ELEC-E8412 **Power Electronics**
Exercise No 03 12.10.2023

Problem 1:

A half-wave rectifier with a 1-kΩ load has a parallel capacitor. The source is 120 V_{rms}, 60 Hz. Determine the peak-to-peak ripple of the output voltage when the capacitor is

a) 4000 µF

When $\omega RC \gg 1$ The ripple voltage can be approximated as

$$\Delta V_o \approx V_m\left(\frac{2\pi}{\omega RC}\right) = \frac{V_m}{fRC}$$

When $\omega RC > 1$ (exact relation)

$$\Delta V_o = V_m - V_m \sin\alpha = V_m(1 - \sin\alpha)$$

C=4000 µF $\omega RC = 377 * 1000 * 4 * 10^{-3} = 1508 \gg 1$

$$\Delta V_0 \approx \frac{V_m}{fRC} = \frac{120\sqrt{2}}{60 * 1000 * 4 * 10^{-3}} = 0.707\ V$$

b) 20 µF.

C=20 µF $\omega RC = 377 * 1000 * 20 * 10^{-6} = 7.54 > 1$ (approximation is not valid here)

$$\theta = \pi - tan^{-1}(RC\omega) = \pi - tan^{-1}(7.54) = 1.7027 rad$$

$$sin\alpha - sin\theta . e^{-(2\pi+\alpha-\theta)/\omega RC} = 0$$

$$\alpha = 30.2° = 0.5275 rad$$

$\Delta V_0 = V_m(1 - sin\alpha) = 120\sqrt{2}(1 - 0.5034) = 83.26V$ (correct answer)

α here is calculated using matlab code. In exam, its value will be given.

Problem 2:
A half-wave rectifier with a capacitor filter has V_m=200 V, R=10 kΩ, C=1000 μF, and ω=377.
Determine

a) Peak-to peak ripple voltage using the exact equations.

$$\theta = \tan^{-1}(-\omega RC) = -\tan^{-1}(\omega RC) + \pi$$

= 1.5711 rad

$$sin\alpha - sin\theta . e^{-(2\pi+\alpha-\theta)/\omega RC} = 0$$

$$\alpha = 86.7° = 1.513 rad$$

$$\Delta V_0 = V_m(1 - sin\alpha) = 200(1 - sin\alpha) = 200(1 - 0.9983) = 0.34\ V$$

b) Peak-to peak ripple voltage using the approximate formula.

$$\Delta V_0 \approx \frac{V_m}{fRC} = \frac{200}{60 * 10000 * 1000 * 10^{-6}} = 0.333\ V$$

Problem 3:

For the controlled half-wave rectifier with resistive load, the source is 120 V_{rms} at 60 Hz. The resistance is 100 Ω, and the delay angle α is 45.

Determine

a) **average voltage across the resistor**

$$V_o = \frac{V_m}{2\pi}(1 + cos\alpha) = \frac{120\sqrt{2}}{2\pi}(1 + cos45) = 46.11\ V$$

b) **power absorbed by the resistor**

$$P = \frac{{V_{rms}}^2}{R}$$

$$V_{rms} = \frac{V_m}{2}\sqrt{1 - \frac{\alpha}{\pi} + \frac{sin2\alpha}{2\pi}} = \frac{120\sqrt{2}}{2}\sqrt{1 - \frac{0.785}{\pi} + \frac{sin2\alpha}{2\pi}} = \frac{120\sqrt{2}}{2} * 0.953 = 80.91V$$

$$\alpha = 45° = \frac{\pi}{4}rad = 0.785rad$$

$$P = \frac{{V_{rms}}^2}{R} = \frac{(80.91)^2}{100} = 65.46W$$

c) **power factor**

$$pf = \sqrt{\frac{1}{2} - \frac{\alpha}{2\pi} + \frac{sin2\alpha}{4\pi}} = 0.67$$

Problem 4:
A half-wave rectifier has a 120 V rms, 60 Hz ac source. The load is 750 Ω. Determine

a) value of a filter capacitor to keep the peak-to-peak ripple across the load to less than 2 V.

$$\Delta V_0 \approx \frac{V_m}{fRC} \qquad C > \frac{120\sqrt{2}}{60 * 750 * 2} = 1885\ \mu F$$

b) peak values of diode current

Peak diode current is

$$I_{D,\text{ peak}} = \omega C V_m \cos\alpha + \frac{V_m \sin\alpha}{R} = V_m\left(\omega C \cos\alpha + \frac{\sin\alpha}{R}\right)$$

$I_{D,peak} = 120 * \sqrt{2}(2 * pi * 60 * 1885 * 10^{-6} * \cos(81.2) + \sin(81.2)/750)$

$I_{D,peak} = 18.7$ A