PEOPLE`S DEMOCRATIC REPUBLIC OF ALGERIA
MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH
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Faculty of Technology
Department of Electrical Engineering
Power Electronics

2nd Year Professional License
Renewable Energies and Environment
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First Series of Exercises :

AC/DC Converters (Rectifiers)

Exercise 1:

1- Consider the rectifier represented in Figure 1, which is connected to a power supply Vs(t)= 240V, 50Hz.

a. For a purely resistive load R = 10 Ω, plot the waveforms of the current (I_L), the output voltage (V_L), and the voltage across the diode (V_D).

b. Finding the Performance Parameters of the Rectifier (V_{dc}, I_{dc}, V_{rms}, I_{rms}, P_{dc}, P_{ac}, η, FF, RF, TUF and PF.

c. Repeat question (a) for a load consisting of an inductance L = 0.1 H in series with a resistance R = 10 Ω.

2- Replace the diode in Figure 1 with a thyristor.

a. What is the difference between a diode and a thyristor?

b. For a purely resistive load R = 10 Ω, plot the waveforms of the current (I_L), the output voltage (V_L), then calculate the average value V_{dc} for a firing angle of 0°, 45°, 90°, 135°, 180°. What is your conclusion?

3- Consider the rectifier represented in Figure 2

a. What is the role of the diode?

b. Calculate V_{dc} for a firing angle of 0°, 45°, 90°.

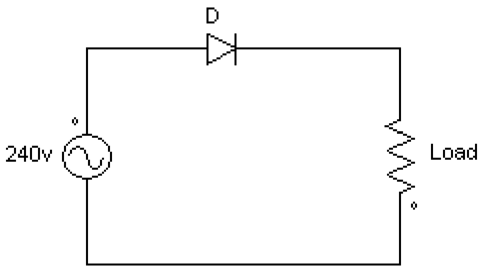


Figure 1

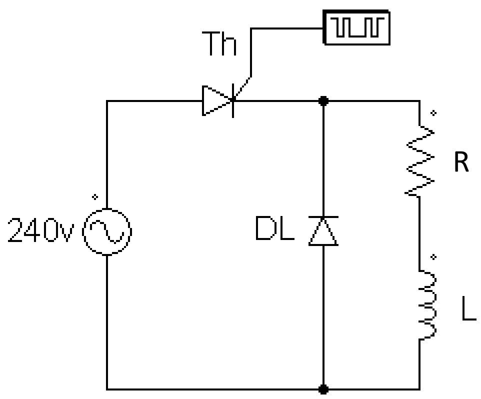
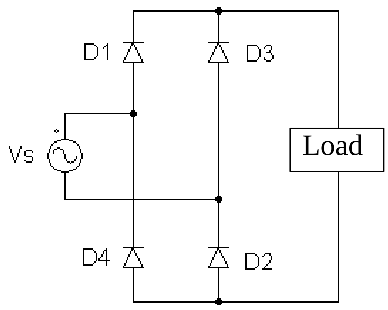


Figure 2

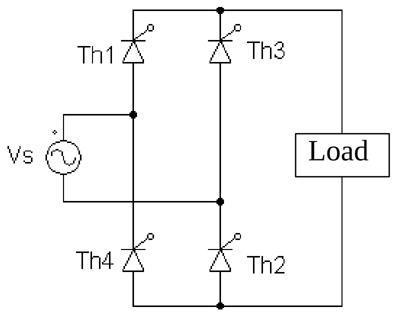
Exercise 2:

A voltage of 120V is applied to a single-phase bridge rectifier for:

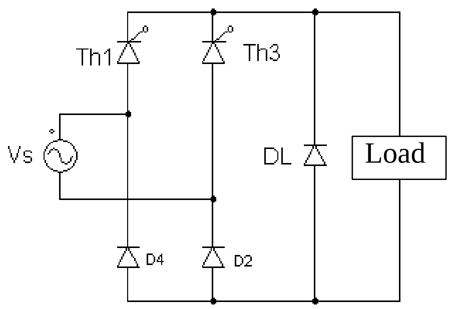
1. A diode rectifier (Figure (a)), determine the average load voltage, neglecting the diode voltage drop.
2. A fully controlled rectifier (Figure (b)),
   - Determine the average voltage of the load for the following firing angles: α =0°, 45° and 90°. The voltage drop across each thyristor is 1.5v.
   - Calculate the peak reverse voltage of each thyristor.
3. A semi-controlled rectifier (Figure (c)),
   - Determine the characteristics of the components for a highly inductive load consumes 25A. Neglect voltage drops.
4. Repeat question 3 for α =90° and assume that the voltage drops of the thyristors and diodes are respectively 1.5v and 0.7v.



(a)



(b)



(c)

Exercise 3 :

Given data

- Supply voltage:
  $v_s(t) = V_m \sin(\omega t)$
  $V_{\text{rms}} = 240\text{ V} \Rightarrow V_m = \sqrt{2}\,240 \approx 339.4\text{ V}$
- Frequency: $f = 50\,\text{Hz} \Rightarrow \omega = 2\pi f = 314\,\text{rad/s}$
- Diode: ideal
- Load resistance: $R = 10\,\Omega$

(a) Purely resistive load (R = 10 Ω)

Operating principle

- Diode conducts only during **positive half-cycles** of the input voltage.
- For $0 < \omega t < \pi$:

$$v_L(t) = v_s(t), \quad i_L(t) = \frac{v_s(t)}{R}$$

- For $\pi < \omega t < 2\pi$:

$$v_L(t) = 0, \quad i_L(t) = 0$$

1. Waveforms description

Output voltage (load voltage V_L):

$$V_L(t) = \begin{cases} V_m \sin(\omega t), & \text{if diode ON} \\ 0, & \text{if diode OFF} \end{cases}$$

Diode ON: $0 < \omega t < \pi$ (only positive half-cycle in theory), but actually **half-wave**: diode conducts from 0 to π each cycle, then off from π to 2π.

So:

$$V_L(t) = \begin{cases} V_m \sin(\omega t), & 0 \le \omega t \le \pi \\ 0, & \pi < \omega t < 2\pi \end{cases}$$

Load current $I_L(t)$:
Since purely resistive:

$$I_L(t) = \frac{V_L(t)}{R} = \begin{cases} \frac{V_m}{R} \sin(\omega t), & 0 \le \omega t \le \pi \\ 0, & \pi < \omega t < 2\pi \end{cases}$$

$V_m/R = 339.41/10 \approx 33.941$ A peak.

Diode voltage $V_D(t)$:
Define $V_D = V_{anode} - V_{cathode}$ (usual convention for diode forward drop is ignored in ideal analysis).

- **When diode ON:** $V_D \approx 0$ (ideal diode).
- **When diode OFF:** Cathode potential $V_L = 0$, Anode potential $V_s(t)$, so $V_D(t) = V_s(t) - 0 = V_m \sin(\omega t)$, which is negative during negative half-cycle? Wait — careful.

Part (b) – Performance parameters for resistive load

Half-wave rectifier formulas:

Average (DC) voltage:

$$V_{dc} = \frac{V_m}{\pi} \qquad V_{dc} \approx \frac{339.41}{\pi} \approx 108.04\text{ V}$$

$$I_{dc} = \frac{V_{dc}}{R} = \frac{V_m}{\pi R} \qquad I_{dc} = \frac{V_{dc}}{R} \approx \frac{108.04}{10} = 10.804\text{ A}$$

RMS voltage:

$$V_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{\pi} V_m^2 \sin^2\theta \, d\theta}$$

$$\sin^2\theta = \frac{1-\cos 2\theta}{2}$$

So,

$$\int_0^{\pi} \sin^2\theta \, d\theta = \int_0^{\pi} \frac{1-\cos 2\theta}{2} \, d\theta = \frac{\theta}{2} - \frac{\sin 2\theta}{4}\Big|_0^{\pi} = \frac{\pi}{2}$$

$$V_{rms} = \sqrt{\frac{V_m^2}{2\pi} \cdot \frac{\pi}{2}} = \sqrt{\frac{V_m^2}{4}} = \frac{V_m}{2}$$

$$V_{rms} \approx \frac{339.41}{2} \approx 169.705 \text{ V}$$

RMS current:

$$I_{rms} = \frac{V_{rms}}{R} \approx 16.9705 \text{ A}$$

DC power: $$P_{dc} = V_{dc} I_{dc} \approx (108.04)(10.804) \approx 1167.5 \text{ W}$$

AC power (input power to load):

$$P_{ac} = V_{rms} I_{rms} \qquad P_{ac} = I_{rms}^2 R = (16.9705)^2 \times 10 \approx 2880 \text{ W}$$

Efficiency η:

$$\eta = \frac{P_{dc}}{P_{ac}} \times 100\% = \frac{4}{\pi^2} \times 100\% \approx 40.5\%$$

Form Factor:

$$FF = \frac{V_{rms}}{V_{dc}} = \frac{V_m/2}{V_m/\pi} = \frac{\pi}{2} \approx 1.571$$

Ripple Factor:

$$RF = \sqrt{FF^2 - 1} = \sqrt{{\frac{\pi}{2}}^2 - 1} \approx \sqrt{2.4674 - 1} = \sqrt{1.4674} \approx 1.211$$

Transformer Utilization Factor (TUF):

For half-wave:

$$TUF \approx 0.287$$

$$TUF = \frac{P_{dc}}{V_{rms(supply)} \cdot I_{rms(supply)}}$$

$$TUF \approx \frac{1167.5}{240 \times 16.9705} \approx \frac{1167.5}{4072.92} \approx 0.286$$

Power Factor

$$PF = \frac{P_{ac}}{V_{s,rms} I_{s,rms}} \approx$$