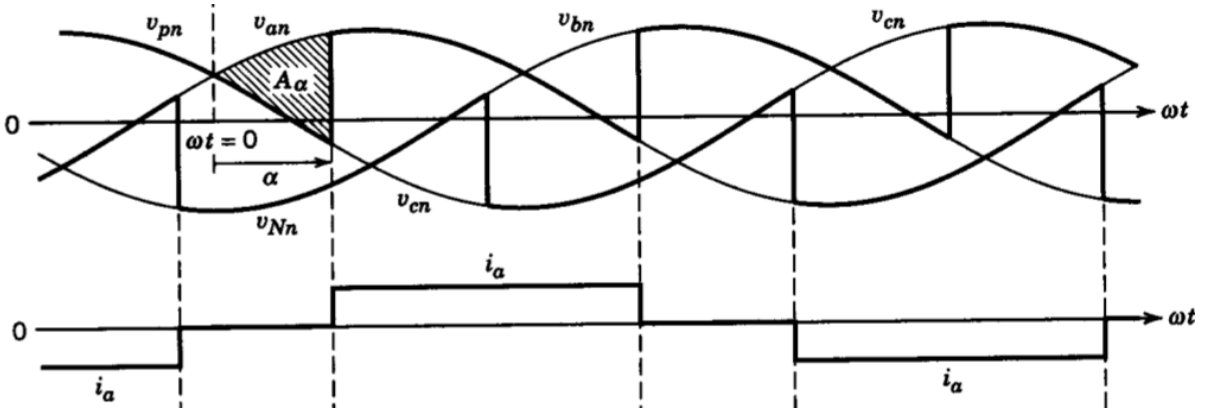
$$V_{d(\alpha)} = \frac{3\sqrt{2}}{\pi} V_{ll,rms} cos(\alpha)$$

Full-bridge Thyristor Rectifier

What about the current?

Full-bridge Thyristor Rectifier

What about the current?



Current Waveform: No triple harmonics

Comparison: Single Phase, Three Phase

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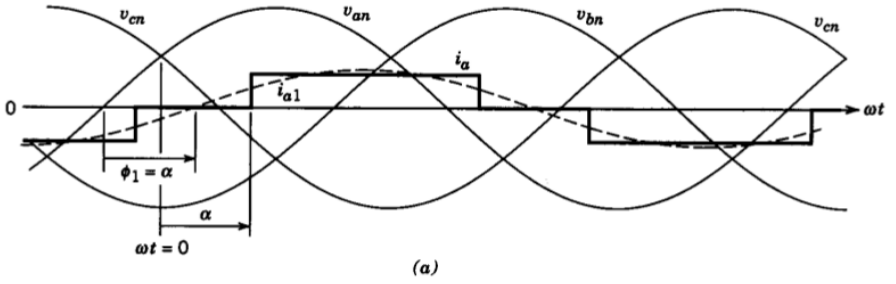
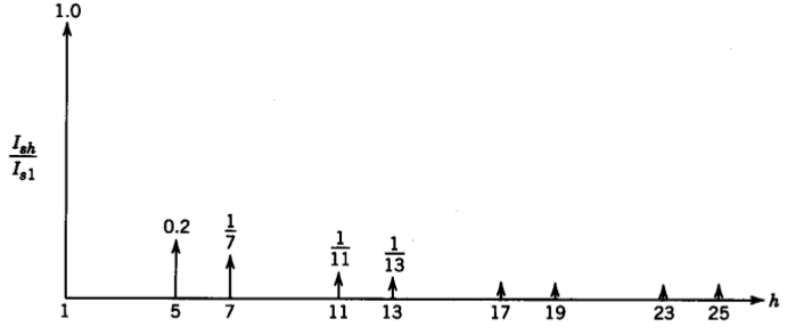
Comparison: Single Phase, Three Phase



(a)



Current Waveform:

Full-bridge Thyristor Rectifier

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Current Waveform:

Fundamental RMS: $I_{s1} = \frac{\sqrt{6}}{\pi} = 0.78 I_d$

Full-bridge Thyristor Rectifier

Current Waveform:

Fundamental RMS: $I_{s1} = \frac{\sqrt{6}}{\pi} = 0.78 I_d$

Total RMS: $I_s = \sqrt{\frac{2}{3}} I_d = 0.816 I_d$

Full-bridge Thyristor Rectifier

Current Waveform:

Fundamental RMS: $I_{s1} = \frac{\sqrt{6}}{\pi} = 0.78 I_d$

Total RMS: $I_s = \sqrt{\frac{2}{3}} I_d = 0.816 I_d$

THD= 31.08 %

Effect of Ls (Commutation)

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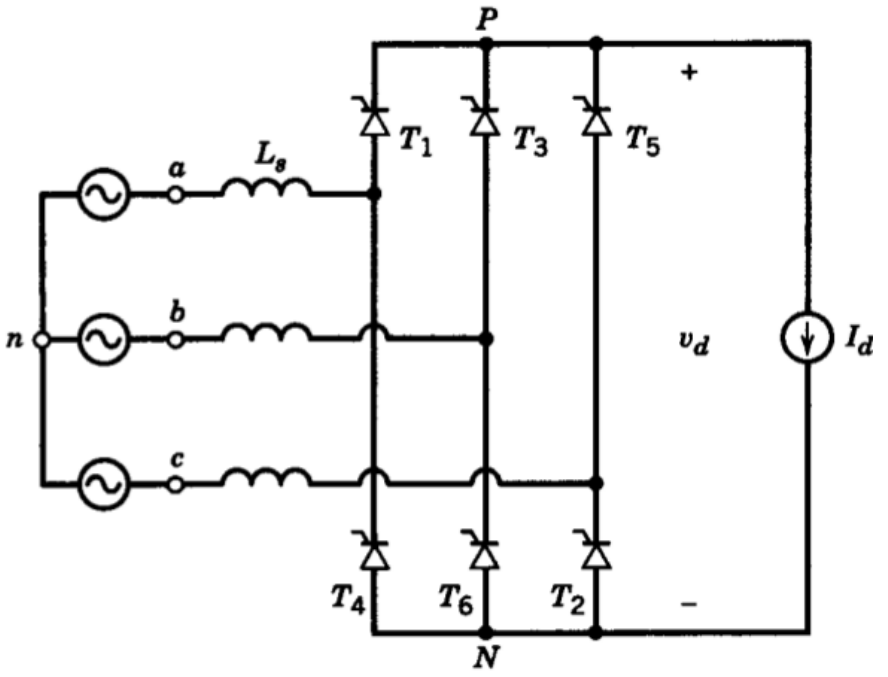
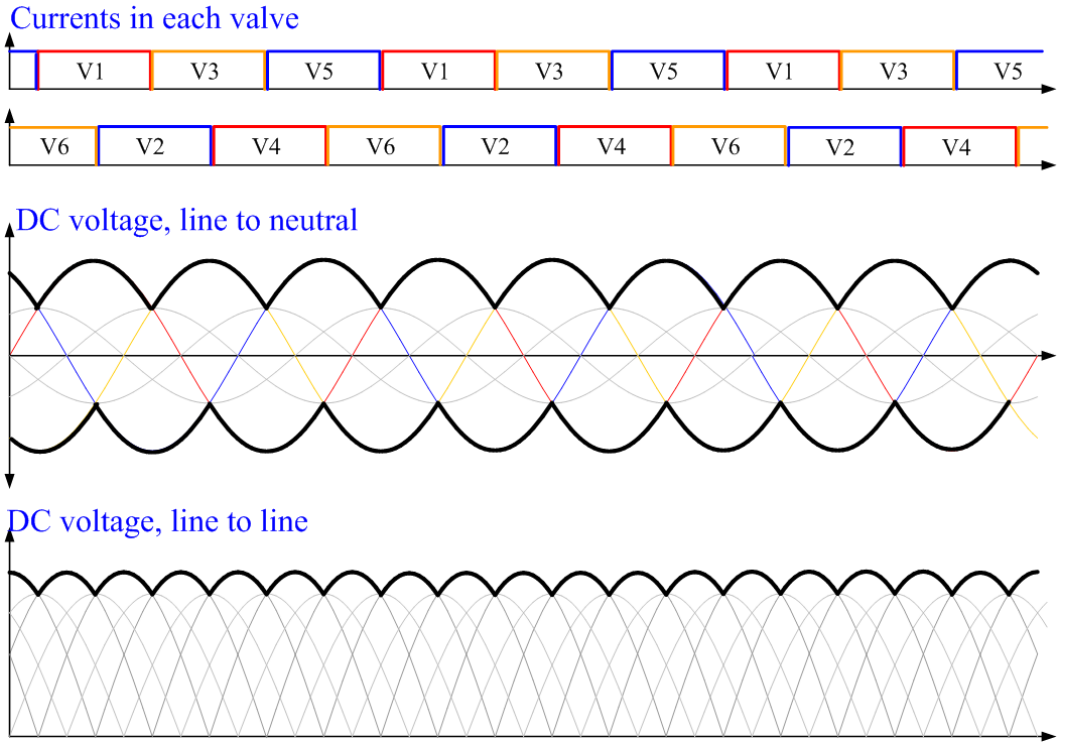
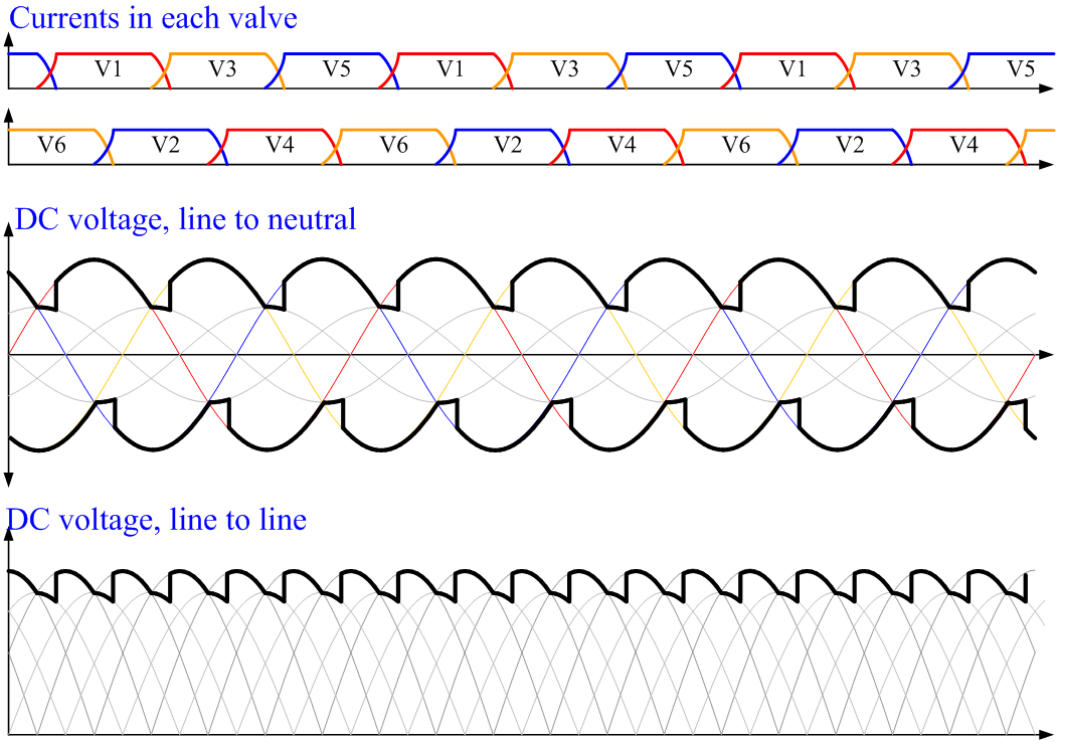


Effect of Ls (Commutation)

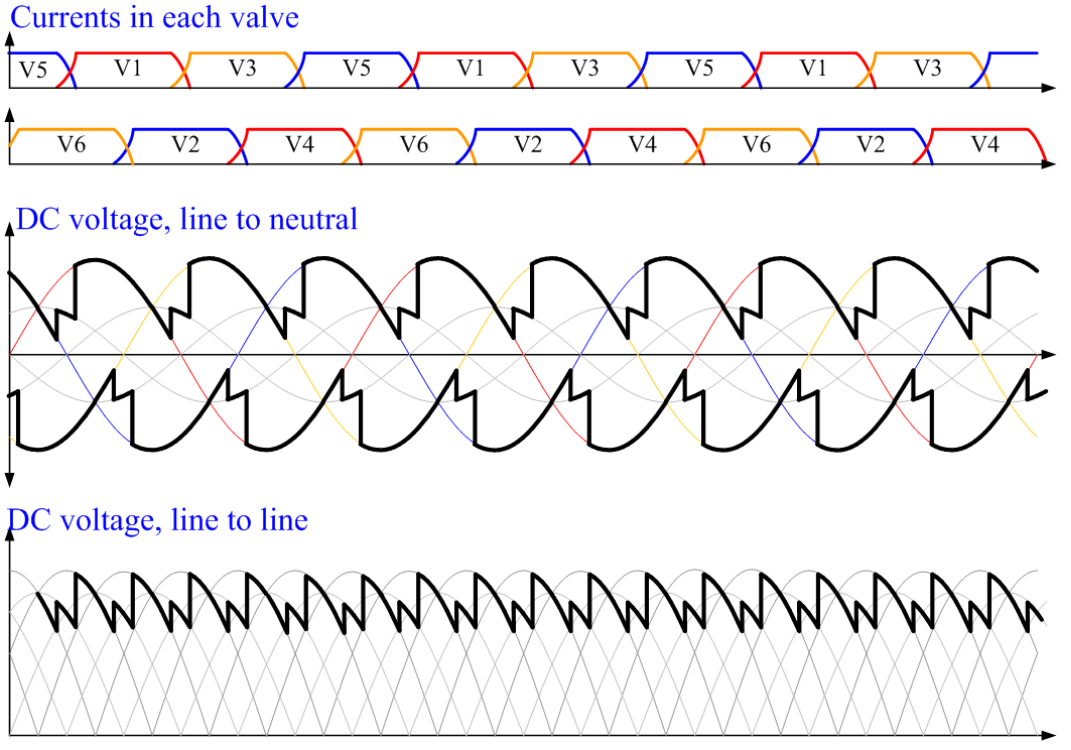
Commutation: $\alpha = 0, L_s = 0$



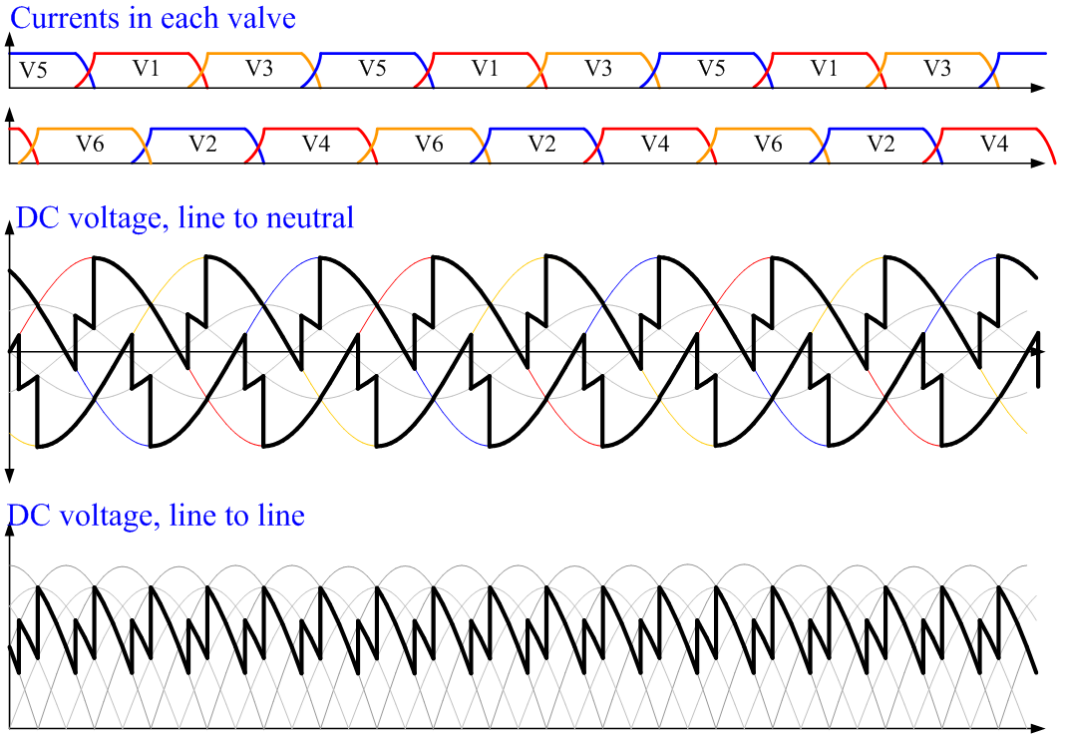
Commutation: $\alpha = 0, L_s > 0$



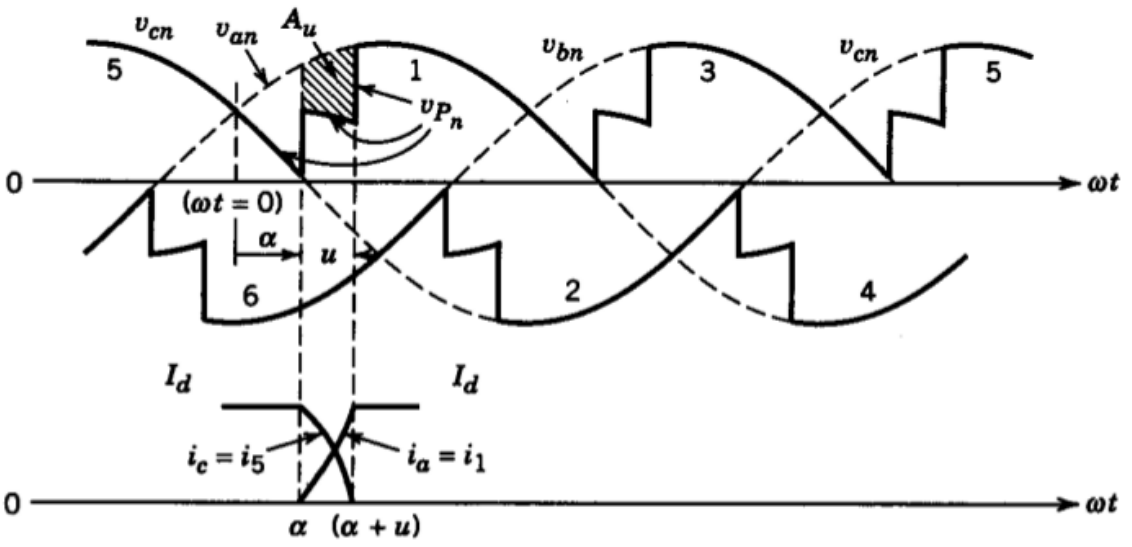
Commutation: $\alpha = 20, L_s > 0$



Commutation: $\alpha = 40, L_s > 0$



Effect of Ls (Commutation)



Effect of Ls (Commutation)

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$A_u = \omega L s I d$ (repeats itself every $\pi/3$)

Effect of Ls (Commutation)

$A_u = \omega LsId$ (repeats itself every $\pi/3$)

$$V_{d(\alpha)} = \frac{3\sqrt{2}}{\pi} V_{ll,rms} cos(\alpha) - \frac{3\omega LsId}{\pi}$$

Effect of Ls (Commutation)

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Introduces a voltage drop on the rectified side

- Single Phase: $\frac{2\omega L_s}{\pi} I_a$

Effect of Ls (Commutation)

Introduces a voltage drop on the rectified side

- Single Phase: $\frac{2\omega L_s}{\pi} I_a$
- Three Phase: $\frac{3\omega L_s}{\pi} I_a$

Effect of Ls (Commutation)

Introduces a voltage drop on the rectified side

- Single Phase: $\frac{2\omega L_s}{\pi} I_a$
- Three Phase: $\frac{3\omega L_s}{\pi} I_a$
- Resultant voltage in a 3-ph rectifier:

$$V_{d\alpha} = \frac{3\sqrt{2}}{\pi} V_{l-l} cos(\alpha) - \frac{3\omega L_s}{\pi} I_a$$

Inverter Mode of Operation

Two Quadrant Operation

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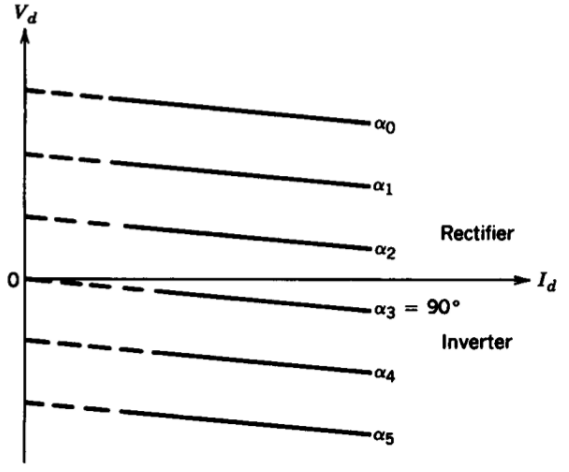
Two Quadrant Operation



Two quadrant operation with source side voltage (i.e. DC motor)

How can you obtain four-quadrant operation?

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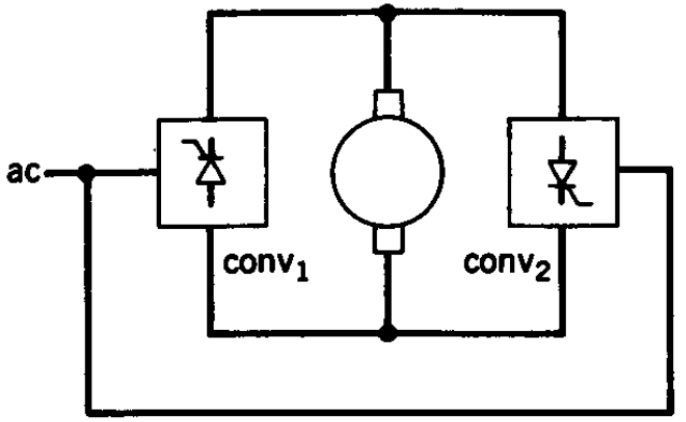
Use two separate converters



Ref: Mohan Chapter 13 DC Motor Drives

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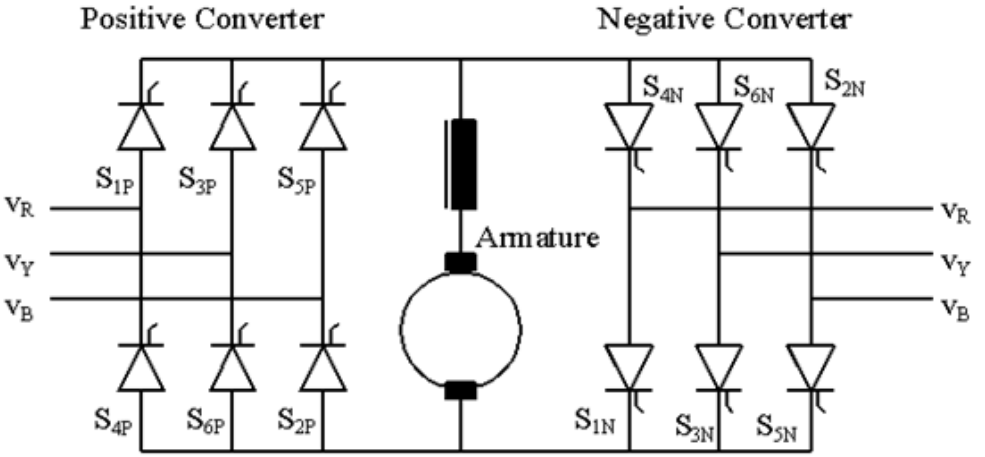

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