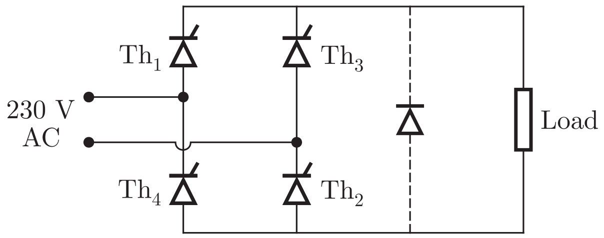
CHAPTER 8.4

PHASE CONTROLLED CONVERTERS

Statement for Common Data Questions Q. 1 - 3

A single phase 230 V, 50 Hz ac source is feeding a fully controlled bridge converter shown in the figure. The firing angle is 30°.



8.4.1 The dc output voltage will be

(A) 126.8 V
(B) 96.6 V
(C) 179.3 V
(D) 63.4 V

8.4.2 If a freewheeling diode is connected across the load, then what is the value of dc output voltage ?

(A) 193.2 V
(B) 136.6 V
(C) 386.4 V
(D) 273.2 V

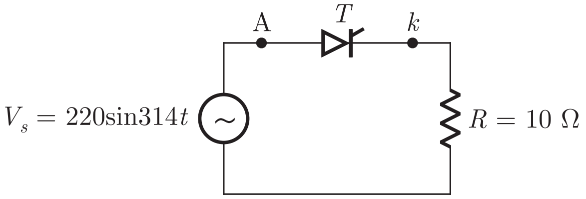
8.4.3 When the thyristor Th$_3$ gets open circuited, the value of dc output current flowing through a load of $10\,\Omega$ is

(A) 9.7 A
(B) 19.3 A
(C) 13.7 A
(D) 17.8 A

8.4.4 A three-phase, half-wave controlled converter is fed from a 380 V (line), 50 Hz ac supply and is operating at a firing angle of 45°. The thyristors have a forward voltage-drop of 1.2 V. What will be the approximate average load voltage ?

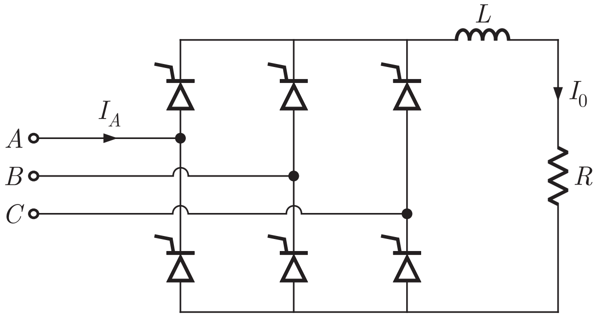
(A) 127 V
(B) 180.2 V
(C) 256.3 V
(D) 103.5 V

8.4.5 In the circuit shown below, the thyristor is fired at an angle $\pi/4$ in every positive half-cycle of the input ac voltage. The average power across the load will be



(A) 2.2 kW (B) 4.4 kW
(C) 1.1 kW (D) 8.8 kW

8.4.6 A line commutated ac to dc converter is shown in the figure. It operates from a three phase, 50 Hz, 580 V (line to line) supply. The load current I_0 is ripple free and constant at 3464 A. For an average output voltage of 648 V, the delay angle α is



(A) 34.2° (B) 78.1°
(C) 62.5° (D) 40.6°

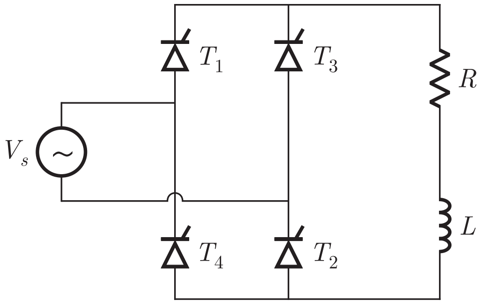
8.4.7 A single-phase half controlled bridge rectifier is operated from a source $V_s = 100\sin 314t$. The average power drawn by a resistive load of 10 ohms at a firing angle $\alpha = 45°$ is

(A) 295.5 W (B) 500 W
(C) 267 W (D) 454.5 W

8.4.8 In a fully-controlled converter the load voltage is controlled by which of the following quantity ?

(A) extension angle (B) firing angle
(C) conduction angel (D) none

8.4.9 The fully controlled bridge converter shown in the figure is fed from a single-phase source. The peak value of input voltage is V_m, What will be the average output dc voltage V_{dc} for a firing of 30° ?



(A) $0.6\,V_m$ (B) $.077\,V_m$

(C) $0.155\,V_m$ (D) $0.424\,V_m$

8.4.10 When the firing angle α of a single phase fully controlled rectifier feeding constant d.c. current into the load is 30°, what is the displacement factor of the rectifier ?

(A) 1 (B) 0.5

(C) $\sqrt{3}$ (D) $\frac{\sqrt{3}}{2}$

8.4.11 In a single phase full wave controlled bridge rectifier, minimum output voltage and maximum output voltage are obtained at which conduction angles ?

(A) $0^\circ, 180^\circ$ respectively (B) $180^\circ, 0^\circ$ respectively

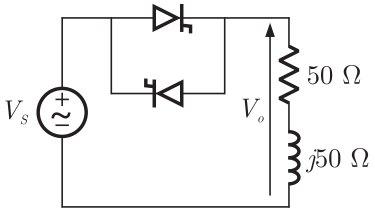
(C) $0^\circ, 0^\circ$ respectively (D) $180^\circ, 180^\circ$ respectively

8.4.12 A half-controlled bridge converter is operating from an r.m.s input voltage of 120 V. Neglecting the voltage drops, what are the mean load voltage at a firing delay angle of 0° and 180°, respectively ?

(A) $\frac{120\times 2\sqrt{2}}{\pi}$ V and 0 (B) 0 and $\frac{120\times 2\sqrt{2}}{\pi}$ V

(C) $\frac{120\sqrt{2}}{\pi}$ V and 0 (D) 0 and $\frac{120\sqrt{2}}{\pi}$ V

8.4.13 In the single phase voltage controller circuit shown in the figure, for what range of triggering angle (α), the input voltage (V_0) is not controllable ?



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(A) $0^\circ < \alpha < 45^\circ$ (B) $45^\circ < \alpha < 135^\circ$
(C) $90^\circ < \alpha < 180^\circ$ (D) $135^\circ < \alpha < 180^\circ$

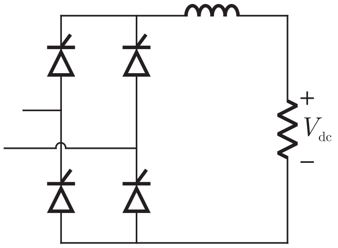
8.4.14 A single-phase full-bridge converter with a free-wheeling diode feeds an inductive load. The load resistance is $15.53\,\Omega$ and it has a large inductance providing constant and ripple free d.c. current. Input to converter is from an ideal 230 V, 50 Hz single phase source. For a firing delay angle of 60°, the average value of diode current is

(A) 10 A (B) 8.165 A
(B) 5.774 A (D) 3.33 A

8.4.15 A single phase fully controlled bridge converter feeds an inductive load. Assume the load current to be constant and the firing angle is 45°, the input harmonic factor is

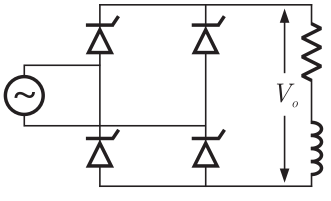
(A) 0.636 (B) 0.210
(C) 0.482 (D) 0.562

8.4.16 The fully controlled thyristor converter in the figure is fed from a single-phase source. When the firing angle is 0°, the dc output voltage of the converter is 300 V. What will be the output voltage for a firing angle of 60°, assuming continuous conduction



(A) 150 V (B) 210 V
(C) 300 V (D) 100π V

8.4.17 A single-phase half controlled converter shown in the figure feeding power to highly inductive load. The converter is operating at a firing angle of 60°.



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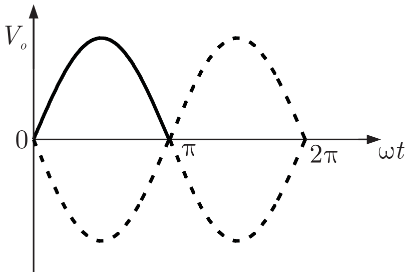
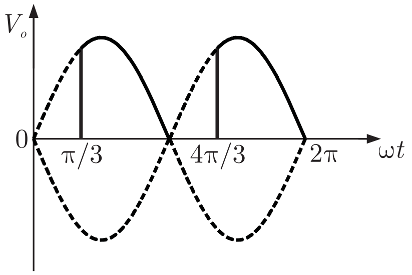
If the firing pulses are suddenly removed, the steady state voltage (V_0) waveform of the converter will become

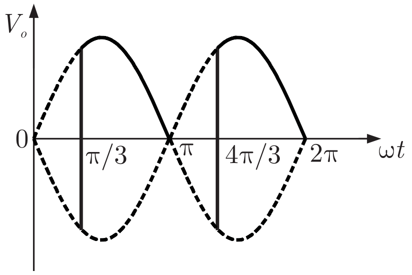
(A)



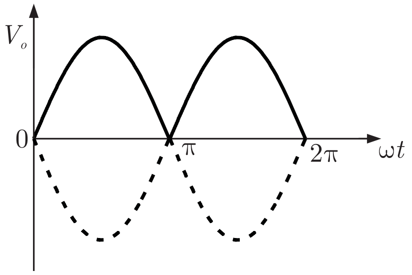
(B)



(C)



(D)



8.4.18 A three pulse converter is feeding a purely resistive load. What is the value of firing delay angle α, which dictates the boundary between continuous and discontinuous mode of current conduction ?

(A) $\alpha = 0^\circ$ (B) $\alpha = 30^\circ$

(C) $\alpha = 60^\circ$ (D) $\alpha = 150^\circ$

8.4.19 A single phase fully controlled bridge converter supplies a load drawing constant and ripple free load current, if the triggering angle is 30°, the input power factor will be

(A) 0.65 (B) 0.78

(C) 0.85 (D) 0.866

8.4.20 The total harmonic distortion (THD) of ac supply input current of rectifiers is maximum for

(A) single-phase diode rectifier with dc inductive filter

(B) 3-phase diode rectifier with dc inductive filter

(C) 3-phase thyristor with inductive filter

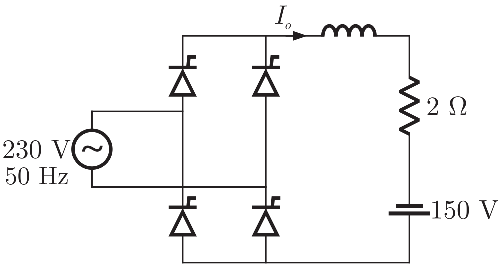
(D) Single-phase diode rectifier with capacitive filter

8.4.21 A six pulse thyristor rectifier bridge is connected to a balanced 50 Hz three phase ac source. Assuming that the dc output current of the rectifier is constant, the lowest frequency harmonic component in the ac source line current is

(A) 100 Hz (B) 150 Hz

(C) 250 Hz (D) 300 Hz

8.4.22 A single phase fully controlled converter bridge is used for electrical braking of a separately excited dc motor. The dc motor load is represented by an equivalent circuit as shown in the figure.



Assume that the load inductance is sufficient to ensure continuous and ripple free load current. The firing angle of the bridge for a load current of $I_0 = 10$ A will be

(A) 44° (B) 51°

(C) 129° (D) 136°

8.4.23 A three phase fully controlled bridge converter is feeding a load drawing a constant and ripple free load current of 10 A at a firing

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angle of 30°. The approximate Total harmonic Distortion (%THD) and the rms value of fundamental component of input current will respectively be

(A) 31% and 6.8 A (B) 31% and 7.8 A

(C) 66% and 6.8 A (D) 66% and 7.8 A

8.4.24 A single-phase fully controlled thyristor bridge ac-dc converter is operating at a firing angle of 25° and an overlap angle of 10° with constant dc output current of 20 A. The fundamental power factor (displacement factor) at input ac mains is

(A) 0.78 (B) 0.827

(C) 0.866 (D) 0.9

8.4.25 A single phase full-wave half-controlled bridge converter feeds an inductive load. The two SCRs in the converter are connected to a common DC bus. The converter has to have a freewheeling diode.

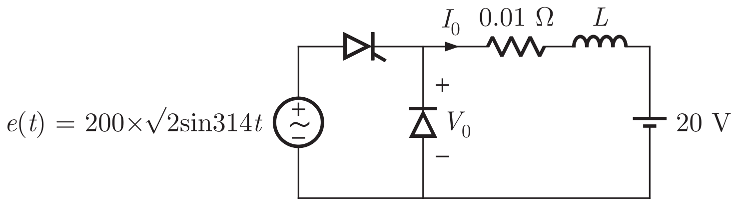
(A) because the converter inherently does not provide for free-wheeling

(B) because the converter does not provide for free-wheeling for high values of triggering angles

(C) or else the free-wheeling action of the converter will cause shorting of the AC supply

(D) or else if a gate pulse to one of the SCRs is missed, it will subsequently cause a high load current in the other SCR.

8.4.26 In the circuit shown in Figure, L is large and the average value of I_0 is 100 A. Then which of the following is true for the circuit ?



(A) The thyristor is gated in the positive half cycle of $e(t)$ at a delay angle α equal to 167.9°.

(B) The thyristor is gated in the negative half cycle of $e(t)$ at a delay angle α equal to 122.25°.

(C) The thyristor is gated in the positive half cycle of $e(t)$ at a delay angle α equal to 122.25°.

(D) The thyristor is gated in the negative half cycle of $e(t)$ at a delay angle α equal to 167.9°.

8.4.27 When a line commutated converter operates in the inverter mode

(A) it draws both real and reactive power from the A.C. supply.

(B) it delivers both real and reactive power to the A.C. supply

(C) it delivers real power to the A.C. supply

(D) it draws reactive power from the A.C. supply.

8.4.28 In a 3-phase controlled bridge rectifier, with an increase of overlap angle, the output dc voltage.

(A) decreases (B) increases

(C) does not change (D) depends upon load inductance

8.4.29 In a dual converter, the circulating current

(A) allows smooth reversal of load current, but increases the response time

(B) does not allow smooth reversal of load current, but reduces the response time

(C) allows smooth reversal of load current with improved speed of response

(D) flows only if there is no interconnecting inductor.

8.4.30 A PWM switching scheme is used with a three phase inverter to

(A) reduce the total harmonic distortion with modest filtering.

(B) minimize the load on the DC side

(C) increase the life of the batteries

(D) reduce low order harmonics and increase high order harmonics

8.4.31 A half controlled bridge converter feeds a resistive load of $10\,\Omega$ with ripple free current. If the input voltage is 240 V, 50 Hz and the triggering angle is 60° then the value of rms input current is

(A) 12.63 A (B) 16.20 A

(C) 15.38 A (D) 13.23 A

8.4.32 A three phase fully controlled bridge converter is fed from a 400 V (line to line) ac source. A resistive load of $100\,\Omega$ draws 400 W of power form the converter, the input power factor will be

(A) 0.5 (B) 0.21

(C) 0.37 (D) 0.86

8.4.33 A single-phase half-wave controlled converter is fed from a sinusoidal source. If the average output voltage is 25% of the maximum possible average output voltage for a purely resistive load, then firing angle is

(A) $\pi/4$ (B) $\pi/2$

(C) $\pi/3$ (D) $\pi/6$

8.4.34 A single-phase half-controlled bridge rectifier is feeding a load drawing a constant and ripple free load current at a firing angle $\alpha = \pi/6$. The harmonic factor(HF) of input current and the input power factor respectively are

(A) 30.80%, 0.922 (B) 4.72%, 0.6

(C) 60%, 0.827 (D) 96.6%, 0.477

8.4.35 A full-wave controlled bridge rectifier is fed by an ac source of 230 V rms, 50 Hz . The value of load resistance is 15 ohm. For a delay angle of 30° the input power factor is

(A) 0.840 (B) 0.70

(C) 0.985 (D) 0.492

8.4.36 In the continuous conduction mode the output voltage waveform does not depend on

(A) firing angle (B) conduction angle

(C) supply (D) load

8.4.37 The rectification efficiency of a single phase half-wave controlled rectifier having a resistive load and the delay angle of $\pi/2$ is

(A) 24.28% (B) 45.04%

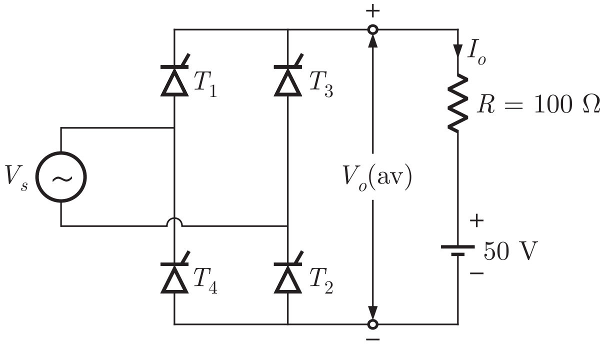
(C) 20.28% (D) 26.30%

8.4.38 For a single phase half-controlled bridge converter having highly inductive load, the delay angle is $\pi/2$. The harmonic factor will be

(A) 30.80% (B) 12.10%

(C) 48.34% (D) 23.37%

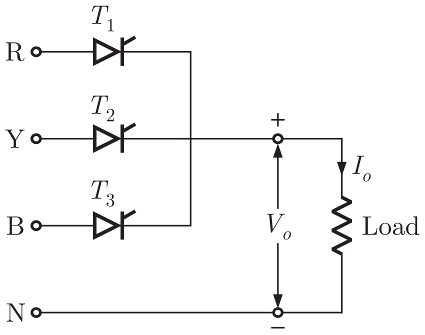
8.4.39 In the circuit shown in the figure, the SCRs are triggered at 30° delay. The current through $100\,\Omega$ resistor is



(A) 1.85 A (B) 2.35 A

(C) 1.35 A (D) 1.50 A

8.4.40 A three phase half wave controlled rectifier circuit is shown in the figure. It is operated from 3-ϕ star connected, supply transformer with a line to line ac supply voltage of 440 volts rms, at 50 Hz. The thyristor are triggered at a delay angle of $\alpha = 30°$. Assume continuous ripple free current.

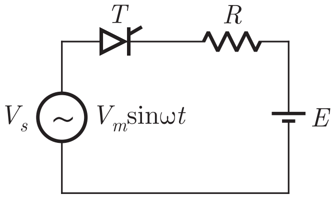


The average output current is

(A) 7.42 A (B) 40.4 A

(C) 12.86 A (D) 16.57 A

8.4.41 In the circuit shown in figure, a battery of 6 V is charged by a 1-ϕ one pulse thyristor controlled rectifier. A resistance R is to be inserted in series with the battery to limit the charging current to 4 A. The value of R is



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(A) 3.30 Ω (B) 6.0 Ω

(C) 2.54 Ω (D) 9.10 Ω

8.4.42 A single-phase, 230 V, 50 Hz ac mains fed step down transformer (4:1) is supplying power to a half-wave uncontrolled ac-dc converter used for charging a battery(12 V dc) with the series current limiting resistor being 19.04 Ω. The charging current is

(A) 2.43 A (B) 1.65 A

(C) 1.22 A (D) 1.0 A

8.4.43 A 3-phase fully controlled bridge converter with free wheeling diode is fed from 400 V, 50 Hz AC source and is operating at a firing angle of 60°. The load current is assumed constant at 10 A due to high load inductance. The input displacement factor (IDF) and the input power factor (IPF) of the converter will be

(A) IDF = 0.867; IPF = 0.828 (B) IDF = 0.867; IPF = 0.552

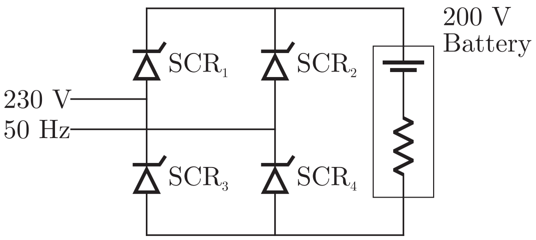
(C) IDF = 0.955; IPF = 0.478 (D) IDF = 0.5; IPF = 0.318

8.4.44 A solar cell of 350 V is feeding power to an ac supply of 440 V, 50 Hz through a 3-phase fully controlled bridge converter. A large inductance is connected in the dc circuit to maintain the dc current at 20 A. If the solar cell resistance is 0.5 Ω,then each thyristor will be reverse biased for a period of

(A) 125° (B) 120°

(C) 60° (D) 55°

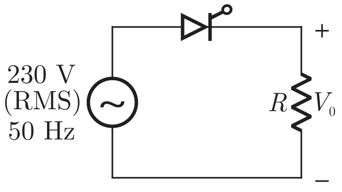
8.4.45 A single-phase bridge converter is used to charge a battery of 200 V having an internal resistance of 0.2 Ω as shown in figure. The SCRs are triggered by a constant dc signal. If SCR_2 gets open circuited, what will be the average charging current ?



(A) 23.8 A (B) 15 A

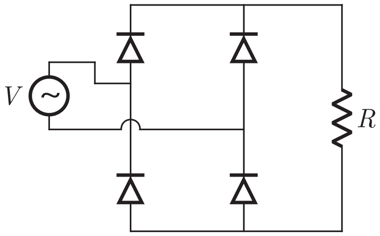
(C) 11.9 A (D) 3.54 A

8.4.46 Consider a phase-controlled converter shown in the figure. The thyristor is fired at an angle α in every positive half cycle of the input voltage. If the peak value of the instantaneous output voltage equals 230 V, the firing angle α is close to



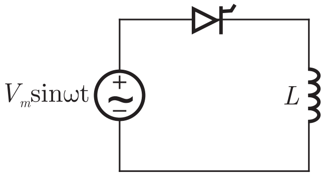
(A) 45°
(B) 135°
(C) 90°
(D) 83.6°

8.4.47 In the single phase diode bridge rectifier shown in figure, the load resistor is $R = 50\,\Omega$. The source voltage is $V = 200\sin(\omega t)$, where $\omega = 2\pi \times 50$ radians per second. The power dissipated in the load resistor R is



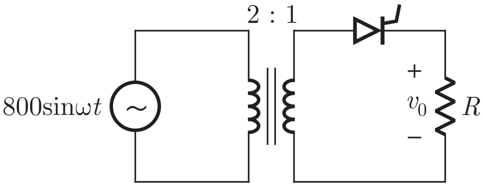
(A) $\frac{3200}{\pi}$ W
(B) $\frac{400}{\pi}$ W
(C) 400 W
(D) 800 W

8.4.48 A half-wave thyristor converter supplies a purely inductive load as shown in figure. If the triggering angle of the thyristor is 120°, the extinction angle will be



(A) 240°
(B) 180°
(C) 200°
(D) 120°

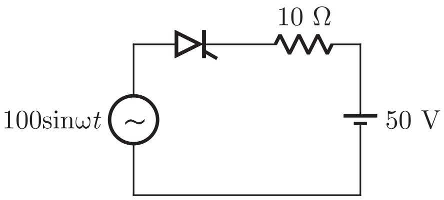
8.4.49 A single phase half wave rectifier circuit is shown in the figure. The thyristor is fired at 30° in each positive half cycle. The values of average load voltage and the rms load voltage will respectively be



(A) 475.2 V, 190.9 V (B) 237.64 V, 194.2 V

(C) 118.8 V, 197.1 V (D) 237.6 V, 197.1 V

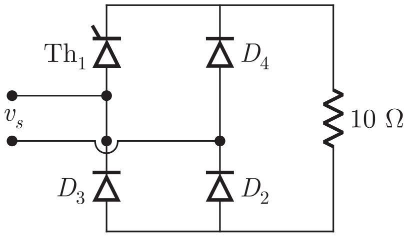
8.4.50 A dc battery of 50 V is charged through a $10\,\Omega$ resistor as shown in the figure. Assume that the thyristor is continuously fired. The average value of charging current is



(A) 0.19 A (B) 6.85 A

(C) 1.09 A (D) 2.75 A

8.4.51 A bridge converter is fed from a source $V_s = V_m \sin \omega t$ as shown in the following figure. What will be the output voltage for a firing angle of α ? Assume continuous conduction.



(A) $\frac{2V_m}{\pi}\cos\alpha$ (B) $\frac{V_m}{2\pi}(1+\cos\alpha)$

(C) $\frac{V_m}{2\pi}(3+\cos\alpha)$ (D) $\frac{V_m}{\pi}\cos\alpha$

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SOLUTIONS

8.4.1 DC output voltage

$$V_{dc} = \frac{2V_m}{\pi}\cos\alpha = \frac{2\sqrt{2}\,(230)}{\pi}\cos 30^\circ = 179.3\text{ V}$$

Hence (C) is correct option.

8.4.2 When free wheeling diode is present, Th_1 and Th_2 will conduct from α to π while Th_3 and Th_4 will conduct for $\pi + \alpha$ to 2π.

$$V_{dc} = \frac{1}{\pi}\int_{\alpha}^{\pi}\sqrt{2}\,(230)\sin d\theta = \frac{\sqrt{2}\,(230)}{\pi}(1+\cos\alpha)$$

$$= \frac{\sqrt{2}\,(230)}{\pi}(1+\cos 30^\circ) = 193.185\text{ V}$$

Hence (A) is correct option.

8.4.3 When Th$_3$ gets open circuited, the circuit will work as a half wave rectifier, the output dc voltage

$$V_{dc} = \frac{1}{2\pi}\int_{\alpha}^{\pi}\sqrt{2}\,(230)\sin\theta\, d\theta$$

$$= \frac{(230)}{\sqrt{2}\,\pi}(1+\cos\alpha) = \frac{230}{\sqrt{2}\,\pi}(1+\cos 30^\circ) = 96.6\text{ V}$$

Average dc output current

$$I_{dc} = \frac{96.6}{10} = 9.7\text{ A}$$

Hence (A) is correct option.

8.4.4 Here $V_m = \frac{380\sqrt{2}}{\sqrt{3}} = 310.3\text{ V}$

Let the thyristor voltage drop is (V_t), then average dc voltage

$$V_{dc} = \frac{3\sqrt{3}}{2\pi}V_m\cos\alpha - V_t = \frac{3\sqrt{3}\times 380\sqrt{2}}{2\pi\sqrt{3}}\cos 45^\circ - 1.2$$

$$= 180.2\text{ V}$$

Hence (B) is correct option.

8.4.5 RMS load voltage

$$V_{dc(\text{rms})} = V_m\left[\frac{\pi-\alpha}{4\pi} + \frac{\sin 2\alpha}{8\pi}\right]^{\frac{1}{2}}$$

$$= 220\left[\frac{\pi - \frac{\pi}{4}}{4\pi} + \frac{\sin\frac{\pi}{2}}{8\pi}\right]^{\frac{1}{2}} = 104.88\text{ V}$$

Average power across the load

$$P_{ac} = \frac{V_{dc(\text{rms})}^2}{R} = \frac{(104.88)^2}{10} = 1.1\,\text{kW}$$

Hence (C) is correct option.

8.4.6 Here $V_{\text{Line}} = 580$ V

Average output voltage

$$V_{dc} = \frac{3\sqrt{3}}{\pi} V_m \cos\alpha = \frac{3\sqrt{2}}{\pi} V_{\text{Line}} \cos\alpha$$

$$648 = \frac{3 \times \sqrt{2} \times 580}{\pi} \cos\alpha$$

or $\alpha = 34.18^\circ$

Hence (A) is correct option.

8.4.7 $V_s = 100 \sin 314t,\ R = 10\,\Omega,\ \alpha = 45^\circ$

RMS load voltage

$$V_{dc(\text{rms})} = V_m \left[\frac{\pi - \alpha}{2\pi} + \frac{\sin 2\alpha}{4\pi}\right]^{1/2}$$

$$V_{dc(\text{rms})} = 100 \left[\frac{\pi - \frac{\pi}{4}}{2\pi} + \frac{\sin\frac{\pi}{2}}{4\pi}\right]^{1/2} = 67.42\text{ V}$$

The average power delivered to the load is

$$P_{ac} = \frac{V_{dc(\text{rms})}^2}{R} = \frac{(67.42)^2}{10} = 454.5\text{ W}$$

Hence (D) is correct option.

8.4.8 The average value of dc voltage i.e. load voltage can be varied by controlling the phase angle(α) of firing pulses.

Hence (B) is correct option.

8.4.9 The average output dc voltage

$$V_{dc} = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin\omega t\, d(\omega t) = \frac{V_m}{\pi}(-\cos\omega t)_{\alpha}^{\pi+\alpha}$$

$$= \frac{V_m}{\pi}[\cos\alpha - \cos(\pi + \alpha)] = \frac{2V_m}{\pi}\cos\alpha$$

Given $\alpha = 30^\circ$, the average dc output voltage

$$V_{dc} = \frac{2V_m}{\pi}\cos\alpha = \frac{2V_m}{\pi}\cos(30^\circ) = 0.155132\,V_m$$

Hence (C) is correct option.

8.4.10 For a 1-ϕ full converter the displacement factor is

$$\text{DF} = \cos\alpha = \cos 30^\circ = \frac{\sqrt{3}}{2}$$

Hence (D) is correct option.

8.4.11 For a single phase fully controlled bridge rectifier, the average output voltage is given by

$$V_0 = \frac{V_m}{\pi}(1 + \cos\alpha)$$

Output voltage is minimum for $\alpha = 180^\circ$ and maximum for $\alpha = 0^\circ$.

Hence (B) is correct option.

8.4.12 For half-controlled bridge rectifier, average output voltage

$$V_0 = \frac{V_m}{\pi}[1 + \cos\alpha]$$

For $\alpha = 0^\circ$, $$V_0 = \frac{120\sqrt{2}}{\pi}[1 + \cos 0^\circ] = \frac{120 \times 2\sqrt{2}}{\pi}$$

For $\alpha = 180^\circ$, $$V_0 \frac{120\sqrt{2}}{\pi}[1 + \cos 180^\circ] = 0$$

Hence (A) is correct option.

8.4.13

$$R + jXL = 50 + 50j$$

$$\tan\phi = \frac{\omega L}{R} = \frac{50}{50} = 1 \quad \text{or} \quad \phi = 45^\circ$$

so, firing angle 'α' must be higher the 45°, Thus for $0 < \alpha < 45^\circ$, V_0 is uncontrollable.

Hence (A) is correct option.

8.4.14 Average output current

$$I_0 = \frac{V_m}{\pi R}(1 + \cos\alpha) \ \frac{230\sqrt{2}}{\pi \times 15.53}(1 + \cos 60^\circ)$$

Average current through diode

$$I_{FW} = \frac{1}{\pi}\int_0^{\pi/3} I_o \, d(\omega t) = \frac{1}{3} \times 10 = 3.33 \text{ A}$$

Hence (D) is correct option.

8.4.15 Input harmonic factor $= \left[\frac{\pi^2}{8} - 1\right]^{1/2} = 0.482$

Hence (C) is correct option.

8.4.16 Given fully-controlled thyristor converter, when firing angle $\alpha = 0$, dc output voltage $V_{dc_0} = 300$ V

If $\alpha = 60^\circ$, then $V_{dc} = ?$

For fully-controlled converter

$$V_{dc_0} = \frac{2\sqrt{2}\ V_{dc_1}}{\pi}\cos\alpha$$

Since $\alpha = 0$, $V_{dc_0} = 300$ V

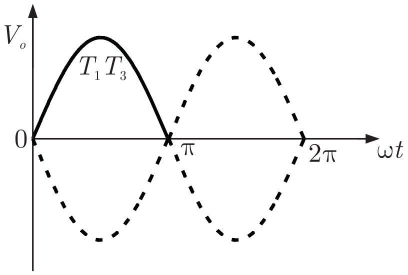
$$300 = \frac{2\sqrt{2}\ V_{dc_1}}{\pi}\cos 0^\circ$$

$$V_{dc_1} = \frac{300\pi}{2\sqrt{2}}$$

At $\alpha = 60°$, $V_{dc_2} = \frac{2\sqrt{2}}{\pi} \times \frac{300\pi}{2\sqrt{2}} \cos 60° = 300 \times \frac{1}{2} = 150$ V

Hence (A) is correct option.

8.4.17 Output of this



Here the inductor makes T_1 and T_3 in ON because current passing through T_1 and T_3 is more than the holding current.
Hence (A) is correct option.

8.4.18 Hence (D) is correct option.

8.4.19 Given $\alpha = 30°$, in a 1-ϕ fully bridge converter
we know that,

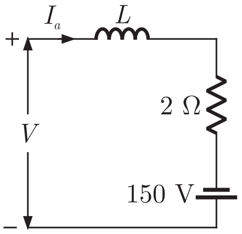
$$\text{Power factor} = \text{Distortion factor} \times \cos\alpha$$
$$\text{D.f. (Distortion factor)} = I_{s(\text{fundamental})}/I_s = 0.9$$
$$\text{power factor} = 0.9 \times \cos 30° = 0.78$$

Hence (B) is correct option.

8.4.20 Single phase diode rectifier with capacitive filter has maximum THD.
Hence (D) is correct option.

8.4.21 For six pulse thyristor rectifier bridge the lowest frequency component in AC source line current is of 250 Hz.
Hence (C) is correct option.

8.4.22 Here for continuous conduction mode, by Kirchoff's voltage law, average load current



Sample Chapter GATE MCQ FOR Electrical Engineering Vol-1, 2
Authors: RK Kanodia & Ashish Murolia
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$$V - 2I_a + 150 = 0$$

$$I_a = \frac{V+150}{2}$$

$\therefore$ $I_1 = 10$ A, So $\quad V = -130$ V

$$\frac{2V_m}{\pi}\cos\alpha = -130$$

$$\frac{2\times\sqrt{2}\times 230}{\pi}\cos\alpha = -130^\circ$$

$$\alpha = 129^\circ$$

Hence (C) is correct option.

8.4.23 Total rms current $I_a = \sqrt{\frac{2}{3}}\times 10 = 8.16$ A

Fundamental current $I_{a1} = 0.78\times 10 = 7.8$ A

$$\text{THD} = \sqrt{\frac{1}{\text{DF}^2} - 1}$$

where $\quad \text{DF} = \frac{I_{a1}}{I_a} = \frac{0.78\times 10}{0.816\times 10} = 0.955$

$\therefore \quad \text{THD} = \sqrt{\left(\frac{1}{0.955}\right)^2 - 1} = 31\%$

Hence (B) is correct option.

8.4.24 Firing angle $\quad \alpha = 25^\circ$

Overlap angle $\quad \mu = 10^\circ$

so, $\quad I_0 = \frac{V_m}{\omega Ls}[\cos\alpha - \cos(\alpha+\mu)]$

$\therefore \quad 20 = \frac{230\sqrt{2}}{2\pi\times 50Ls}[\cos 25^\circ - \cos(25^\circ + 10^\circ)]$

$\therefore \quad Ls = 0.0045$ H

$$V_0 = \frac{2V_m\cos\alpha}{\pi} - \frac{\omega LsI_0}{\pi}$$

$$= \frac{2\times 230\sqrt{2}\cos 25^\circ}{3.14} - \frac{2\times 3.14\times 50\times 4.5\times 10^{-3}\times 20}{3.14}$$

$$= 187.73 - 9 = 178.74^\circ$$

$$\text{Displacement factor} = \frac{V_0I_0}{V_sI_s} = \frac{178.25\times 20}{230\times 20} = 0.78$$

Hence (A) is correct option.

8.4.25 Single phase full wave half controlled bridge converter feeds an Inductive load. The two SCRs in the converter are connected to a common dc bus. The converter has to have free wheeling diode because the converter does not provide for free wheeling for high values of triggering angles.

Hence (B) is correct option.

8.4.26 Assuming continuous conduction. We have

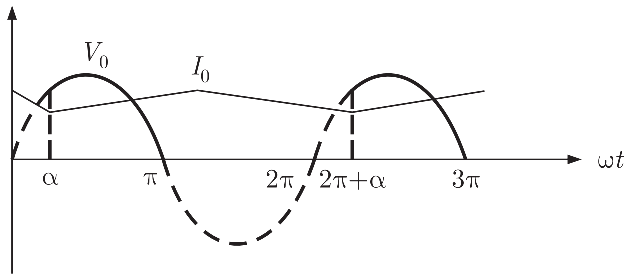
so $$V_0 = I_0 R + E = 100 \times 0.01 + 20 = 21$$

For a single-phase half-wave converter, average output voltage is

$$V_0 = 21 = \frac{V_m(1+\cos\alpha)}{2\pi}$$

$$(1+\cos\alpha) = \frac{21 \times 2\pi}{\sqrt{2} \times 200} \Rightarrow \alpha = 122.25^\circ$$

From the output waveform given below, we observed that the thyristor is gated in positive half cycle.



Hence (C) is correct option.

8.4.27 In the inverting mode a line commutated converted operates for phase angles 90° to 180°. When the dc voltage is negative power flow is from dc to ac and the converter functions as inverter. As dc power is fed back, it is real power.

Hence (C) is correct option.

8.4.28 For a 3-phase fully-controlled converter, output dc voltage is given as

$$V_{dc} = \frac{3\sqrt{3}\,V_{mph}}{\pi}\cos(\alpha+\mu) + \frac{30\omega L_s}{\pi} I_d$$

Where μ is the overlap angle. So when the overlap angle is increased, the cosine term in the above expression decreases and the output dc voltage also decreases.

Hence (A) is correct option.

8.4.29 The circulating current helps in maintaining continuous conduction of both the converters irrespective of load and the time response to change the operation from one quadrant to other is faster.

Hence (C) is correct option.

8.4.30 In a three-phase inverter, the supply current consists of one pulse per half-cycle and the lowest order harmonic is third. It is difficult to eliminate the lowest order harmonic current. The lowest order

Sample Chapter GATE MCQ FOR Electrical Engineering Vol-1, 2
Authors: RK Kanodia & Ashish Murolia
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harmonics can be reduced if the supply current has more than one pulse per half-cycle. In PWM lowest order harmonic can be eliminated and higher order harmonics can be increased.
Hence (D) is correct option.

8.4.31

$$V_{dc} = \frac{V_m}{\pi}(1+\cos\alpha)$$

$$= \frac{\sqrt{2}\,(240)}{\pi}(1+\cos 60^\circ)$$

$$= 162.03\text{ V}$$

Load current $I = \frac{V_{dc}}{R_L} = \frac{162.03}{10} = 16.203\text{ A}$

RMS input current

$$I_s = I\left(1-\frac{\alpha}{\pi}\right)^{0.5} = 16.203\left(1-\frac{60^\circ}{\pi}\right)^{0.5} = 13.23\text{ A}$$

Hence (D) is correct option.

8.4.32 Load Current

$$I_L = \left(\frac{400}{100}\right)^{0.5} = 2\text{ A}$$

In a three-phase fully controlled bridge converter input rms current I_s or the current in each supply phase exists for 120° in every 180°. Therefore rms value of input current

$$I_s = \left(\frac{2\times 120}{180}\right)^{0.5} = 1.15\text{ A}$$

$$\text{Input apparent power} = \sqrt{3}\times 400\times 1.15 = 796.72\text{ VA}$$

$$796.72\cos\theta = 400$$

Power factor $\cos\theta = 0.5$ lagging

Hence (A) is correct option.

8.4.33 Average output voltage

$$V_{dc} = \frac{V_m}{2\pi}(1+\cos\alpha)$$

The maximum output voltage is obtained when $\alpha = 0$

$$V_{dc_{\max}} = \frac{V_m}{\pi}$$

Given $V_{dc} = 25\%\left(\frac{V_m}{\pi}\right) = 0.25\frac{V_m}{\pi}$

So $0.25\frac{V_m}{\pi} = \frac{V_m}{2\pi}(1+\cos\alpha)$

The Firing angle is

$$\alpha = 60^\circ$$

Hence (C) is correct option.

8.4.34 Supply rms current

$$I_{rms} = I_{dc}\left(1-\frac{\alpha}{\pi}\right)^{1/2} = I_{dc}\left(1-\frac{\pi/6}{\pi}\right)^{1/2} = 0.91 I_{dc}$$

Now, the rms value of the supply fundamental component of input current.

$$I_{rms1} = \frac{2\sqrt{2}\,I_{dc}}{\pi}\cos\alpha/2 = \frac{2\sqrt{2}}{\pi}I_{dc}\cos 15 = 0.869 I_{dc}$$

Harmonic factor (HF) on input current

$$\text{HF} = \left[\left(\frac{I_{rms}}{I_{rms\,1}}\right)^2 - 1\right]^{1/2} = \left[\left(\frac{0.91}{0.869}\right)^2 - 1\right]^{1/2} = 30.80\,\%$$

$$\text{Input power factor} = \frac{I_{rms\,1}}{I_{rms}}\cos\alpha/2 = 0.922\,(\text{lagging})$$

Hence (A) is correct option.

8.4.35 The rms load voltage,

$$V_{rms} = V_m\left[\frac{\pi-\alpha}{2\pi} + \frac{\sin 2\alpha}{4\pi}\right]^{1/2}$$

$$= \sqrt{2}\times 230\left[\frac{\pi-\frac{\pi}{6}}{2\pi} + \frac{\sin\frac{2\pi}{6}}{4\pi}\right]^{1/2} = 226.713\text{ V}$$

$$\text{Input power factor} = \frac{V_{\text{rms}}}{V_s} = \frac{226.713}{230}$$

$$\cos\phi = 0.985\text{ lag}$$

Hence (C) is correct option.

8.4.36 Hence (D) is correct option.

8.4.37 Average load voltage is given by

$$V_{0(\text{av})} = \frac{V_m}{2\pi}(1+\cos\alpha) = \frac{V_m}{2\pi}\left(1+\cos\frac{\pi}{2}\right) = 0.159\,V_m$$

Average load current

$$I_{0(\text{av})} = \frac{V_{0(\text{av})}}{R} = \frac{0.159\,V_m}{R}$$

RMS load voltage

$$V_{0(\text{rms})} = V_m\left[\frac{\pi-\alpha}{4\pi} + \frac{\sin 2\alpha}{8\pi}\right]^{\frac{1}{2}}$$

$$= V_m\left[\frac{\pi-\pi/2}{4\pi} + \frac{\sin\left(2\times\frac{\pi}{2}\right)}{8\pi}\right]^{\frac{1}{2}} = 0.353\,V_m$$

RMS load current

$$I_{0(\text{rms})} = \frac{V_{0(\text{rms})}}{R} = \frac{0.353\,V_m}{R}$$

To obtain rectification efficiency

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{V_{0(\text{av})}I_{0(\text{av})}}{V_{0(\text{rms})}I_{0(\text{rms})}}$$

$$= \frac{0.159\,V_m \times \frac{0.159\,V_m}{R}}{0.353\,V_m \times \frac{0.353\,V_m}{R}} = 0.2028 \text{ or } 20.28\%$$

Hence (C) is correct option.

8.4.38 Let the average load current is I_{dc}

Fundamental RMS current

$$I_{rms} = I_{dc}\left(1 - \frac{\alpha}{\pi}\right)^{1/2}$$

The fundamental component of RMS current

$$I_{rms1} = \frac{2\sqrt{2}\,I_{dc}}{\pi}\cos\frac{\alpha}{2}$$

The harmonic factor (HF) is given as,

$$HF = \sqrt{\frac{I_{rms}^2}{I_{rms1}^2} - 1}$$

Putting values in above equation,

$$HF = \sqrt{\frac{I_{dc}^2\left(\frac{\pi - \alpha}{\pi}\right)}{\frac{8I_{dc}^2}{\pi^2}\cos^2\frac{\alpha}{2}} - 1} = \sqrt{\frac{\pi(\pi - \alpha)}{8\cos^2\frac{\alpha}{2}} - 1}$$

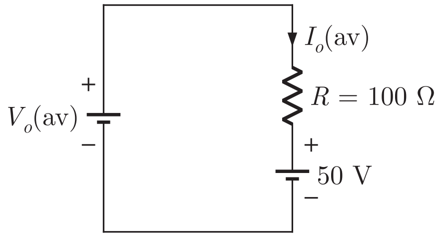
For $\alpha = \pi/2$, $$HF = \sqrt{\frac{\pi(\pi - \pi/2)}{8\cos^2\frac{\pi}{4}} - 1} = \sqrt{1.23 - 1} = 0.4834$$

Hence (C) is correct option.

8.4.39 This is a fully controlled bridge. The average value of output voltage.

$$V_{0(\text{av})} = \frac{V_m}{\pi}(1 + \cos\alpha) = \frac{230\sqrt{2}}{\pi}(1 + \cos 30^\circ) = 184.8 \text{ V}$$

This voltage is applied to the load. The equivalent circuit is shown in the figure



Applying KVL to above circuit,

$$V_{0(\text{av})} = I_{0(\text{av})}R + 50$$

$$\therefore \quad 184.8 = I_{0(\text{av})} \times 100 + 50$$

$$I_{0(\text{av})} = 1.348 \text{ A}$$

Hence (C) is correct option.

Sample Chapter GATE MCQ FOR Electrical Engineering Vol-1, 2
Authors: RK Kanodia & Ashish Murolia
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8.4.40 The average output voltage for continuous ripple free output current is,

$$V_{0(av)} = \frac{3\sqrt{3}\,V_m}{2\pi}\cos\alpha$$

Here V_m is peak value of supply phase voltage. We have

$$V_{line(rms)} = 440\text{ V}$$

$$\therefore \quad V_{ph(\text{rms})} = \frac{V_{line}}{\sqrt{3}} = \frac{440}{\sqrt{3}} = 254\text{ V}$$

$$\therefore \quad V_m = \sqrt{2}\,V_{ph(\text{rms})} = \sqrt{2}\times 254 = 359.26\text{ V}$$

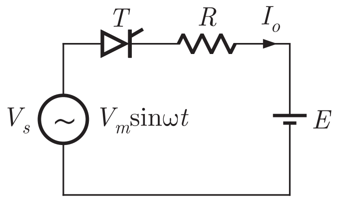
$$\therefore \quad V_{0(av)} = \frac{3\sqrt{3}\times 359.26}{2\pi}\cos 30^\circ = 257.3\text{ V}$$

Average output current $I_{0(av)}$

$$I_{0(av)} = \frac{V_{0(av)}}{R} = \frac{257.3}{20} = 12.86\text{ A}$$

Hence (C) is correct option.

8.4.41



Let the supply is $V_S = V_m\sin\omega t$ and battery emf is E. For the circuit voltage equation is

$$V_m\sin\omega t = E + I_0 R$$

$$\text{or,} \quad I_0 = \frac{V_m\sin\omega t - E}{R}$$

Since the SCR is turn on when $V_m\sin\theta_1 = E$ and is turned off when $V_m\sin\theta_2 = E$, where $\theta_2 = \pi - \theta_1$.

$$\therefore \quad \theta_1 = \sin^{-1}\left(\frac{E}{V_m}\right) = \sin^{-1}\left(\frac{6}{30}\right) = 11.53^\circ$$

The battery charging requires only the average current I_0 given by:

$$I_0 = \frac{1}{2\pi R}\left[\int_{\theta_1}^{\pi-\theta_1}(V_m\sin\omega t - E)\,d(\omega t)\right]$$

$$= \frac{1}{2\pi R}[2V_m\cos\theta_1 - E(\pi - 2\theta_1)]$$

$$\therefore \quad 4\text{ Amp} = \frac{1}{2\pi R}\left[2\times\sqrt{2}\times 30\cos 11.53 - 6\left(\pi - \frac{2\times 11.53\pi}{180}\right)\right]$$

$$4\text{ Amp} = \frac{1}{2\pi R}[83.13 - 19.172] = \frac{1}{2\pi R}[63.95]$$

or $$R = \frac{1}{2\pi \times 4}[63.95]\,\Omega = 2.544\,\Omega$$

Hence (C) is correct option.

8.4.42 $$V_s = \frac{230}{4} = 57.5$$

Here charging current $= I$

$$V_m \sin\theta = 12$$
$$\theta_1 = 8.486 = 0.148 \text{ radian}$$
$$V_m = 81.317 \text{ V}$$
$$\varepsilon = 12 \text{ V}$$

There is no power consumption in battery due to ac current, so average value of charging current.

$$I_{av(\text{charging})} = \frac{1}{2\pi \times 19.04}[2\,V_m \cos\theta_1 - \varepsilon(\pi - 2\theta_1)]$$
$$= \frac{1}{2\pi \times 19.04}[2 \times V_m \times \cos\theta_1 - 12(\pi - 2\theta_1)]$$
$$= 1.059\ \Omega/\text{A}$$

Hence (D) is correct option.

8.4.43 Given that

400 V, 50 Hz AC source, $\alpha = 60^\circ$, $I_L = 10$ A

so,

Input displacement factor $= \cos\alpha = 0.5$

and, input power factor $=$ D.F. $\times \cos\alpha$

$$\text{distortion factor} = \frac{I_{s(\text{fundamental})}}{I_s} = \frac{\frac{4 \times 10}{\pi \times \sqrt{2}}\sin 60^\circ}{10 \times \sqrt{2/3}}$$
$$= 0.955$$

so, input power factor $= 0.955 \times 0.5 = 0.478$

Hence (C) is correct option.

8.4.44 Let we have

$$R_{\text{solar}} = 0.5\,\Omega,\ I_0 = 20 \text{ A}$$

so $$V_s = 350 - 20 \times 0.5 = 340 \text{ V}$$

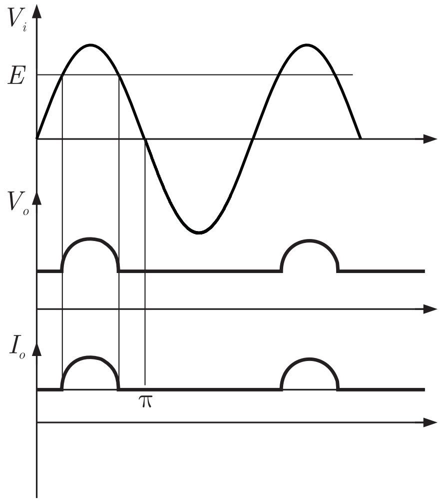
$\therefore$ $$340 = \frac{3 \times 440 \times \sqrt{2}}{\pi}\cos\alpha$$

$$\cos\alpha = 55^\circ$$

So each thyristor will reverse biased for $180^\circ - 55^\circ = 125^\circ$.

Hence (A) is correct option.

8.4.45 In this circuitry if SCR gets open circuited, than circuit behaves like a half wave rectifier.



So

$$\begin{aligned} I_{\text{avg}} &= \text{Average value of current} \\ &= \frac{1}{2\pi R}\int_{\theta_1}^{\pi-\theta_1}(V_m \sin \omega t - E)\, d\theta \end{aligned}$$

$$\because \quad \begin{aligned} I_{0(\text{avg})} &= \frac{1}{2\pi R}[2V_m \cos\theta - E(\pi - 2\theta_1)] \\ &= \frac{1}{2\pi \times 2}[2 \times (230 \times \sqrt{2})\cos\theta - 200(\pi - 2\theta_1)] \\ \theta_1 &= \sin^{-1}\left(\frac{E}{V_m}\right) \\ &= \sin^{-1}\left(\frac{200}{230 \times \sqrt{2}}\right) = 38^\circ = 0.66 \text{ Rad} \end{aligned}$$

$$\therefore \quad \begin{aligned} I_{0(\text{avg})} &= \frac{1}{2\pi \times 2}[2\sqrt{2} \times 230 \cos 38^\circ - 200(\pi - 2 \times 0.66)] \\ &= 11.9 \text{ A} \end{aligned}$$

Hence (C) is correct option.

8.4.46 We know that $V_{\text{rms}} = 230$ V

so, $V_m = 230 \times \sqrt{2}$ V

If whether $\alpha < 90^\circ$

Then $V_{\text{peak}} = V_m \sin\alpha = 230$

$$\begin{aligned} 230\sqrt{2}\sin\alpha &= 230 \\ \sin\alpha &= \frac{1}{\sqrt{2}} \\ \text{angle } \alpha &= 135^\circ \end{aligned}$$

Hence (B) is correct option.

8.4.47 Given that, $V = 200 \sin \omega t$

$f = 50$ Hz

Power dispatched in the load resistor $R = ?$

First we have to calculate output of rectifier.

$$(V_0)_{\text{rms}} = \left[\frac{1}{\pi}\int_0^{\pi}(200\sin\omega t)^2\,d\omega t\right]^{1/2} = \frac{200}{\sqrt{\pi}}\left[\int_0^{\pi}\left(\frac{1-\cos 2\omega t}{2}\right)d\omega t\right]^{1/2}$$

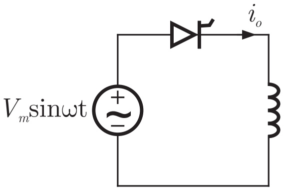
$$= \frac{200}{\sqrt{\pi}}\left[\frac{1}{2}\left(\omega t - \frac{\sin 2\omega t}{2}\right)_0^{\pi}\right]^{1/2} = \frac{200}{\sqrt{\pi}}\left[\frac{1}{2}\times\pi\right]^{1/2} = \frac{200}{\sqrt{2}}$$

Power dissipated to resistor

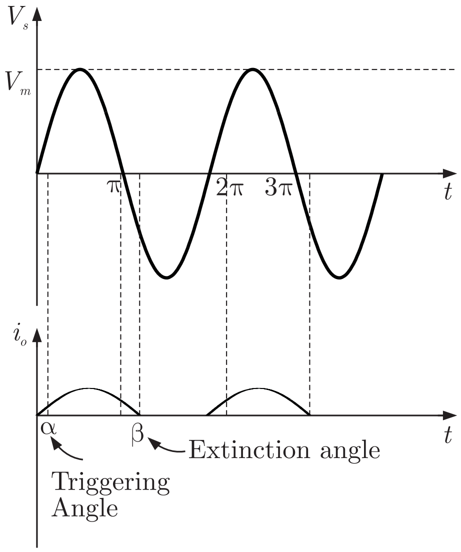
$$P_R = \frac{(V_0)^2_{\text{rms}}}{R} = \left(\frac{200/\sqrt{2}}{50}\right)^2 = 400\text{ W}$$

Hence (C) is correct option.

8.4.48 Given a half wave Thyristor converter supplies a purely inductive load where triggering angle is $\alpha = 120^\circ$



First we have to draw its output characteristics as shown below



Output is given by

$$i_0 = \frac{V_m}{Z}\sin(\omega t-\phi) - \frac{V_m}{Z}\sin(\alpha-\phi)\exp\left(\frac{-R}{\omega L}-\alpha\right) \quad \text{...(1)}$$

We know at extinction angle i.e. $\omega t = \beta$, $i_0 = 0$

from equation (1), at $(\omega t = \beta)$

$$0 = \frac{V_m}{Z}\sin(\beta-\phi) - \frac{V_m}{Z}\sin(\alpha-\phi)\,e^{\circ}$$

or $\sin(\beta-\phi) = \sin(\alpha-\phi)$

or $\beta-\phi = \alpha-\phi$

or $$\beta = \alpha = 120^\circ$$

Hence (D) is correct option.

8.4.49 Peak value of secondary voltage

$$V_m = \frac{800}{2} = 400\text{ V}$$

and $$\alpha = 30^\circ$$

Average dc voltage is given by

$$V_{dc} = \frac{V_m}{2\pi}(1+\cos\alpha) = \frac{400}{2\pi}(1+\cos 30^\circ) = 118.8\text{ V}$$

RMS voltage

$$V_{rms} = V_m\left(\frac{\pi-\alpha}{4\pi}+\frac{\sin 2\alpha}{8\pi}\right)^{1/2}$$

$$= 400\left(\frac{\pi-30^\circ}{4\pi}+\frac{\sin 60^\circ}{8\pi}\right)^{1/2} = 197.1\text{ V}$$

Hence (C) is correct option.

8.4.50 SCR will conduct when the instantaneous value of ac voltage is more than 50 V or

$$100\sin\omega t = 50$$

or $$\omega t = \frac{\pi}{6}\text{ and }\frac{5\pi}{6}$$

$$i = \frac{100\sin\omega t - 50}{10} = 10\sin\omega t - 5$$

$$\text{Average current} = \frac{1}{2\pi}\int_{\pi/6}^{5\pi/6}(10\sin\omega t - 5)\,d(\omega t)$$

$$= \frac{1}{2\pi}\left|-10\cos\omega t - 5\omega t\right|_{\pi/6}^{5\pi/6}$$

$$= \frac{1}{2\pi}\left(-10\cos\frac{5\pi}{6}+10\cos\frac{\pi}{6}-5\times\frac{5\pi}{6}+5\times\frac{\pi}{6}\right)$$

$$= 1.09\text{ A}$$

Hence (C) is correct option.

8.4.51 In positive half cycle Th_1 and D_2 conduct from α to π. During negative half cycle D_3 and D_4 are forward biased and conduct from π to 2π. From $\omega t = 0$ to $\omega t = \alpha$, Th_1 is off but D_2 is forward biased. D_4 continues to conduct during this interval because it was conducting prior to $\omega t = 0$ i.e. during previous negative half cycle. Therefore from 0 to α, D_2 and D_4 conduct, the load is short circuited and load voltage is zero.

The input output voltage waveforms are shown as below

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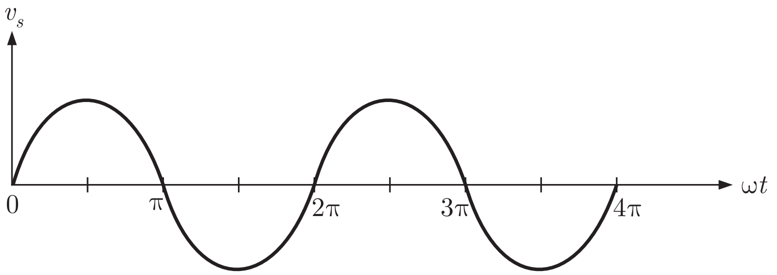

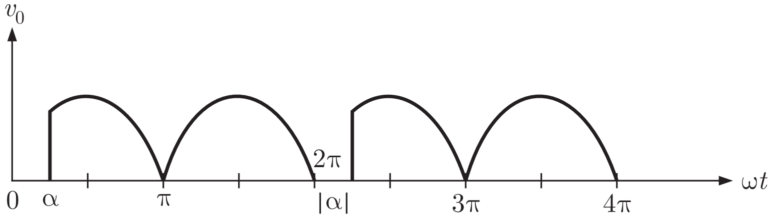

Output voltage

$$V_0 = \frac{1}{2\pi}\left[\int_{\alpha}^{\pi} V_m \sin\omega t d(\omega t) + \int_{\alpha}^{2\pi} V_m \sin\omega t d(\omega t\right]$$

$$= \frac{V_m}{2\pi}(3 + \cos\alpha)$$

Hence (C) is correct option.

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