1 [25 Marks]

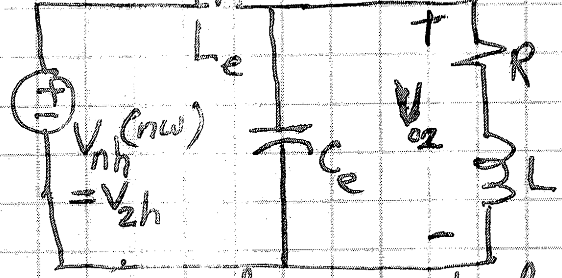
(الأكرستا = لعشري '١')

$R = 40\,\Omega$

$L = 10\text{ mH}$, $f = 60\text{ Hz}$

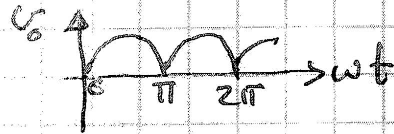
$RF = 0.1$

$L_e = ?$, $C_e = ?$



Equivalent circuit of harmonics

Solution



→ * To avoid passing of nth harmonic ripple through load,

step 1 $\dfrac{1}{n\omega C_e} << \sqrt{R^2 + (n\omega L)^2}$

5 step 2 take $10 * \dfrac{1}{n\omega C_e} = \sqrt{R^2 + (n\omega L)^2} \Rightarrow \boxed{C_e = 326\,\mu F}$

→ * For the 1-ϕ, full-wave uncontrolled rectifier, the dominant harmonic is the second. So the subscript 2 in the following steps denotes the second harmonic.

5 step 1 $V_{odc} = \dfrac{1}{\pi}\displaystyle\int_0^{\pi} V_m \sin\omega t \, d\omega t = \dfrac{2V_m}{\pi}$

5 step 2 From Fourier analysis of the waveform, the second harmonic voltage is

$v_{2h}(\omega t) = \dfrac{4V_m}{3\pi}\cos 2\omega t$

$V_{2h\,rms} = \dfrac{4V_m}{3\sqrt{2}\,\pi}$ ← the source of harmonics

5 step 3 $V_{o2\,rms} = V_{2h\,rms}\left|\dfrac{-1/n\omega C_e}{n\omega L_e - \dfrac{1}{n\omega C_e}}\right|$ ← (using voltage divider)

5 step 4 $RF = 0.1 = \dfrac{V_{ac}}{V_{dc}} = \dfrac{V_{o2\,rms}}{V_{odc}}$

$= \dfrac{V_{2h\,rms}}{V_{odc}} \cdot \dfrac{1}{(4\pi f)^2 L_e C_e - 1} = \dfrac{\sqrt{2}}{3}\cdot\dfrac{1}{(4\pi f)^2 L_e C_e - 1}$

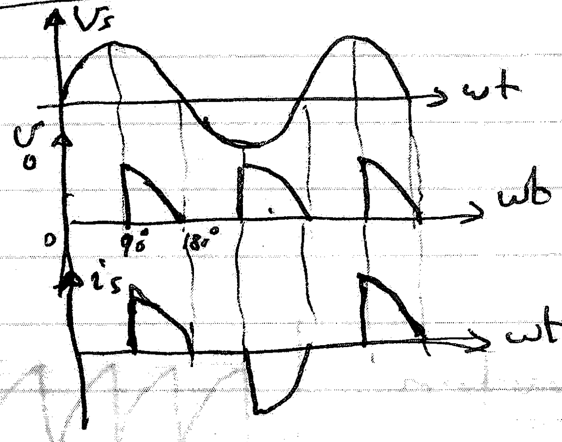
$\Rightarrow \boxed{L_e = 30.8\text{ mH}}$

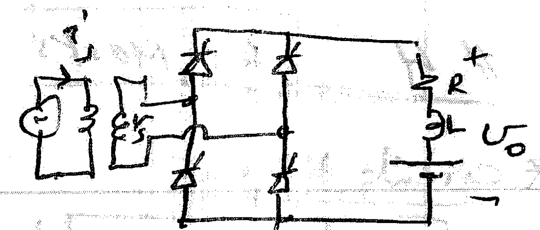
$4\pi f \leftarrow n\omega$, $n = 2$, $\omega = 2\pi f$, $f = 60\text{ Hz}$

2 [20 Marks]

a) $E = 0,\ L = 0,\ \alpha = 90^\circ$

6



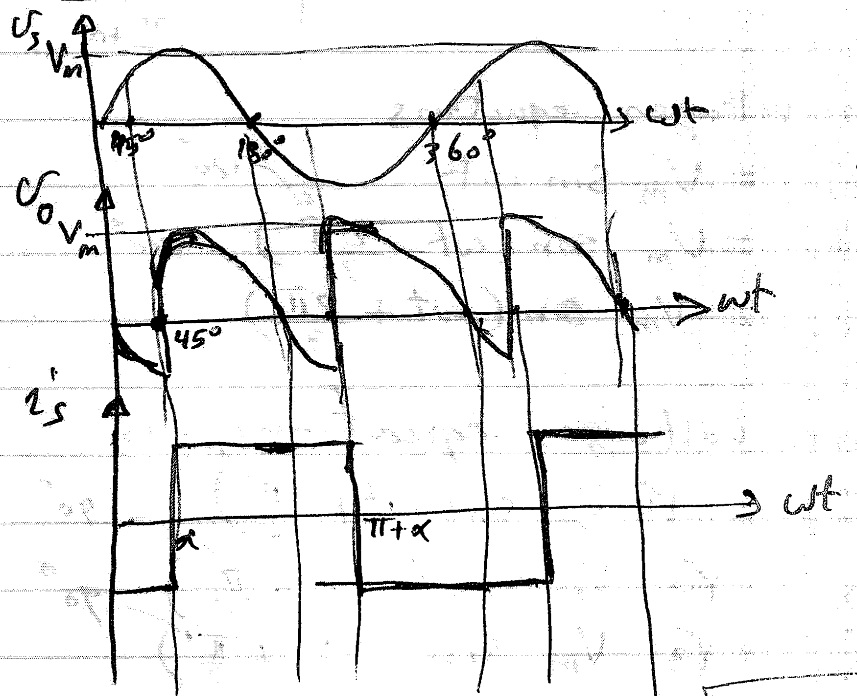


$$V_{dc} = \frac{1}{\pi}\int_\alpha^{\pi} V_m \sin\omega t \, d\omega t$$

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

b) $E = 0,\ L = \infty,\ \alpha = 45^\circ$

7



$$V_{dc} = \frac{1}{\pi}\int_\alpha^{\pi+\alpha} V_m \sin\omega t \, d\omega t = \boxed{\frac{2V_m}{\pi}\cos\alpha} = \frac{\sqrt{2}V_m}{\pi}$$

45°

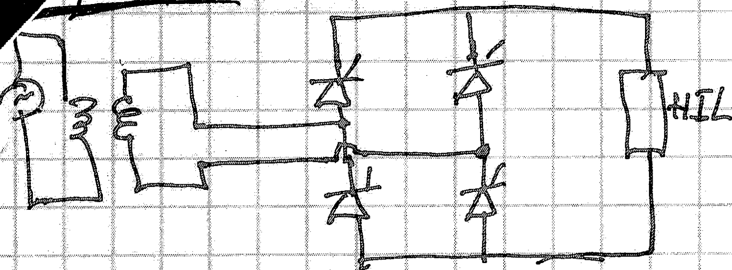
c) $E = 50$ Volt, $L = \infty$, $\alpha = 45^\circ$

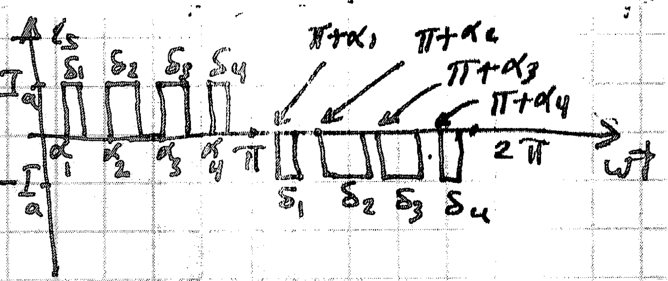
7

same solution as case b).

$$\frac{2V_m}{\pi} \times \frac{1}{\sqrt{2}} \times \frac{\sqrt{2}}{\sqrt{2}}$$

25 Marks





Circuit Diagram

5 **step①** Assume values of $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \delta_1, \delta_2, \delta_3, \delta_4$

(لاحظ ان مجموع ON و off لكل نصف دورة يساوي π)

5 **step②** Due to symmetry of source current waveform (i_s'), $I_{dc}=0$ and $a_n = 0$.

$$b_n = \frac{1}{\pi}\int_0^{2\pi} i_s'(t) \sin n\omega t \, d(\omega t)$$

$$= \frac{1}{\pi}\Big[\int_{\alpha_1}^{\alpha_1+\delta_1} I_a \sin n\omega t \, d(\omega t) + \int_{\alpha_2}^{\alpha_2+\delta_2} I_a \sin n\omega t \, d\omega t + \int_{\alpha_3}^{\alpha_3+\delta_3} I_a \sin n\omega t \, d\omega t$$

$$+ \int_{\alpha_4}^{\alpha_4+\delta_4} I_a \sin n\omega t \, d\omega t - \int_{\pi+\alpha_1}^{\pi+\alpha_1+\delta_1} I_a \sin n\omega t \, d\omega t - \int_{\pi+\alpha_2}^{\pi+\alpha_2+\delta_2} I_a \sin n\omega t \, d\omega t$$

$$- \int_{\pi+\alpha_3}^{\pi+\alpha_3+\delta_3} I_a \sin n\omega t \, d\omega t - \int_{\pi+\alpha_4}^{\pi+\alpha_4+\delta_4} I_a \sin n\omega t \, d\omega t\Big]$$

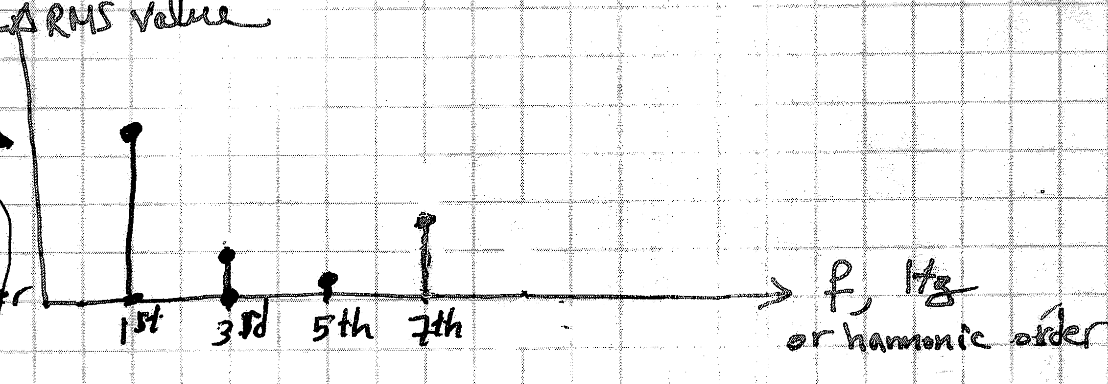
بعد التعويض بقيم step① وكذلك اجراء التكامل

5 **step③** $$i_s'(t) = \sum_{n=1,3,5,7,9} b_n \sin n\omega t$$

5 **step④** Calculate I_{s_1} (at $n=1$), I_{s_3}, I_{s_5}, I_{s_7}, I_{s_9}

5 **step⑤** Draw spectrum diagram

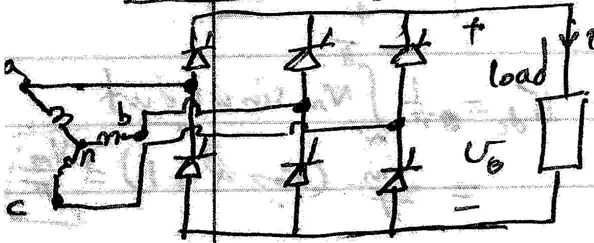
- 1st should be the highst
- 5th close to zero in case of 4 pulses per π,
- then rms increases as the harmonic order increasing.



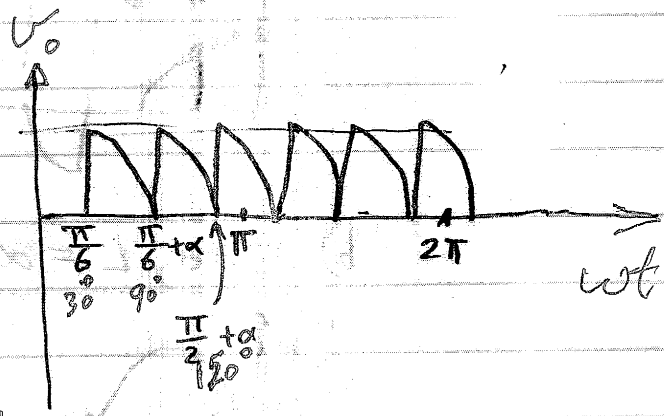
(4 Marks for each)

4 $\boxed{20 \text{ Marks}}$

* circuit diagram 4



* output voltage waveform 4



* phase voltages equations 4

$$v_{an} = V_m \sin \omega t$$

$$v_{bn} = V_m \sin\left(\omega t - \frac{2\pi}{3}\right) \quad 120^\circ$$

$$v_{cn} = V_m \sin\left(\omega t + \frac{2\pi}{3}\right) \quad 120^\circ$$

* line voltages equations 30° 4

$$v_{ab} = \sqrt{3}\, V_m \sin\left(\omega t + \frac{\pi}{6}\right) \quad 90^\circ$$

$$v_{bc} = \sqrt{3}\, V_m \sin\left(\omega t - \frac{\pi}{2}\right) \quad \cancel{90^\circ}$$

$$v_{ca} = \sqrt{3}\, V_m \sin\left(\omega t \cancel{+\frac{\pi}{2}}\right) \quad -210^\circ$$

* Average output voltage 4

$$V_{dc} = \frac{3}{\pi} \int_{\pi/6+\alpha}^{\pi/2+\alpha} v_{ab}\, d(\omega t) = \frac{3}{\pi} \int_{\pi/6+\alpha}^{\pi/2+\alpha} \sqrt{3}\, V_m \sin\left(\omega t + \frac{\pi}{6}\right) d(\omega t)$$

$$= \frac{3\sqrt{3}\, V_m}{\pi} \cos\alpha$$