Power converters AC/DC and DC/AC - MM1

By
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Content MM1

2. Purpose and content

Purpose

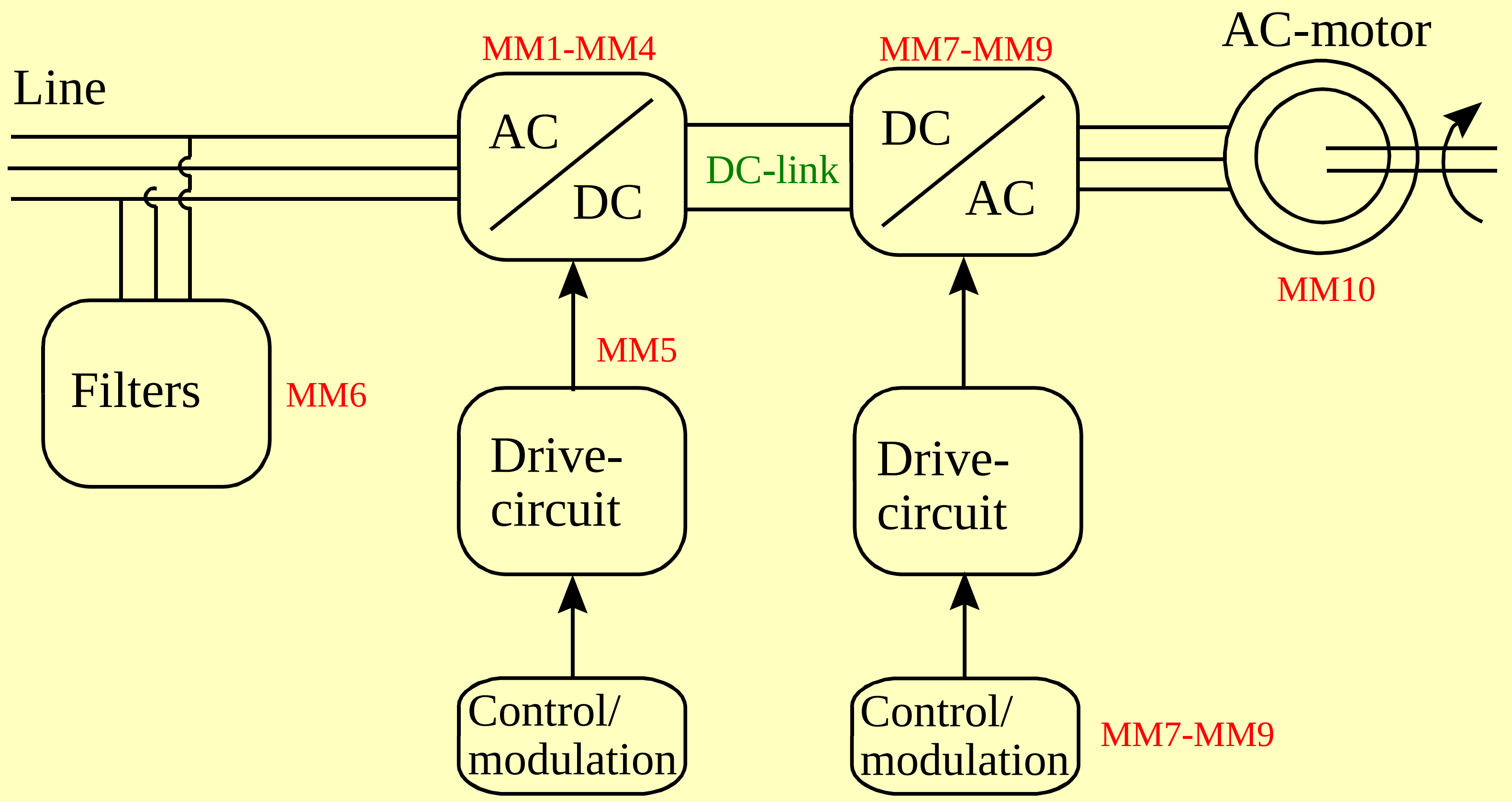
- To understand single- and three-phase AC/DC and DC/AC power conversion
- Design aspects about single and three phase converters

Main content

MM1-MM2	Single- and three-phase AC/DC converters	POR
MM3-MM4	Single- and three-phase AC/DC and DC/AC Thyristor converters	POR
MM5	Thyristors operation mode	POR
MM6	Filters (power)	POR
MM7-MM9	DC/AC conversion with high switching frequency	SMN
MM10	Interaction with electrical motors	SMN

2. Purpose and content

Example : A drive system



2. Purpose and content

More goals

- To use the content of the course in the project
- Get more experience with circuit-simulation tools (P-Spice)
- More experience with power electronics

The form of the course

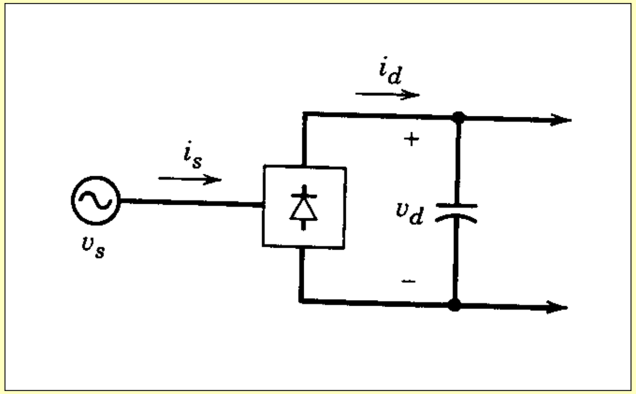
- 2 times lectures of 45 min. per. Mini-Module (MM)
- Exercises
- I expect that the material to each MM are read.
- Primary overheads
- Feedback from you !!. This is very important (Don’t be afraid to put questions)
- Course home-page with overheads, exercises and latest information

Course Home-page

http://www.iet.auc.dk/~por/teaching/power/power.html

3. Rectifier principles

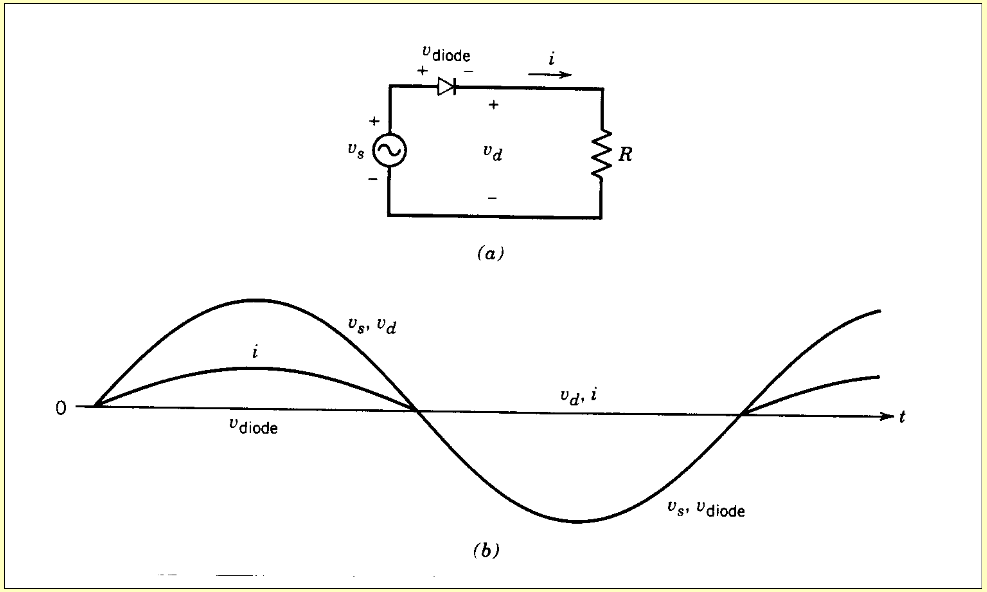
AC/DC



- DC-voltage
- Load depend
- Current from the grid

- Power supplies
- Drive systems etc.

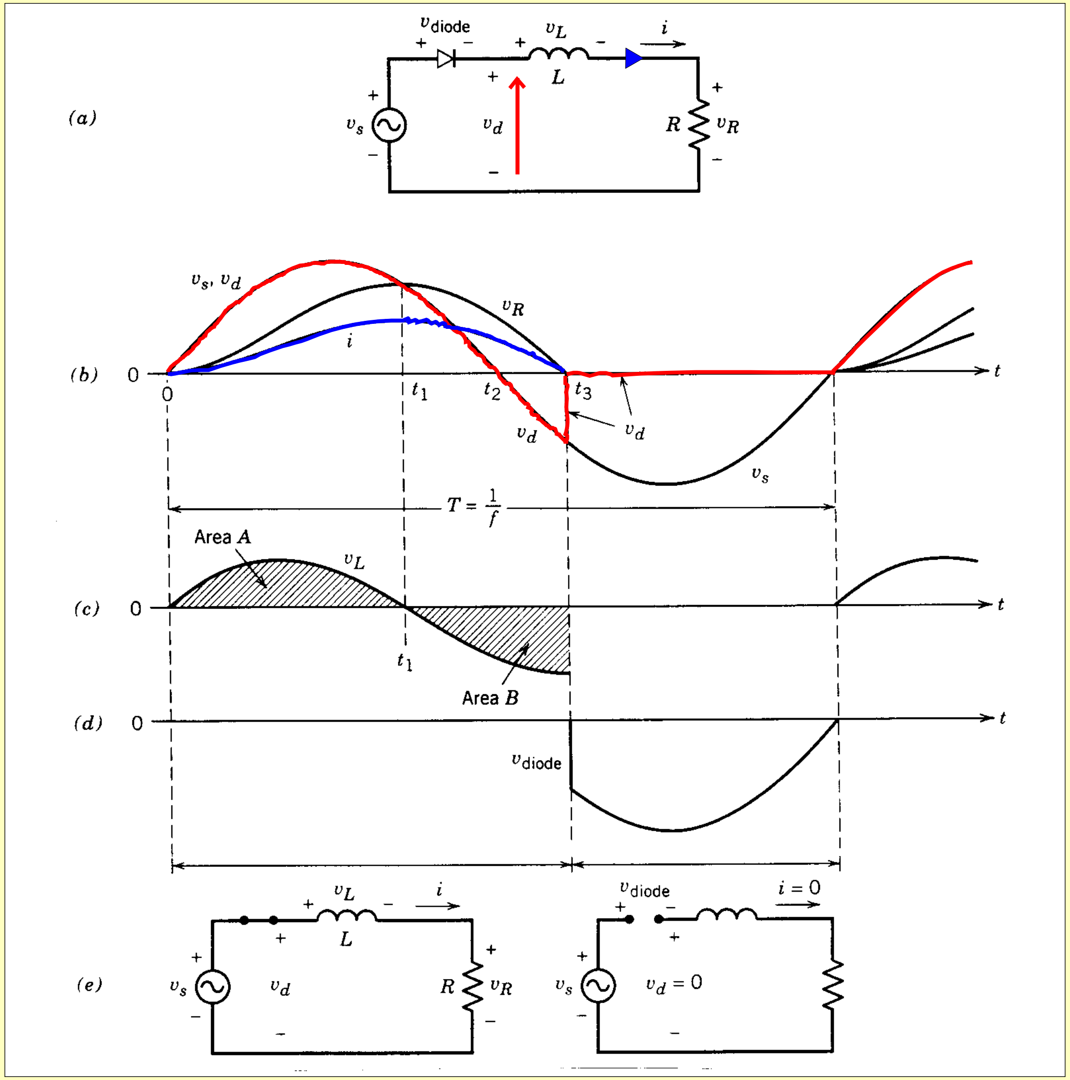
Resistive Load



$V_{diode} > 0 \Rightarrow$ Current
$V_{diode} < 0 \Rightarrow 0$

Inductive load

3. Rectifier principles



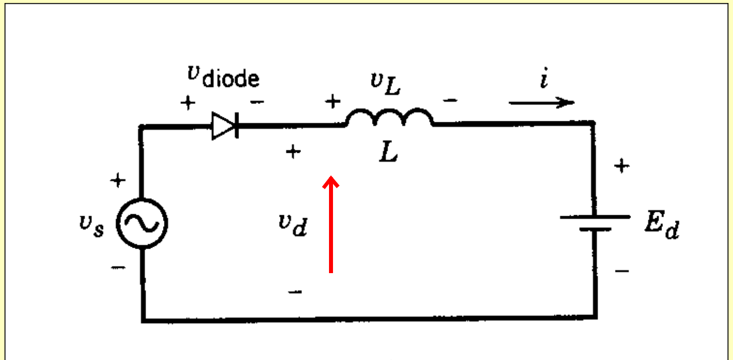
Basic rules used in power electronics

$$u = L\frac{di}{dt} \qquad Steady-state: \int_0^T u\,dt = 0$$

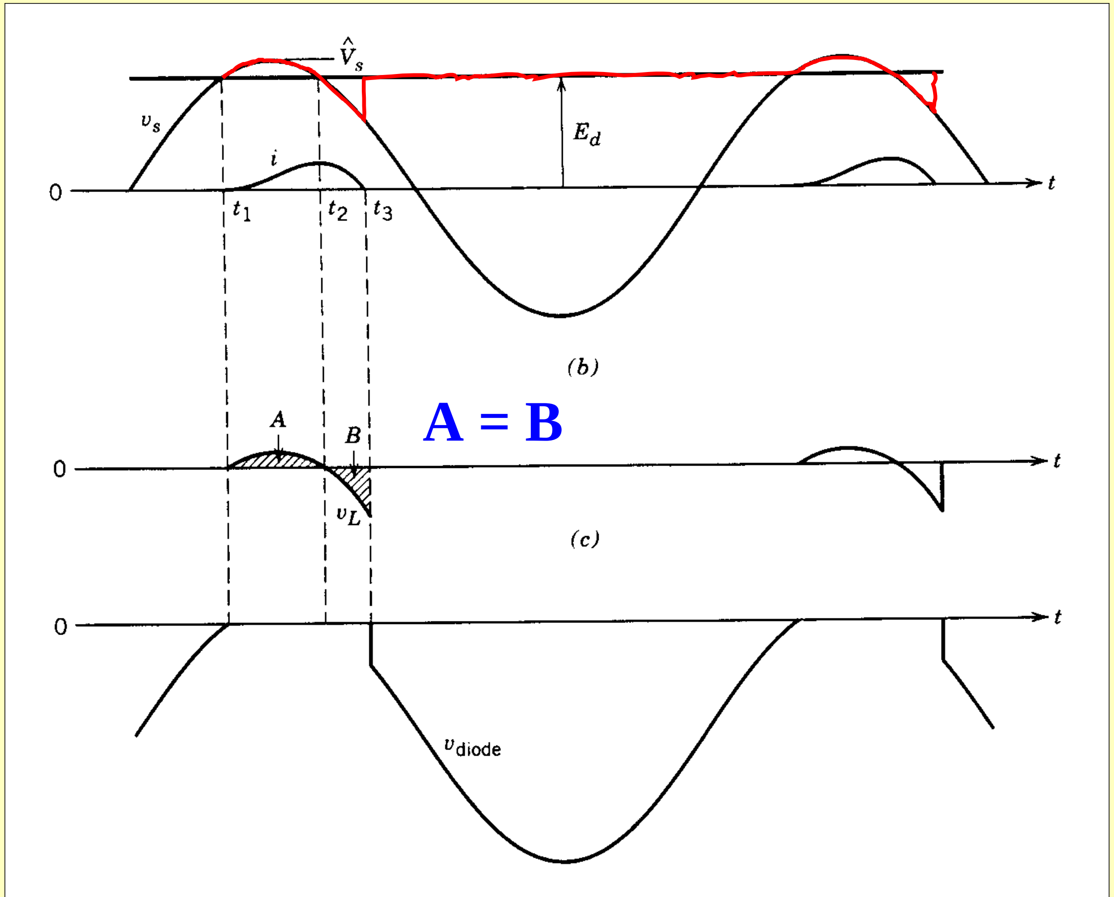
$$i = C\frac{du}{dt} \qquad Steady-state: \int_0^T i\,dt = 0$$

3. Rectifier principles

Internal DC voltage E



(a)



(b)

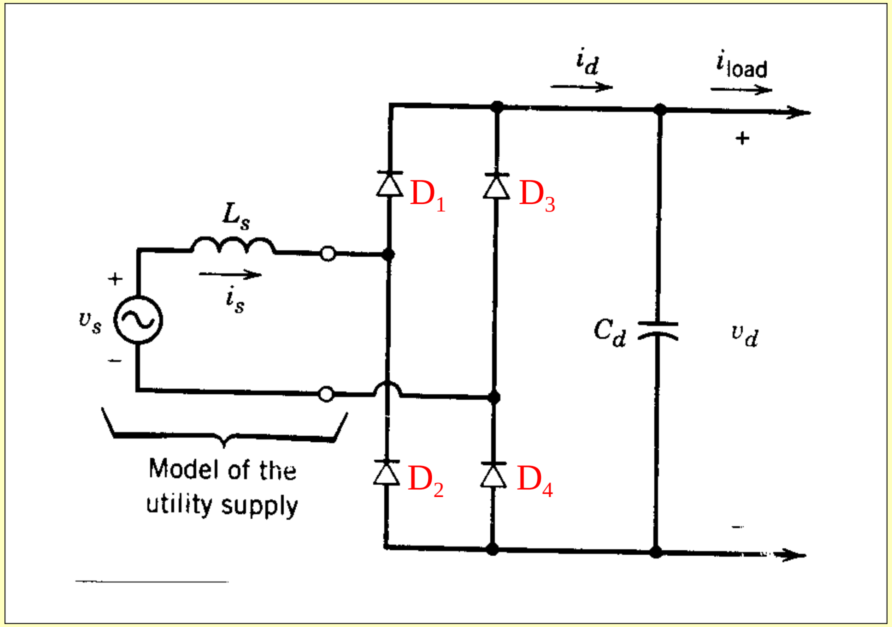
(c)

(d)

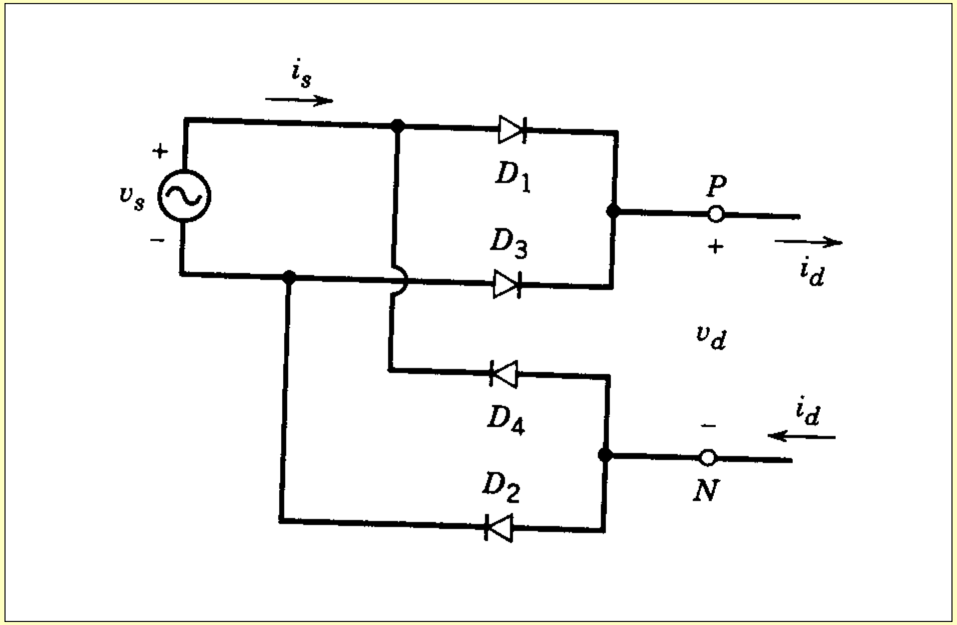
- Capacitor
- Batteries
- DC-motors

4. Single phase rectifier

Real rectifier



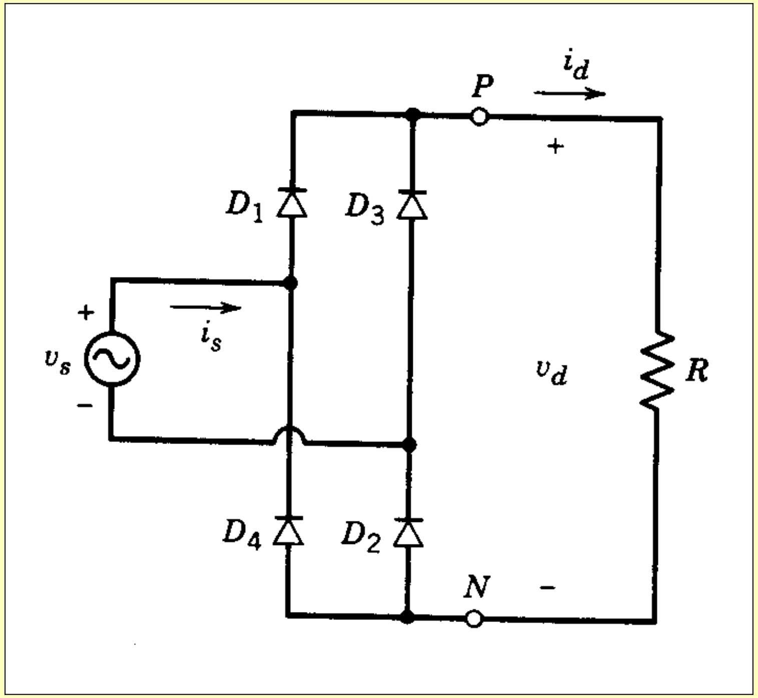
Ideal rectifier



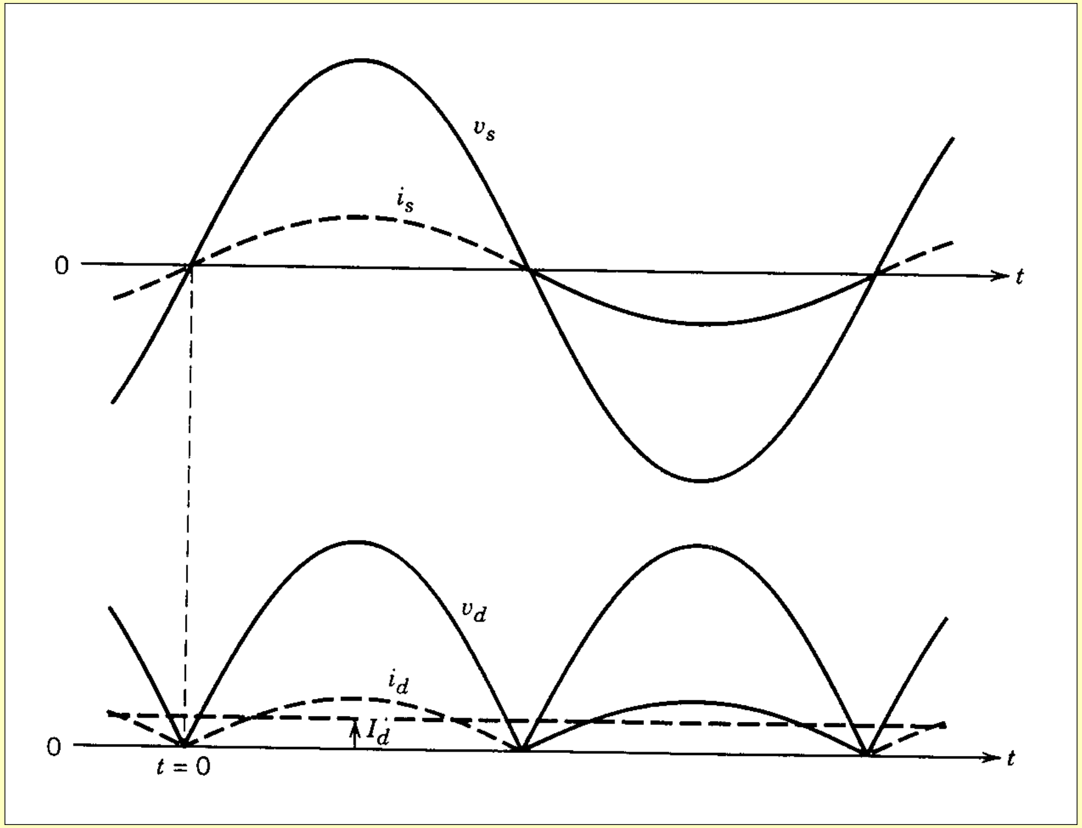
L_s is a model of the line. Typical very dominating in relation to R.

4. Single phase rectifier

Resistive load



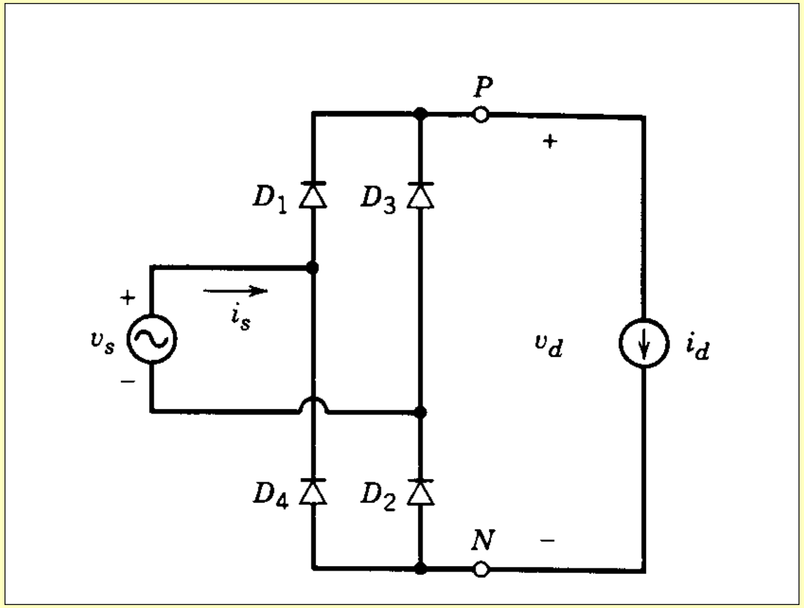
$L_s = 0$

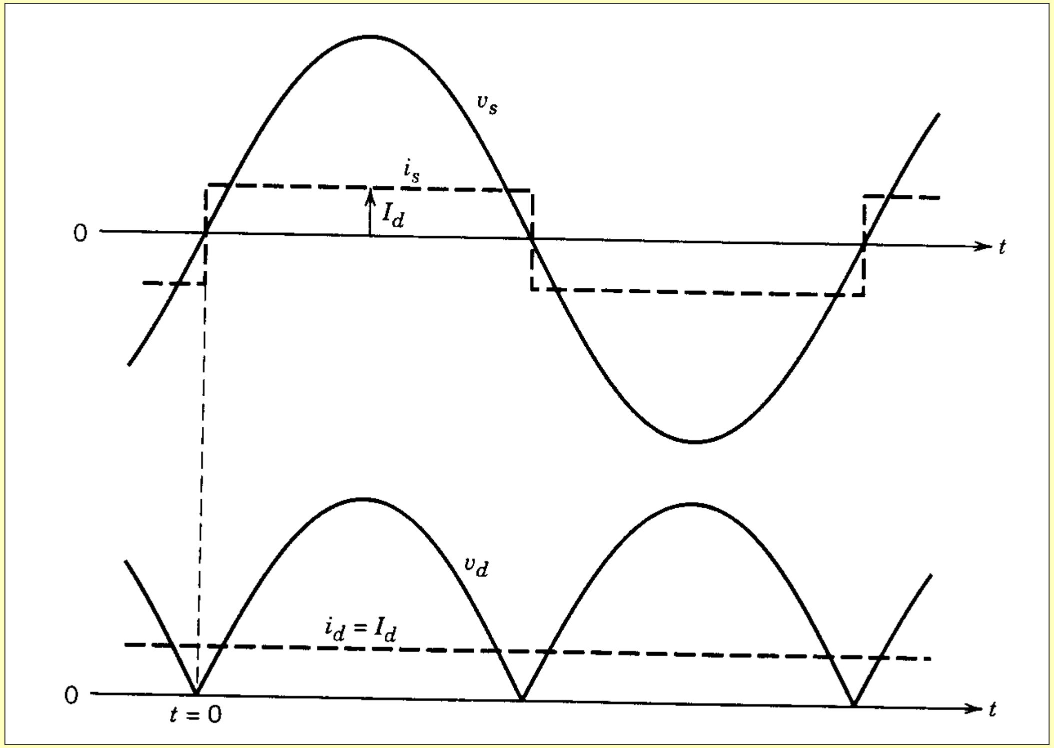


$$I_d = \int_0^T i_d \, dt$$

4. Single phase rectifier

Constant current load (Large inductance)





Average voltage

$$V_{d0} = \frac{2}{\pi}\sqrt{2}V_s \approx 0.9V_s$$

4. Single phase rectifier

Definitions

Total Harmonic distortion

$$\%THD_i = 100 \times \frac{I_{dis}}{I_{s1}}$$
$$= 100 \times \frac{\sqrt{I_s^2 - I_{s1}^2}}{I_{s1}}$$
$$= 100 \times \sqrt{\sum_{h \neq 1} \left(\frac{I_{sh}}{I_{s1}}\right)^2}$$

Power factor

$$PF = \frac{P}{S}$$

$$PF = \frac{V_s I_{s1} \cos \phi_1}{V_s I_s} = \frac{I_{s1}}{I_s} \cos \phi_1$$

Crest factor

$$CF = \frac{I_p}{I_{rms}}$$

Power

$$P = \frac{1}{T_1}\int_0^{T_1} p(t)\, dt = \frac{1}{T_1}\int_0^{T_1} v_s(t) i_s(t)\, dt$$

We assume that the voltage is pure sinusoidal

$$P = \frac{1}{T_1}\int_0^{T_1} \sqrt{2} V_s \sin \omega_1 t \cdot \sqrt{2} I_{s1} \sin(\omega_1 t - \phi_1)\, dt = V_s I_{s1} \cos \phi_1$$

$S = V_s I_s$ (Apparent power)

Displacement power factor

$$DPF = \cos \phi_1$$

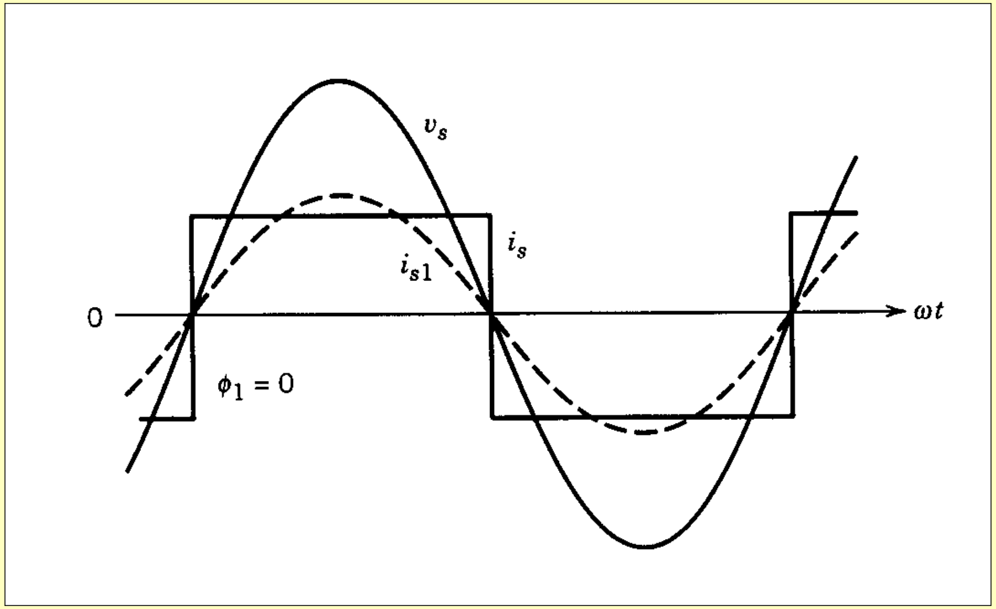
$$PF = \frac{I_{s1}}{I_s} DPF$$

$$PF = \frac{1}{\sqrt{1 + THD_i^2}} DPF$$

4. Single phase rectifier

Analysis

Fourier analysis



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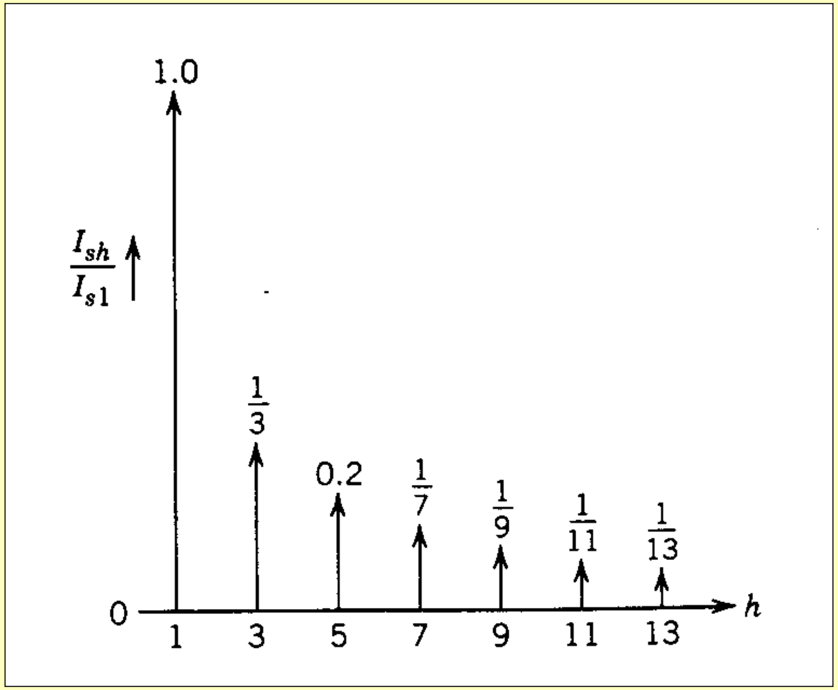
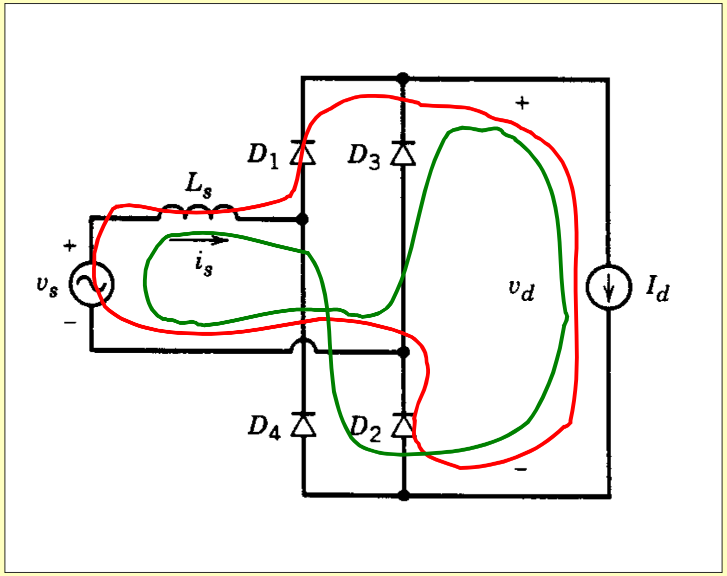


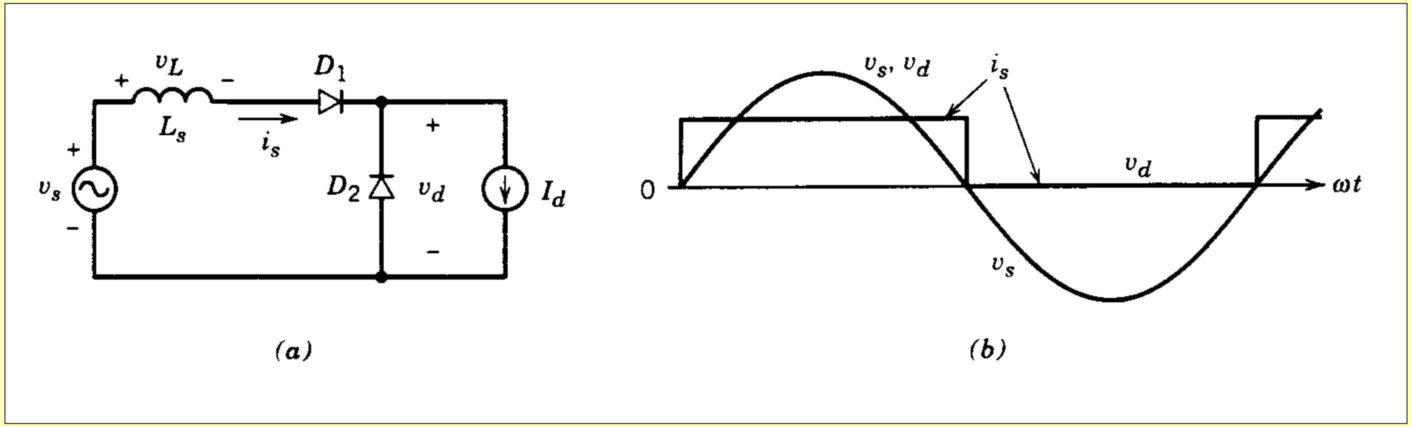
$$THD = 100 \cdot \frac{I_{dis}}{I_{s1}} = 100 \cdot \sqrt{\left(\frac{1}{3}\right)^2 + \left(\frac{1}{5}\right)^2 + \left(\frac{1}{7}\right)^2 + \ldots\ldots} = 48\ \%$$

5. Commutation

Ideal operation (L_s = 0)

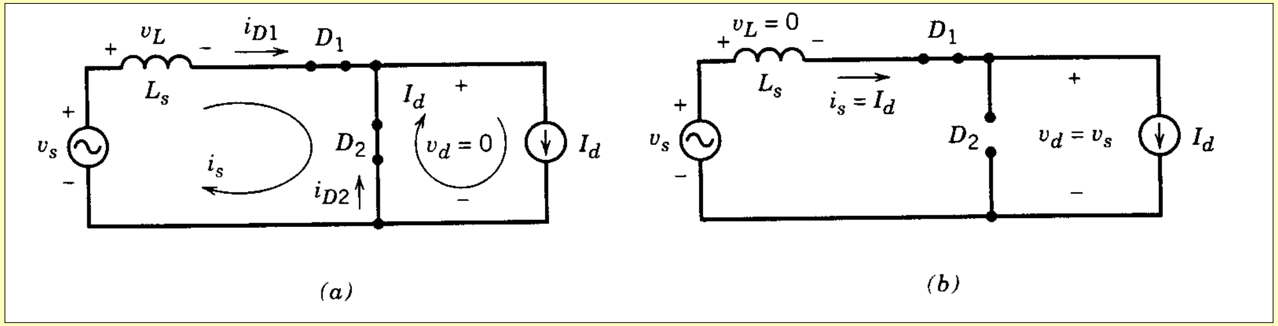


Simplified

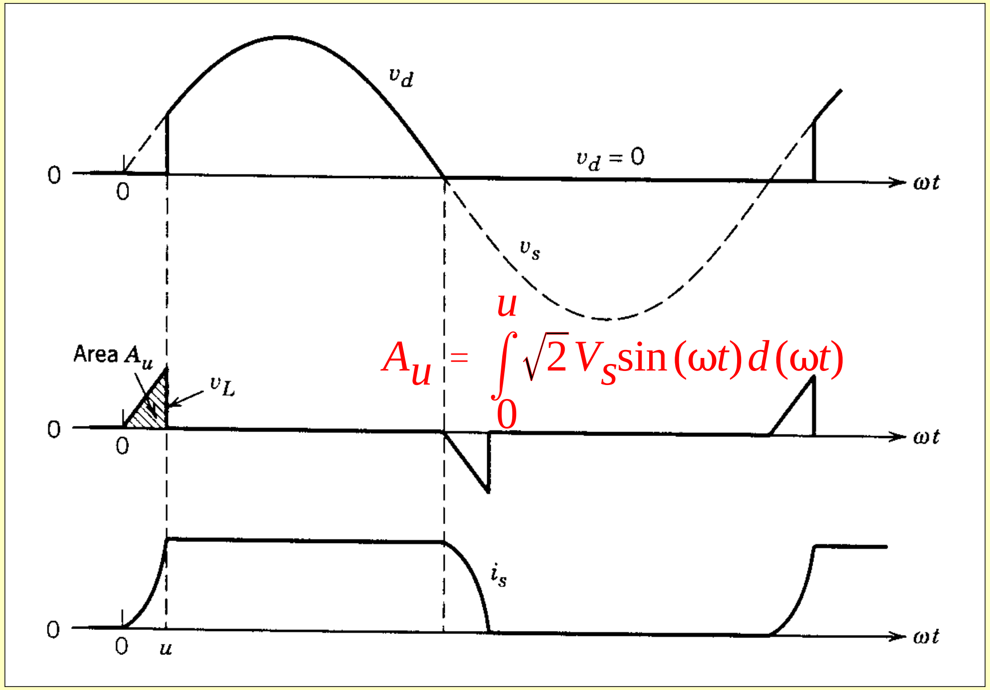


5. Commutation

Non-ideal operation ($L_s \neq 0$)



$$A_u = \int_0^u \sqrt{2} V_s \sin(\omega t)\, d(\omega t) = \omega L_s \int_o^{I_d} di_s$$



$$A_u = \int_0^u \sqrt{2} V_s \sin(\omega t)\, d(\omega t)$$

Commutation angle

Found from

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

Ideal average voltage

$$V_{do} = \frac{1}{2\pi} \int_o^{\pi} \sqrt{2} V_s \sin\omega t \, d(\omega t) = 2\frac{\sqrt{2}}{2\pi} V_s = 0.45 V_s$$

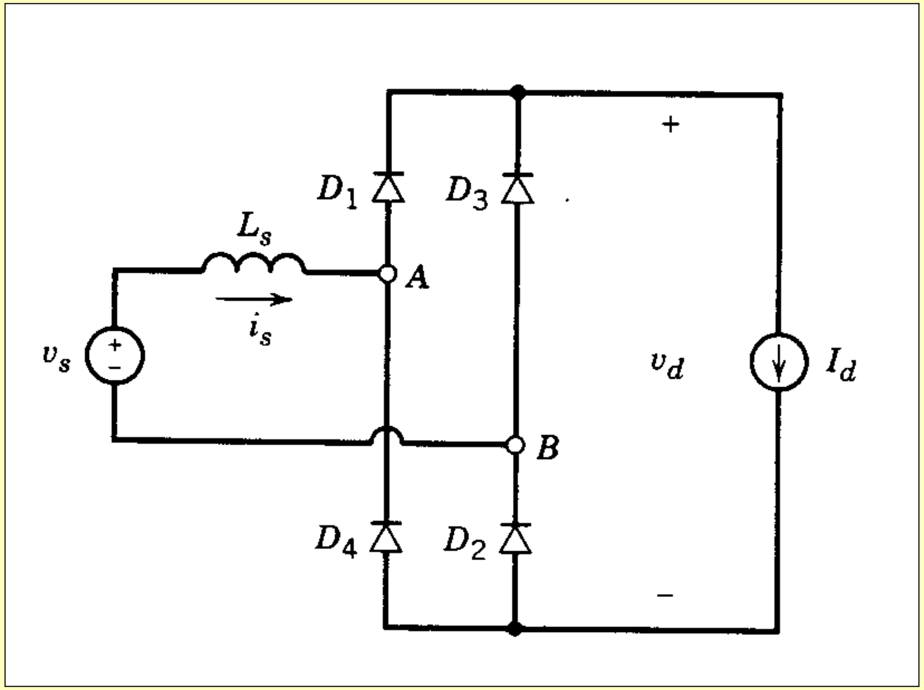
Non-ideal average voltage

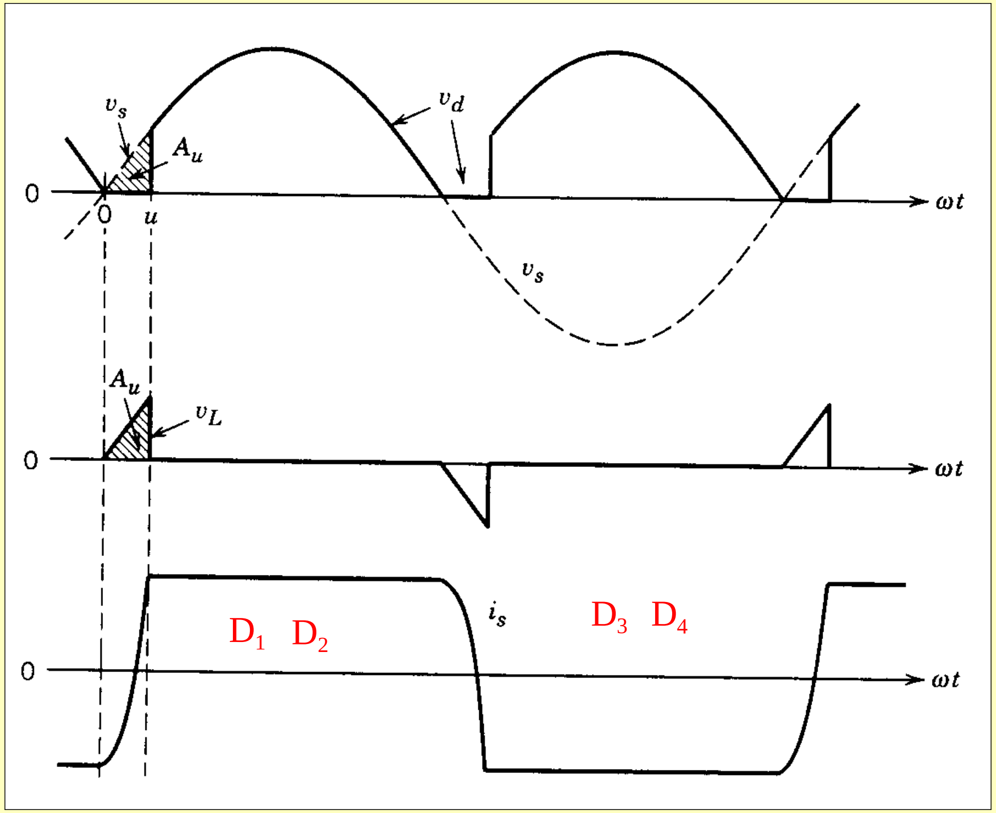
$$V_d = 0.45 V_s - \frac{\text{area } A_u}{2\pi} = 0.45 V_s - \frac{\omega L_s}{2\pi} I_d$$

Reduction in output voltage

5. Commutation

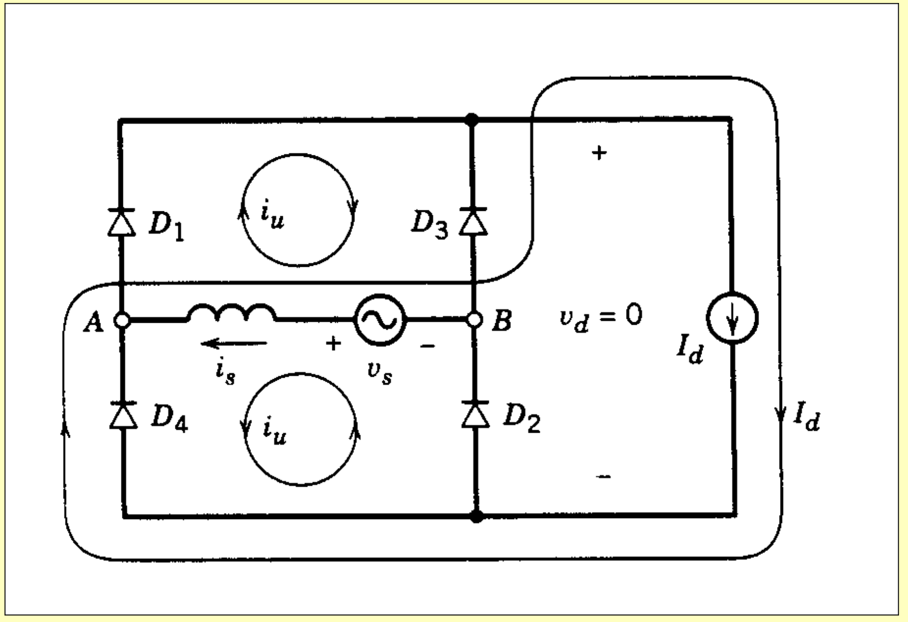
Full-bridge





5. Commutation

Full-bridge



Average voltage

$$V_d = V_{do} - \frac{\text{area } A_u}{\pi} = 0.9\ V_s - \frac{2\omega L_s I_d}{\pi}$$

Same procedure at last method ($-I_d \rightarrow I_d$)

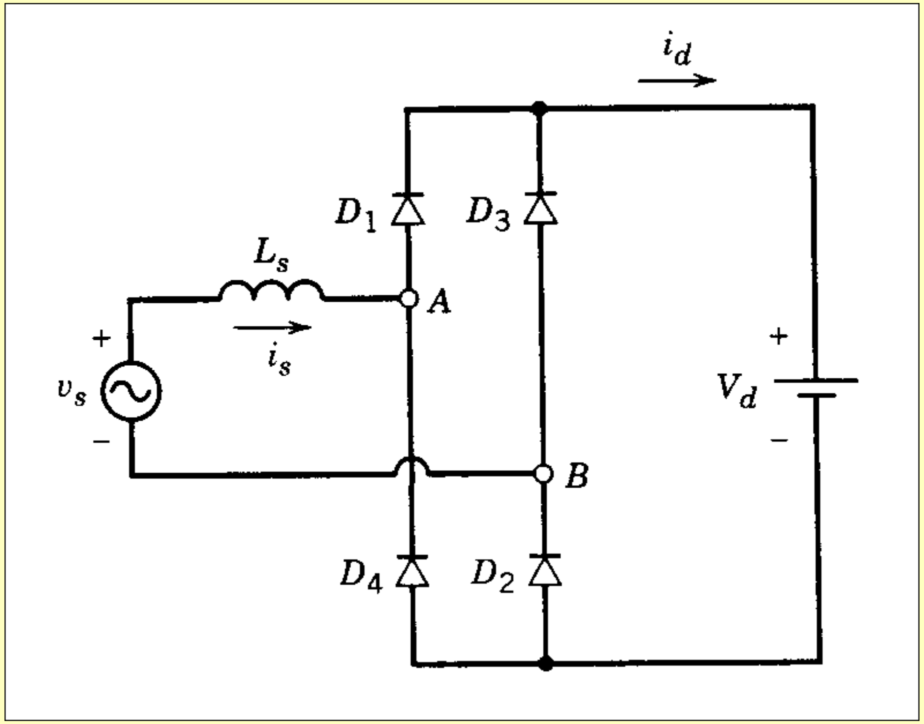
L_s large $\Rightarrow$ Large reduction in voltage

Twice as before

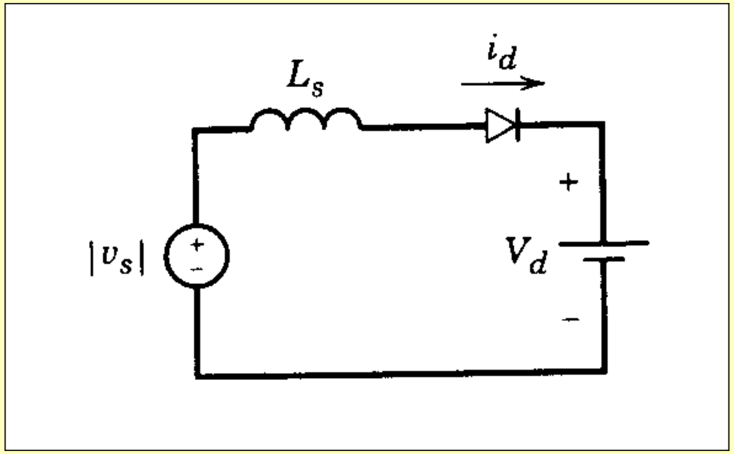
$$\cos u = 1 - \frac{2\omega L_s I_d}{\sqrt{2}\ V_s}$$

6. Constant DC-link voltage

Circuit



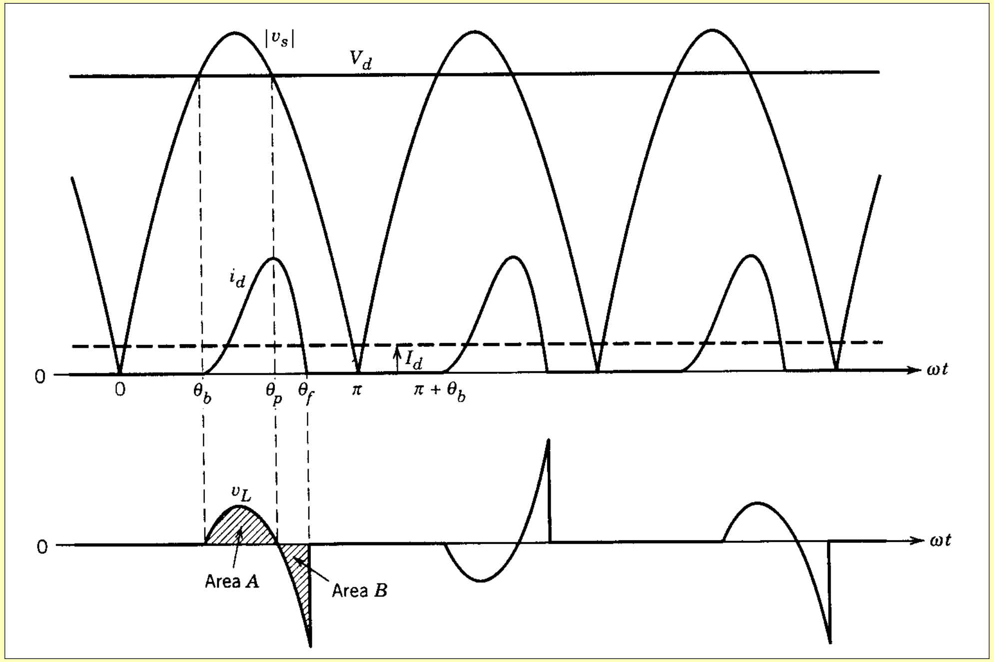
Equivalent



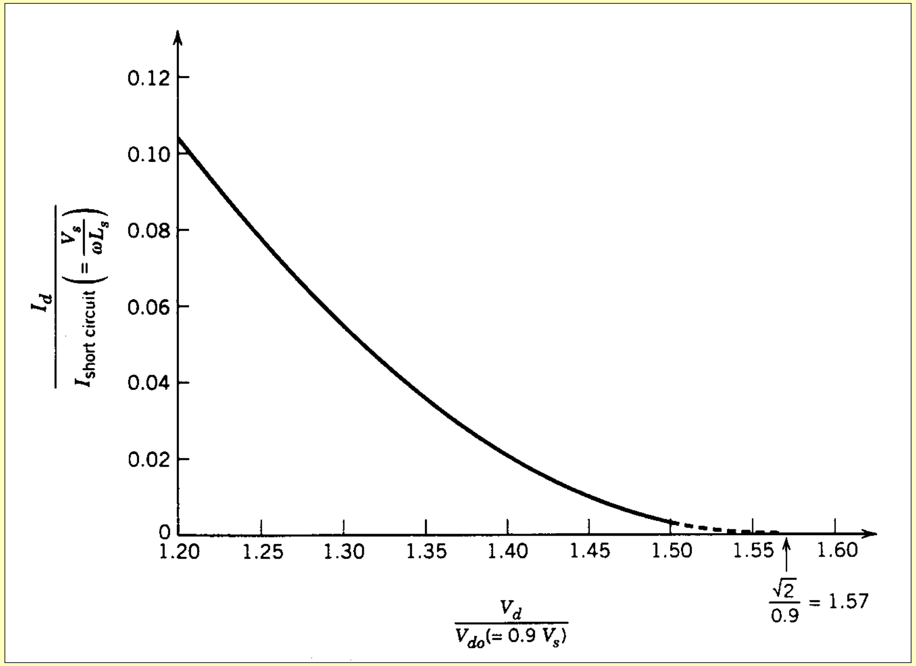
$I_{short\ circuit} = ?$

6. Constant DC-link voltage

Curves

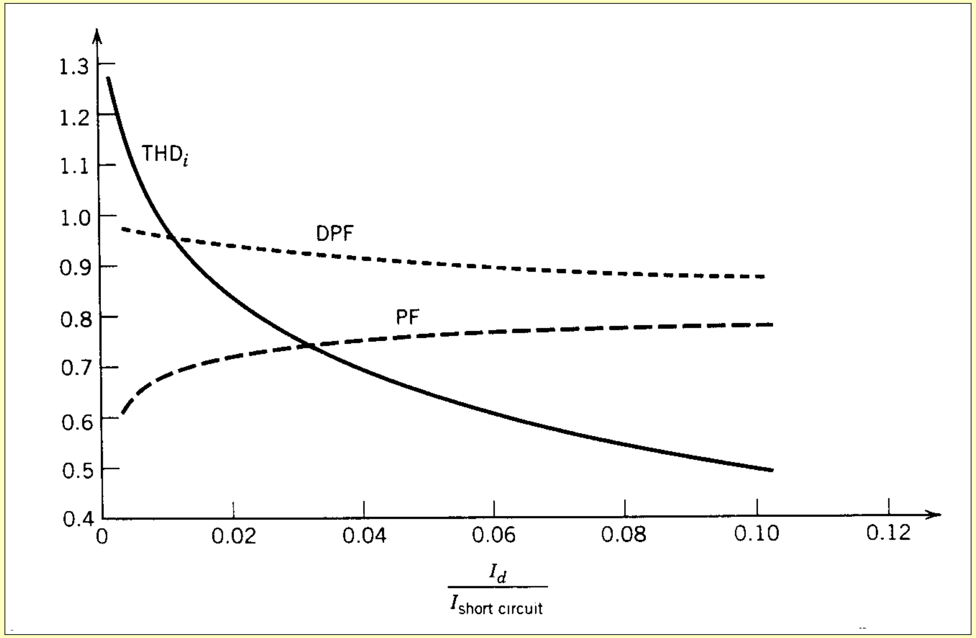


Load current against voltage

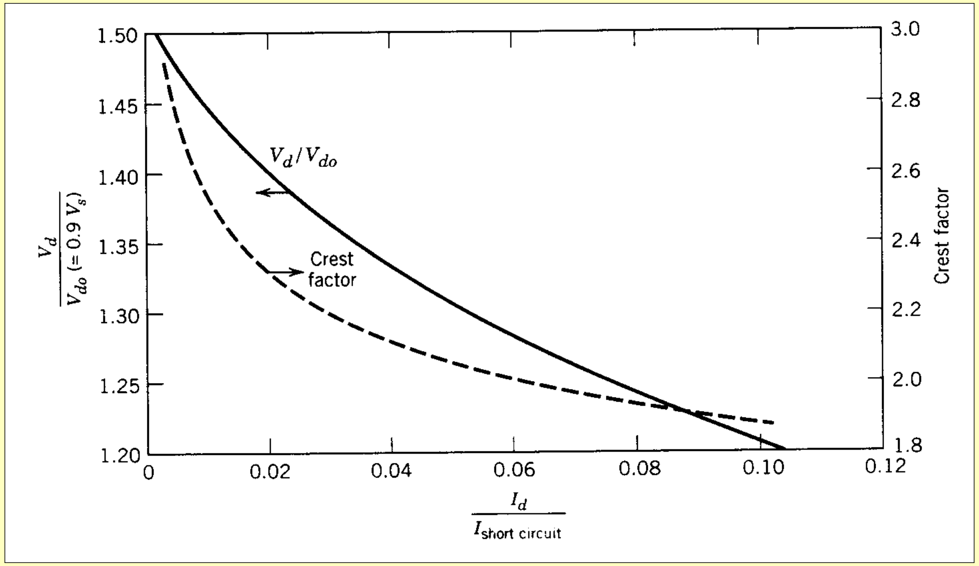


7. Characteristics

Harmonics

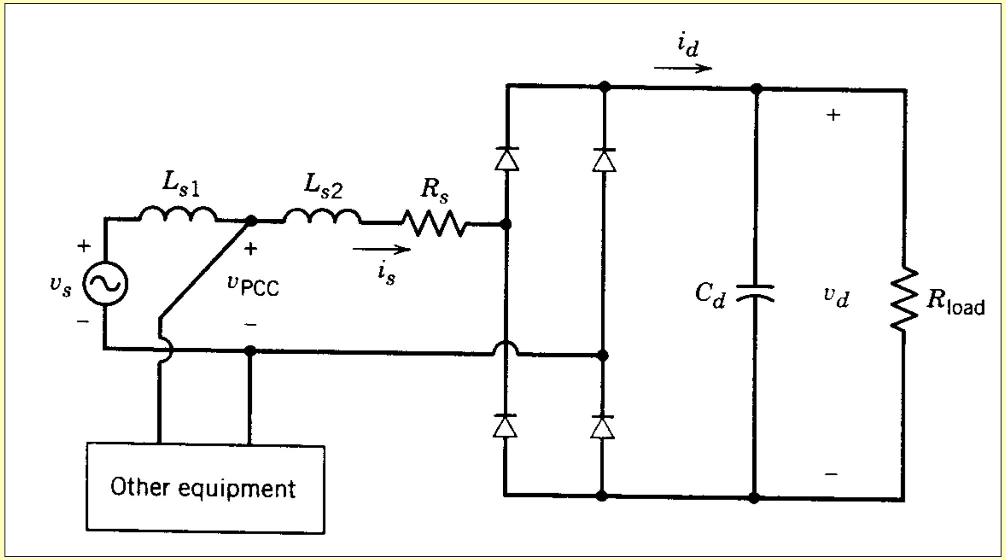


Crest factor

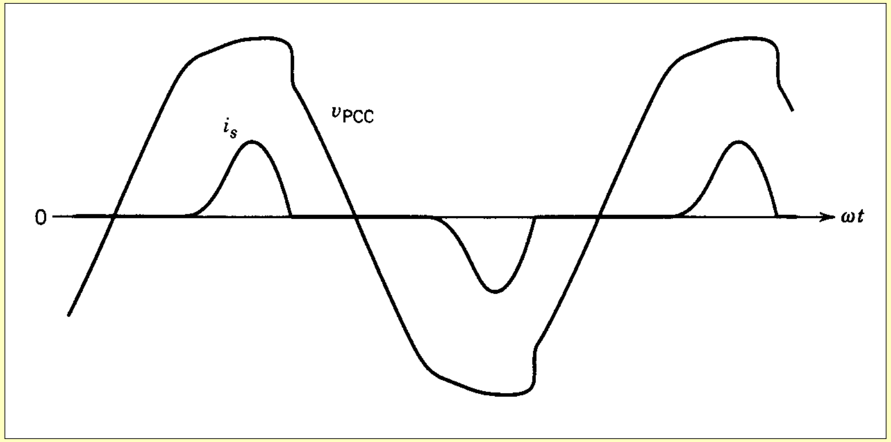


7. Characteristics

Line connected



Curves with line connection



8. Exercises

Exercises

Exercise 5.11

Simulation in PSpice

Exercise 5.14