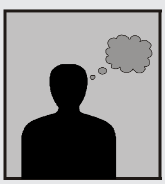
2017

MADE EASY WORKBOOK



Detailed Explanations of Try Yourself Questions

Electrical Engineering
Power Electronics

MADE EASY
Publications

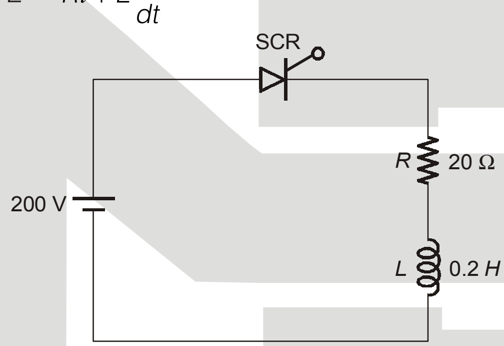
1 Power Semiconductor Devices

Detailed Explanation of Try Yourself Questions

T1 : Solution

The voltage equation for *RL* load is

$$E = Ri + L\frac{di}{dt}$$



$$i = \frac{E}{R}\left[1 - e^{-\frac{R}{L}t}\right]$$

$$0.1 = \frac{200}{20}\left[1 - e^{-100t}\right]$$

$$e^{-100t} = 0.99$$

$$t = 100.5\ \mu s$$

T2 : Solution

(c)

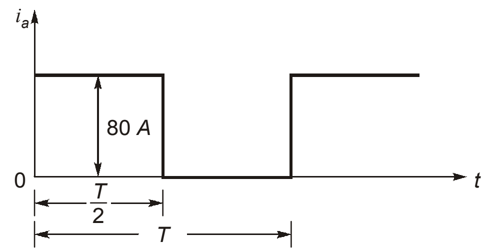
The equation of the straight line

$$y = mx + c$$

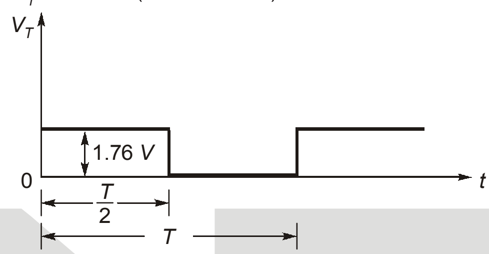
$m = 83.33$; $C = -66.64$

$\therefore$ $V_T = 0.8 + 0.12\, i_a$

the load condition is a constant current of 80 A for one half cycle.



Voltage drop across thyristor is $V_T = 0.8 + (0.012 \times 80) = 1.76$ V



Average on state powerloss in thyristor is

$$P_{av} = \frac{1}{T}\int_0^{T/2} V_T \cdot i_a dt = \frac{1}{T}\int_0^{T/2} 1.76 \times 80\ dt = \frac{1.76 \times 80 \times T}{2T}$$

$$= 70.4 \text{ W}$$

rms current rating of thyristor is,

$$I_{Th,rms} = \sqrt{\frac{(80)^2 \times T}{2T}} = 56.57 \text{ A}$$

T3 : Solution

(d)

$$\left(\frac{di}{dt}\right)_{max} = \left(\frac{V_{s_{max}}}{L}\right)$$

$$= \frac{\sqrt{2} \times 230}{15 \times 10^{-6}} = 21.685 \text{ A/}\mu\text{s}$$

$$\left(\frac{dv}{dt}\right)_{max} = R_s\left(\frac{di}{dt}\right)_{max} = 10 \times 21.685$$

$$= 216.85 \text{ V/}\mu\text{ sec}$$

T4 : Solution

(d)

KVL in the loop is,

$$-V + L\frac{di}{dt} = 0$$

$$V = L\frac{di}{dt}$$

$$dt = \frac{L}{V}di$$

Integrating on both sides,

$$\int dt = \int \frac{L}{V}di$$

$$t_{min} = \frac{0.1}{100} \times 4 \times 10^{-3}$$

$$t_{min} = 4\ \mu s$$

∴ The minimum width of the gating pulse required to properly turn on the SCR is 4 μs.

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2 Controlled and Uncontrolled Rectifiers

Detailed Explanation of Try Yourself Questions

T1 : Solution

(b)

Average current rating of SCR,

$$I_{TA} = \frac{I_0}{3} = \frac{36}{3} = 12 \text{ A}$$

Average power dissipated in each SCR

$$= I_{TA} \times V_T$$
$$= 12 \times 1.4 = 16.8 \text{ W}$$

T2 : Solution

(b)

Average output voltage

$$V_0 = \frac{2V_m}{\pi}\cos\alpha = \frac{2\sqrt{2}\times 230}{\pi}\cos 45° = 146.42 \text{ V}$$

$$I_0 = \frac{V_0}{R} = \frac{146.42}{10} = 14.642 \text{ A}$$

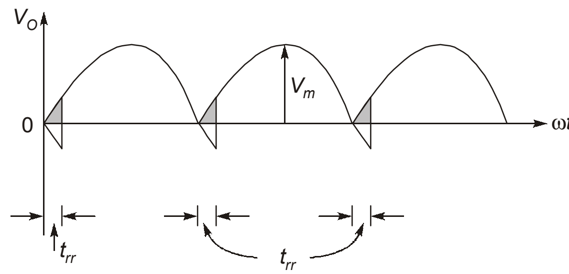
reactive power input to the converter is

$$Q_i = \frac{2V_m}{\pi} I_0 \sin\alpha$$

$$= \frac{2\sqrt{2}\times 230}{\pi}\times 14.642 \times \sin 45°$$

$$Q_i = 2143.92 \text{ VAr}$$

T3 : Solution



If reverse recovery time is taken into consideration, the diodes D_1 and D_2 will not be off at $\omega t = \pi$, but will continue to conduct until

$$t = \frac{\pi}{\omega} + t_{rr}$$

the reduction in output voltage is given by cross hatched area.
Average value of this reduction in output voltage is given by

$$V_r = \frac{1}{\pi}\int_0^{t_{rr}} V_m \sin\omega t \; d(\omega t)$$

$$V_r = \frac{V_m}{\pi}(1 - \cos\omega\, t_{rr})$$

with zero reverse recovery time, average output voltage

$$V_0 = \frac{2V_m}{\pi} = \frac{2\sqrt{2}\times 230}{\pi} = 207.07 \text{ V}$$

for $f = 2500$ Hz, the reduction in the average output voltage,

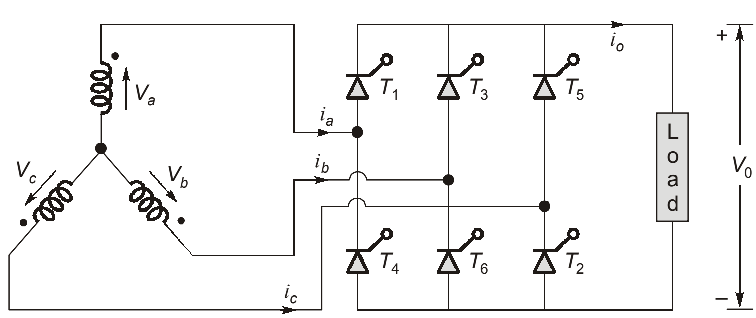
$$V_r = \frac{V_m}{\pi}(1 - \cos\omega t_{rr})$$

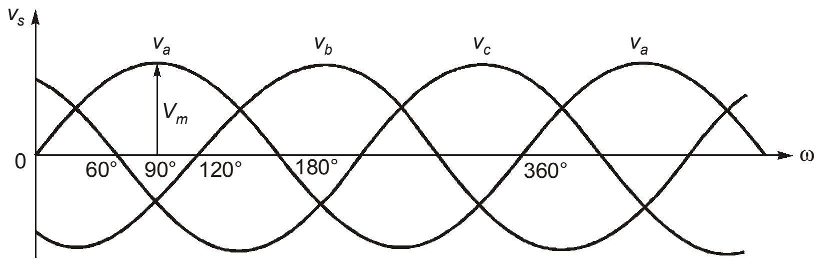
$$= \frac{\sqrt{2}\times 230}{\pi}\left(1 - \cos 2\pi \times 2500 \times 40 \times 10^{-6} \times \frac{180}{\pi}\right) = 19.77 \text{ V}$$

percentage reduction in average output voltage $= \frac{19.77}{207.07} \times 100 = 9.55\%$

T4 : Solution

(a)





$$V_A = V_m \sin\omega t$$

Phase A will get maximum voltage at $\omega t = 90°$. At this instant

$$V_0 = V_A - V_B$$
$$V_0 = V_m \sin\omega t - V_m \sin(\omega t - 120°)$$
$$= V_m - V_m \sin(-30°) \qquad [\because \ \omega t = 90°]$$
$$V_0 = 1.5\, V_m$$

T5 : Solution

(a)

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

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

$\therefore$
$$V_{ph(rms)} = \frac{V_{line}}{\sqrt{3}} = \frac{440}{\sqrt{3}} = 254.03 \text{ V}$$

$\therefore$
$$V_m = \sqrt{2}\, V_{ph(rms)}$$
$$= \sqrt{2} \times 254 = 359.21 \text{ V}$$

$\therefore$
$$V_{0(av)} = \frac{3\sqrt{3} \times 359.21}{2\pi}\cos 30° = 257.26 \text{ V}$$

Average output current,

$$I_{0(av)} = \frac{V_{0(av)}}{R} = \frac{257.26}{20} = 12.86 \text{ A}$$

T6 : Solution

The half-wave diode rectifier uses a step-up transformer therefore, ac voltage applied to rectifier

$$= 230 \times 460 \text{ V} = V_s$$

Average value of load voltage

$$V_0 = \frac{V_m}{\pi} = \frac{\sqrt{2} \times 460}{\pi} = 207.04 \text{ V}$$

Output dc power,
$$P_{dc} = \frac{V_o^2}{R} = \frac{207.04^2}{60} = 714.43 \text{ W}$$

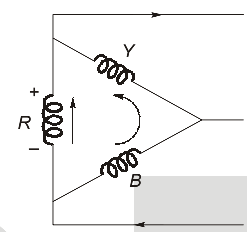
It is seen from the table that *TUF* for 1-phase half-wave diode rectifier is 0.2865.

$\therefore$ VA rating of transformer $= \frac{P_{dc}}{TUF} = \frac{714.43}{0.2865} = 2493.65$ VA

So choose a transformer with 2.5 kVA (next round figure) rating.

T7 : Solution

(b)

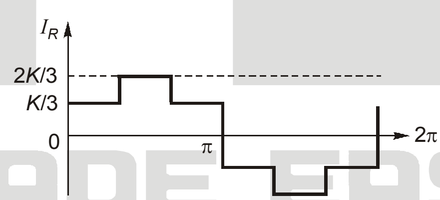


The currents are divided into *R* and *YB* winding.

Current through, $R = \frac{I_0 \times 2R}{3R} = \frac{2I_0}{3}$

Current through, $BY = \frac{I_0 R}{3R} = \frac{I_0}{3}$

Current through primary, $I_p = KI_s$



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3 Inverters

Detailed Explanation of Try Yourself Questions

T1 : Solution

[Ans. : (a)]

T2 : Solution

The rms value of load current,

$$I_{01} = \frac{230}{\sqrt{[2^2 + (8-6)^2]}} = 81.31 \text{ A}$$

phase angle,

$$\phi_1 = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = 45°$$

for $R = 2\ \Omega$, $X_L = 8\ \Omega$ and $X_C = 6\ \Omega$, the fundamental component of load current lags the output voltage by 45°,

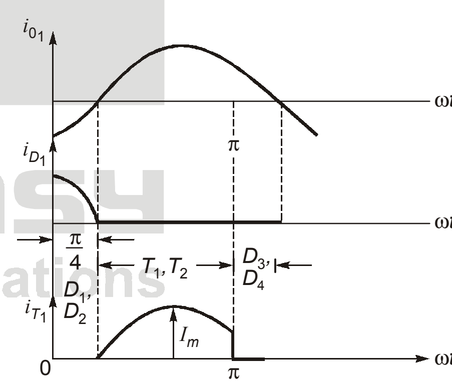
$$\therefore \quad I_{T_1} = \sqrt{\left[\frac{1}{2\pi}\int_0^{\frac{3\pi}{4}} (I_m \sin \omega t)^2 \cdot d(\omega t)\right]}$$

$$= \frac{I_m}{2\sqrt{\pi}}\left[\left|\omega t - \frac{\sin 2\omega t}{2}\right|_0^{\frac{3\pi}{4}}\right]^{\frac{1}{2}}$$

$$= 0.47675\, I_m$$

$$= 0.47675 \times \sqrt{2} \times 81.317$$

$$= 54.82 \text{ A}$$



T3 : Solution

(d)

$$V_{03} = \frac{4\,V_s}{3\pi}\sin 3(\omega t) = \frac{4\times 230}{3\times\pi}\sin 3(\omega t) = 97.6150\sin(942.47t)$$

$$Z_3 = R + j\left(3\omega L - \frac{1}{3\omega C}\right)$$

$$= 4 + j\left(3\times 2\pi\times 50\times 35\times 10^{-3} - \frac{1}{3\times 2\pi\times 50\times 155\times 10^{-6}}\right)$$

$$= 4 + j(32.986 - 6.8453)$$

$$= \sqrt{4^2 + (26.1407)^2}$$

$$Z_3 = 26.44\ \Omega$$

$$I_0 = \frac{97.6150}{\sqrt{2}}\times\frac{1}{26.44} = 2.61\text{ A}$$

T4 : Solution

(a) The load voltage waveform v_0 and its fundamental component v_{01}.
Rms value of load voltage,

$$V_{01} = \frac{4V_s}{\pi\sqrt{2}} = \frac{4\times 230}{\pi\sqrt{2}} = 207.1\text{ V}$$

Rms value of current, $$I_{01} = \frac{V_{01}}{Z_1}$$

$$= \frac{V_{01}}{\left[R^2 + \left(\omega L - \frac{1}{\omega L}\right)^2\right]^{1/2}} = \frac{207.1}{\left[1^2 + (-1)^2\right]^{1/2}} = \frac{207.1}{\sqrt{2}} = 146.46\text{ A}$$

$$\phi_1 = \tan^{-1}\frac{X_L - X_C}{R} = \tan^{-1}(-1) = -45°$$

The fundamental component of current i_{01} as a function of time is

$$i_{01} = \sqrt{2}\,I_{01}\sin(\omega t - \phi_1)$$

$$= \sqrt{2}\,\frac{207.1}{\sqrt{2}}\sin(\omega t - 45°) = 207.1\sin(\omega t + 45°)$$

Load current i_{01} and source current i_s and the conducting components are also indicated.

(b) Power delivered to load $= I_{01}^2 R = \left(\frac{207.1}{\sqrt{2}}\right)^2 \times 1 = 21.445$ kW

This must be equal to the power P_s delivered by the source

$\therefore$ $$P_s = V_s I_s \text{ watts}$$

where I_s = average value of the fundamental component of source current

$$= \frac{1}{\pi}\int_0^{\pi} \sqrt{2}\, I_{01} \sin(\omega t + 45°)\, d(\omega t)$$

$$= \frac{207.1}{\pi}\Big[-\cos(\omega t + 45°)\Big]_0^{\pi} = \frac{207.1}{\pi}[2\cos 45°] = 93.23 \text{ A}$$

∴ $$P_s = 230 \times 93.23 = 21.443 \text{ kW}$$

(c) Figure reveals that v_{T1} is negative for some time before $T3$, $T4$ are triggered. Thus circuit turn-off time can be obtained from

or $$\omega t_c = \frac{\pi}{4}$$

$$t_c = \frac{1}{4}\cdot\frac{T}{2} = 0.125 \text{ ms} = 125\ \mu\text{s}$$

As voltage drop in diodes D1, D2 reverse biases T1, T2 for 125 μs, which is more than the thyristor turn-off time of 100 μs, no forced commutation is required.

T5 : Solution

(a) Here $V_s = 220$ V, $f = 50$ Hz; $R = 6\ \Omega$, $L = 30$ mH and $C = 180\ \mu$F

$$X_L = 2\pi \times 50 \times 30 \times 10^{-3} = 9.425\ \Omega \text{ and } X_C = \frac{10^6}{2\pi \times 50 \times 180} = 17.684\ \Omega$$

$$Z_n = \left[6^2 + \left(9.425n - \frac{17.684}{n}\right)^2\right]^{1/2} \text{ and } \phi_n = \tan^{-1}\left[\frac{9.425n - \frac{17.684}{n}}{6}\right]$$

(a) Rms value of output voltage, $V_{or} = V_s = 220$ V

Rms value of fundamental component of output voltage,

$$V_{01} = \frac{4 + 220}{\sqrt{2} \times \pi} = 198.07 \text{ V}$$

Rms value of all harmonic voltages, $V_{oh} = \sqrt{V_{or}^2 - V_{01}^2} = \sqrt{220^2 - 198.07^2} = 95.751$ V

$$\text{THD} = \frac{V_{oh}}{V_{01}} = \frac{95.751}{198.07} = 0.4834 \text{ or } 48.34\%$$

Distortion factor, $$\mu = \frac{V_{01}}{V_{or}} = \frac{198.07}{220} = 0.9$$

(b) Fundamental component of load current,

$$I_{01} = \frac{V_{01}}{Z_1}$$

$\therefore$ $$I_{01} = \frac{198.07}{[6^2 + (9.425 - 17.684)^2]^{1/2}} = 19.403 \text{ A}$$

and $$\phi_1 = \tan^{-1}\left[\frac{9.425 - 17.684}{6}\right] = -54°$$

$$I_{03} = \frac{V_{03}}{Z_3} = \frac{4 \times 220}{3\pi \times \sqrt{2}} \times \frac{1}{\left[6^2 + \left(9.425 \times 3 - \frac{17.684}{3}\right)^2\right]^{1/2}} = 2.849 \text{ A}$$

and $$\phi_3 = \tan^{-1}\left[\frac{9.425 \times 3 - \frac{17.684}{3}}{6}\right] = 75°$$

$$I_{05} = \frac{V_{05}}{Z_5} = \frac{4 \times 220}{5\pi \times \sqrt{2}} \times \frac{1}{\left[6^2 + \left(9.425 \times 5 - \frac{17.684}{5}\right)^2\right]^{1/2}} = 0.9 \text{ A}$$

and $$\phi_5 = \tan^{-1}\left[\frac{9.425 \times 5 - \frac{17.684}{5}}{6}\right] = 82.16°$$

Similarly, $I_{07} = 0.444$ A and $\phi_7 = 84.6°$

Therefore, load current expression in Fourier series is

$$i_0(t) = \sqrt{2}[19.403 \sin(\omega t + 54°)] + 2.849 \sin(3\omega t - 75°)$$
$$+ 0.9 \sin(\omega t - 82.16° + 0.444 \sin(7\omega t - 84.6°) + \ldots]$$
$$= 27.44 \sin(\omega t + 54°) + 4.03 \sin(3\omega t - 75°)$$
$$+ 1.273 \sin(5\omega t - 82.16°) + 0.628 \sin(7\omega t - 84.6°) + \ldots.$$

$\therefore$ Fundamental rms load current, $I_{01} = 19.403$ A

(c) Peak load current, $I_m = [27.44^2 + 4.03^2 + 1.273^2 + 0.628^2]^{1/2}$
$= 27.77$ A

Rms value of harmonic load current,

$$I_{oh} = \left[\frac{I_m^2 + I_{m_1}^2}{2}\right]^{1/2} = \left[\frac{27.77^2 - 27.44^2}{2}\right]^{1/2} = 3.0182 \text{ A}$$

$$\text{THD} = \frac{I_{oh}}{I_{01}} = \frac{3.0182}{19.403} = 0.1555 \text{ or } 15.55\%$$

Rms load current, $$I_{or} = \frac{I_m}{\sqrt{2}} = \frac{27.77}{\sqrt{2}} = 19.64 \text{ A}$$

Distortion factor, $$\mu = \frac{I_{01}}{I_{or}} = \frac{19.403}{19.64} = 0.988$$

(d) Load power, $P_0 = I_{or}^2 \times R = 19.64^2 \times 6 = 2314.4$ W

Average value of source current $= \dfrac{P_o}{V_s} = \dfrac{2314.4}{220} = 10.52$ A

(e) Expression for fundamental component of load current, $i_{01} = 27.44 \sin(\omega t + 54°)$. It shows that current leads the voltage by 54°.

$\therefore$ Conduction time of each transistor $= (180 - 54) \times \dfrac{\pi}{180} \times \dfrac{1}{2\pi \times 50} = 7.0$ ms

Conduction time of each diode $= \dfrac{1}{2f} - 7.0 \times 10^{-3} = \dfrac{1}{100} - 7 \times 10^{-3} = 3$ ms

(f) Peak transistor current, $I_p = I_{01m} = 27.44$ A

Since each transistor conducts for 126° for every 360° or output cycle, rms value of transistor current,

$$I_{T1} = \frac{I_{01m}}{2\sqrt{\pi}}\left[126 \times \frac{\pi}{180} - \frac{\sin 252°}{2}\right] = 0.46135\, I_{01m}$$

$$= 0.46135 \times 27.44 = 12.66 \text{ A}$$

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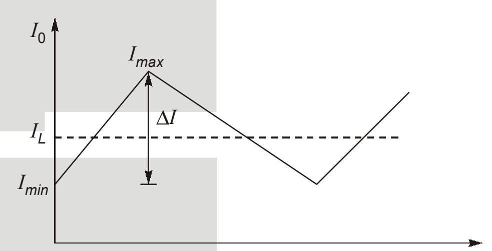
4 Choppers

Detailed Explanation of Try Yourself Questions

T1 : Solution

(a)

Given chopper is a buck chopper so, $V_0 = \alpha V_s$



$$\Delta I = \frac{V_0 T_{OFF}}{L}$$

$$\Delta I = 2I_L = 2I_0$$

This is applicable only at boundary of continuous and discontinuous condition

$$L_C = \frac{\alpha V_s(1-\alpha)}{2I_0 f}$$

T2 : Solution

Average load current, $I_0 = \frac{I_1 + I_2}{2} = \frac{12+16}{2} = 14$ A

Average load voltage, $V_0 = I_0 R = 14 \times 10 = 140$ V

$V_0 = \alpha V_s$

$\therefore$ Duty cycle, $\alpha = \frac{T_{ON}}{T_{ON} + T_{OFF}} = \frac{V_0}{V_s} = \frac{140}{200} = 0.7$

$$0.3\, T_{ON} = 0.7\, T_{OFF}$$

$$\frac{T_{ON}}{T_{OFF}} = \frac{0.7}{0.3} = 2.33$$

T3 : Solution

Circuit turnoff time,

$$t_c = \frac{CV_s}{I_0} = \frac{8 \times 10^{-6} \times 250}{20} = 1 \times 10^{-4}\ s$$

Maximum value of duty cycle,

$$\alpha_{max} = (1 - 2ft_c)$$
$$= (1 - 2 \times 250 \times 1 \times 10^{-4})$$
$$\alpha_{max} = 0.95$$

maximum load or output voltage,

$$V_{0,\,max} = V_s[\alpha_{max} + 2ft_c]$$
$$= 250\left[0.95 + (2 \times 250 \times 1 \times 10^{-4})\right]$$
$$V_{0,\,max} = 250\ \text{V}$$

T4 : Solution

(a)

The circuit shown in the figure is a step down chopper therefore, average output voltage, $V_0 = \alpha V_s$

$\Rightarrow$ $$V_0 = 0.8 \times 100 = 80\ \text{V}$$

$$I_0 = \frac{V_0}{R} = \frac{80}{8} = 10\ \text{A} \quad \text{(output current is ripple free)}$$

At $t = 0$, capacitor is charged upto V_s with right plate positive. Now, T_A is turned on immediately after T_A is on, capacitor voltage V_s applies a reverse voltage across T_m and T_m is turned off.

So $$|V_{T_m}| = |V_c| \text{ Capacitor voltage}$$

Maximum allowable reapplied dV/dT on T_m is 50 V/μs

$$\frac{dV_c}{dt} = \frac{dV_{T_m}}{dt} = 50\ \text{V/μs} \quad \text{(i)}$$

$$C\frac{dV_c}{dt} = I_0$$

From equation (i),

$$C \times \left(50\frac{V}{\mu s}\right) = 10 \Rightarrow C = 0.2\ \mu s$$

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5 Resonant Converters and Power Electronics Applications (Drives & SMPS)

Detailed Explanation of Try Yourself Questions

T1 : Solution

(c)

The fundamental rms value of output voltage is

$$V_{0,\,rms} = V_{ph}\left(\frac{m}{\pi}\right)\sin\left(\frac{\pi}{m}\right) = 200\left(\frac{3}{\pi}\right)\sin\left(\frac{\pi}{3}\right) = 165.4\text{ V}$$

option 'c' is, $\frac{300\sqrt{3}}{\pi}\text{ V} = 165.4\text{ V}$

T2 : Solution

(b)

Peak value of output voltage for a 6 pulse converter is

$$V_{d0} = \sqrt{2}V_l\left(\frac{m}{\pi}\right)\sin\left(\frac{\pi}{m}\right) = \sqrt{2}\times 400\times\left(\frac{6}{\pi}\right)\sin\left(\frac{\pi}{6}\right)$$

Reduction in voltage due to source inductance, for a 6 pulse converter is $\frac{3\omega L_s}{\pi} I_0$

∴ Peak value of output voltage,

$$V_{0,\,max} = \left(\sqrt{2}\times 400\times\frac{6}{\pi}\sin 30°\right) - \left(\frac{3\times 2\pi\times 50\times 1.2\times 10^{-3}}{\pi}\times 40\right)$$

$$V_{0,\,max} = 525.789\text{ V}$$

∴ Rms value of voltage $= \frac{525.789}{\sqrt{2}} = 371.788\text{ V}$

T3 : Solution

(b)

$$\text{Input p.f.} = \sqrt{k} = \sqrt{\frac{n}{n+m}} = \sqrt{\frac{8}{8+6}} = 0.75 \text{ lagging}$$

$$I_m = \frac{230\sqrt{2}}{15} = 21.68 \text{ A}$$

Average value of thyristor current,

$$I_{TA} = \frac{kI_m}{\pi} = \frac{0.57 \times 21.68}{\pi} = 3.93 \text{ A}$$

T4 : Solution

(a)

Minimum braking speed is

$$\omega_{min} = \frac{I_a r_a}{K_m} = \frac{300 \times 0.2}{1.2} = 50 \text{ rad/s or } 477.46 \text{ rpm}$$

Maximum braking speed is

$$\omega_{max} = \frac{V_s + I_a r_a}{K_m} = \frac{400 + 300 \times 0.2}{1.2} = 383.33 \text{ rad/s or } 3660.56 \text{ rpm}$$

T5 : Solution

At $t = 0$, steady state exists and therefore, generated torque = load torque

$$T_e = T_L$$

In general, the dynamic equation for the motor load combination is

generated torque = inertia torque + friction torque + load torque

$$T_e = J\frac{d\omega_m}{dt} + D\omega_m + T_L$$

As friction torque is zero,

$$D\omega_m = 0$$

The differential equation, governing the speed of the drive at $t > 0$,

$$T_e = J\frac{d\omega_m}{dt} + T_L$$

$$100 = 0.01\frac{d\omega_m}{dt} + 40 \quad \text{...(i)}$$

$$\frac{d\omega_m}{dt} = 6000$$

$$dt = \frac{d\omega_m}{6000}$$

Its integration gives,

$$t = \frac{\omega_m}{6000} + A \quad \text{...(ii)}$$

Initial speed at $t = 0^+$ remains 500 rpm. Therefore,

$$\omega_{m0} = \frac{2\pi \times 500}{60} = \frac{100\pi}{6} \text{ rad/sec}$$

Substituting this value in equation (*ii*),

$$0 = \frac{1}{6000} \times \frac{100\pi}{6} + A \quad \text{or} \quad A = \frac{-\pi}{360}$$

$$t = \frac{\omega_m}{6000} - \frac{\pi}{360}$$

Final speed, $$\omega_m = \frac{2\pi \times 1000}{60} = \frac{200\pi}{6} \text{ rad/sec}$$

$$t = \frac{200\pi}{6000 \times 6} - \frac{\pi}{360} = \frac{\pi}{360} \text{ sec} = 0.0873 \text{ sec}$$

∴ Time taken for the speed to reach 1000 rpm = 0.0873 sec.

T6 : Solution

under rated operating conditions of the separately excited dc motor,

$$V_t = E_a + I_a r_a = k_m \omega_m + I_a r_a$$

$$220 = k_m \frac{2\pi \times 1500}{60} + 10 \times 1 = 50\pi\, k_m + 10$$

∴ motor constant, $$k_m = \frac{220 - 10}{50\,\pi} = 1.337 \text{ V-s/rad}$$

for a torque of 5 Nm, motor armature current,

$$I_a = \frac{5}{1.337} = 3.74 \text{ A}$$

The equation giving the operation of converter motor is

$$V_0 = V_t = E_a + I_a r_a$$

$$\frac{2V_m}{\pi} \cos\alpha = k_m \omega_m + I_a r_a$$

$$\frac{2\sqrt{2} \times 230}{\pi} \cos 30° = 1.337\, \omega_m + 3.74 \times 1$$

$$\omega_m = 131.33 \text{ rad/sec}$$

$$\frac{2\pi N}{60} = 131.33 \text{ rad/sec}$$

$$N = 1254 \text{ rpm}$$

T6 : Solution

[Ans. : (a)]

T6 : Solution

[Ans. : (c)]