EE-463 STATIC POWER CONVERSION-I

Diode Rectifiers

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Line Frequency Diode Rectifiers

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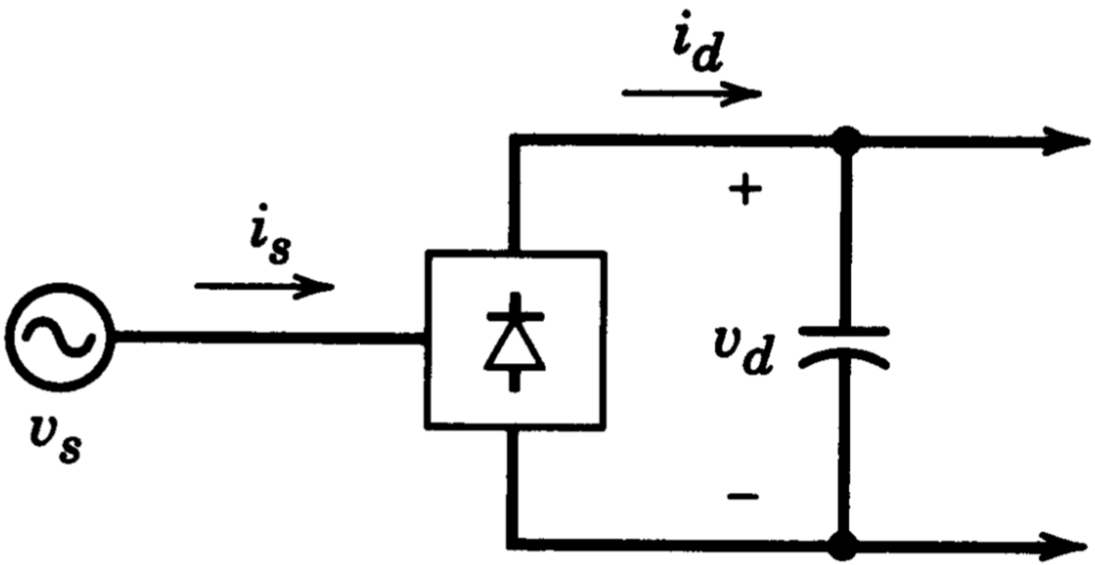

Line Frequency Diode Rectifiers

Ideal Rectifier

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- Ripple free DC output

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- Sinusoidal (THD=0) input current

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Line Frequency Diode Rectifiers

Ideal Rectifier

- Ripple free DC output
- Sinusoidal (THD=0) input current
- High Efficieny
- Small Size (High Power Density)

Simplest Case: One diode with resistive load

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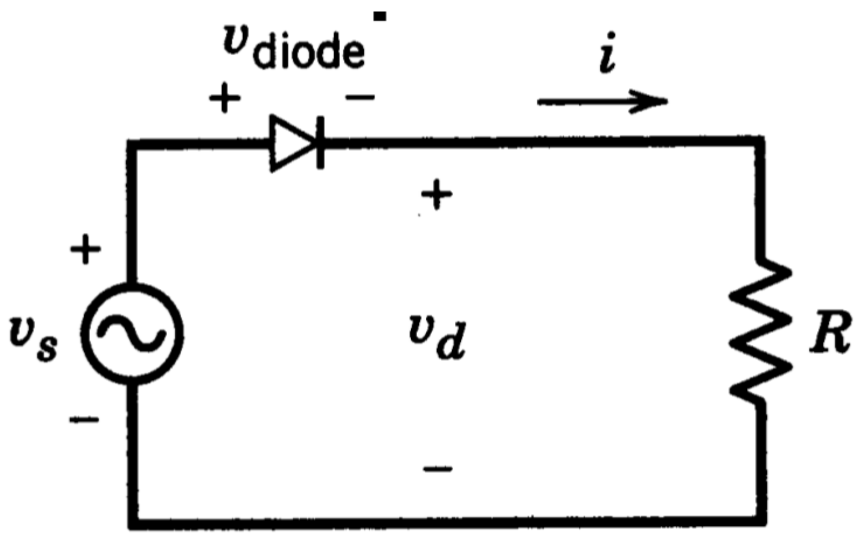
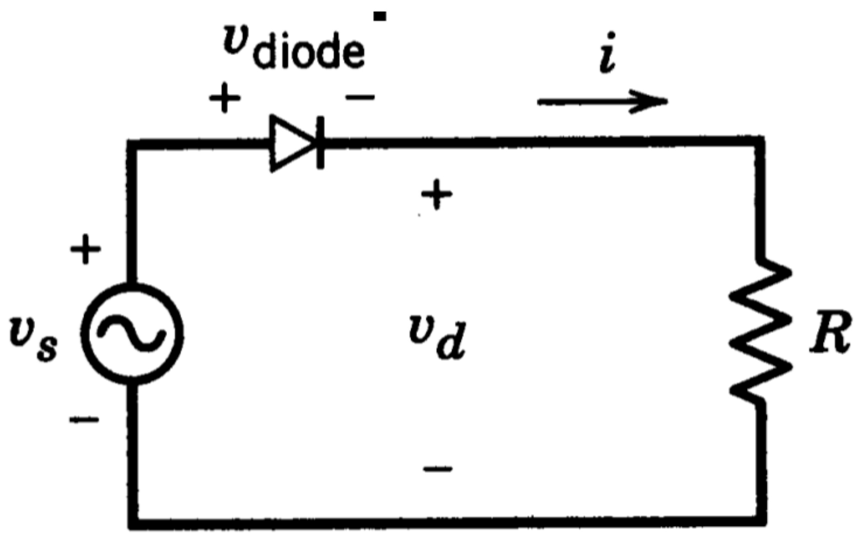


Can you plot the voltage-current waveforms?

Simplest Case: One diode with resistive load



Can you plot the voltage-current waveforms?

What about the average voltage?

One Diode with R-L Load

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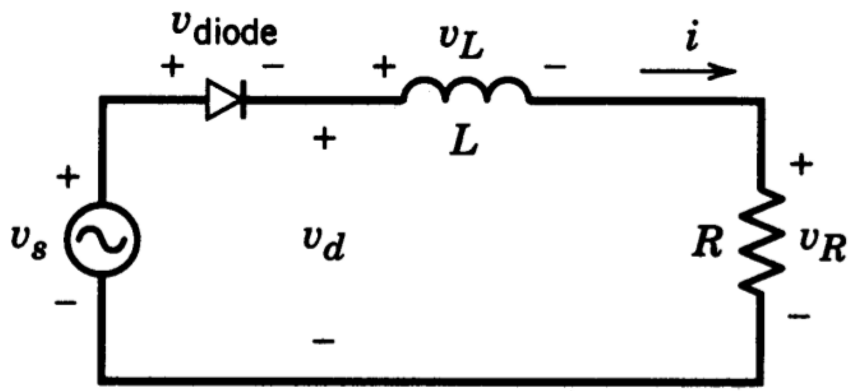
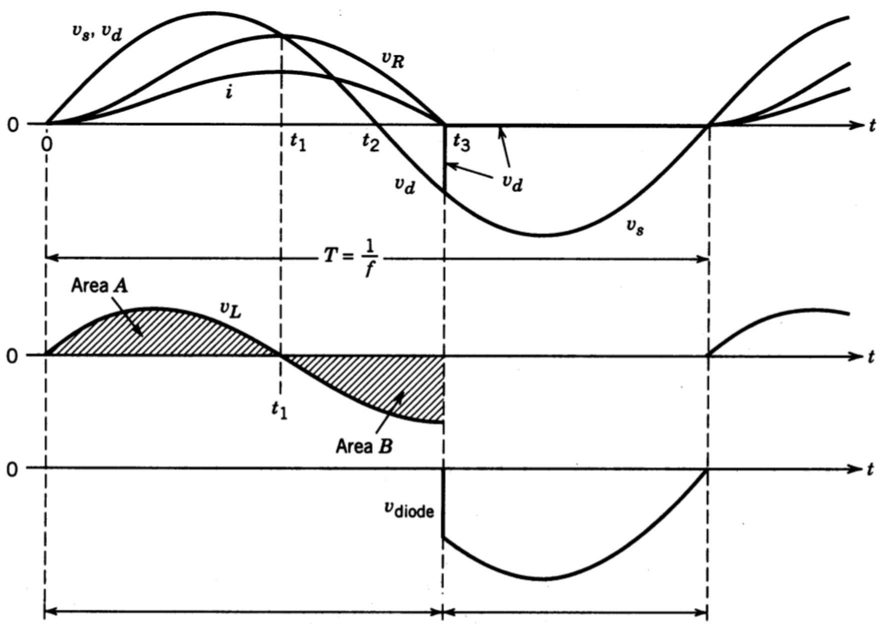


One Diode with R-L Load

Diode continues to conduct for extended period



One Diode with R-L Load

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Diode continues to conduct for extended period:

Commutation!

One Diode with R-L Load

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How does the average voltage change with commutation?

One Diode with R-L Load

Diode continues to conduct for extended period:

Commutation!

How does the average voltage change with commutation?

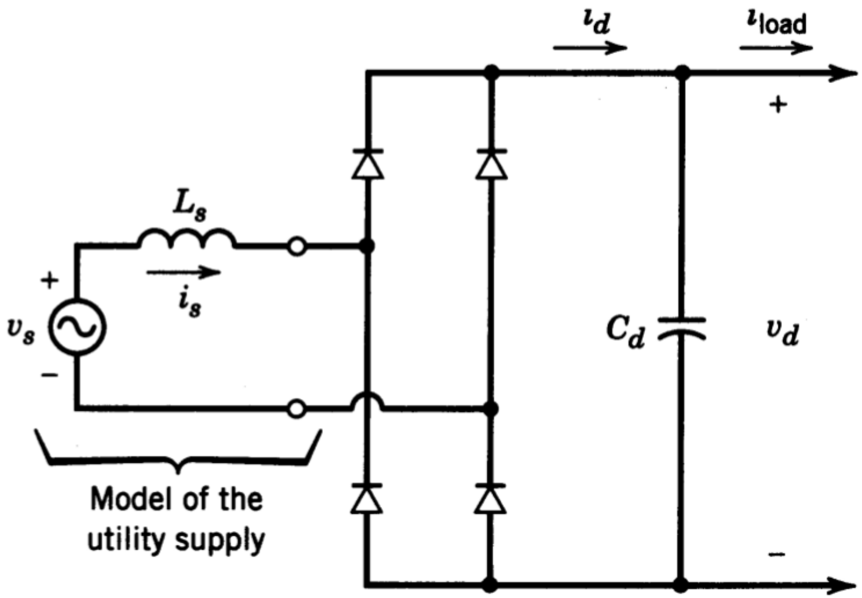
It becomes smaller!

Single-Phase Diode Rectifier

Drawing

Commercial Bridge Rectifiers

Single-Phase Diode Rectifier



Let's assume ideal source (Ls=0) to start with

Single-Phase Diode Rectifier

Also assume load draws constant current (id)

Single-Phase Diode Rectifier

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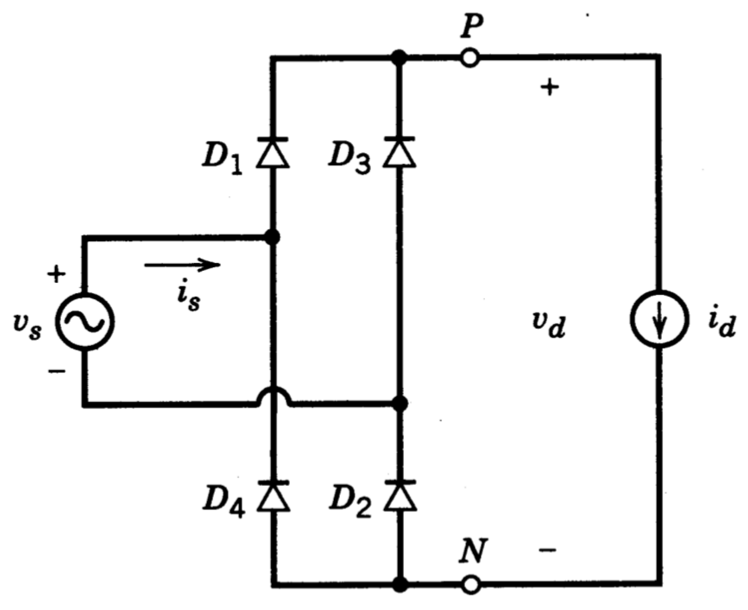
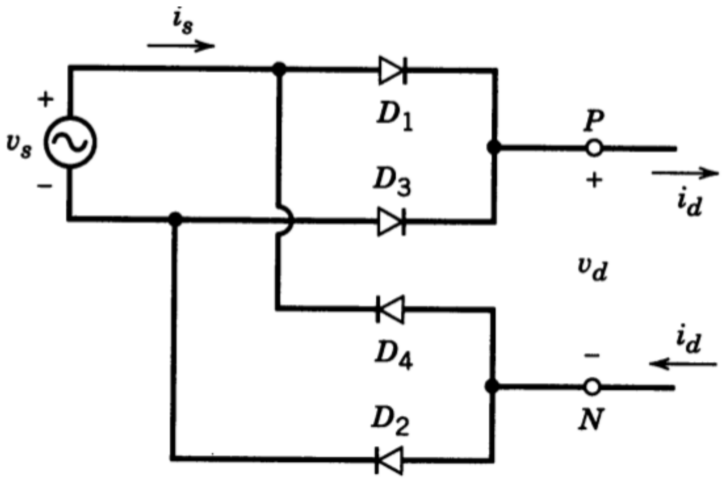


Single-Phase Diode Rectifier

You can redraw it as:



Single-Phase Diode Rectifier

Can you calculate the average output voltage?

Single-Phase Diode Rectifier

Can you calculate the average output voltage?

Can you plot the input current waveform?

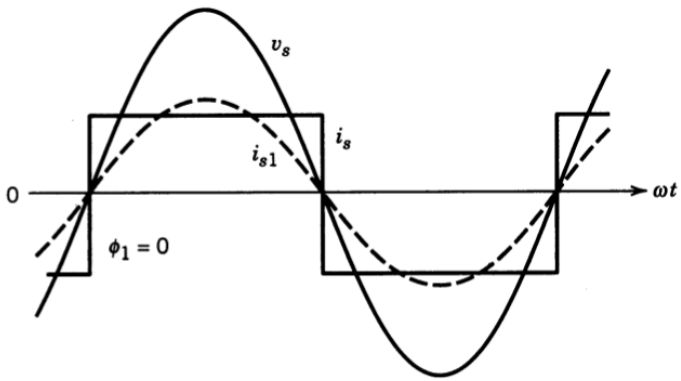
Single-Phase Diode Rectifier

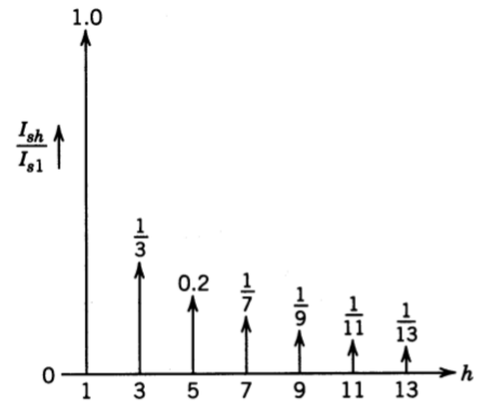
Can you calculate the average output voltage?

Can you plot the input current waveform?

What about the THD of input current?

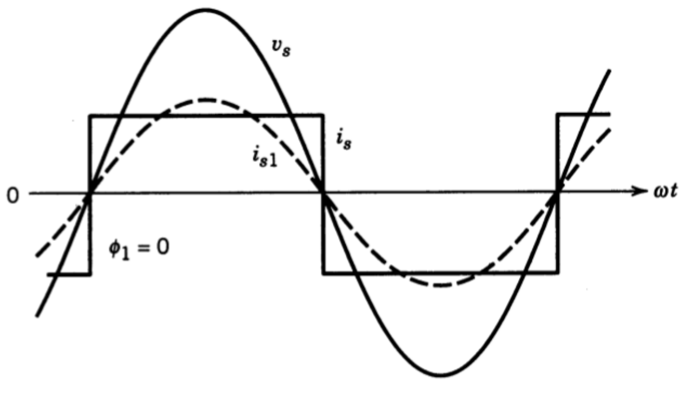
Single-Phase Diode Rectifier

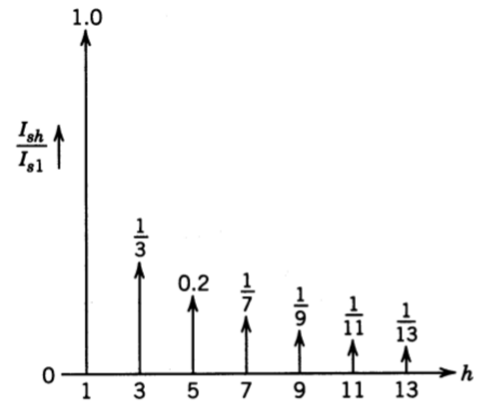




THD of current (square waveform)=

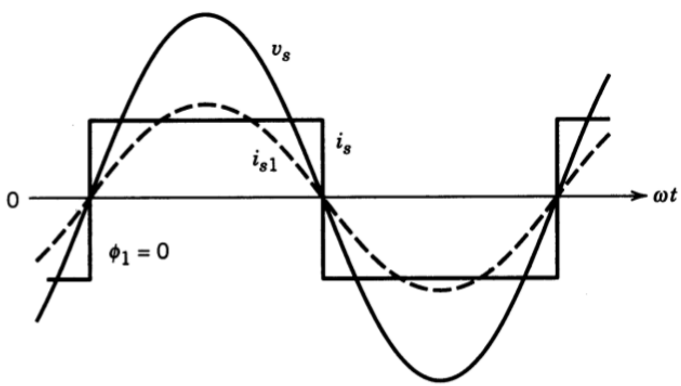
Single-Phase Diode Rectifier

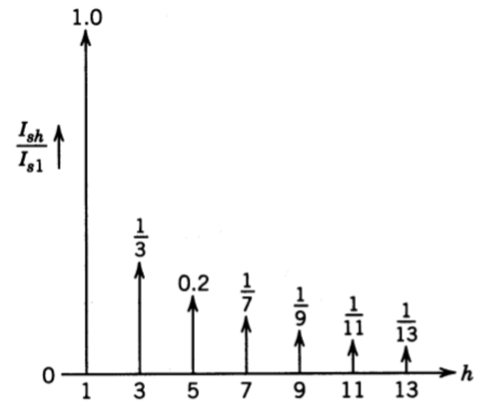




THD of current (square waveform)= $\dfrac{\sqrt{1-\frac{2\sqrt{2}}{\pi}^{\,2}}}{\frac{2\sqrt{2}}{\pi}}$

Single-Phase Diode Rectifier





THD of current (square waveform)=

$$\frac{\sqrt{0.19}}{0.9} = 0.484$$

Short Review of Fourier Series

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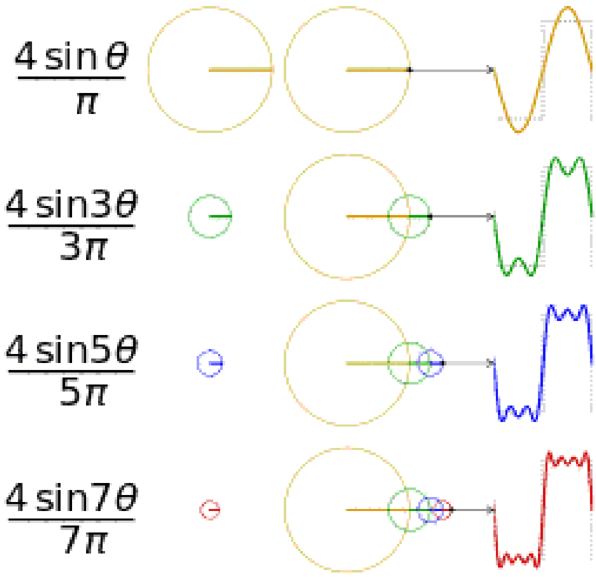
All waveforms, no matter what you scribble or observe in the universe, are actually just the sum of simple sinusoids of different frequencies.

Fourier Series



[Interactive Fourier Series](), [Complex Orbits](), [Singing Train](), [Useful applets](), [Fourier examples]()

[More Useful Links on Fourier Series]()

Fourier Series

$$f(x) = \frac{1}{2} a_0 + \sum_{n=1}^{\infty} a_n \cos(n x) + \sum_{n=1}^{\infty} b_n \sin(n x),$$

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Coefficients

$$\begin{cases} a_0 & = \dfrac{1}{2\pi}\displaystyle\int_{-\pi}^{\pi} f(x)dx, \\ a_n = & = \dfrac{1}{\pi}\displaystyle\int_{-\pi}^{\pi} f(x)\cos(nx)dx, \quad 1 \leq n \\ b_n & = \dfrac{1}{\pi}\displaystyle\int_{-\pi}^{\pi} f(x)\sin(nx)dx, \quad 1 \leq n. \end{cases}$$

Some Important Functions

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Even function:

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$\rightarrow a_h = b_h = 0$ for even harmonics

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Even quarter-wave:

Some Important Functions

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Even quarter-wave: Even function and Half-wave symmetry

Some Important Functions

Even function: $f(-t) = f(t) \rightarrow b_h = 0$

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Even quarter-wave: Even function and Half-wave symmetry

$\rightarrow b_h = 0$ for all harmonics

$\rightarrow a_h = 0$ for even harmonics

Effect of Line Inductance

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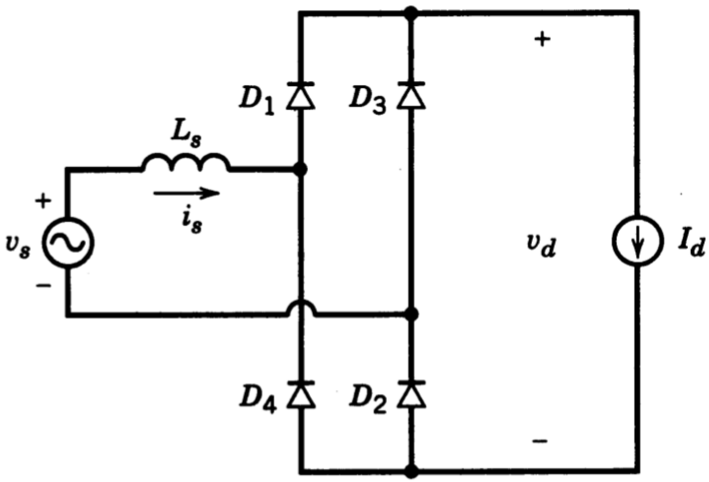
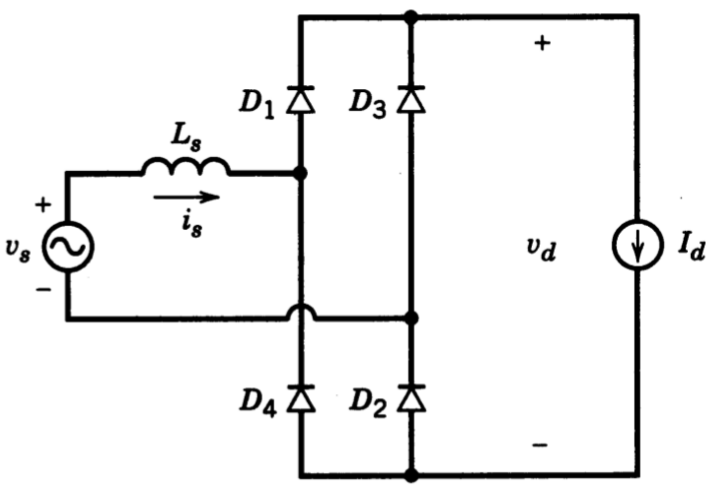


Can you still draw square current from grid?

Effect of Line Inductance



Can you still draw square current from grid?

There has to be finite time between +Id to -Id transition.

Let's start with a simple circuit

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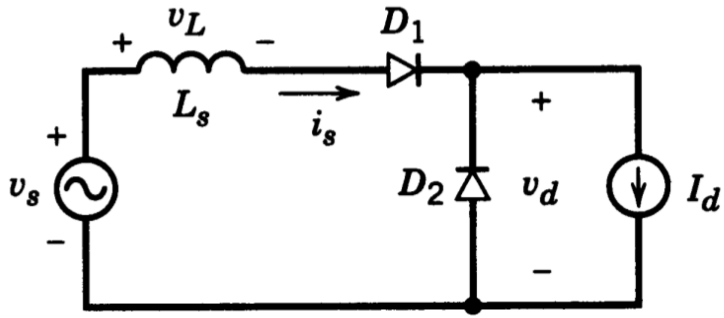
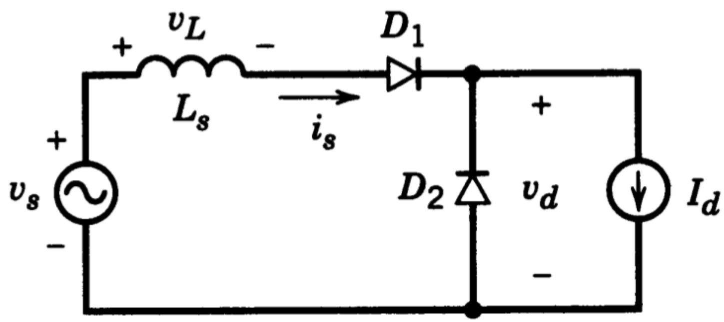


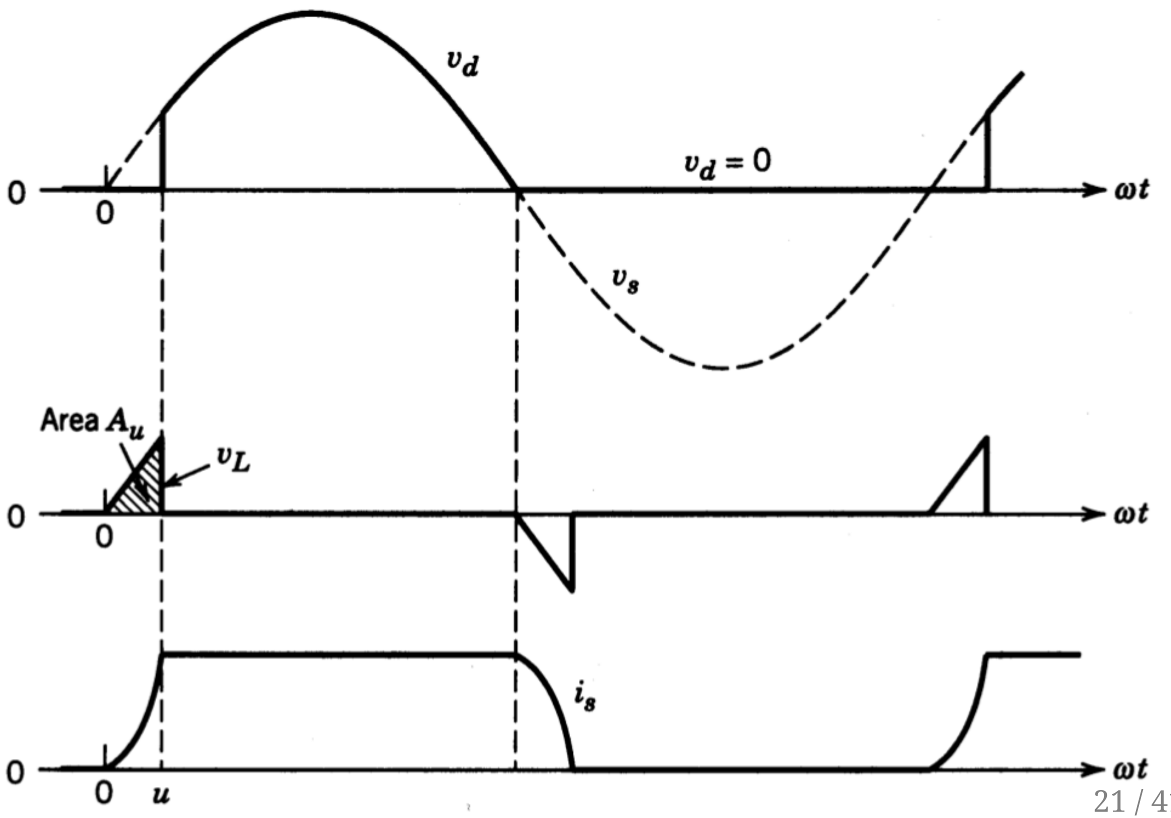
Let's start with a simple circuit



Draw the equivalent circuits at each interval

Voltage Waveforms

Voltage Waveforms



How to calculate the commutation period (u)?

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$$cos(u) = 1 - \frac{\omega L_s I_d}{\sqrt{2} V_s}$$

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$$cos(u) = 1 - \frac{\omega L_s I_d}{\sqrt{2} V_s}$$

- Ls, Id increases commutation time
- Vs reduces commutation time

How does the average voltage changes?

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$$Vd = \frac{0.9Vs}{2} - \frac{Au}{2\pi}$$

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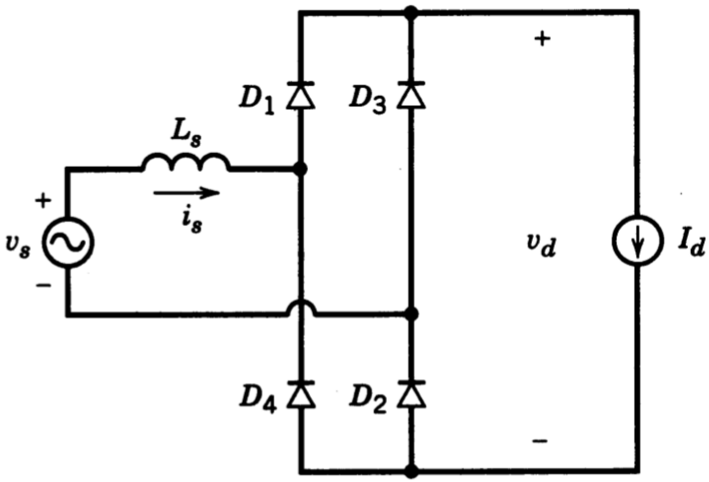
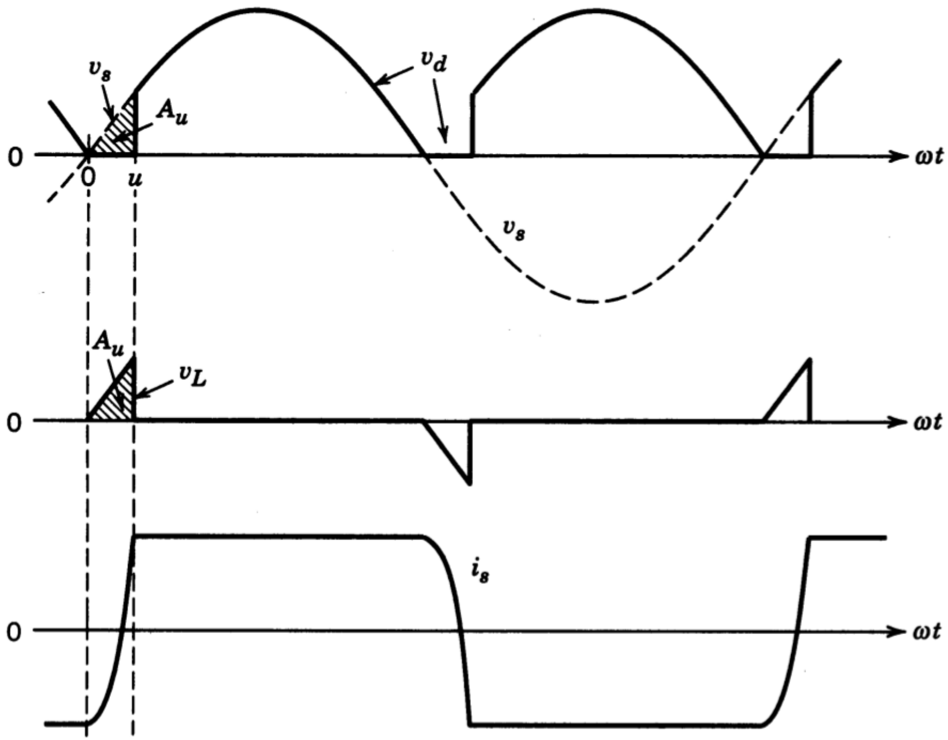
Reduction in average voltage

$$\Delta Vd = \frac{\omega Ls}{2\pi} Id$$

What about commutation in single phase rectifier?



Voltage-Current Waveforms



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Similar to previous case,but:

- Current goes from -Id to Id
- Commutation happens twice (2Au)

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$$Vd = 0.9Vs - \frac{2\omega Ls}{\pi} Id$$

Rectifier with DC Side Voltage

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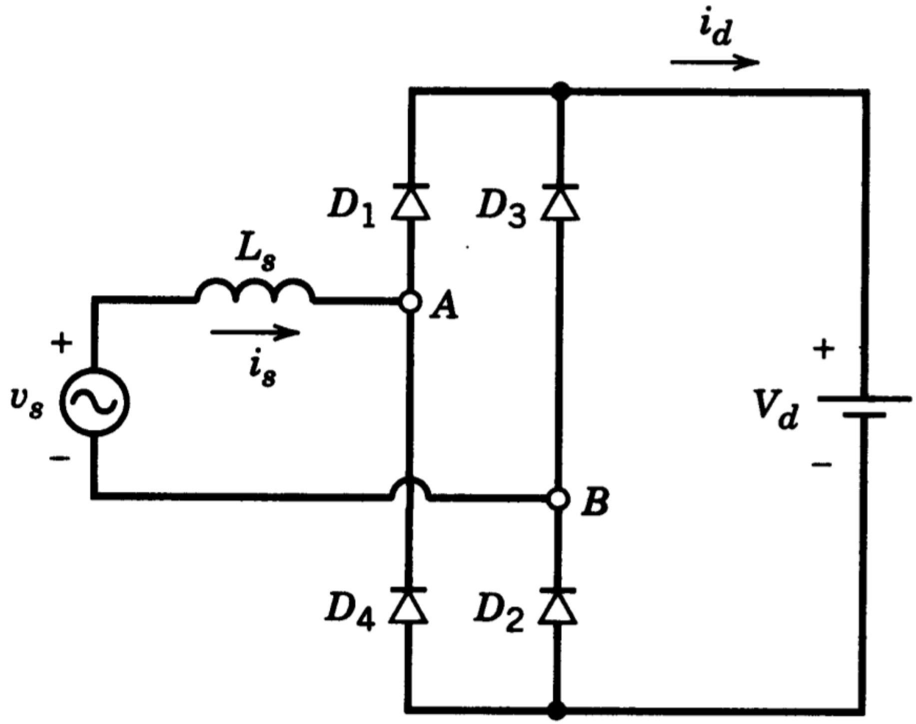

Can you plot the voltage waveforms?

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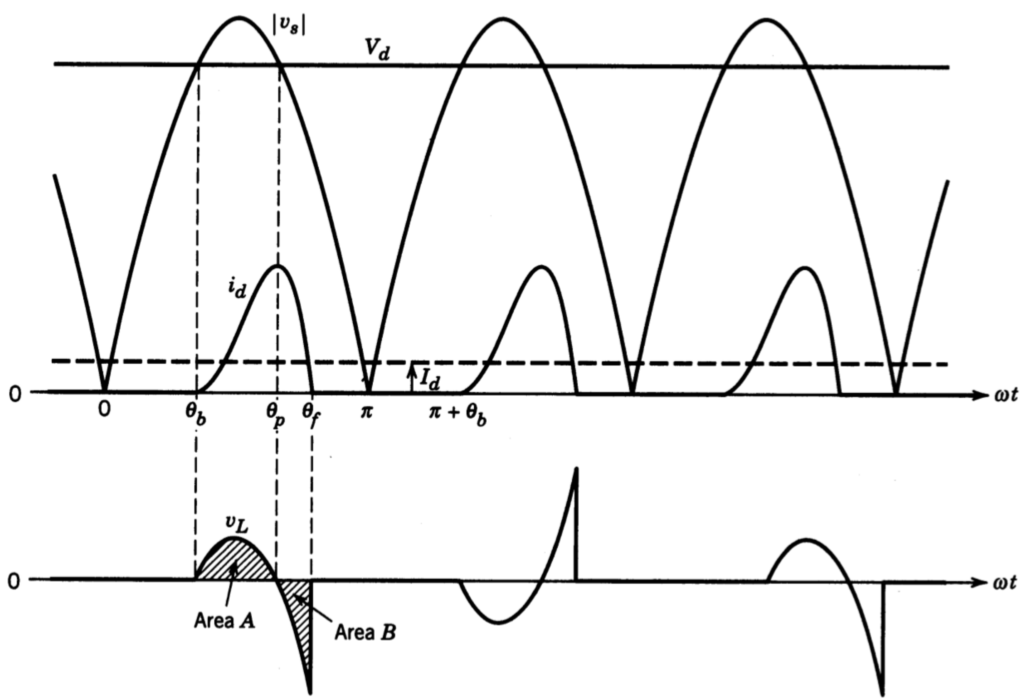

Average current

$$Id_{av} = \frac{\int_{b}^{f} i(\theta)d\theta}{\pi}$$

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What is the short circuit current (when Vd=0)?

Average current

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What is the short circuit current (when Vd=0)?

$$Id_{(short-circuit)} = \frac{Vs}{\omega Ls}$$

Some Alternative Topologies

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Centre-Tap Rectifier

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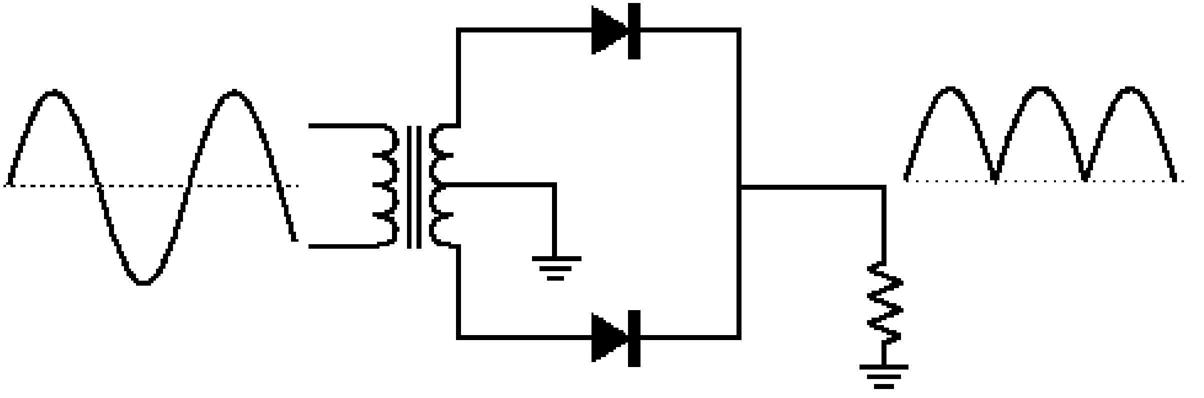
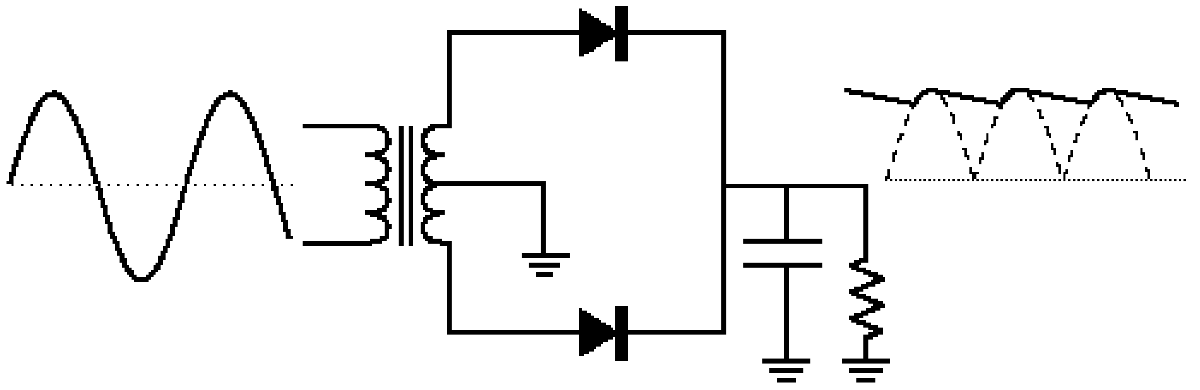


Centre-Tap Rectifier



Centre-Tap Rectifier

Can you compare it with the full-bridge rectifier?

in terms of:

Centre-Tap Rectifier

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in terms of:

- Number of Diodes (and ratings)

Centre-Tap Rectifier

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- Number of Diodes (and ratings)
- Cost

Centre-Tap Rectifier

Can you compare it with the full-bridge rectifier?

in terms of:

- Number of Diodes (and ratings)
- Cost
- Current Waveform

Voltage Doubler Rectifier

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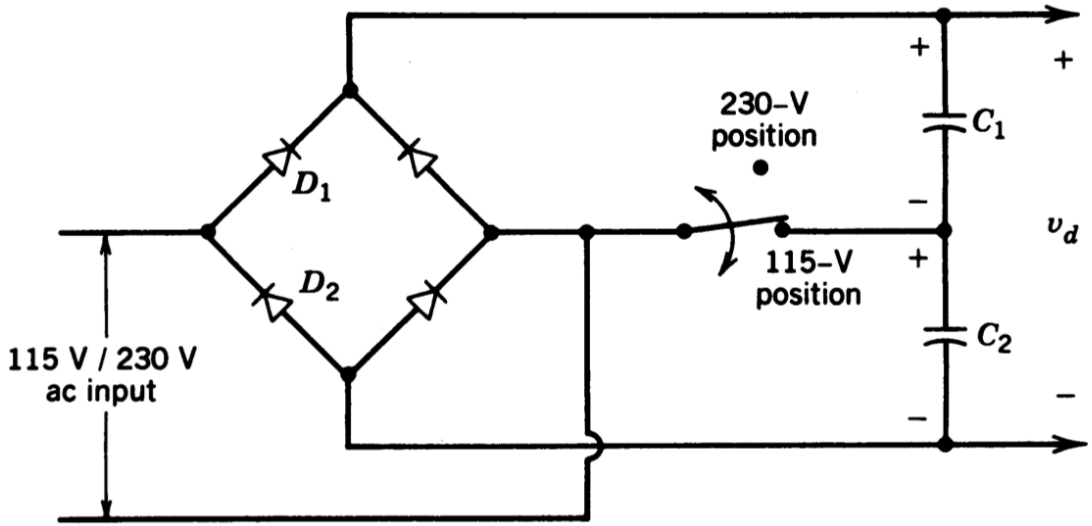
Voltage Doubler Rectifier



Quiz

Quiz

Many single-phase rectifiers are connected to three phase system.

Can you plot the neutral line current?

Effects of Single Phase Rectifiers

Effects of Single Phase Rectifiers

- Voltage Waveform (Notching)

Effects of Single Phase Rectifiers

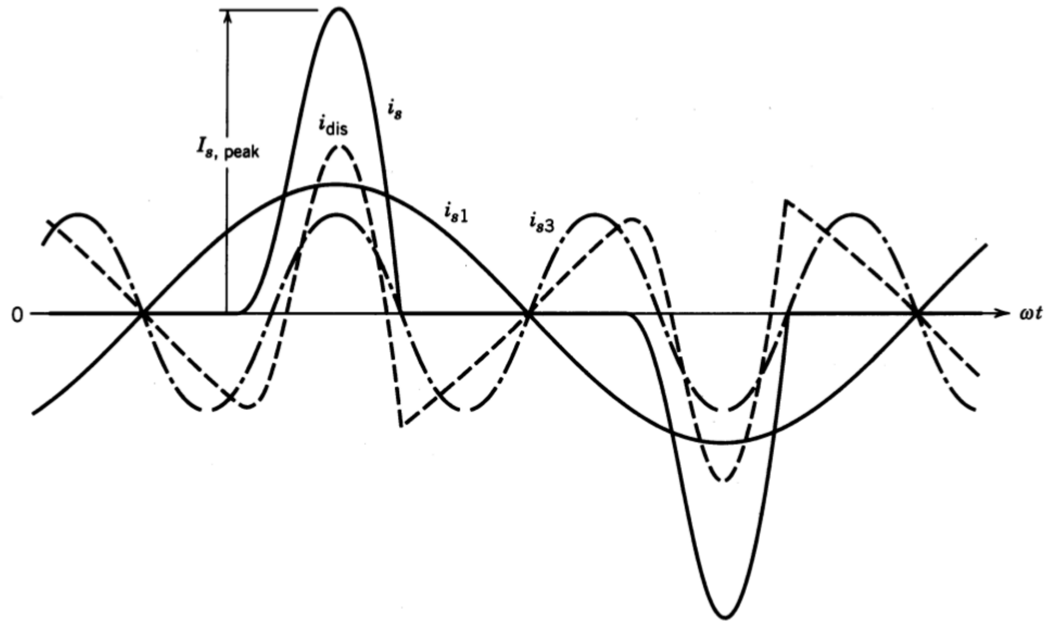
- Voltage Waveform (Notching)
- Neutral Line Current

Effects of Single Phase Rectifiers

- Voltage Waveform (Notching)
- Neutral Line Current
- THD

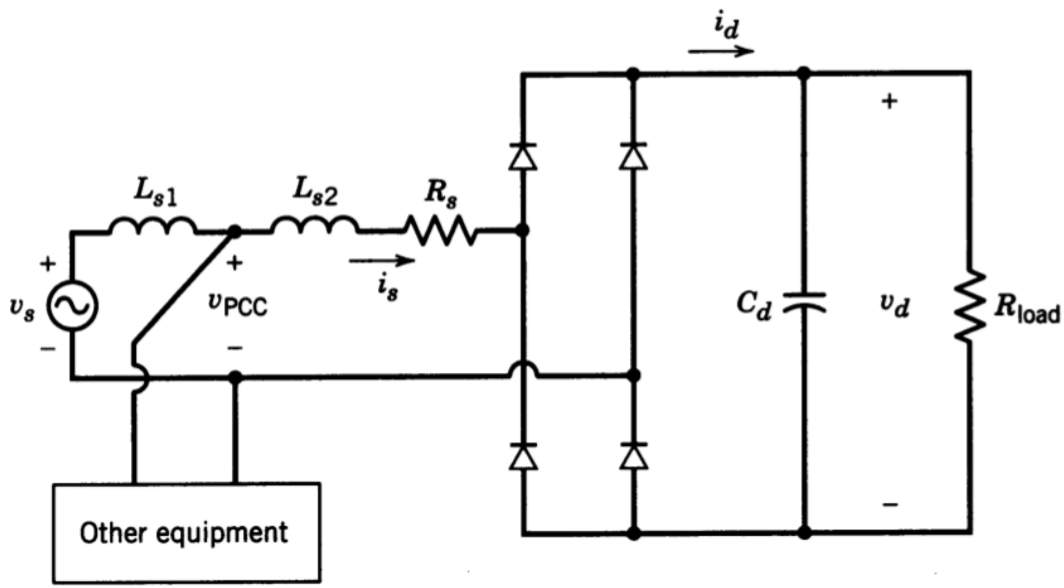
Effects of Single Phase Rectifiers

Current Distortion



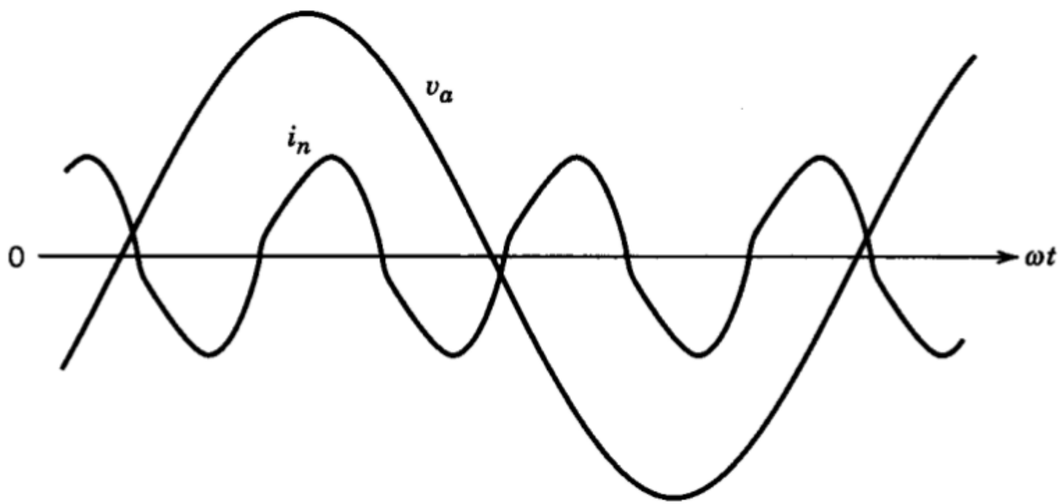
Effects of Single Phase Rectifiers

Line Voltage Distortion



Effects of Single Phase Rectifiers

Neutral Line Current



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