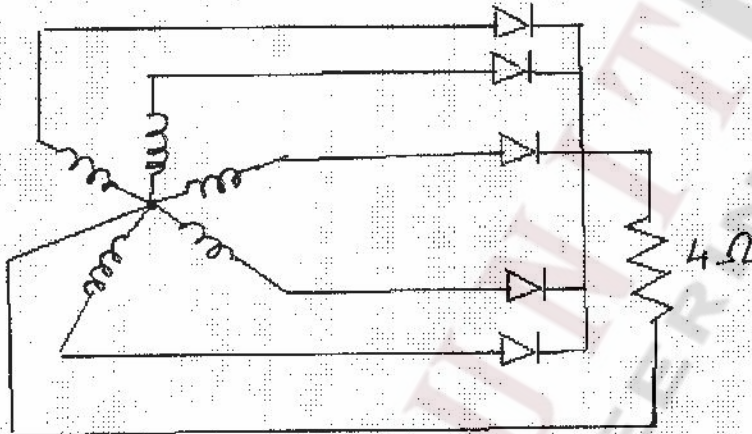


2. For the circuit shown below the power consumed in the load = 100W.
8marks



Find:

- (i) The output rms voltage

$$P = I_{rms}^2 R \quad 100 = I_{rms}^2 \times 4 \quad I_{rms} = 5A$$

$$V_{rms} = 5 \times 4 = 20V$$

- (ii) The maximum supply voltage

$$V_{rms} = \left[\frac{2}{2\pi} \int_0^{\frac{\pi}{5}} V_m^2 \cos^2 \omega t \, d\omega t \right]^{\frac{1}{2}} = V_m \left[\frac{5}{\pi} \left(\frac{\pi}{5} + \frac{1}{2} \sin \frac{2\pi}{5} \right) \right]^{\frac{1}{2}} = 0.937 V_m$$

$$\therefore V_m = 21.34$$

- (iii) The output dc voltage

$$V_{dc} = \frac{2}{2\pi} \int_0^{\frac{\pi}{5}} V_m \cos \omega t \, d\omega t = V_m \cdot \frac{5}{\pi} \sin \frac{\pi}{5} = 0.9354 V_m = 19.963V$$

- (iv) The rms of the current in each diode

$$I_{DRMS} = \frac{I_{rms}}{\sqrt{5}} = \frac{5}{\sqrt{5}} = 2.236A$$

- (v) The dc current in each diode

$$I_{Ddc} = \frac{I_{dc}}{5} = \frac{19.963}{5 \times 4} = 0.99815A$$

- (vi) The transformer utilization factor (TUF)

$$TUF = \frac{P_{dc}}{5V_s I_s} = \frac{19.963^2}{4}{5 \times 21.34 \times \sqrt{2} \times 2.236} = 0.59$$

- (vii) The power factor

$$PF = \frac{P_{ac}}{5V_s I_s} = \frac{20^2}{4}{5 \times 21.34 \times \sqrt{2} \times 2.236} = 0.59$$

- (viii) The peak inverse voltage for each diode

$$PIV = \sqrt{5} V_m = \sqrt{5} \times 21.34 = 47.7V$$

3. A single phase half wave controlled rectifier with an inductive load. $V_s = 230V$, $f = 50Hz$, $R = 10\Omega$ and $L = 0.1H$ 8marks

(i) Starting from the differential equation, derive the expression for the current as function of the delay angle α .

$$L \frac{di}{dt} + Ri = V_m \sin \omega t$$

$$i(\omega t) = \frac{V_m}{Z} \sin(\omega t - \theta) + A e^{-\frac{t}{L/R}}$$

$$\text{At } \omega t = \alpha \quad i = 0 \quad A = -\frac{V_m}{Z} \sin(\alpha - \theta) e^{\frac{\alpha}{\omega L/R}}$$

$$i(\omega t) = \frac{V_m}{Z} \left[\sin(\omega t - \theta) - \sin(\alpha - \theta) e^{\frac{\alpha - \omega t}{\omega L/R}} \right]$$

(ii) Derive the relationship to find α as function of the conduction angle γ .

$$\text{at } \omega t = \beta \quad i = 0 \quad \beta = \gamma + \alpha \quad \frac{\omega L}{R} = \tan \theta = \pi$$

$$\sin(\alpha + \gamma - \theta) = \sin(\alpha - \theta) e^{\frac{\alpha - \alpha - \gamma}{\omega L/R}}$$

$$\sin(\alpha - \theta) \cos \gamma + \sin \gamma \cos(\alpha - \theta) = \sin(\alpha - \theta) e^{-\frac{\gamma}{\tan \theta}}$$

$$\sin(\alpha - \theta) \left[\cos \gamma - e^{-\frac{\gamma}{\tan \theta}} \right] = -\sin \gamma \cos(\alpha - \theta)$$

$$\tan(\alpha - \theta) = \frac{\sin(\alpha - \theta)}{\cos(\alpha - \theta)} = \frac{\sin \gamma}{e^{-\frac{\gamma}{\tan \theta}} - \cos \gamma}$$

(iii) Find the value of the delay angle α for a conduction angle γ of $120^\circ = \frac{2\pi}{3}$

$$\theta = \tan^{-1} \frac{2 \times 50 \times 0.1}{10} = 72.34^\circ$$

$$\tan(\alpha - 72.34^\circ) = \frac{\sin 120}{e^{-\frac{2\pi}{3}} - \cos 120} \quad \alpha = 112.86^\circ$$

(iv) Find the extinction angle β

$$\beta = \alpha + \gamma = 112.86 + 120 = 232.86^\circ$$

(v) Give the equation of the current for the above delay angle in a simplified form

$$i = \frac{230\sqrt{2}}{32.97} \left[\sin(314t - 72.34^\circ) - \sin(112.86 - 72.34) e^{\frac{1.95 - 314t}{\pi}} \right]$$

$$= 9.86 \sin(314t - 72.34^\circ) - 12 e^{-100t}$$

(vi) Calculate the dc output voltage

$\alpha = 1.95 \text{ rad} \quad \beta = 4.05 \text{ rad}$

$$V_{dc} = \frac{V_m}{2\pi} \int_{1.95}^{4.05} \sin \omega t \, d\omega t = \frac{V_m}{2\pi} [\cos 1.95 - \cos 4.05]$$

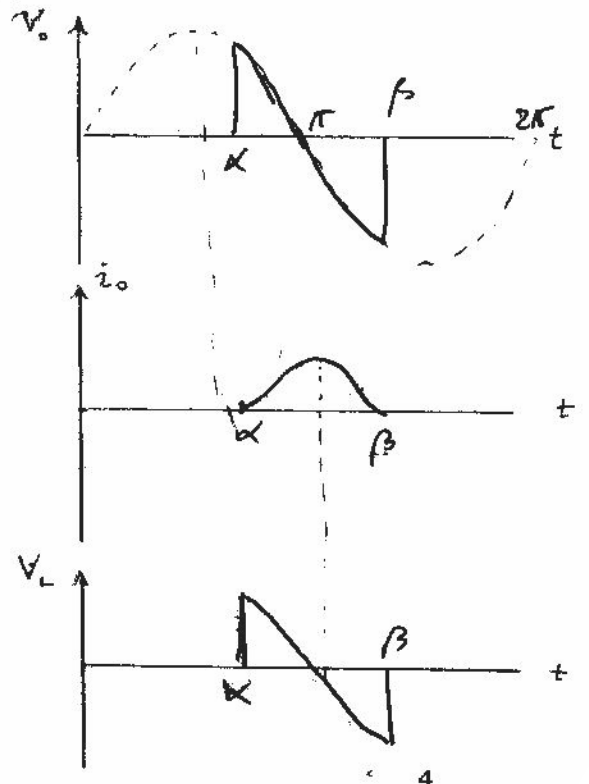
$$= 11.14 \text{ V}$$

(vii) Give the equation of the voltage across the inductance in a simplified form

$$V_L = L \frac{di}{dt} = 0.1 \left[9.86 \times 314 \cos(314t - 72.34) + 12 \times 100 e^{-100t} \right]$$

$$= 309.7 \cos(314t - 72.34) + 120 e^{-100t}$$

(viii) Sketch the waveforms of the output voltage, current and voltage across the inductance



4. For a full wave bridge controlled rectifier with RL load, $R = 10 \Omega$, $L = 0.0318H$, $V_s = 230V$ and $f = 50Hz$. It is required to get a dc output voltage of 200V

8marks

- (i) Find the necessary firing angle α

$$\tan \theta = \frac{\omega L}{R} = \frac{2\pi \times 50 \times 0.0318}{10} \quad \therefore \theta = 45^\circ$$

For continuous Voltage output $V_{dc} = \frac{1}{\pi} \int_{\alpha}^{\alpha+\pi} V_m \sin \omega t = \frac{2V_m \cos \alpha}{\pi}$

$$200 = \frac{2 \times 230\sqrt{2}}{\pi} \cos \alpha \quad \alpha = 14.985^\circ \quad \therefore \alpha < \theta \text{ continuous}$$

- (ii) Find the rms value of the output current

For $\alpha \approx 15^\circ$ From graph

$$V_2 = 0.45 V_m = 0.45 \times 230\sqrt{2} = 146.4$$

$$V_4 = 0.12 V_m = 0.12 \times 230\sqrt{2} = 39$$

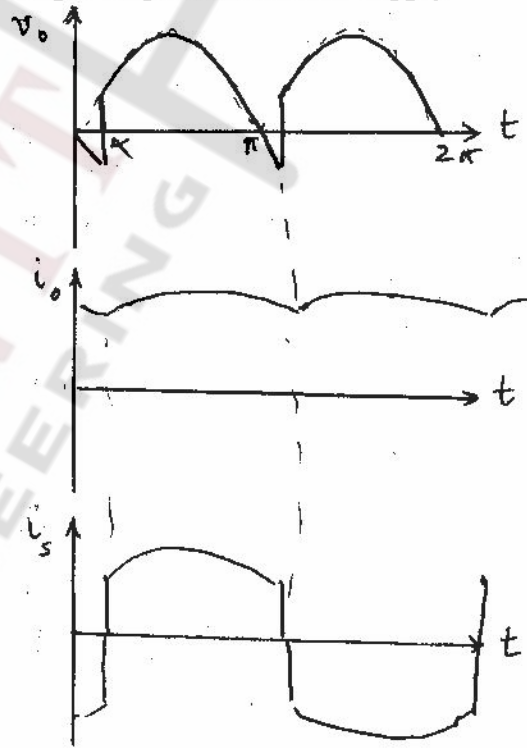
$$V_0 = 200$$

n	V_n	Z_n	I_n	I_{rms}
0	200	20	20	20
2	146.4	22.3	6.56	$\frac{6.56}{\sqrt{2}}$
4	39	41.23	0.945	$\frac{0.945}{\sqrt{2}}$

$$I_{rms} = \sqrt{20^2 + \left(\frac{6.56}{\sqrt{2}}\right)^2 + \left(\frac{0.945}{\sqrt{2}}\right)^2}$$

$$\approx 20.53A$$

- (iii) Sketch the waveforms for the output voltage, output current and supply current



- (iv) Find the output power

$$P_o = I_{rms}^2 R = 20.53^2 \times 10 = 4215 \text{ W}$$

- (v) Find dc current in each thyristor

$$I_{DC} = \frac{200}{10} = 20 \text{ A} \quad I_{DC TH} = \frac{I_{DC}}{2} = \frac{20}{2} = 10 \text{ A}$$

- (vi) Find the rms value of the current in each thyristor

$$I_{RMS TH} = \frac{I_{RMS}}{\sqrt{2}} = \frac{20.53}{\sqrt{2}} = 14.52$$

- (vii) Find the rms value of the supply current

$$I_s = I_{RMS} = 20.53 \text{ A}$$

