ELEC-E8412 Power Electronics

/ Exercise # 4_ Solutions 5.11.2020

Problem 1:

A single-phase full-wave rectifier has a resistive load of 12 Ω and an ac source of 120-V rms and 60 Hz. Determine

(a) the average, peak, and rms currents in the load and in each diode.
(b) Determine the peak reverse voltage across each of the diodes

Solution:

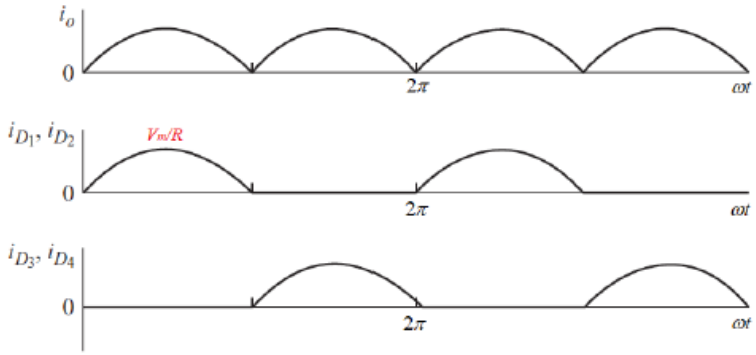
$V_{rms} = 120\ V\ ,\ V_m = 120\sqrt{2} = 169.7\ V$

Part (a)

The average current in the load and in each diode:

$$\langle i_o \rangle = \frac{\langle V_o \rangle}{R} = \frac{2V_m}{\pi R} = \frac{2 * 120\sqrt{2}}{\pi * 12} = 9\ A$$

$$\langle i_D \rangle = \frac{\langle i_o \rangle}{2} = 4.5\ A$$



The peak current of load and each diode:

$$\langle i_{o,m} \rangle = \langle i_{D,m} \rangle = \frac{V_m}{R} = \frac{169.7}{12} = 14.14\ \ A$$

The rms current of load and each diode:

$$I_{o,rms} = \frac{V_{o,rms}}{R} = \frac{120}{12} = 10\ A$$

$$I_{D,rms} = \frac{I_{o,rms}}{\sqrt{2}} = 7.07\ A$$

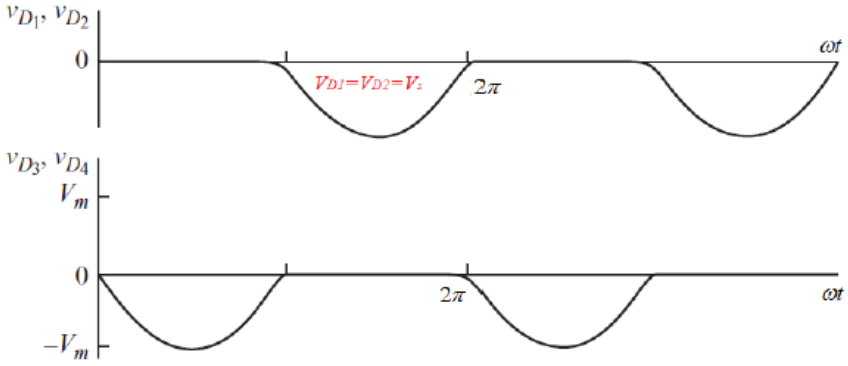
$$I_{o,rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} \frac{V_m^2}{R^2}(sinwt)^2 d(wt)} = \frac{V_m}{\sqrt{2}R}$$

$$I_{D,rms} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} \frac{V_m^2}{R^2}(sinwt)^2 d(wt)} = \frac{V_m}{2R}$$

Part (b)

The maximum voltage across a reverse-biased diode is the peak value of the source voltage

$$V_m = 120\sqrt{2} = 169.7\ V$$



Problem 2:

A single-phase full-wave rectifier with an ac source of 200 Sin(377t) V has a resistive load of 20 Ω. Determine

(a) the average current in the load and in each diode,
(b) the peak reverse voltage across each of the diodes,
(c) the power factor

Solution:

Part (a)

$$\langle i_o \rangle = \frac{\langle V_o \rangle}{R} = \frac{2V_m}{\pi R} = \frac{2 * 200}{\pi * 20} = 6.366\ A$$

$$\langle i_D \rangle = \frac{\langle i_o \rangle}{2} = 3.183\ A$$

Part (b)

peak reverse voltage across each of the diodes $=V_m = 200\ V$

Part (c)

$$PF = \frac{average\ output\ power}{apparent\ input\ power} = \frac{R * I_{o,rms}^2}{V_{in,rms} * I_{in,rms}} = \frac{20 * (\frac{200}{20 * \sqrt{2}})^2}{\frac{200}{\sqrt{2}} * \frac{200}{20 * \sqrt{2}}} = 1$$

$$I_{o,rms} = \frac{V_{o,rms}}{R} = \frac{V_m}{\sqrt{2}R} = I_{in,rms}$$

Problem 3:

The controlled single-phase bridge rectifier has an 18 Ω resistive load and has a 120-V rms, 60-Hz ac source. The delay angle is 45°. Determine

(a) the average load current,
(b) the rms load current,
(c) the rms source current,
(d) the power factor.

Solution:

$V_{rms} = 120\ V\ ,\ V_m = 120\sqrt{2} = 169.7\ V$

Part (a)

$$\langle i_o \rangle = \frac{\langle V_o \rangle}{R} = \frac{V_m(1 + cos\alpha)}{\pi R} = \frac{120\sqrt{2}(1 + 0.707)}{\pi * 18} = 5.12\ \ A$$

Part (b)

$$I_{rms} = \frac{V_m}{R}\sqrt{\frac{1}{2} - \frac{\alpha}{2\pi} + \frac{sin2\alpha}{4\pi}} = \frac{169.7}{18}\sqrt{\frac{1}{2} - \frac{0.785}{2\pi} + \frac{1}{4\pi}} = 6.35\ A$$

$\alpha = 45° = 0.785\ rad$

Part (c)

The rms current in the source is the same as the rms current in the load. So,

$I_{in,rms} = I_{o,rms} = 6.35\ \ A$

Part (d)

$$pf = \sqrt{1 - \frac{\alpha}{\pi} + \frac{sin2\alpha}{2\pi}} = \sqrt{1 - \frac{0.785}{\pi} + \frac{1}{2\pi}} = 0.953$$

$$pf = \frac{R * I_{o,rms}^2}{V_{in,rms} * I_{in,rms}} = \frac{18 * (6.35)^2}{120 * 6.35} = 0.953$$

Problem 4:

The full-wave rectifier has a 120-V rms 60 Hz source, R=200 Ω and C=200 μF. Determine

(a) the peak-to-peak voltage variation of the output
(b) the filter capacitance required to limit the peak-to-peak output voltage ripple to 1 percent of the dc output.

Solution:

$V_{rms} = 120\ V\ ,\ V_m = 120\sqrt{2} = 169.7$

Part (a)

$\theta = \pi - tan^{-1}(RCw) = \pi - tan^{-1}(200 * 200 * 10^{-6} * 377) = 1.637\ rad$

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

$$\alpha = 57.7° = 1.007\ rad$$

$$\Delta V_0 = V_m(1 - sin\alpha) = 169.7(1 - 0.8452) = 26.27\ V$$

Part (b)

$$\Delta V_0 \approx \frac{V_m}{2fRC} \longrightarrow \frac{\Delta V_0}{V_m} \approx \frac{1}{2fRC} \approx 0.01 \longrightarrow C \approx \frac{1}{2fR\left(\frac{\Delta V_0}{V_m}\right)} = \frac{1}{2(60)(200)(0.01)} = 4166\ \mu F$$

Problem 5:

The full-wave rectifier has a 60-Hz ac source with maximum voltage of 100 V. It is to supply a load that requires a dc voltage of 100 V and will draw 0.4 A. Determine the filter capacitance required to limit the peak-to-peak output voltage ripple to 1 percent of the dc output.

Solution:

$V_m = 100$, output dc voltage=100 V

$$R = \frac{100}{0.4} = 250\ \Omega$$

$$\Delta V_0 \approx \frac{V_m}{2fRC} \longrightarrow \frac{\Delta V_0}{V_m} \approx \frac{1}{2fRC} \approx 0.01 \longrightarrow C \approx \frac{1}{2fR\left(\frac{\Delta V_0}{V_m}\right)} = \frac{1}{2(60)(250)(0.01)} = 3333\ \mu F$$