Dept. of Elect. Engg. Mid Exam

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Programmable Calculators with storage memory are not allowed

Derive any formula you use.

4marks

1. Answer the following:

(i) What is the difference between latching current and holding current?

Latching current is current required to trigger the thyristor

holding current is the minimum current for the thyristor untill it switches off

$I_{latching} > I_{holding}$

(ii) Give 2 advantages of GTO over SCR

① No Electromagnetic harmonics

② higher voltage capabilities X

(iii) Give 2 disadvantages of GTO compared to SCR

① higher overshoot current X

② higher $\frac{di}{dt}$ X

1.5

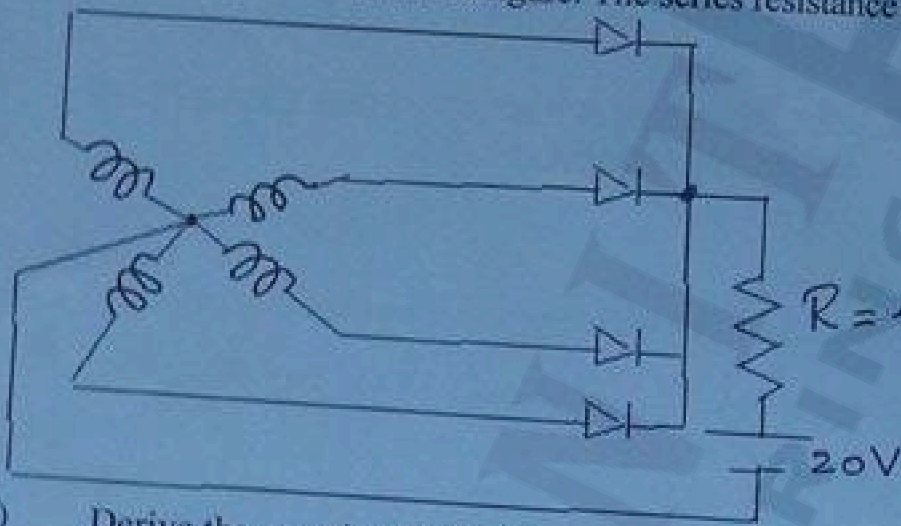
(iv) Give 2 advantages of GTO over power transistor

① higher $\frac{dv(t)}{dt}$

② needs more width of pulses to turn on. X

2. ABET Problem for evaluating Students Outcome E:

It is required to supply a 100W to the 20V battery using a 4-phase star connected transformer secondary winding as shown in the figure. The series resistance is 1Ω. **10marks**



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(i) Derive the equation for the **dc** and the **rms** output voltage.

q = 4

$$V_{dc} = \frac{2}{\frac{2\pi}{4}} \int_0^{\pi/4} V_m \cos(\omega t)\, d\omega t = 2\frac{4}{\pi} \int_0^{\pi/4} V_m \cos(\omega t)\, d\omega t$$

$$= \frac{4V_m}{\pi} \sin(\omega t) \Big|_0^{\pi/4} = 2\frac{4V_m}{\pi}\frac{\sqrt{2}}{2} = \frac{2\sqrt{2}V_m}{\pi} = V_{dc}$$

$$V_{rms} = \sqrt{\frac{1}{\frac{\pi}{4}} \int_0^{\pi/4} V_m^2 \cos^2(\omega t)\, d\omega t} = V_m \sqrt{\frac{4}{\pi} \int_0^{\pi/4} \cos^2(\omega t)\, d\omega t}$$

$$V_{rms} = V_m \sqrt{\frac{4}{\pi} \int_0^{\pi/4} \left[\frac{1}{2} + \frac{1}{2}\cos(2\omega t)\right] d\omega t} = V_m \sqrt{\frac{4}{\pi}\left(\frac{\pi}{24} + \frac{1}{4}\sin(\pi/2)\right)}$$

Find:

$$V_{rms} = V_m \sqrt{\frac{4}{\pi}\left(\frac{\pi}{8} + \frac{1}{4}\right)}$$

(ii) The maximum supply voltage

$$V_{dc} = 20 + \left(\frac{100}{20} \times 1\right) \rightarrow I_o R \Rightarrow V_{dc} = 25\text{V}$$

($20 \rightarrow V_{battery}$)

$$\therefore \frac{2\sqrt{2}V_m}{\pi} = V_{dc} \Rightarrow \frac{2\sqrt{2}V_m}{\pi} = 25 \Rightarrow V_m = 27.768\text{V}$$

(iii) The rms value of the output voltage

$$\therefore V_{rms} = V_m \sqrt{\frac{4}{\pi}\left(\frac{\pi}{8} + \frac{1}{4}\right)} \Rightarrow V_{rms} = 25.119\text{V}$$

(iv) The ac component of the output voltage

$V_o(\omega t) = 27.768 \sin(\omega t)$ ✗

(v) The ac component and the rms of the current in the resistor

$I_{rms} = \frac{25.119}{1} = 25.119 A = \frac{V_{rms}}{R}$

$i(\omega t) = \frac{27.68}{1} \sin(\omega t)$ ✗

(vi) The dc value of each diode current

$I_{dc} = \frac{100}{20} = 5 \Rightarrow I_{dc\,diode} = \frac{5}{q} = \frac{5}{4} = 1.25 A$ ✓

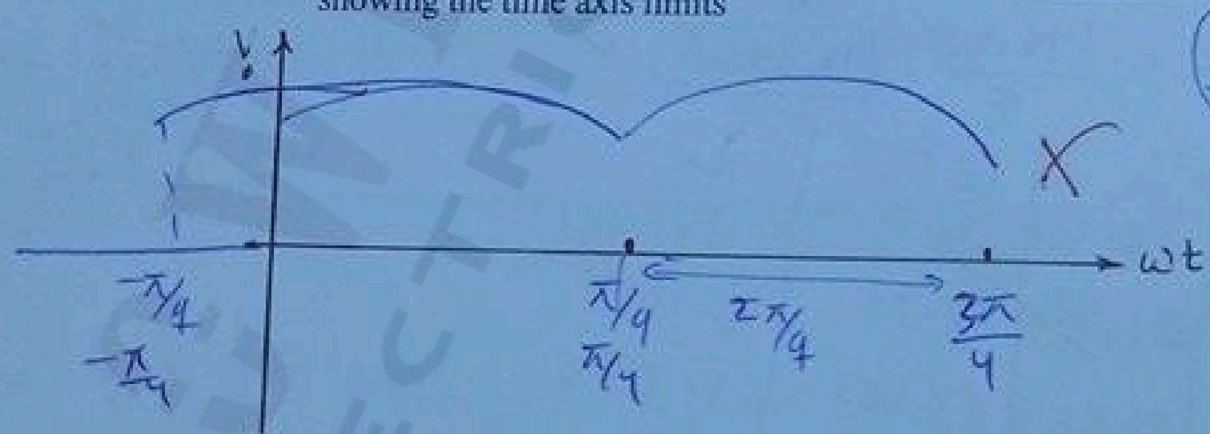
(vii) The transformer utilization factor

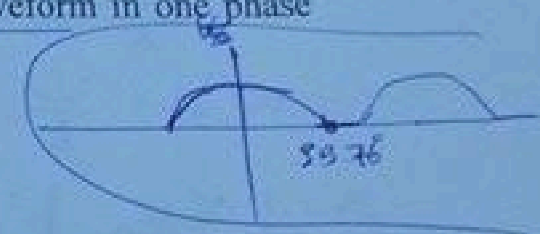
$TUF = \frac{P_{dc}}{4 V_s I_s} = \frac{(5)(25)}{(4)(25.119)\left(\frac{25.119}{\sqrt{4}}\right)} = 9.91\%$ ✗ !!

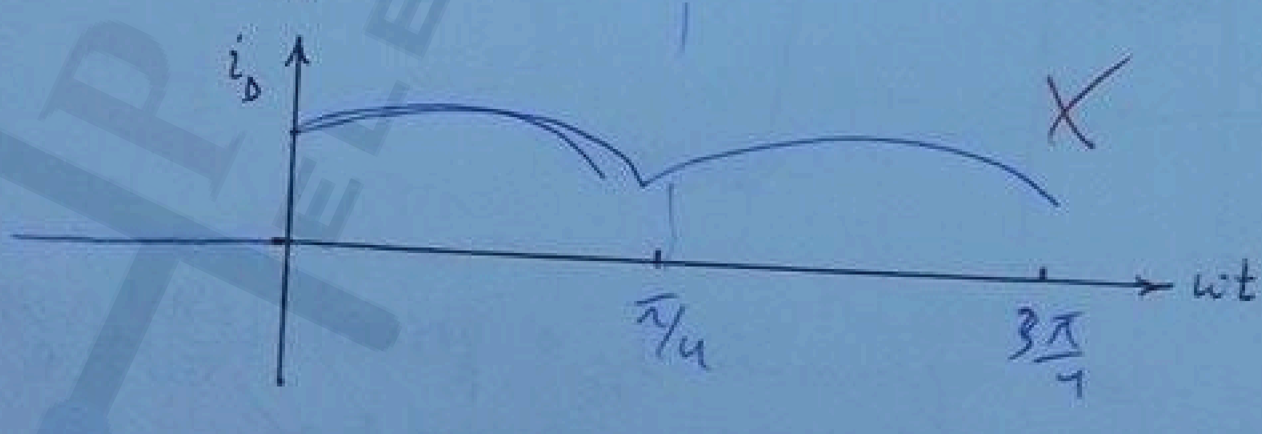
(viii) The peak inverse voltage for each diode

$PIV = \sqrt{q}\, V_m = \sqrt{4} \times 27.768$ ✓

(ix) Sketch the output voltage waveform and the current waveform in one phase showing the time axis limits

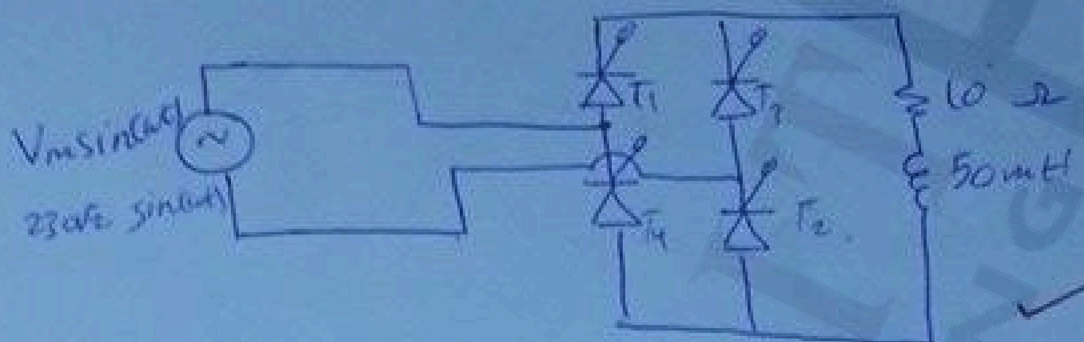






...50mH.. The firing angle is adjusted at 45°.
α

(i) Draw the circuit diagram **10marks**



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(ii) Is the output current continuous or discontinuous? Why?

$\theta = \tan^{-1}\left(\frac{\omega L}{R}\right) = \tan^{-1}\left(\frac{2\pi \times 50 \times 50 \times 10^{-3}}{10}\right) = 57.52°$

$\alpha = 45°$

$\alpha < \theta \Rightarrow$ continous

Continous because α is smaller than θ

(iii) Find the rms value of the output current.

$V_o = \frac{2V_m}{\pi}\cos(\alpha) \Rightarrow V_o = \frac{2(230)(\sqrt{2})}{\pi}\cos(45°) = 146.423V$

$\Rightarrow I_o = \frac{V_o}{R} = \frac{146.425}{10} = \boxed{14.6423A}$

finding ...

n	V_n/V_m	V_n	$\lvert Z \rvert$	I_n
0	✓	146.423	10	14.6423
2	0.65	211.425	32.97	6.413
4	0.25	81.32	63.623	1.278
6				neglegable

$Z_2 = \sqrt{10^2 + (2(2\pi)50 \times 50 \times 10^{-3})^2}$

$\therefore I_{rms} = \sqrt{(14.6423)^2 + \left(\frac{6.413}{\sqrt{2}}\right)^2}$

$= 15.355 A$

(iv) Find the rms value of the current in each thyristor $\frac{15.355}{\sqrt{2}}$

$$I_{rms\,thyristor} = \frac{I_{rms}}{\sqrt{2}} = 10.857\ A$$

(v) Find the rms value of the supply current

$$I_{rms\,supply} = I_{rms\,load} = 15.355\ A$$

(vi) Find the average current in each thyristor

$$I_{dc\,thyristor} = \frac{I_{dc}}{2} = \frac{14.6432}{2} = 7.3216\ A$$

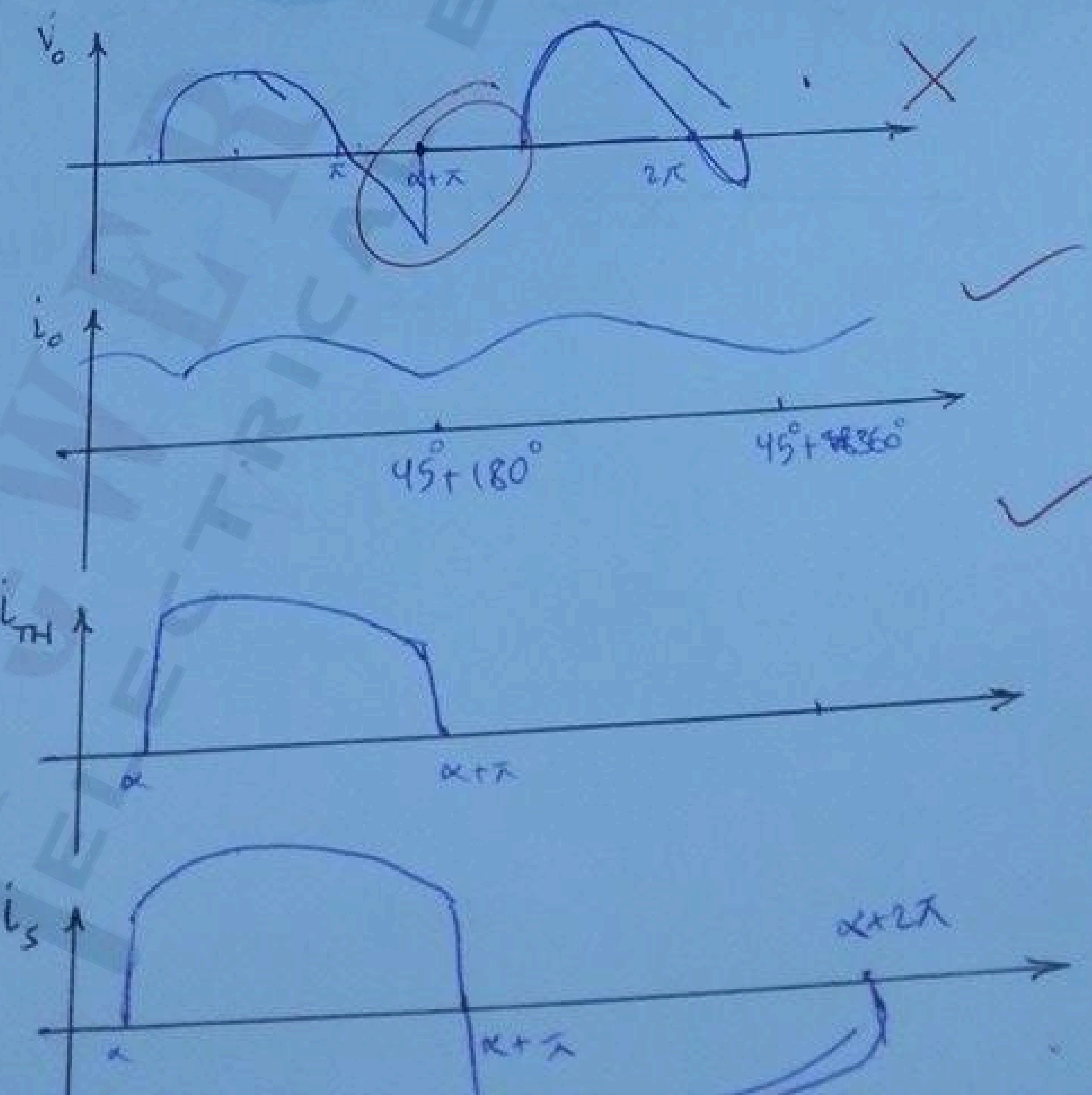
(vii) Find the efficiency of the converter

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{(14.6432)^2(10)}{(15.355)^2(\sqrt{2})(230)} = 42.93\%$$

(viii) Find the power factor

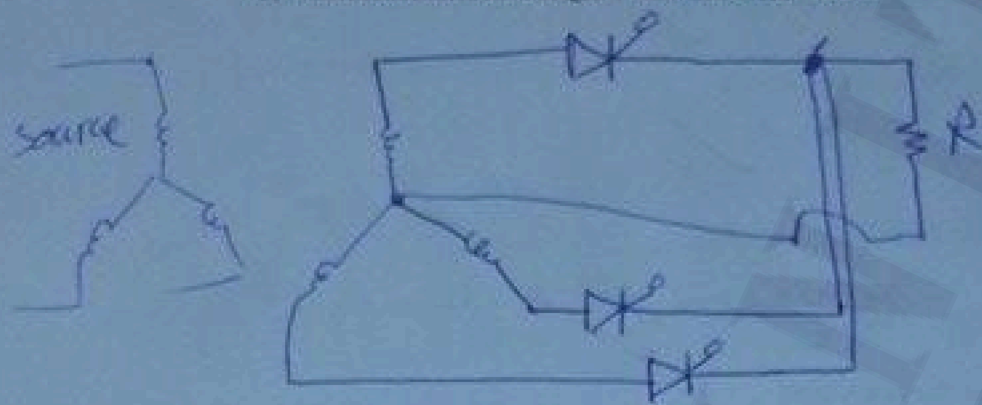
$$P.f = \frac{P_{ac}}{V_s I_s} = \frac{(15.355)^2(10)}{(\sqrt{2})(230)(15.355)} = 0.472$$

(ix) Sketch the waveforms of the output voltage, the output current, the current in one of the thyristors and the supply current.



4. A line to line voltage of 400V , 3-phase, half wave converter supplying an average voltage of 200V dc to a pure resistive load. of 10Ω **6marks**

(i) Sketch the circuit diagram for this converter.



(ii) Find the firing angle of each thyristor.(Hint: check whether the current is continuous or discontinuous)

assume $\alpha < 30°$

$$V_o = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m \sin(\omega t) = \frac{3\sqrt{3}V_m}{2\pi}\cos(\alpha)$$

$$200 = \frac{3\sqrt{3}\left(\frac{400}{\sqrt{3}}\sqrt{2}\right)}{2\pi}\cos(\alpha)$$

$\cos(\alpha) = 0.7404 \Rightarrow \alpha = 42.227 > 30$

wrong

& α is continuous

$$V_o = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{\pi} V_m \sin(\omega t)\,d\omega t = \frac{3V_m}{2\pi}\left[1+\cos(\pi/6+\alpha)\right]$$

$\pi/6 = 3$

$$200 = \frac{3\left(\frac{400}{\sqrt{3}}\sqrt{2}\right)}{2\pi}\left[1+\cos(\pi/6+\alpha)\right]$$

$1.283 = 1 + \cos(\pi/6+\alpha)$

$\alpha = 73.59°$

$$\alpha = \frac{73.59 \times \pi}{180°} = 1.284 \text{ radians}$$

4.5

$\alpha = 1.284\ r$

(iii) Find the rms value of the output voltage

$$V_{rms} = \sqrt{\frac{3}{2\pi}\int_{\pi/6+\alpha}^{\pi} V_m^2 \sin^2(\omega t)\,d\omega t} = \sqrt{3}\,V_m\left[\frac{5}{24} - \frac{\alpha}{4\pi} + \frac{1}{8\pi}\sin\left(\frac{\pi}{3}+2\alpha\right)\right]^{1/2}$$

$$= 167.765\ V$$ ✗

(v) Find the rms value of the current in each thyristor

$$I_{rms\ thyristor} = \frac{I_{rms}}{\sqrt{3}} = \frac{V_{rms}}{R\sqrt{3}} = \frac{167.765}{R\sqrt{3}}$$

$$= \frac{167.765}{10\sqrt{3}} = 9.686\ A$$

(vi) Sketch the waveform of the output voltage and current in one thyristor.