Power Electronics (ELEC-E8412)

Exercise# 03 with solution

Question No. 1

A half wave rectifier with a load of 100 kΩ and a parallel capacitor. The source is 120 V RMS. Find the peak-to-peak ripple in the output voltage when $\propto$=0.527 rad and,

a) For 400 μF:

We check ωRC,

$\omega RC = 2\pi f RC$

ωRC = 2 x 3.14 x 60 x 100 x 103x 400 x 10−6

ωRC = 15072 $\gg$ 1

So, we use approximate formula,

$$\Delta V_0 = \frac{V_m}{fRC}$$

$$\Delta V_0 = \frac{V_{rms}\ x\ \sqrt{2}}{fRC}$$

$$\Delta V_0 = \frac{120\ x\ \sqrt{2}}{60\ x\ 100\ x\ 10^3 x\ 400\ x\ 10^{-6}}$$

$$\Delta V_0 = 0.07\ V$$

b) 2 μF capacitor.

We check ωRC,

$\omega RC = 2\pi f RC$

ωRC = 2 x 3.14 x 60 x 100 x 103x 2 x 10−6

ωRC = 75.36 > 1

So, we can use exact formula,

$\Delta V0 = Vm\ (1 - sin \propto)$

$\Delta V0 = 169.7\ (1 - sin 0.527)$

$\Delta V0 = 84.35\ V$

Question No. 2

A half wave rectifier has a 120 V-RMS, 60 Hz AC source. The load is 750 Ω. Find,

a) Value of filter capacitance to keep the peak-to-peak voltage ripple less than 2 V.

b) Peak diode current.

Solution:

a) Value of Capacitance:

The value of capacitor to keep $\Delta V_0 < 2V$ is,

$$\Delta V_0 = \frac{V_m}{fRC}$$

$$C = \frac{V_m}{fR\Delta V_0}$$

$$C = \frac{V_m}{fR\Delta V_0} = \frac{120\ x\ \sqrt{2}}{60\ x\ 750\ x\ 2}$$

$$C = 1885\mu\text{F}$$

This value of C keeps the peak-to-peak ripples to less than 2 V.

b) Peak Diode Current:

For peak diode current, we have

$$i_{d\ (peak)} = V_m\left(C\omega Cos \propto + \frac{Sin \propto}{R}\right)$$

For $\propto$, we use the formula,

$$\Delta V_0 = V_m(1 - sin \propto)$$

$$2 = 169.7(1 - sin \propto)$$

$$2 = 169.7 - 169.7 sin \propto$$

Re-arranging,

$$\propto = \sin^{-1} 0.988214 = 1.417\ rad = 81.20°$$

So,

$$i_{d\ (peak)} = 169.7\left(1885\ x\ 10^{-6}\ x\ 2\ x\ 3.14\ x\ 60\ x\ Cos\ 81.20 + \frac{Sin\ 81.20}{750}\right)$$

$$i_{d\ (peak)} = 18.7\ A$$

Question No. 3

The half wave rectifier with RC load has a 200 V-RMS source at 60 Hz, R = 100 Ω, C = 100 uF, ∝ = 0.843 rad. Find the following,

a) Peak to peak voltage.

b) Peak diode current.

c) Value of capacitor such that the output ripples are 10% of Vm.

Solutions:

a) Peak to Peak Voltage Ripples:

We check ωRC,

$$\omega RC = 2\pi f RC$$
$$\omega \mathrm{RC} = 2 \text{ x } 3.14 \text{ x } 60 \text{ x } 100 \text{ x } 100 \text{ x } 10^{-6}$$
$$\omega \mathrm{RC} = 3.76 > 1$$

So, we can use exact formula,

$$\Delta V_0 = V_m(1 - sin \propto)$$
$$\Delta V_0 = 200 \; x \sqrt{2}(1 - sin 0.843)$$
$$\Delta V_0 = 71.66 \; V$$

b) Peak Diode Current:

For peak diode current, we have

$$i_{d\ (peak)} = V_m \left(C\omega Cos \propto + \frac{Sin \propto}{R} \right)$$

$$i_{d\ (peak)} = 200\ x\ \sqrt{2}\left(100\ x\ 10^{-6}\ x\ 377\ x\ Cos\ 0.843 + \frac{Sin\ 0.843}{100}\right)$$

$$i_{d\ (peak)} = 9.20\ A$$

c) <u>Value of Capacitor:</u>

$$\Delta V_0 = \frac{V_m}{fRC}$$

$$C = \frac{V_m}{fR\Delta V_0}$$

$$C = \frac{200\ x\ \sqrt{2}}{60\ x\ 100\ x\ 0.1\ (200\ x\ \sqrt{2})} = 1.66\ uF$$

Question No. 4

A half wave-controlled rectifier has a 120 V-RMS, 60 Hz AC source. The load resistance is 100 Ω and the delay angle is 45 degrees. Find,

a) Average voltage across the load.

b) Power absorbed by the load.

c) Power factor seen by the source.

Solution:

a) <u>Average Voltage across Load:</u>

We have the formula,

$$V_{o\,(avg)} = \frac{V_m}{2\pi}(1 + Cos \propto)$$

$$V_{o\,(avg)} = \frac{120\ x\ \sqrt{2}}{2\pi}(1 + Cos45) = 46.11\ V$$

b) <u>Power Absorbed by Load:</u>

We know that,

$$P_o = \frac{V_{o\,(rms)}^2}{R}$$

and,

$$V_{o\,(rms)} = \frac{V_m}{2}\sqrt{\left(1 - \frac{\propto}{\pi}\right) + \left(\frac{Sin\ 2 \propto}{2\pi}\right)}$$

$$V_{o\,(rms)} = \frac{120\ x\ \sqrt{2}}{2}\sqrt{\left(1 - \frac{0.785}{\pi}\right) + \left(\frac{Sin\ 2(0.785)}{2\pi}\right)} = 80.91\ V$$

So,

$$P_o = \frac{(80.91)^2}{100} = 65.46\ W$$

c) <u>Power Factor:</u>

We have,

$$PF = \frac{P}{S} = \frac{P}{V_{in\,(rms)}\ x\ i_{in\,(rms)}}$$

where,

$$i_{in\,(rms)} = i_{o\,(rms)} = \frac{V_{o\,(rms)}}{R} = \frac{80.91}{100} = 0.8091\ A$$

So,

$$PF = \frac{65.46}{120\ x\ 0.8091} = 0.67$$