Power Electronics and Electromechanics (EEE213)

Assignment Solutions with Marking Scheme

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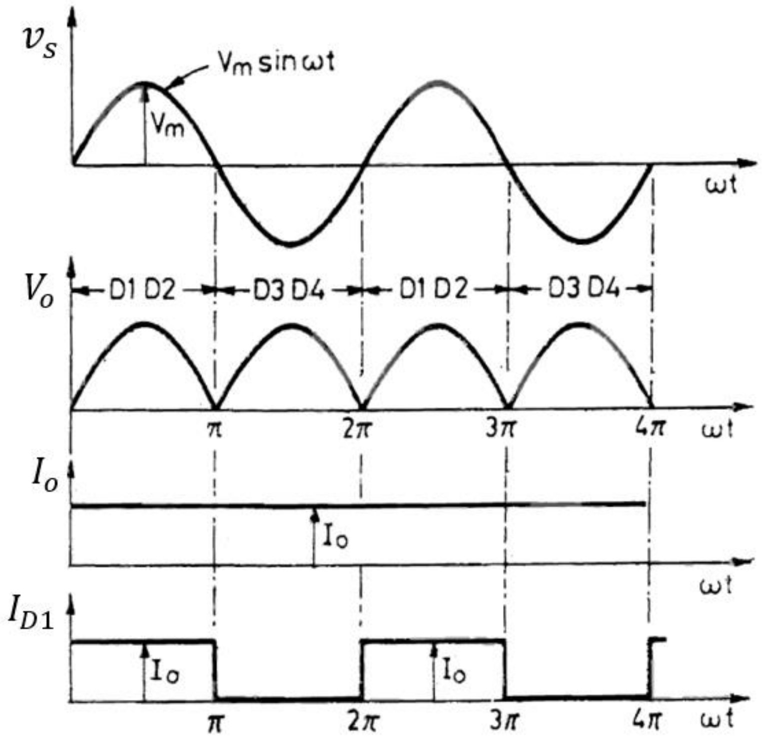
1)

Solution:

(a) Waveforms



(b) Average output voltage, $V_o = \frac{2V_m}{\pi} = \frac{2\times\sqrt{2}\times 220}{\pi} = 198.165\ V$

(c) Average load current, $I_o = \frac{V_o}{R} = \frac{198.165}{20} = 9.9\ A$

(d) Average diode current, $I_{d,a} = \frac{1}{2\pi}\int_0^{\pi} I_o\, d(\omega t) = \frac{I_o\times\pi}{2\pi} = \frac{9.9}{2} = 4.95\ A$

(e) RMS value of diode current, $I_{DRMS} = \sqrt{\frac{{I_o}^2\times\pi}{2\pi}} = \frac{I_o}{\sqrt{2}} = \frac{9.9}{\sqrt{2}} = 7.0\ A$

(f) DC output power, $P_{dc} = V_o \times I_o = 198.1 \times 9.9 = 1961.83\ W$

2)

Solution:

Given: $V = 220$ V $R = 10$ Ω and $\alpha = 45° = 0.785$ rad

(a) The average output voltage is equal to

$$V_o = \frac{\sqrt{2}V}{2\pi}(1 + cos\alpha) = \frac{\sqrt{2}\times 220}{2\pi}(1 + cos45) = 84.56 \text{ V}$$

(b) The rms value of output voltage is

$$V_{rms} = \frac{V}{\sqrt{2}}[\frac{1}{\pi}(\pi - \alpha + \frac{1}{2}sin2\alpha)]^{\frac{1}{2}} = 148.35 \text{ V}$$

(c) The form factor, $FF = \frac{V_{rms}}{V_o} = \frac{148.35}{84.56} = 1.754$

(d) The ripple factor, $RF = \sqrt{FF^2 - 1} = \sqrt{1.754^2 - 1} = 1.441$

(e) The dc output current, $I_o = \frac{V_o}{R} = \frac{84.56}{10} = 8.456$ A

$P_{dc} = V_{dc}I_{dc} = V_o \times I_o = 84.56 \times 8.456\, Watt = 715.039\, W$

The rms output current, $I_{rms} = \frac{V_{rms}}{R} = \frac{148.35}{10} = 14.835$ A

The ac output power, $P_{ac} = V_{rms}I_{rms} = 148.35 \times 14.835 = 2200.77\, W$

Rectification efficiency $= \frac{P_{dc}}{P_{ac}} \times 100\% = \frac{715.039}{2200.77} \times 100\% = 32.49\%$

(f) The volt ampere rating of transformer is

$VA = VI_{rms} = 220 \times 14.835\, VA = 3263.7\, VA$

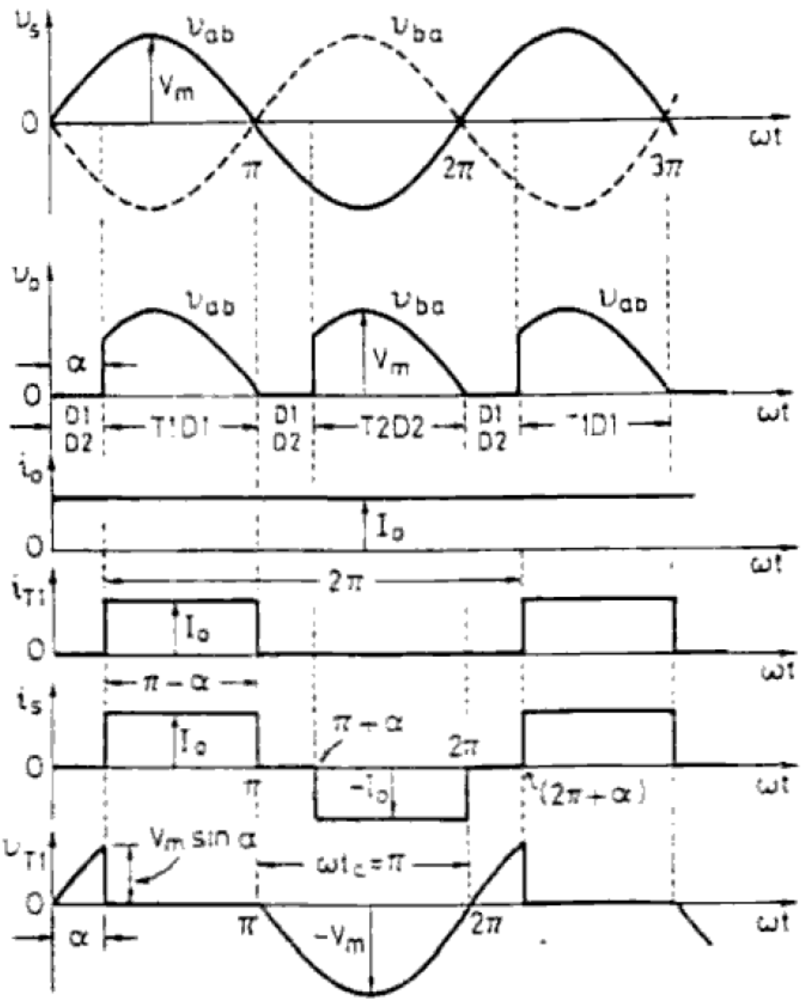
Transformer utilization factor is

$$TUF = \frac{Power\ delivered\ to\ load}{Input\ VA} = \frac{P_{dc}}{VA} = \frac{715.039}{220 \times 14.835} = 0.219$$

(g) Peak inverse voltage, $PIV = \sqrt{2}V = \sqrt{2} \times 220V = 311.08$ V

3)

Solution:



4)

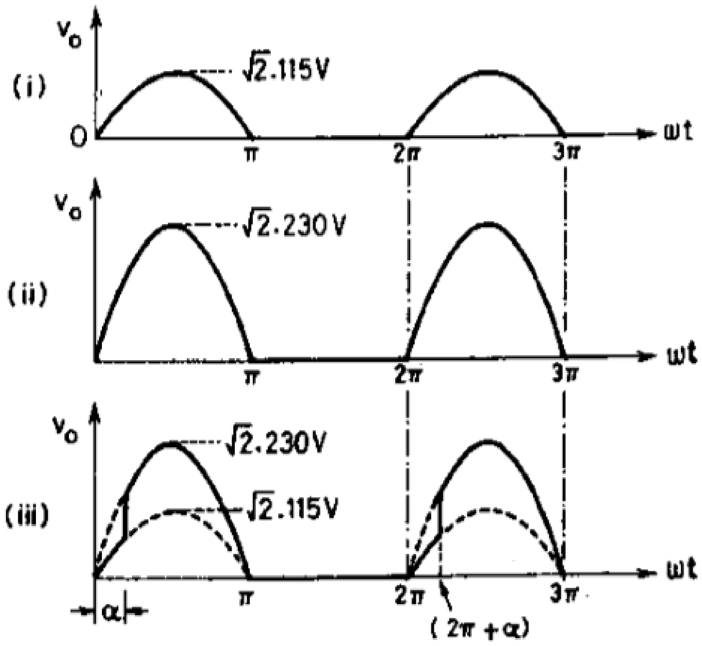
Solution:

a) $V_o = \frac{1}{2\pi/3}\int_{-\left(\frac{\pi}{3}-\alpha\right)}^{\frac{\pi}{3}+\alpha} V_m \cos \omega t \; d(\omega t) = \frac{3\sqrt{3}}{2\pi} V_m \cos \alpha.$

b) $V_{RMS} = \left[\frac{1}{2\pi/3}\int_{-\left(\frac{\pi}{3}-\alpha\right)}^{\frac{\pi}{3}+\alpha} V_m^2 \cos^2 \omega t \, d(\omega t)\right]^{1/2} = \sqrt{3}V_m \left[\frac{1}{6} + \frac{\sqrt{3}}{8\pi} \cos 2\alpha\right]^{1/2}.$

5)

Solution:



6)

Solution:

(a) Average output voltage, $V_{o(av)} = \frac{V_{in}}{1-D} \Rightarrow D = 1 - \frac{V_{in}}{V_{o(av)}} = 0.667$

(b) Time period, $T = T_{ON} + T_{OFF} = \frac{1}{f} = \frac{1}{1\times10^3} = 1\ ms$

$$D = \frac{T_{ON}}{T} \Rightarrow T_{ON} = DT = 0.667 \times 1 \times 10^{-3} = 0.667\ ms$$

$$T_{OFF} = T - T_{ON} = 1 \times 10^{-3} - 0.667 \times 10^{-3} = 0.333\ ms$$

c) Average output current, $I_{o(av)} = \frac{V_{o(av)}}{R} = \frac{60}{10} = 6A$

d) Average inductor current, $I_{L(av)} = I_{i(av)} = \frac{I_{o(av)}}{1-D} = \frac{6}{1-0.667} = 18A$

e) The maximum I_{max} and minimum I_{min} input currents

$$I_{max} = I_{i(av)} + \frac{1}{2}\Delta I_L = 18.667\ A \qquad I_{min} = I_{i(av)} - \frac{1}{2}\Delta I_L = 17.33\ A$$

$$\Delta I_L = \frac{V_{i(av)}}{L} T_{ON} = \frac{20}{10\times10^{-3}} \times 0.667 \times 10^{-3} = 1.334\ A$$

7)

Solution:

a) The rms value of fundamental component of output voltage is

$$V_{1(rms)} = \frac{1}{\sqrt{2}}\frac{4V_s}{\pi} = \frac{1}{\sqrt{2}}\frac{4\times200}{\pi} = 179.99\ V$$

b) The rms value of output voltage, $V_{0(rms)} = V_s = 200\ V$

The output power, $P_0 = \frac{{V_o}^2}{R} = 8000\ W$

c) The lowest order harmonics, $V_{3(rms)} = \frac{1}{\sqrt{2}}\frac{4V_s}{3\pi} = 59.99\ V$

Harmonic factor, $HF_3 = \frac{V_{3(rms)}}{V_{1(rms)}} = 0.333$

d) Third harmonic distortion factor, $DF_3 = \frac{V_{3(rms)}}{V_1 \times n^2} = 0.037 = 3.7\%$

8)

Solution:

$$V_{o(av)} = E + I_a R_a = K_v \omega + I_a R_a \Rightarrow 220 = K_v \frac{2\pi\times1000}{60} + 60\times0.1$$

$$\Rightarrow K_v = 2.044\ Vs/rad$$

a) For rated motor torque, armature current = 60 A

$$V_{o(av)} = K_v \omega + I_a R_a \Rightarrow \frac{2\sqrt{2}\times230}{\pi}\cos\alpha = 2.044\frac{2\pi\times600}{60} + 60\times0.1 = 134.4V$$

Therefore, $\alpha = \cos^{-1}\left[\frac{134.4\times\pi}{2\sqrt{2}\times230}\right] = 49.51$

b) At -500 rpm

$$\frac{2\sqrt{2}\times230}{\pi}\cos\alpha = 2.044\frac{2\pi\times(-500)}{60} + 60\times0.1 = -101.02V$$

Therefore, $\alpha = \cos^{-1}\left[\frac{-101.02\times\pi}{2\sqrt{2}\times230}\right] = 119.27$

c) At half-rated torque, motor armature current = ½ rated current = ½*60=30A

$$\frac{2\sqrt{2}\times230}{\pi}\cos 150 = 2.044\times\omega + 30\times0.1 \Rightarrow \omega = -89.18\ \text{rad/sec}$$