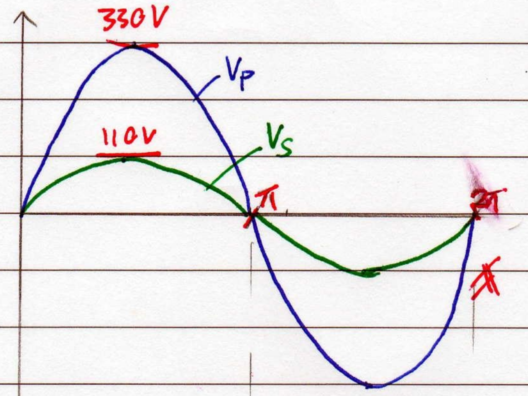
PYP EE4532 NOV/DEC 13 Megarine Tee

1)

$V_m = 110V$, $E = 12V$, $I_{o\,avg} = 4A$

a i)

V



$V_m \sin\alpha - E = 0$

$\Rightarrow \sin\alpha = \frac{E}{V}$

$\Rightarrow \alpha = \sin^{-1}\left(\frac{E}{V}\right) = 6.263^\circ = 0.10931\,rad$

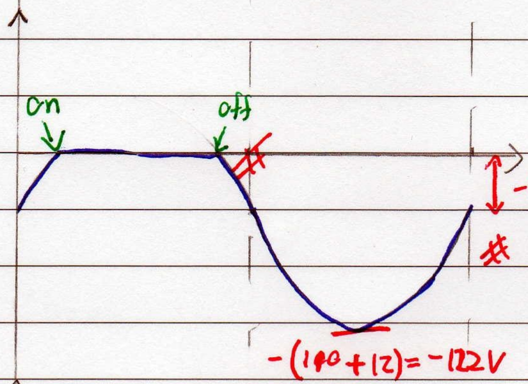
$V_{R\,avg} = \frac{1}{2\pi}\int_{\alpha}^{\pi-\alpha}\left(\frac{V_m \sin\omega t - E}{\cancel{R}}\right) d\omega t$

$= \frac{1}{2\pi \cancel{R}}\left[-V_m \cos\omega t - E\omega t\right]_{\alpha}^{\pi-\alpha}$

$= 29.22V$

ii)

V_{Diode}



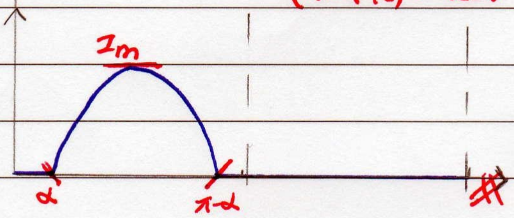
$I_{R\,avg} = I_{o\,avg} = V_{R\,avg}/R$

$\Rightarrow R = 7.306\,\Omega$

$I_m = (V_m - E)/R$

$= 13.41A$

I_{Diode}



iii) $PIV = \cancel{110}\ \cancel{100}\ 110 + 12 = 122V$ #

b i) Assume $f = 50Hz$, $T = 0.02s$,

$\therefore t_{on} = T \times (\pi - 2\alpha)/(2\pi) = 9.304\,ms$ #

$t_{off} = T - t_{on} = 10.695\,ms$ #

ii) $P_{bat.} = I_{o\,avg} \times E = 48W$ #

iii) Charging time = Capacity / P_{bat} = 1.667 hr. #

iv) $R = 7.306\,\Omega$ #, to provide average current. #

v) $$I_{R\,rms} = \left[\frac{1}{2\pi R^2} \int_{\alpha}^{\pi-\alpha} (V_m \sin \omega t - E)^2 \, d\omega t \right]^{1/2}$$

$$= \left[\frac{1}{2\pi R^2} \int_{\alpha}^{\pi-\alpha} \left[V_m^2 \sin^2 \omega t + E^2 - 2E V_m \sin \omega t \right] d\omega t \right]^{1/2}$$

$$= \left[\frac{1}{2\pi R^2} \int_{\alpha}^{\pi-\alpha} \left[\frac{V_m^2}{2} - \frac{V_m^2}{2} \cos 2\omega t - 2E V_m \sin \omega t + E^2 \right] d\omega t \right]^{1/2}$$

$$= \left[\frac{1}{2\pi R^2} \left[\left[\left(\frac{V_m^2}{2} + E^2 \right) \omega t \right]_{\alpha}^{\pi-\alpha} + \left[2E V_m \cos \omega t \right]_{\alpha}^{\pi-\alpha} - \left[\frac{V_m^2}{4} \sin 2\omega t \right]_{\alpha}^{\pi-\alpha} \right] \right]^{1/2}$$

$$= \left[\frac{1}{2\pi R^2} \left[18105 - 5248 + 1312 \right] \right]^{1/2}$$

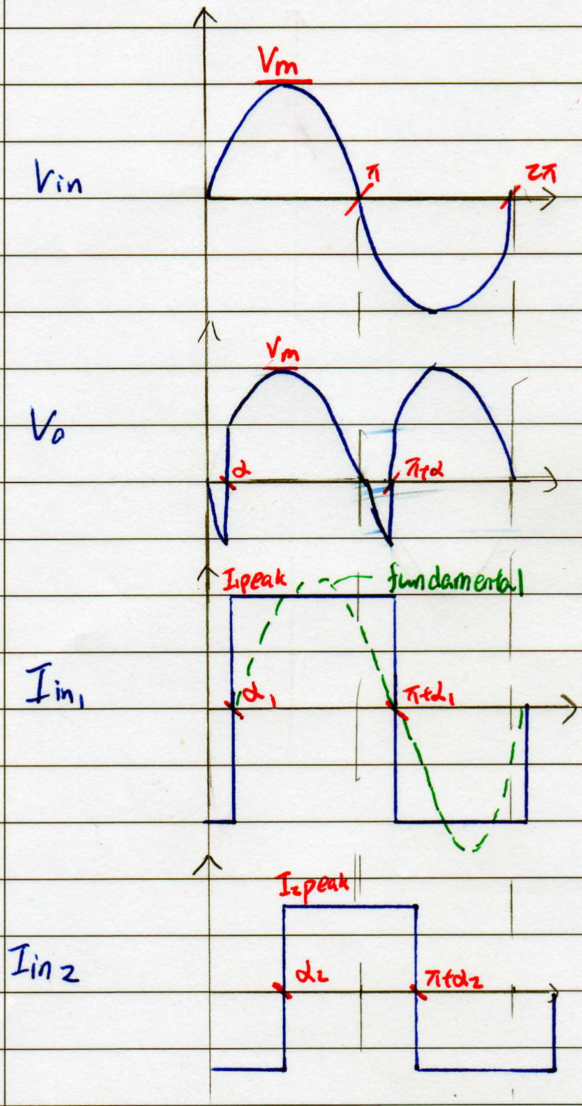
$$= 6.499\,A$$

$$\eta = \frac{P_{bat}}{P_{bat} + I_{R\,rms}^2 \times R} \times 100\% = \frac{48}{48 + 308.6} \times 100\%$$

$$= 16.\cancel{03}\% \; \# \quad 13.46\% \; \#$$

2) Highly inductive $V_{in\,rms} = 230V$, $V_m = \sqrt{2} \times 230V$

a)



$\alpha_1 = 30^\circ$, $\alpha_2 = 60^\circ$

$$V_{o\,avg} = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin\omega t \, d\omega t$$
$$= \frac{V_m}{\pi}\left[-\cos\omega t\right]_{\alpha}^{\pi-\alpha}$$
$$= \frac{2}{\pi} V_m \cos\alpha$$

$$I_{o\,avg} = V_{o\,avg}/R = \frac{2V_m}{\pi R}\cos\alpha$$

To find fundamental peak:

$$b_1 = \frac{I_{o\,avg} \times 2}{\pi}\int_0^{\pi} \sin\omega t \, d\omega t$$
$$= \frac{4}{\pi} I_{o\,avg} = \frac{8V_m}{\pi^2 R}\cos\alpha$$

$$I_{1\,rms} = \frac{8V_m}{\pi^2 R\sqrt{2}}\cos\alpha$$

$$I_{in\,rms} = \frac{2V_m}{\pi R}\cos\alpha$$

$$PF = \frac{I_{1\,rms}}{I_{in\,rms}}\cos\alpha = \frac{2\sqrt{2}}{\pi}\cos\alpha$$

Input current is affected by varying α. Higher α will result in lower current as shown in the above derivation.
The PF is not affected by the current ~~by~~ but is affected by α. As α increase, PF will decrease. #

b) $V_{o\,avg} = 120V$, $V_m = \sqrt{2} \times 230V$, $R = 8\Omega$

i) $I_{o\,avg} = V_{o\,avg}/R = 15A$

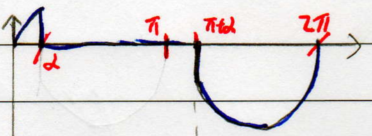
$\frac{2V_m}{\pi R} \cos\alpha = I_{o\,avg} = 15A \quad \Rightarrow \alpha = 54.58°$ #

ii) $V_{o\,avg} = 120V$ #

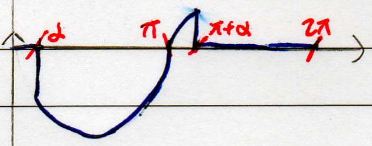
$I_{o\,avg} = 15A$ #

$I_{o\,rms} = 15A$ #

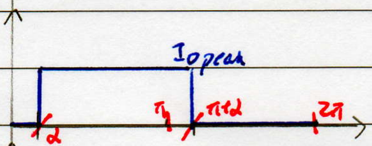
iii) V_{D1}, V_{D4}



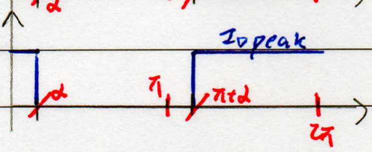
V_{D2}, V_{D3}



I_{D1}, I_{D4}



I_{D2}, I_{D3}



$PIV = V_m = 325.3V$

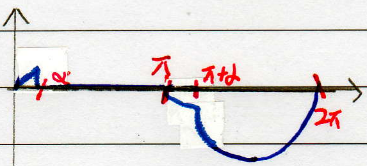
$I_{D\,peak} = 15A$

$I_{D\,avg} = 15/2 = 7.5A$

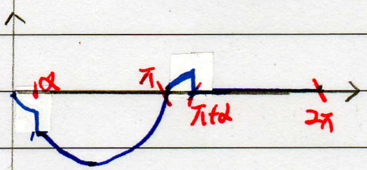
$I_{D\,rms} = 15 \times \sqrt{\frac{1}{2}} = 10.61A$

Under inductive load

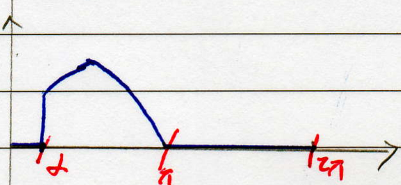
V_{D1}, V_{D4}



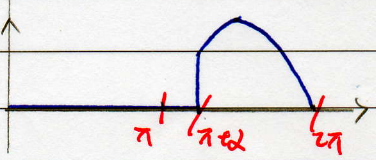
V_{D2}, V_{D3}



I_{D1}, I_{D4}



I_{D2}, I_{D3}



Under resistive load

iv) Under inductive:

$V_{in\ rms} = 230V$

$I_{in\ rms} = \frac{2V_m}{\pi R}\cos\alpha = 15A$

Transformer kVA $= V_{in\ rms} \times I_{in\ rms} = 3.450$ kVA #

Under resistive:

$$I_{in\ rms} = \left[\frac{1}{\pi}\int_\alpha^\pi \left(\frac{V_m \sin\omega t}{R}\right)^2 d\omega t\right]^{1/2} = \left[\frac{V_m^2}{\pi R^2}\int_\alpha^\pi \sin^2\omega t\, d\omega t\right]^{1/2}$$

$$= \left[\frac{V_m^2}{\pi R^2}\int_\alpha^\pi \left[\frac{1}{2} - \frac{1}{2}\cos 2\omega t\right] d\omega t\right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi R^2}\left[\omega t - \frac{1}{2}\sin 2\omega t\right]_\alpha^\pi\right]^{1/2} = 26.46A$$

Transformer kVA $= 26.46 \times 230 = 6.0858$ kVA #

v) $PF = \frac{2\sqrt{2}}{\pi}\cos\alpha = 0.52179$ # (inductive)

$$V_{o\,rms} = \left[\frac{1}{\pi}\int_\alpha^\pi V_m^2 \sin^2\omega t\, d\omega t\right]^{1/2} = \left[\frac{V_m^2}{2\pi}\int_\alpha^\pi [1-\cos 2\omega t]\, d\omega t\right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi}\left[\omega t - \frac{1}{2}\sin 2\omega t\right]_\alpha^\pi\right]^{1/2}$$

$$= 211.7V$$

$P_{o\,rms} = V_{o\,rms}^2 / R = 5.601$ kVA

$PF = P_{o\,rms}$ / Transformer KVA $= 5.601 / 6.0858$

$= 0.92$ (resistive)

$\therefore$ resistive load PF is higher than inductive load. #

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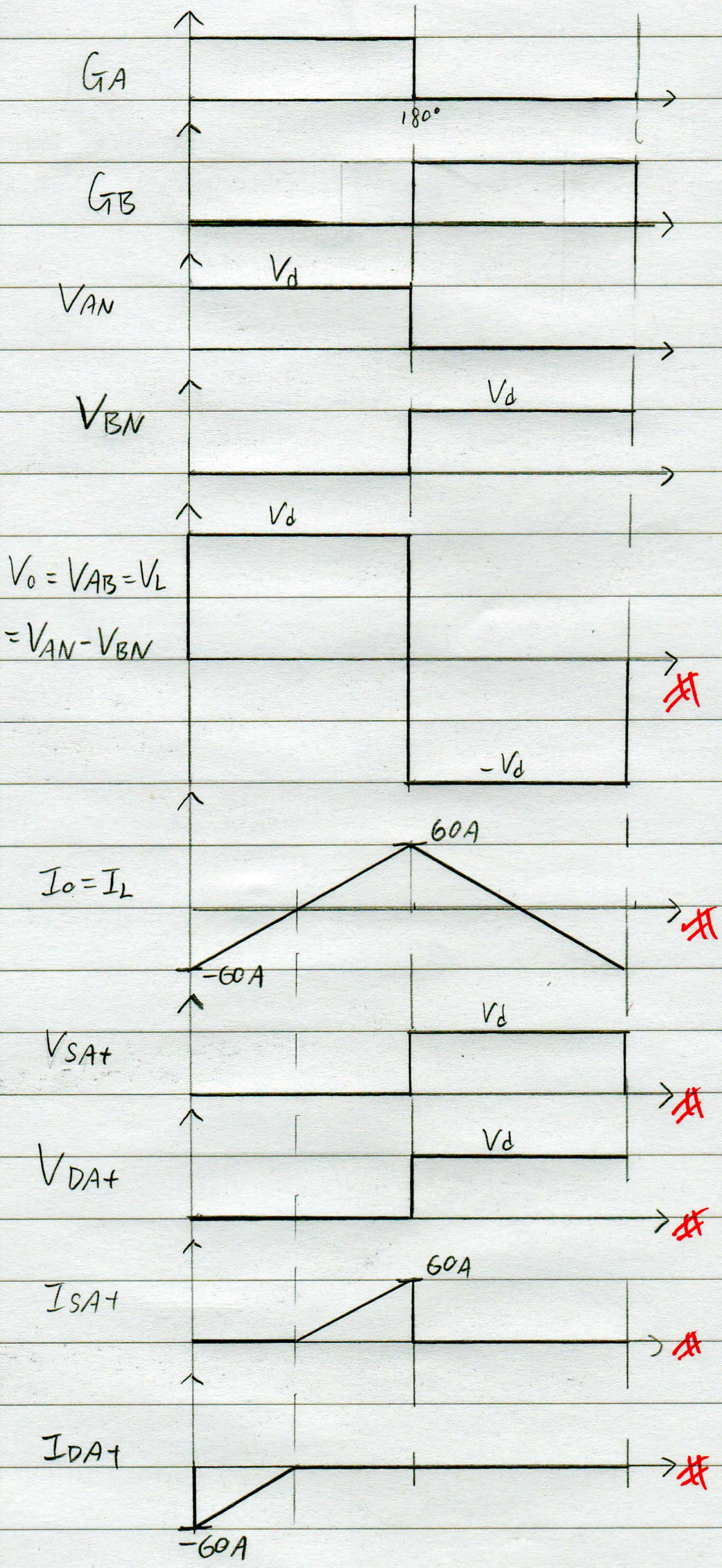
3)

$V_d = 120V$, $\beta = 180°$

$f_s = 50Hz$, $T_s = 0.02\ s$

$t_{on} = t_{off}$

a)



$I_{Lpeak} = \frac{1}{2}\Delta I_L$, $L = 10mH$

$\Delta I_L = \frac{V_d}{L} t_{on}$

$= \frac{V_d}{L} \times \frac{T_s}{2}$

$= 120A$

$\therefore I_{Lpeak} = 120/2 = 60A$ #

b) Voltage across RL = $V_o - V_{ac}$,

$R = 1\Omega$, $L = 10mH$, $f = 50Hz$

For fundamental, $n = 1$

$$b_1 = \frac{1}{\pi}\int_0^{2\pi} [V_o - V_{ac}] \sin(\omega t)\, d\omega t$$

$$= \frac{1}{\pi}\int_0^{\pi} [V_d \sin\omega t - 50\sin^2\omega t] + \frac{1}{\pi}\int_{\pi}^{2\pi} [-V_d \sin\omega t - 50\sin^2\omega t]\, d\omega t$$

$$= \frac{V_d}{\pi}[-\cos\omega t]_0^{\pi} - \frac{50}{2\pi}\int_0^{\pi}(1-\cos 2\omega t)\,d\omega t - \frac{V_d}{\pi}[-\cos\omega t]_{\pi}^{2\pi} - \frac{50}{2\pi}\int_{\pi}^{2\pi}(1-\cos 2\omega t)\,d\omega t$$

$$= \frac{2}{\pi}V_d + \frac{2}{\pi}V_d - \frac{50}{2\pi}[\pi] + \left[\frac{50}{4\pi}\sin 2\omega t\right]_0^{\pi} - \frac{50}{2\pi}[\pi] + \left[\frac{50}{4\pi}\sin 2\omega t\right]_{\pi}^{2\pi}$$

$$= \frac{4}{\pi}V_d - 50$$

$\Rightarrow V_{RL(1)} = \left(\frac{4}{\pi}V_d - 50\right)\sin\omega t$ Same as $V_{o(1)} - V_{ac}$

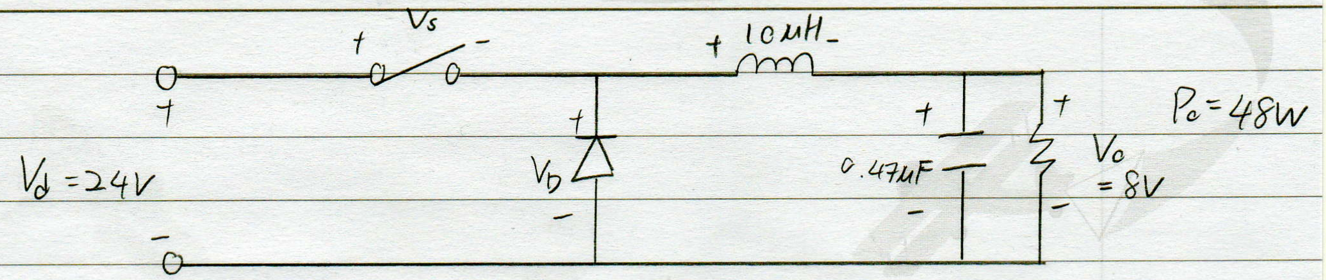
$\therefore V_{RL(1)\,rms} = \left[\frac{4}{\pi}V_d - 50\right]/\sqrt{2} = 72.68V$

$I_{o(1)\,rms} = V_{RL(1)\,rms}/Z = 72.68/\left[\sqrt{R^2 + (2\pi f_1 L)^2}\right]$

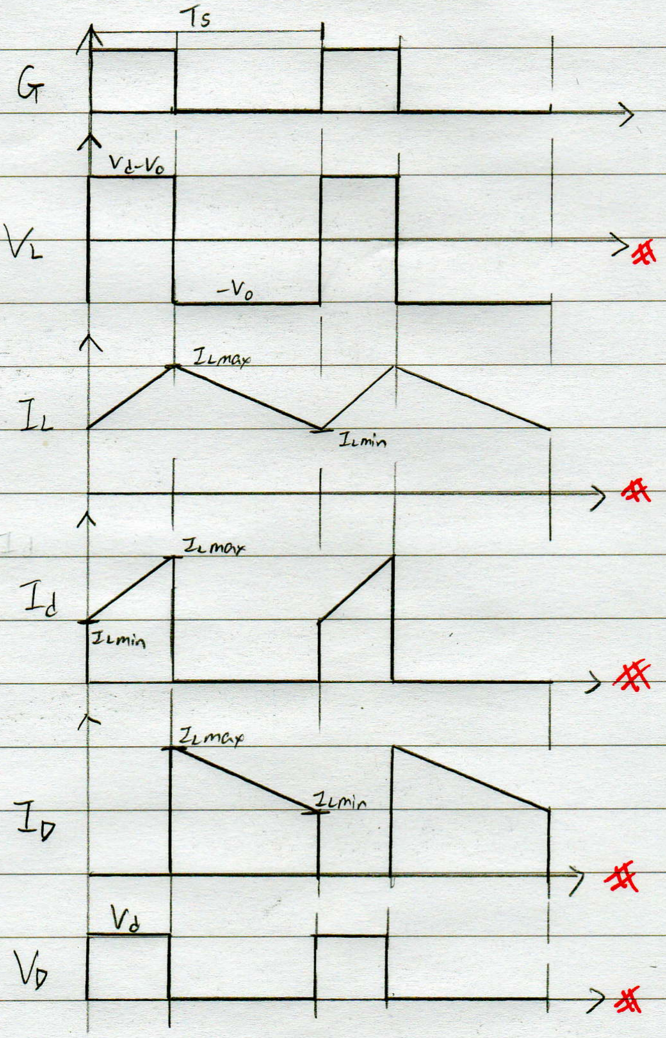
$= 22.045A$ #

Average output power = 0W, since $V_{o\,avg}$ = 0V. #

4)



a) $f_s = 50\,kHz$, $T_s = 0.02\,ms$, $\cancel{D = \frac{8}{24} = 1/5}$



b) $\frac{V_o}{V_d} = D \Rightarrow D = \frac{8}{24} = 1/3$ #

$P_o = V_o I_o = V_d I_d \Rightarrow I_o = P_o/V_o = 6A$ #

$I_d = P_o/V_d = 2A$ #

c) Find I_{Lmax} & I_{Lmin}, $I_{Lmax} = I_o + \frac{1}{2}\Delta I_L$, $I_{Lmin} = I_o - \frac{1}{2}\Delta I_L$

$$\Delta I_L = \frac{V_d - V_o}{L} t_{on} = \frac{V_d - V_o}{L} D T_s = \frac{24-8}{10\times10^{-6}} \times \frac{1}{3} \times 0.02\times10^{-3} = 10.667A$$

$\therefore I_{Lmax} = [10.667]/2 + 6 = 11.333A$

$I_{Lmin} = 6 - [10.667]/2 = 0.6665A$

Under BCM, $I_{oB} = I_{LB}$

$I_{oB} = [\frac{1}{2} \times T_s \times \Delta I_L]/T_s = \frac{1}{2}\Delta I_L = 10.667/2 = 5.3335A$

$I_{oB} = \frac{V_o}{R_B} \Rightarrow R_B = V_o/I_{oB} = 1.5 \cancel{A}\ \Omega$

d) When $P_o = 5W$, $V_o = 8V$,

$I_o = P_o/V_o = 0.625A$

Since $I_o < I_{oB}$, $\therefore$ DCM