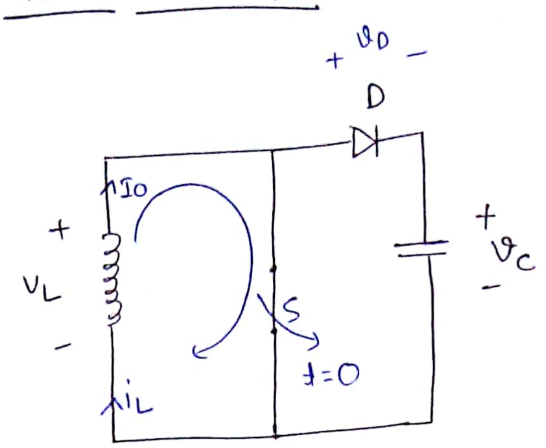
Power Electronics

Q



Switch opened at $t=0$, Find the volt across cap^c when diode stops conducting

and $v_c[t=0] = 0$

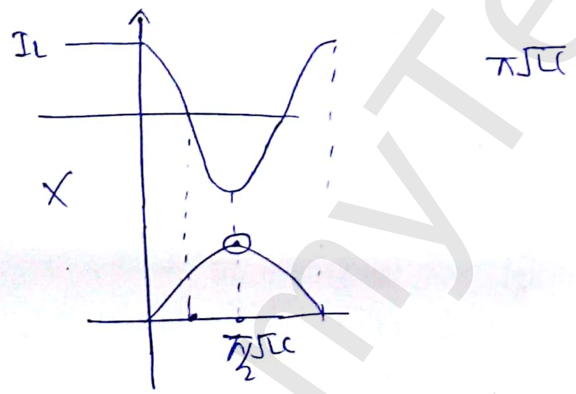
$i_L(t=0) = I_o$

Sol^n

$$-v_L + v_D + v_c = 0$$

$$v_L = v_c$$

$$L\frac{di_L}{dt} = \frac{1}{C}\int i_L\,dt$$



By Sir:

Energy relation

At $t=0$ ← Initial energy

$\frac{1}{2} L I_o^2$ → converted into $\frac{1}{2} \cdot C \cdot V_m^2$ → voltage at which cap^c finally charge.

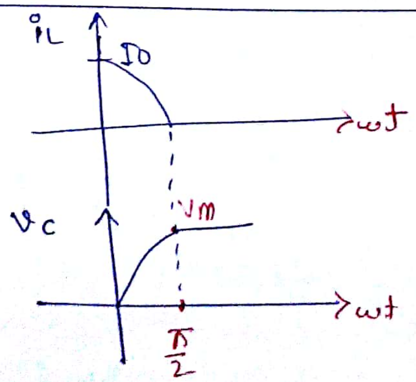
$$\frac{1}{2} L I_o^2 = \frac{1}{2} C V_m^2$$

$$\boxed{V_m = I_o\sqrt{\frac{L}{C}}}$$

i_L ↓ing so $i_L = I_o \cos\omega_o t$

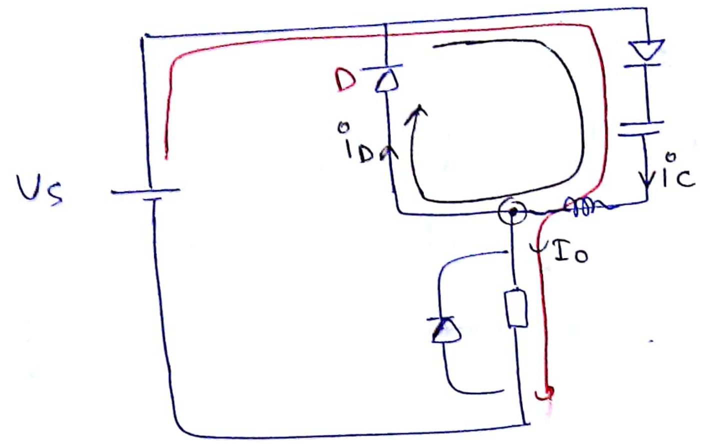
V_c ↑ing so $v_c = V_m \sin\omega_o t$

$$v_c = I_o\sqrt{\frac{L}{C}} \sin\omega_o t$$

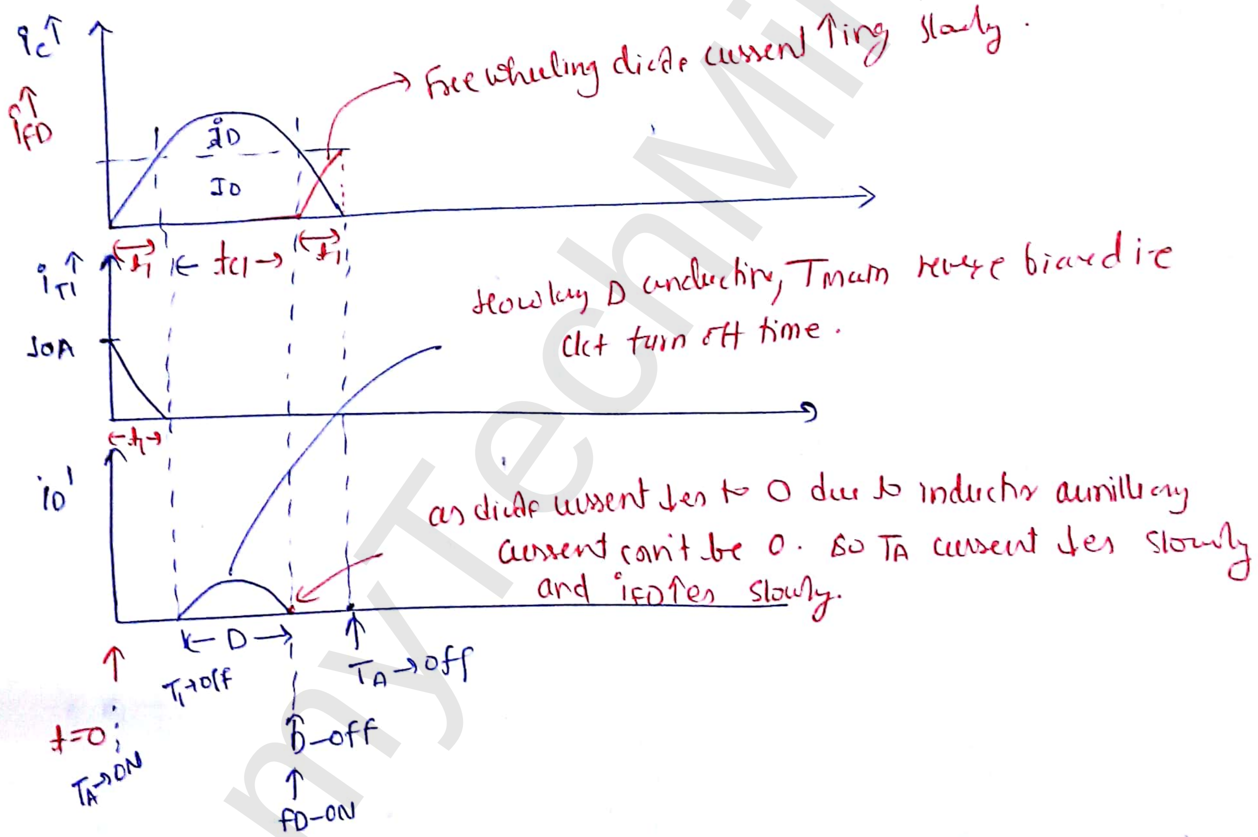


Diode will conduct for

$\frac{\pi}{2}$ ~~rad~~ radian



$i_C = I_0 + i_D$



$t_1 = 10\ \mu sec$

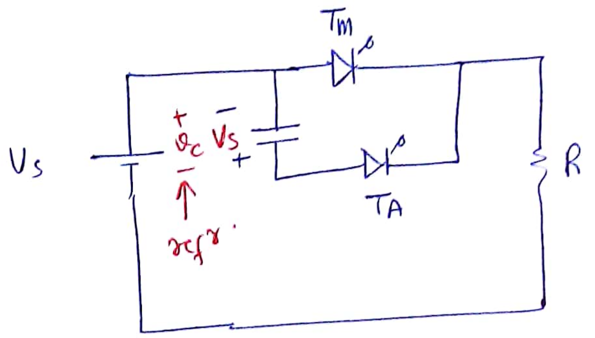
$t_{c1} = \pi\sqrt{LC} - 2t_1$

$= 198.6\ \mu s - 2(10\ \mu s)$

$= 178.6\ \mu sec$

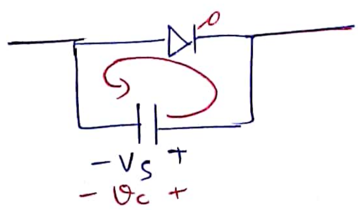
Q For a voltage commutated thys ckt shown in fig cap' is initially Charged to V_s voltage with polarity shown in fig Find the ckt turn off time of main thyristor

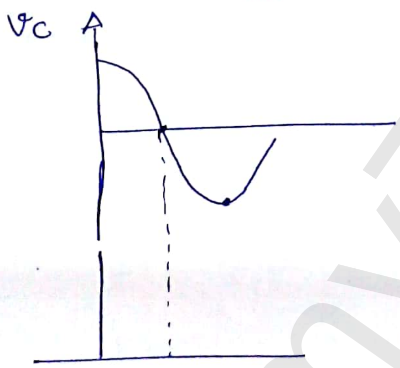
$C = 10\mu F$, $R = 5\Omega$, $V_s = 200V$



Soln

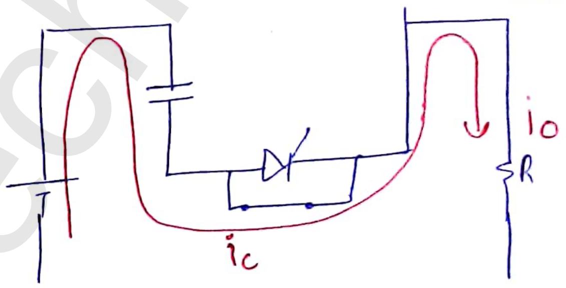
at $t=0$ TA → ON





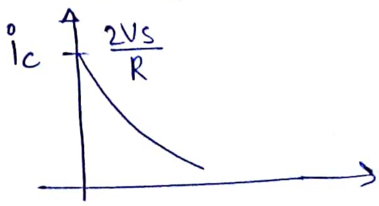
By Sir.

at $t=0$ TA → ON Tm → off (Immediately) i.e impulse commutation



RC N/w, exponential decay of cap' is i.e charging current ^ exponential decay.
so current cap' voltage will be exponential

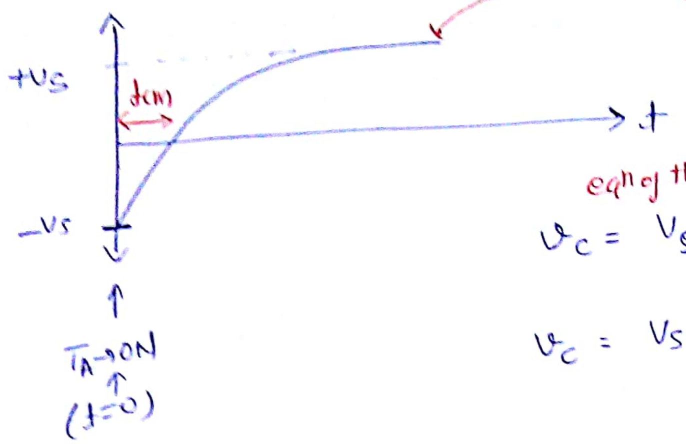
Here i_c and i_o are same



at the end of mode cap' vltge opposite

$v_c[t=0] = -V_s$

$V_c[\text{Final value}] = +V_s$



eqn of this curve, this curve exponential

$$v_c = V_s(1-e^{-t/RC}) - V_s e^{-t/RC}$$

$$v_c = V_s\left[1-2e^{-t/RC}\right]$$

At $t = t_{cm}$

$v_c = 0$

$0 = V_s(1-2e^{-t_{cm}/RC})$

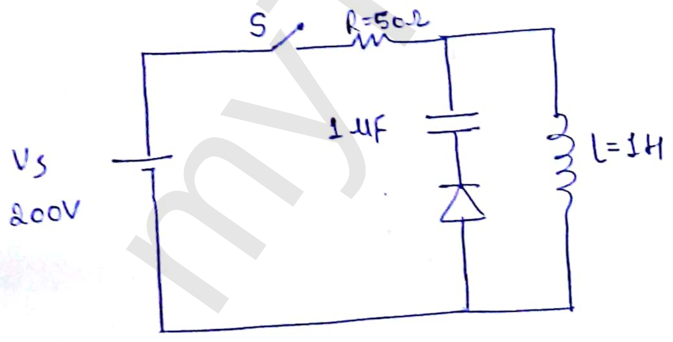
$t_{cm} = RC \ln 2$

$t_{cm} = 34.65\ \mu sec$

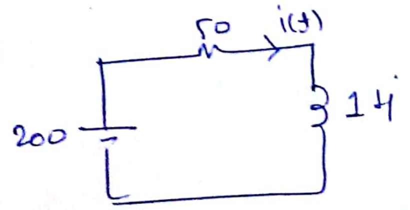
ckt turn off time of main thyristor.

Q4 In the ckt in the fig the switch S closed at $t=0$ and opens after 10 msec what will be the current in R, L and voltage across the capacitor after 9 msec when the switch is open. assume diode to be ideal

$V_s = 200\Omega$ $R = 50\Omega$ $C = 1\mu f$ $L = 1H$



Soln at $t=0$



$v = IR + L\frac{di}{dt}$

$\frac{V(s)}{s} = I(s)R + LsI(s)$

$\frac{V}{s} = I(R+Ls)$

$i_L =$

$\frac{V}{s(R+Ls)}$

$1-e$

$$\frac{V}{s(R+Ls)}$$

~~R+Ls~~
$R+Ls$
$p=-Ls$
$s=-\frac{R}{L}$

$$\frac{V}{R} + \frac{-VL}{R(R+Ls)}$$

$$\frac{V}{R}\left(1-\frac{Le}{L(s+\frac{R}{L})}\right)$$

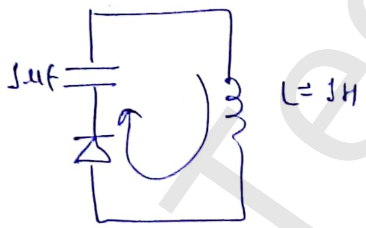
$$\frac{V}{R}\left(1-e^{-\frac{R}{L}t}\right)$$

$$i(t) = \frac{V}{R}\left(1-e^{-\frac{R}{L}t}\right)$$

$$i(10) = \frac{200}{50}\left(1-e^{-\frac{50}{1}\cdot\frac{10\,msec}{1000}}\right)$$

$$i(10) = 4\left(1-e^{-\frac{1}{2}}\right)$$

$$i(10) = 1.5738 \text{ A}$$

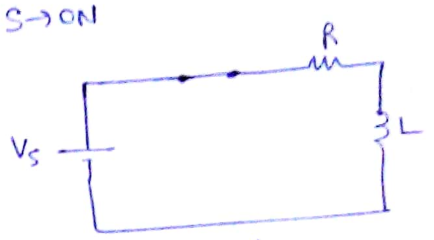


$$I = I_{cp}\cos\omega t$$

$$i(9) = V_s\sqrt{\frac{C}{L}}\cos\frac{1}{\sqrt{LC}} \times \frac{9}{1000}$$

By Sir

S→ON



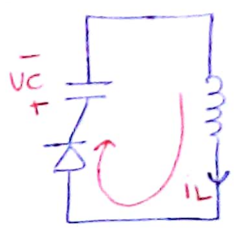
$$i = \frac{V_s}{R}\left(1-e^{-t/\tau}\right)$$

$$i = \frac{200}{50}\left(1-e^{-50t}\right)$$

$$(10m)\,i = 4\left(1-e^{-\frac{50\times10}{1000}}\right)$$

$$i(10) = 1.574 \text{ A}$$

S→open



$$i_L(t'=0) = 1.574 \text{ A} = I_0$$

$$\frac{1}{2}LI_0^2 = \frac{1}{2}C\cdot V_m^2$$

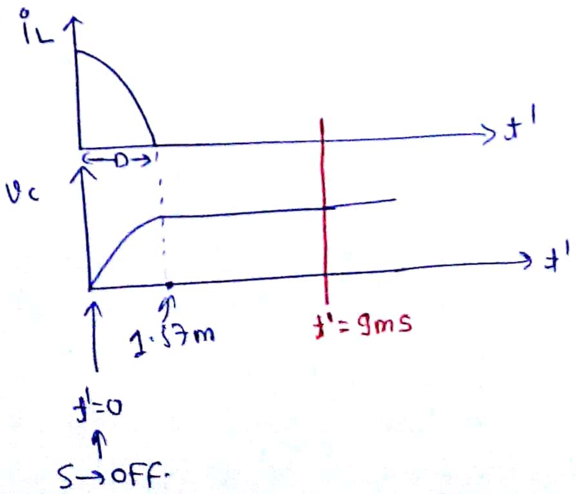
$$i_L\downarrow\text{ing} = I_0\cos\omega_0 t'$$

$$V_c\uparrow\text{ing} = V_m\sin\omega_0 t'$$

diode will conduct for $\frac{\pi}{2}\sqrt{LC}$

$= 1.57$ msec

$$V_m = I_0\sqrt{\frac{L}{C}} = 1.57\text{KV}$$



find the cap^c voltage in and inductor current after 1m sec after switch is open.

$i_L = I_0 \cos \omega_0 t'$

$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{1 \times 1 \times 10^{-6}}} = 1000$

$i_L = 1.574 \cos 1000 \times 1 \times 10^{-3}$

$i_L = 1.574 \cos 1$

$i_L = 0.85$ A

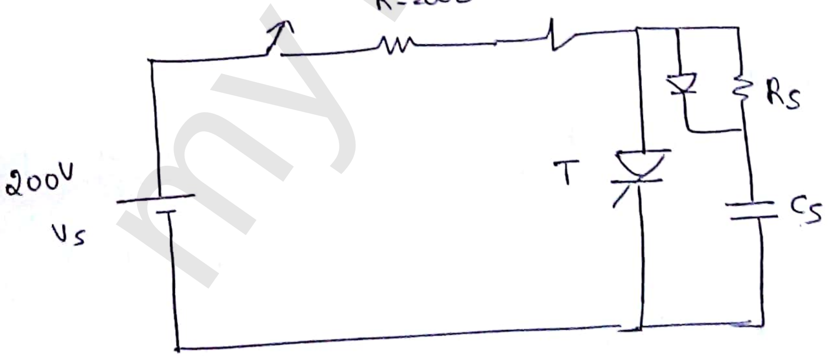
$V = V_m \sin \omega_0 t$

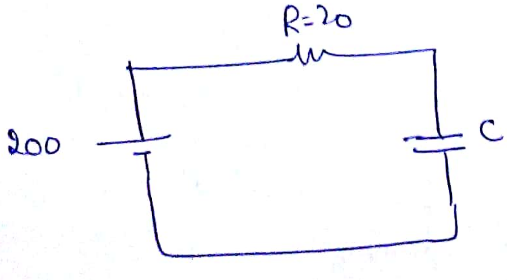
$V(1ms) = 1.57 \times 10^3 \sin 1 \times \frac{180}{\pi}$

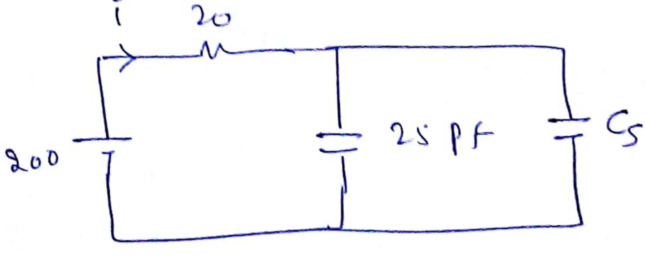
$V(1ms) = 1.32$ KV Answer

Question 5 For the ckt shown in the figure $\frac{dv}{dt}$ rating of thyristor is 400 volts/μsec and its junction cap^c is 25 pF the switch is closed at $t = 0$ sec (a) calc the value of C_s so that the thyristor is not turned on due to $\frac{dv}{dt}$.

(b) In case the max^m current through the thy^r is limited to 40 A determine the value of R_s

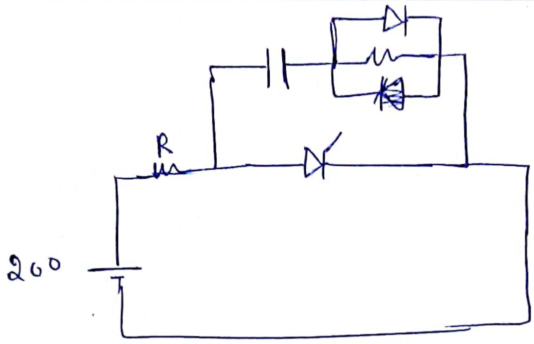


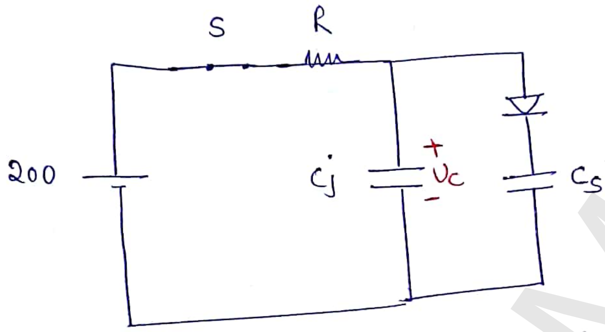


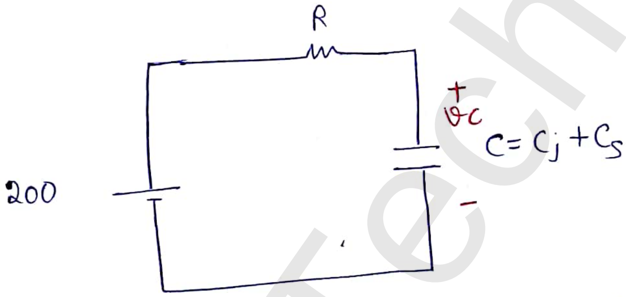


$i = -RC\frac{dv}{dt}$

$i = \frac{200}{20} = 10$







$$v_c = V_s\left[1 - e^{-t/RC}\right] + V_i\, e^{-t/\tau}$$

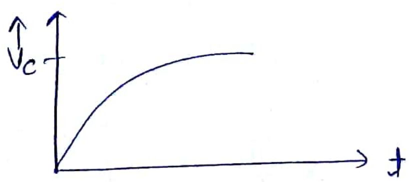
V_s ↑ Final value V_i ↑ initial voltage.

For RC and RL we use exponential func

$$v_c = V_s\left[1 - e^{-t/RC}\right]$$

$$\left.\left(\frac{dV_c}{dt}\right)\right|_{t=0}$$

— $t=0$ bcz we are designing snubber ckt for worst case i.e max^m $\frac{dv}{dt}$



$$\left(\frac{dV_c}{dt}\right)_{t=0} = \left(\frac{dV_c}{dt}\right)_{max} = \frac{V_s}{RC}$$

$$\left(\frac{dV_c}{dt}\right)_{Rating} = \frac{V_s}{RC}$$

$$400 \frac{V}{\mu sec} = \frac{200}{20 \times C}$$

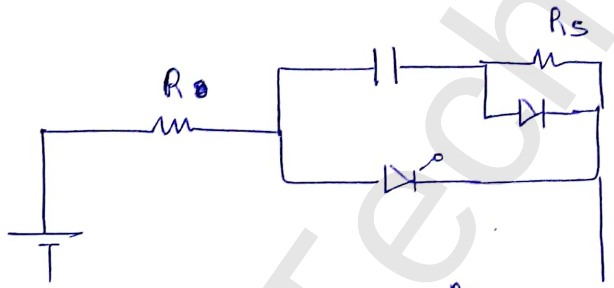
$$C = \frac{200}{20 \times 400} = \frac{1}{40} = 0.025 \ \mu F$$

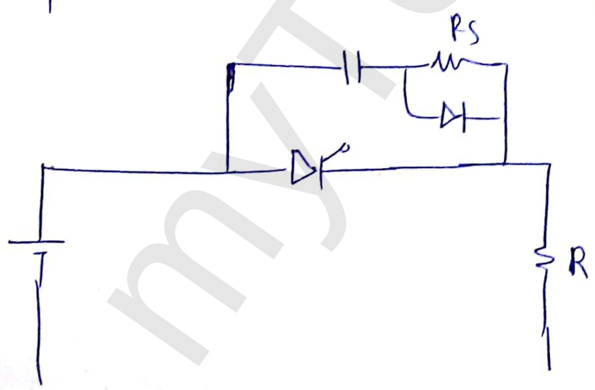
$C = C_j + C_s$

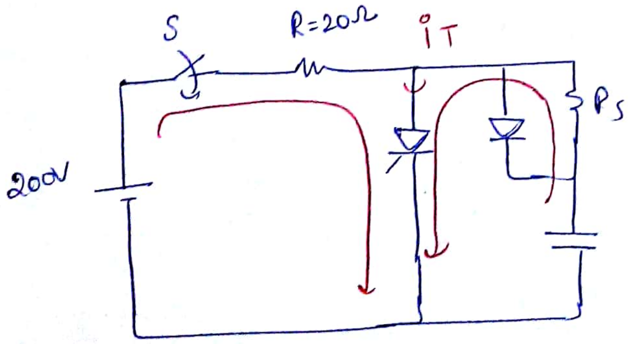
$C \simeq C_s$ bcz $C_j = 25\ pF$ so very small in comparision to μF so neglected

$$\boxed{C_s = 0.025\ \mu F}$$

(6)







$$i_T = \frac{V_s}{R} + \frac{V_s}{R_s} = 10A$$

$$\frac{200}{20} + \frac{200}{R_s} = 40$$

$$R_s = 6.67$$

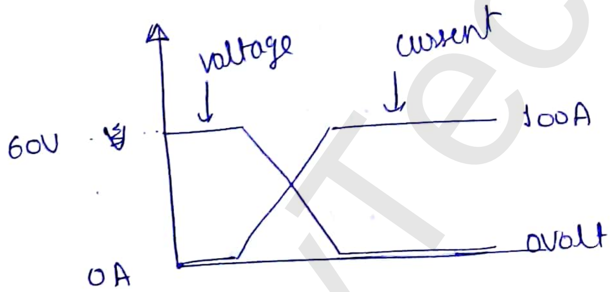
$$R_s \geq 6.67\ \Omega$$

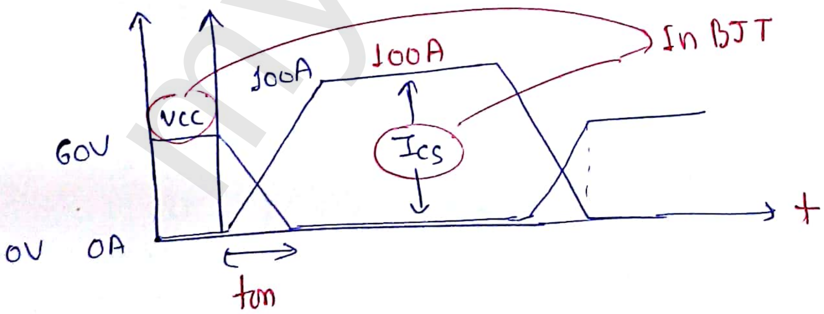
Q A SCR during turn on process has the following data Anode voltage and Anode current

Anode voltage	60V	0V
Anode current	0A	100A

during the turn on time of 5 μsec, the anode voltage and anode current varies linearly if the ~~flickering~~ triggering freq is 100Hz find the avg power loss in the thyristor during turn on

Soln





$$P_{avg} = \frac{1}{T}\int_0^{t_{ON}} V_{AK} \cdot I_A\, dt = \frac{VI}{6} t_{ON} \cdot f$$

$$= \frac{60 \times 100}{6} \times 5\times10^{-6} \times 100 \times 10^{3}$$

$$= 10 \times 10 \times 5 \times 10^{-6} \times 10^{3}$$

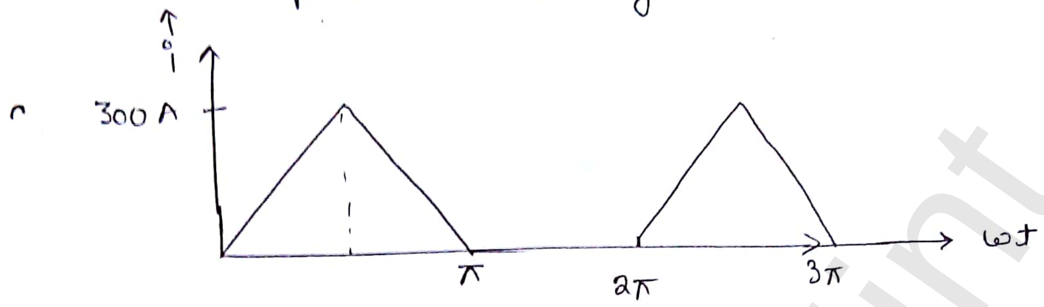
$$= \cancel{500}\text{ watts} = 0.5 \text{ watts}$$

Q A thyristor in a power converter carries a current of the waveform shown in the figure the peak value of current is 300A. the static char' of the thyristor is given by.

voltage across thyr = $1.05 + 0.95 \times 10^{-3} \times i_T$

$v = y$

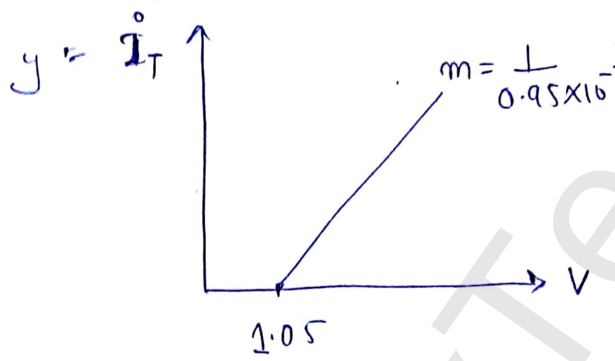
determine the power loss in the thyristor.



Soln

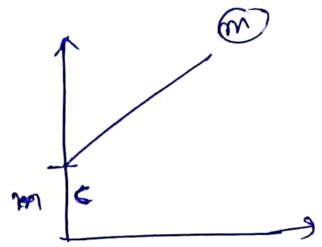
Some time directly V, I curve given, some time eqn given

static char' means VI charc



$m = \frac{1}{0.95 \times 10^{-3}} = \frac{100000}{95} = 1052.63$

$y = mx + c$



$x = my + c$

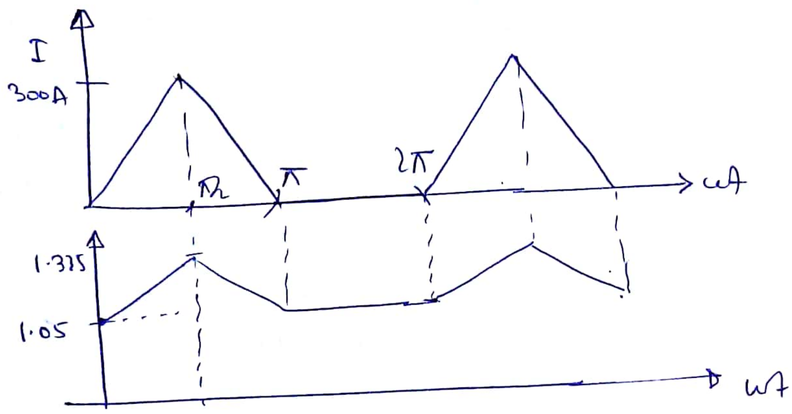
$\frac{100000}{0.95}$

$V = 1.05 + 0.95 \times 10^{-3} \times i_T$

at $i_T = 0$ $V = 1.05$

at $i_T = 300$ $V = 1.05 + 0.95 \times 10^{-3} \times 300$

$= 1.335$



$$P_{avg} = \frac{1}{T}\int_0^T V \times i \; dt \; \cancel{d\omega t}$$

$$= \frac{1}{2\pi}\int_0^{\pi/2} 2 \times \left(\frac{300 \times 2}{\pi}\right)\omega t \times \left(1.05 + \frac{0.285 \times 2}{\pi}\omega t\right) dt$$

$$= \frac{1}{2\pi}\int_0^{\pi/2} 1.05 \times \left(\frac{1200}{\pi}\right)\omega t \; d\omega t + \int \frac{1200}{\pi}\omega t \; \frac{0.285 \times 2}{\pi}\omega t \; d\omega t$$

$$\frac{1}{2\pi}$$

<u>By Sir</u>

$$P_{avg} = \frac{1}{2\pi}\int_0^{2\pi} V_T \cdot i_T \; d(\omega t)$$

$$= \frac{1}{2\pi}\int_0^{2\pi} (1.05 + 0.95 \times 10^{-3} i_T) \cdot i_T \; d(\omega t)$$

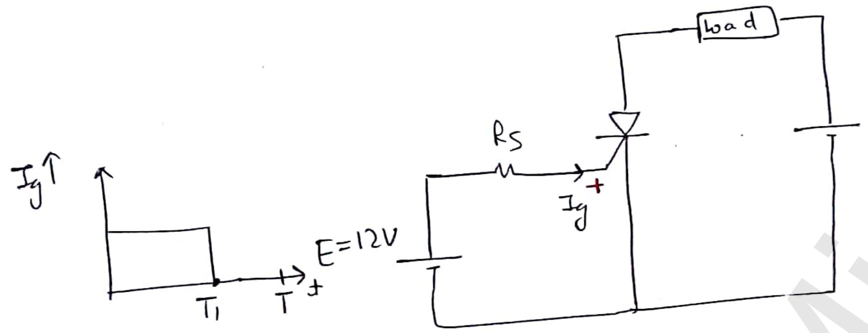
$$= \frac{1}{2\pi}\int_0^{2\pi} 1.05 i_T \; d\omega t + \frac{1}{2\pi}\int_0^{2\pi} 0.95 \times 10^{-3} i_T^2 \; d\omega t$$

$$P_{avg} = 1.05 (I_T)_{Avg} + 0.95 \times 10^{-3} (I_T)^2_{rms}$$

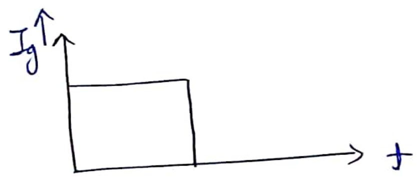
Q The gate cathode char' of an SCR is given by $V_g = 0.5 + 8 I_g$ for triggering of frq^c of 400 Hz the duty cycle is 0.1 compute the value of resistance to be connected in series with the gate ckt.

A rectangular trigger pulse applied to the gate ckt has an amplitude of 12 volts.

The thyristor has an avg gate power loss of 0.5 watt



Sol



$\delta = \frac{T_1}{T}$

$T_1 = T\delta = \frac{\delta}{F} = \frac{0.1}{400} = 250\ \mu sec$

$T_1 > 100\ \mu s$

∴ consider I_g as continious pulse

$\therefore V_g I_g = P_{gAV}$

$V_g I_g = 0.5$

$V_g = 0.5 + 8 I_g$

$V_g I_g = 0.5 I_g + 8 I_g^2$

$0.5 = 0.5 I_g + 8 I_g^2$

$8 I_g^2 + 0.5 I_g - 0.5 = 0$

$\frac{-0.5 \pm \sqrt{(0.5)^2 + 4 \times 8 \times 0.5}}{16} = \frac{-0.5 \pm \sqrt{.25 + 16}}{16} = \frac{4.03 - 0.5}{16}$

$I_g = 0.22\ A.$

$$V_g = \frac{0.5}{0.22} = 2.27$$

$$E = I_g R_s + V_g$$

$$12 = 0.22 \times R_s + 2.27\,V$$

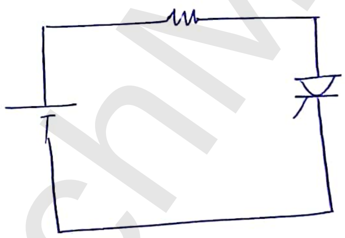
$R_s = 44.21\,\Omega$ ← this much resistance added to limit the gate current.

Q The specification sheet for an SCR use max^m rms on state current as 50 A. if is used in a resistive ckt compute its avg on state current rating for conduction angle of 60° if the current waveform is

(a) Half sine wave

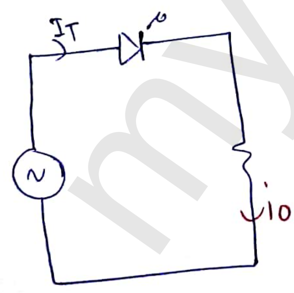
(b) Rectangular wave.

Soln. $i_{Trms} = 50A$



By Sir

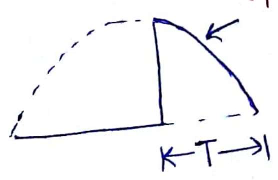
(a)



$T \longrightarrow \alpha$ to π

$T \longrightarrow (\pi - \alpha) = \frac{\pi}{3}$ rad^n

$\alpha = \frac{2\pi}{3}$ rad^n $= 120°$

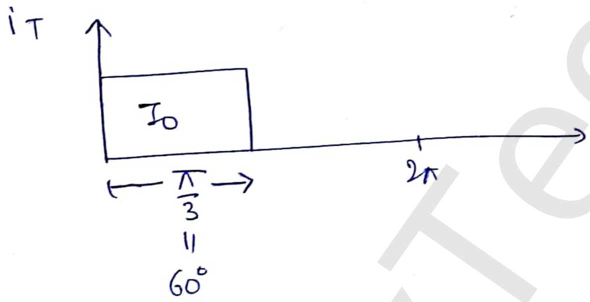


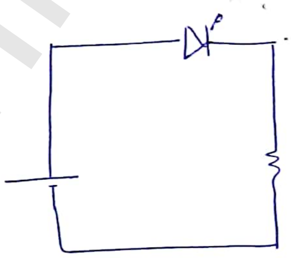
$$(I_T)_{avg} = \frac{(I_T)_{Rms}}{FF} = \frac{50}{FF}$$

$$FF = \frac{i_{T\,Rms}}{i_{T\,avg.}} = \frac{I_{or}}{I_0} = \frac{V_{or}/R}{V_0/R} = \frac{V_{or}}{V_0}$$

$$\frac{V_{or}}{V_o} = \frac{\frac{\cancel{V_m}}{\sqrt{2\cdot 2\pi}}\left[(\pi-\alpha)+\frac{1}{2}\sin 2\alpha\right]^{1/2}}{\frac{\cancel{V_m}}{2\pi}(1+\cos\alpha)}$$

(b) Rectangular Pulse





$$FF = \frac{(I_T)_{rms}}{(I_T)_{Avg}}$$

$$I_{T\,Avg} = \frac{I_o \times \pi/\cancel{3}}{2\pi\ 3} = \frac{I_o}{6}$$

$$I_{T\,rms} = \sqrt{\frac{1}{2\pi}\left(I_o^2 \times \frac{\pi}{3}\right)}$$

$$\frac{I_o^2 \times \pi}{3 \times 2\pi} = \frac{I_o}{\sqrt{6}}$$

$$FF = \frac{I_o\ 6}{\sqrt{6}\ I_o}$$

$$FF = \sqrt{6} = 2.45$$

$$(I_T)_{avg}\ \text{rating} = \frac{(I_T)_{rms}\ \text{Rating}}{FF} = \frac{50}{FF} = \frac{50}{\sqrt{6}} = 20.408$$

Q A power switching device is rated for 600 V and 30 A the device has an on-state voltage drop of 1.5 V to 2.4 volts for conduction current in the range of 15-30 amp. the device has a leakage current of 5 mA while blocking 600V. Find the a) max^m conduction power loss

Sol^n ON state V.drop 1.5 V to 2.4 V

conduction current (I_A) 15 to 30 A

(b) Find the max^m blocking power loss

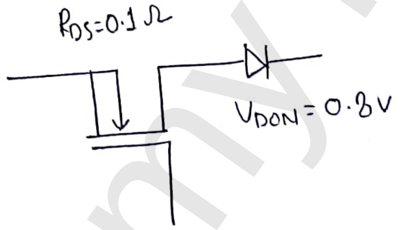
Sol^n max^m conduction loss = 2.4 X 30 = 72 watt

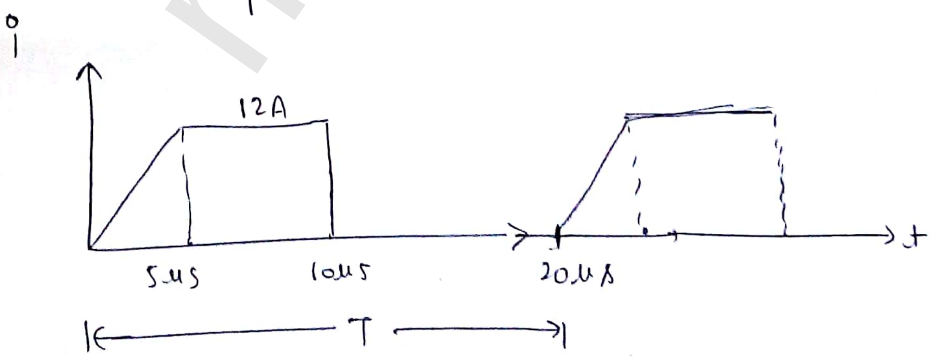
Blocking loss = 600V X 5×10^{-3} = 3 watt

conduction loss very high > Switching losses > Blocking loss (least)

depend on frq^c — most of the time we neglect

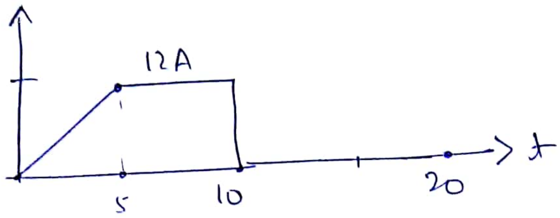
O A composite switch used in a power converter is shown in figure the periodic current through the switch is also shown

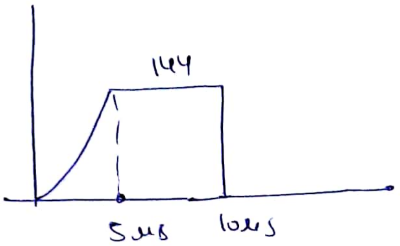




Find the power loss in the mosfet and the diode in a composite switch.

Soln finding rms value of current





$$I_{rms}^2 = \int_0^{5\mu sec} \left(\frac{12}{5\times10^{-6}}\right)^2 t^2\,dt + \left[144 \times 5\,\mu sec\right]$$

$$\frac{12}{5\times10^{-6}} \frac{t^3}{3} + 144\times5\times10^{-6}$$

$$I_{rms} \sqrt{\frac{1}{20\times10^{-6}}\left\{\left(\frac{12}{5\times10^{-6}}\right)^2 \times \frac{(5\times10^{-6})^3}{3}\right\} + 720\times10^{-6}}$$

$$I_{rms}^2 = \frac{1}{20}\left[\frac{12\times12\times125\times\cancel{10^{-6}}}{5\times5\times3} + 720\right] = 48\ A^2$$

$$I_{rms} = 6.93$$

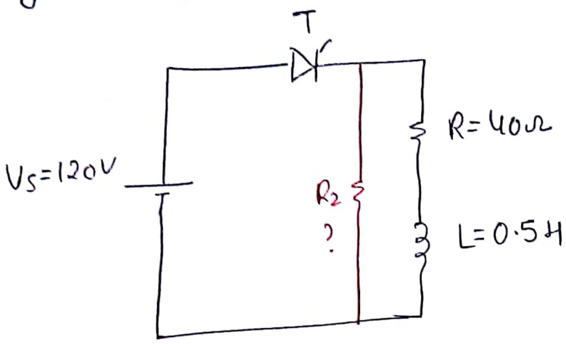
Power loss in MOSFET $= I_{rms}^2 \times R_{ds}$

$= 48 \times 0.1 = 4.8$ watts

$$I_{avg} = \frac{\left[\frac{1}{2}\times5\times12 + 5\times12\right]\times\cancel{10^{-6}}}{20\times\cancel{10^{-6}}} = 4.5\ A$$

Power loss in diode $= V_{\text{ON drop}} \times I_{avg} = 4.5 \times 0.8 = 3.6$ watts

Q) the latching current of a thyristor ckt as shown below is 20mA



To perfectly trigger the thyristor the additional resistance that must be connected in || to the load if the duration of firing pulse is 50μsec is ___kΩ.

Soln

$$i = \frac{V}{R}\left(1 - e^{-t/\tau}\right) \qquad \tau = \frac{L}{R} = \frac{0.5}{40} = \frac{1}{80}$$

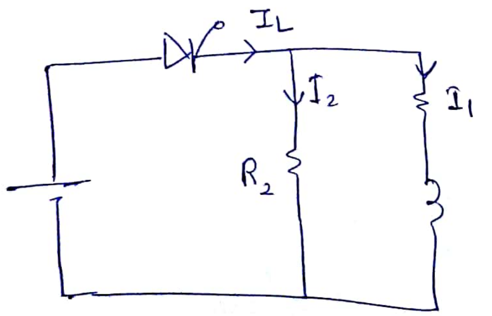
$$i = \frac{120}{40}\left(1 - e^{-tR/L}\right)$$

$$i_A \quad \cancel{20mA} = \frac{120}{40}\left(1 - e^{-\frac{50\times10^{-6}R}{L}}\right)$$

$$\frac{\cancel{20}}{\cancel{1000\times120}} = 3$$

at $t = 50\mu s$ $\quad i_A = 30\left(1 - e^{-50\times10^{-6}\times 80}\right)$

$i_A = 11.97mA < I_L$ ∴ T fails to turn on



$I_L = I_1 + I_2$

$I_2 = I_L - I_1$

$= 20mA - 11.97mA$

$I_2 = 8.03mA$

$\frac{V_S}{R_2} = 8.103 \times 10^{-3}$

$R_2 = \frac{120}{8.103 \times 10^{-3}}$

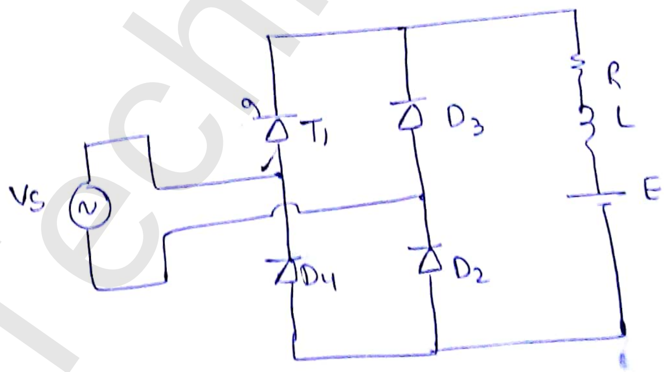
$R_2 = 14.94 k\Omega$

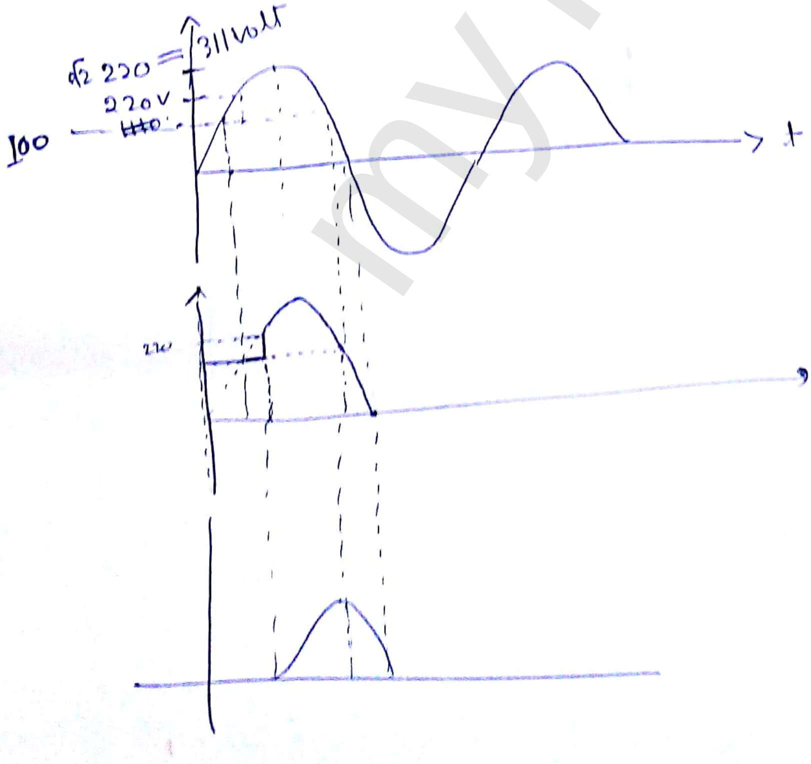
If R_2 is < than 14.94 (no problem) but if $R_2 > 14.94$ the $I_1 + I_2$ will less than latching current.

chapter - 2

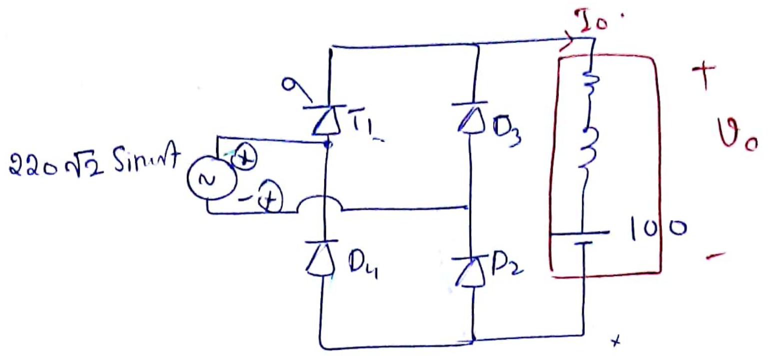
Q A single phase bridge rectifier consist of 1 SCR and 3 diode operating with firing angle of 45° find the avg load current and power delivered to the load where $R = 8.356\,\Omega$ $L = 8\,mH$ $E = 100V$. assume that the load current is constant the ac source voltages is 220V, 50Hz.

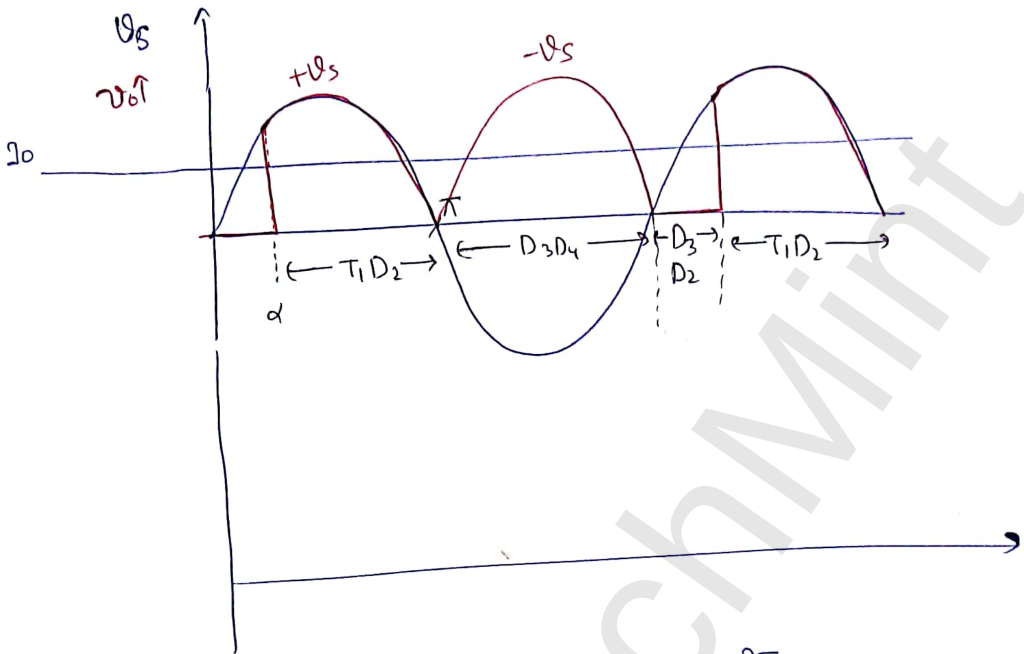
Soln





$311 \sin 45° =$





$$V_0 = \frac{1}{2\pi}\left[\int_{\alpha}^{\pi} V_m \sin\omega t \cdot d(\omega t) + \int_{\pi}^{2\pi} -V_m \sin\omega t \; d(\omega t)\right]$$

$$= \frac{1}{2\pi}\left\{V_m(\cos\alpha - \cos\pi) + V_m[\cos(2\pi) - (\cos\pi)]\right\}$$

$$\left\{V_m\left(\frac{1}{\sqrt{2}} + 1\right) + V_m[1 + 1]\right\}$$

$$\frac{V_m}{2\pi}\left[2 + 1 + \frac{1}{\sqrt{2}}\right]$$

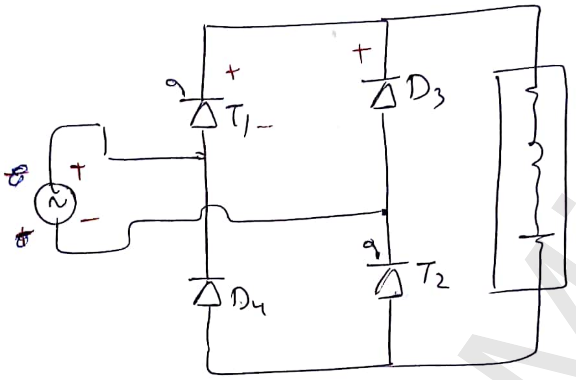
$$V_0 = \left(3 + \frac{1}{\sqrt{2}}\right)\frac{V_m}{2\pi} = 183.56\ V$$

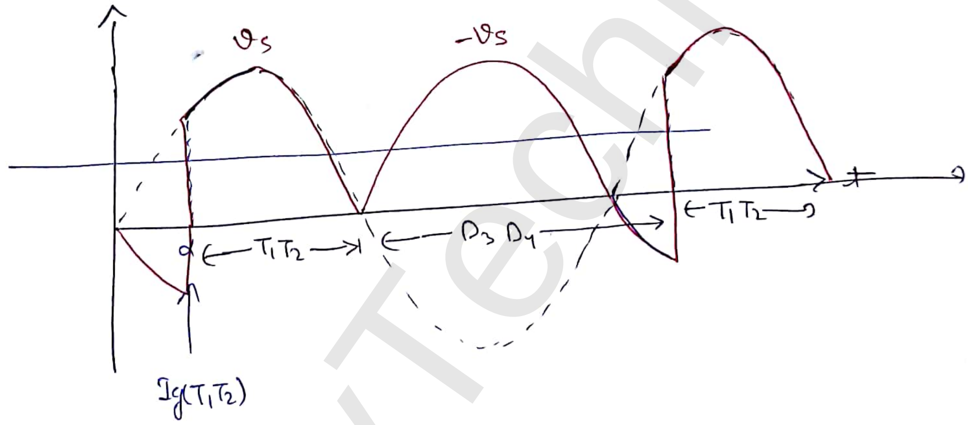
$$V_0 = E_b + I_0 R_a$$

$$I_0 = \frac{V_0 - E_b}{R_a} = \frac{183.56 - 100}{8.356} = \quad I_0 = 10\ A$$

$P_{load} = V_o I_o$
$= 183.56 \times 10$
$= 1835.6$ watt

Q Replace D_2 with T_2





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

$$\frac{1}{2\pi}\left[V_m(\cos\alpha - \cos\pi) - V_m\{\cos(\pi) - \cos(2\pi+\alpha)\}\right]$$

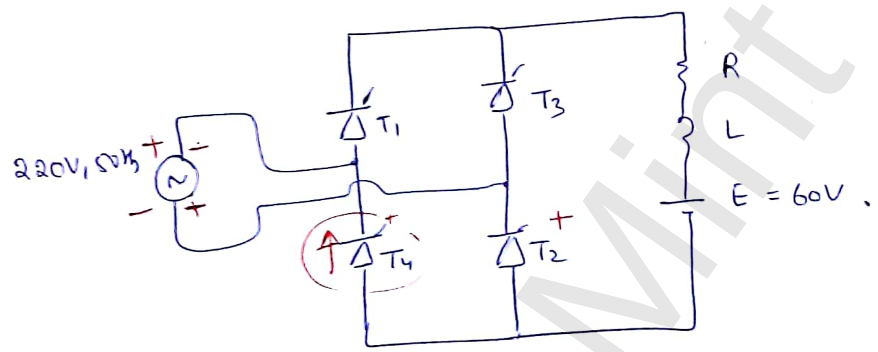
$$V_m \frac{1}{2\pi}\left[\left(\frac{1}{\sqrt{2}}+1\right) - \left(-1 - [\cos 2\pi \cos\alpha - \cancel{\sin 2\pi}\sin\alpha]\right)\right]$$

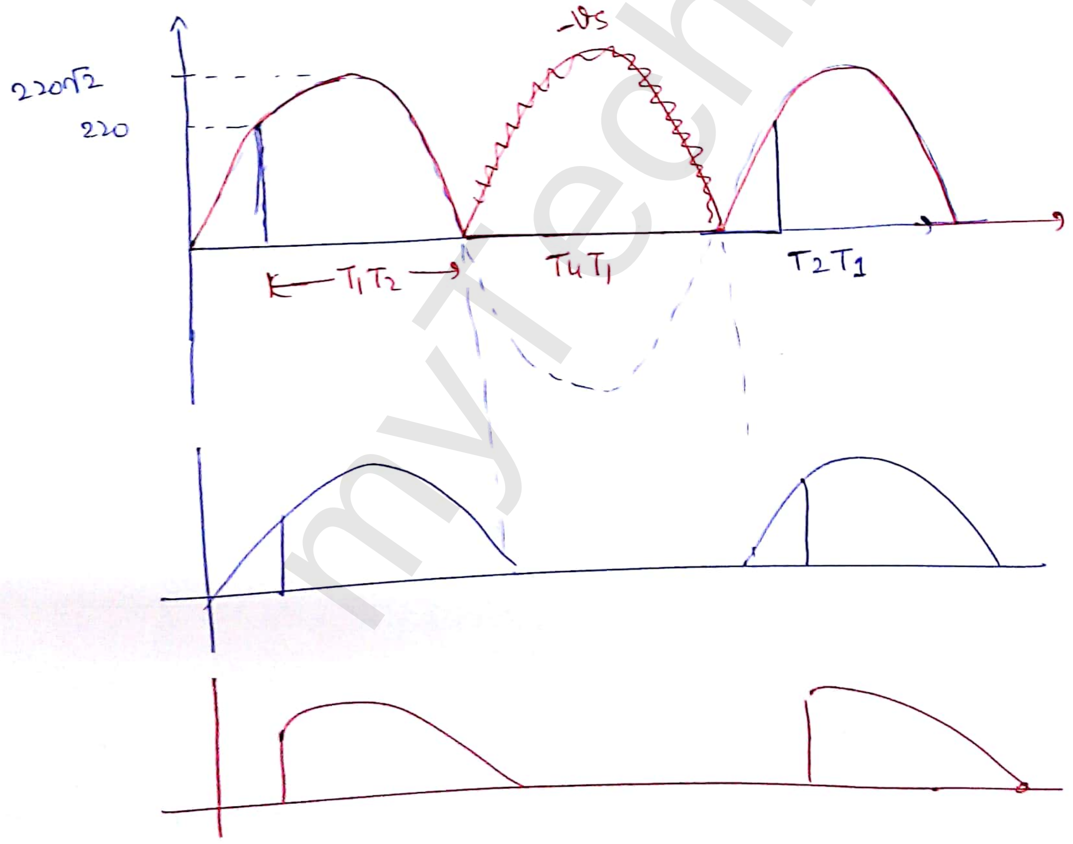
$$-\left(-1 - \frac{1}{\sqrt{2}}\right)$$

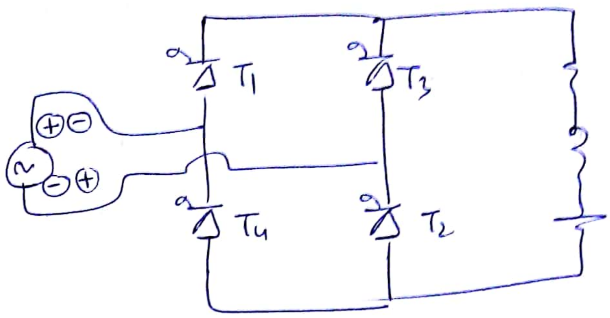
$$\left[\left(1+\frac{1}{\sqrt{2}}\right) + \left(1+\frac{1}{\sqrt{2}}\right)\right] = \frac{V_m}{\pi}\left[1+\frac{1}{\sqrt{2}}\right) = \frac{230\sqrt{2}}{\pi}\left[1+\frac{1}{\sqrt{2}}\right]$$

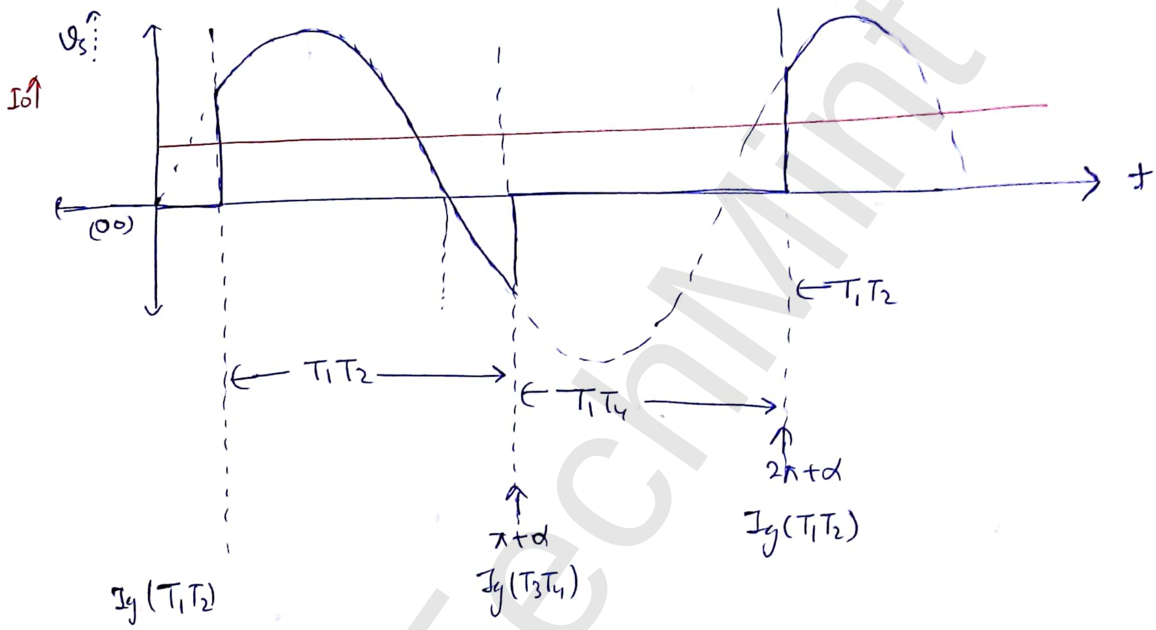
$= 169.06$

Q A Single phase full converter feeds power to RLE load with $R = 10\Omega$ $L = 6mH$, $E = 60V$ the ac source voltage is 220V, 50 Hz in case one of the 4 SCR gets over ckted due to a fault find the avg value of load current by assuming the load current as continious and firing angle 45°









$$V_0 = \int_{\alpha}^{\pi+\alpha} V_m \sin\omega t \, d\omega t = \frac{V_m \cos\alpha}{\pi}$$

$$= \frac{220\sqrt{2}}{\pi} \times \cos 45$$

$$V_0 = 70.028\,V$$

$$V_0 = E_b + I_0 R_a$$

$$I_0 = \frac{V_0 - E_b}{R_a} = \frac{70 - 60}{10} = 1A$$

Q A Single phase one pulse converter with RLE load has the following Paramtrs. supply voltages 230V, 50Hz, $R = 2\Omega$, $L = 1mH$, $E = 120$ volt extinction angle $\beta = 220°$ and $\alpha = 25°$ = firing angle just before the ~~SCR~~

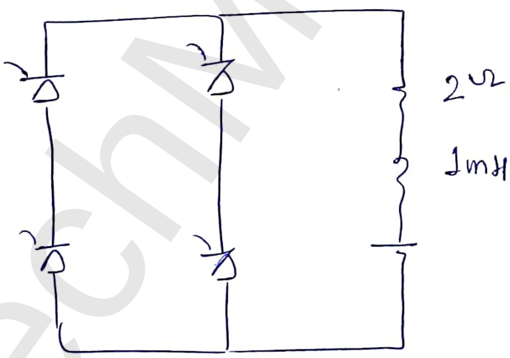
(a) Cal^c the voltage across the thyristor at the instant ~~when~~ SCR is triggered.

~~(b) Cal^c the " " " " just before the SCR is triggered.~~

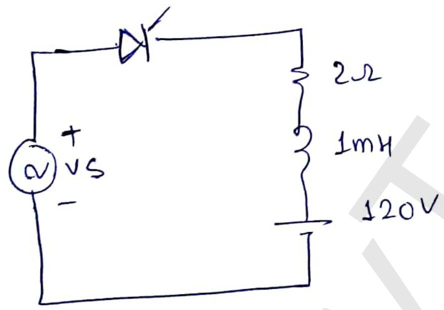
(b) Find the voltage that appears across the SCR immediatly at the instant ~~when~~ at which it stops conducting

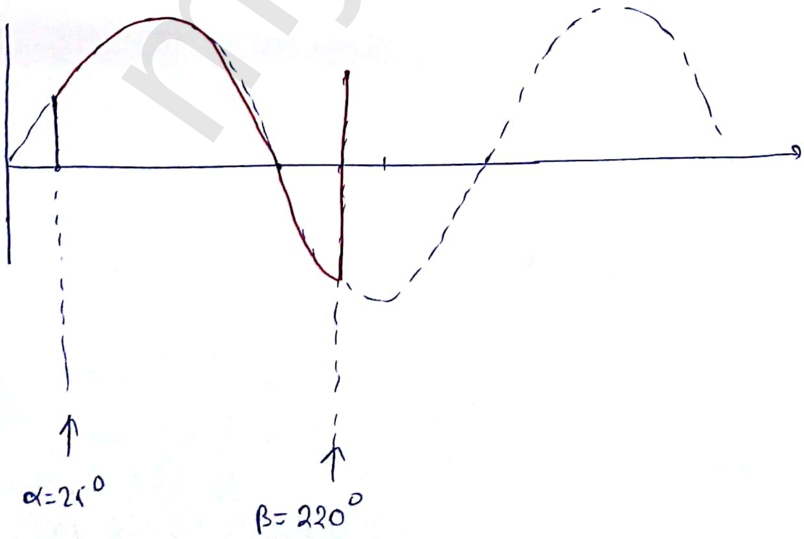
© PIV of the SCR

Sol^n

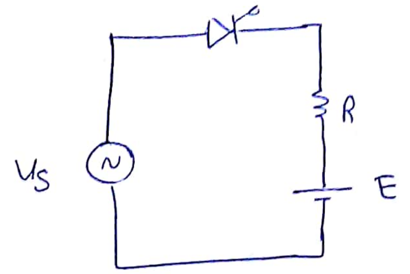


2pulse.





By Sir



at α^-

$-v_s + V_T + E = 0$

$v_T = V_s - E$

$V_T = V_m \sin \alpha - E$

$= 220\sqrt{2} \sin 25 - 120$

$= 17.46$ V

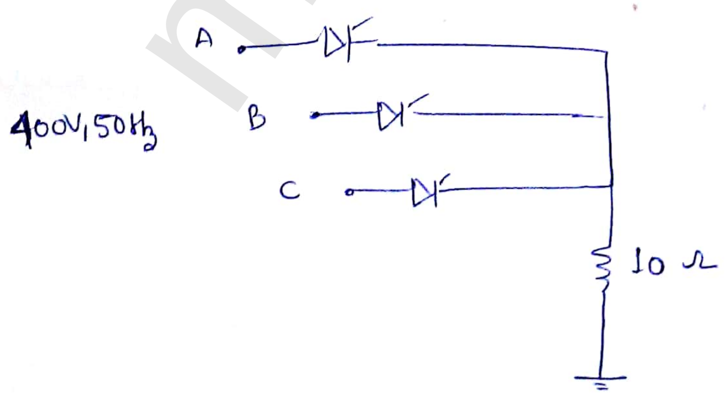
at β^+ $V_T = V_m \sin \beta - E$

$= 230\sqrt{2} \sin 220 - 120$

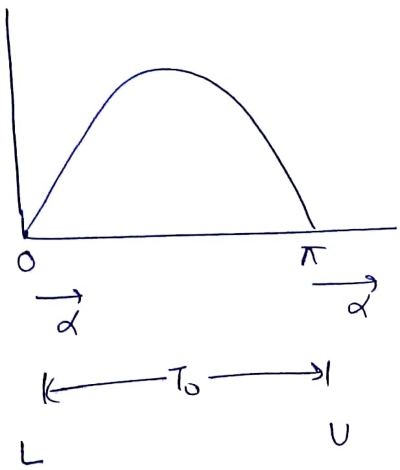
$= -329$ V

Q A 3ϕ Half wave phase controlled rectifier delivers power to a resistive load of 10Ω. i/p to the rectifier is 400V, 50Hz, 3ϕ ac supply find the power delivered to the load at $\alpha = 60°$ and $\alpha = 15°$

Soln



2 pulse



for resistive load upper limit = π only

	L	U		T_0
for inductive load →	$(0+\alpha)$	$(\pi+\alpha)$	→ 2 pulse	(π)
	$\left(\frac{\pi}{6}+\alpha\right)$	$\left(\frac{5\pi}{6}+\alpha\right)$	→ 3 pulse	$\left(\frac{2\pi}{3}\right)$
	$\left(\frac{\pi}{3}+\alpha\right)$	$\left(\frac{2\pi}{3}+\alpha\right)$	— 6 pulse.	$\left(\frac{\pi}{3}\right)$

$T_0 = \frac{2\pi}{m} = \pi$ ← m ← no. of pulse

Inductive load [continious conduction] Vdo Cosα

2 pulse ⇒ $V_0 = \frac{1}{\pi}\int_{0+\alpha}^{\pi+\alpha} V_m \sin\omega t \, d\omega t = \frac{2V_m}{\pi}\cos\alpha$

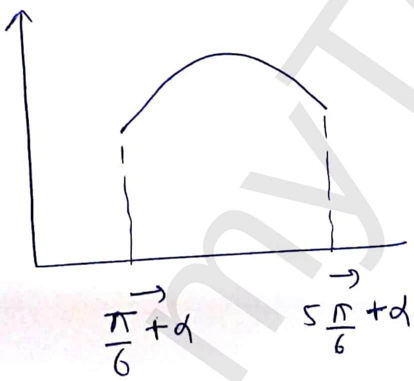
3 pulse

$T_0 = \frac{2\pi}{3} =$

3 pulse $= V_0 = \frac{1}{(2\pi/3)}\int_{\frac{\pi}{6}+\alpha}^{\frac{5\pi}{6}+\alpha} V_{mph} \sin\omega t \, d\omega t = \frac{3\sqrt{3}\, V_{mph}}{2\pi}\cos\alpha =$

$= \frac{3V_{ml}}{2\pi}\cos\alpha$

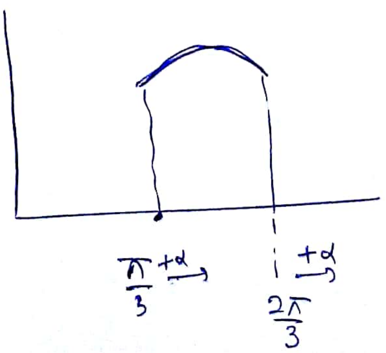
Vdo . Cosα



6 pulse ⇒ $V_0 = \frac{1}{\pi/3}\int_{\pi/3+\alpha}^{\frac{2\pi}{3}+\alpha} V_{mL} \sin\omega t \, d\omega t = \frac{3V_{ml}}{\pi}\cos\alpha$

= Vdo. Cosα

6 pulse



inductive load continious cond^c waveform will remain same for RL, RLE

P.

$$V_{or} = \frac{V_m}{\sqrt{2 \cdot T_0}} \left[(\upsilon - \iota) + \frac{1}{2} (\sin 2\iota - \sin 2\upsilon) \right]^{\frac{1}{2}}$$

when using for 3 pulse $V_m = V_{mph}$

" 6 pulse $V_m = \cancel{V_{line}} V_{ml}$

Resistive load

	L	U	To	
2pulse	$(0+\alpha)$	(π)	π	$V_0 = \frac{1}{\pi}\int_{0+\alpha}^{\pi} V_m \sin\omega t \, d\omega t = \frac{V_m}{\pi}(1+\cos\alpha) \rightarrow$ Discont.
3pulse	$\left(\frac{\pi}{6}+\alpha\right)$	$\left(\frac{5\pi}{6}+\alpha\right)$	$\frac{2\pi}{3}$	$V_0 = \frac{1}{2\pi/3}\int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_{mph} \sin\omega t \, d\omega t = \frac{3\sqrt{3}\, V_{mph}\cos\alpha}{2\pi} =$

$\alpha \le \pi/6$, $U \le \pi$

$\frac{3V_{mL}}{2\pi}\cos\alpha = V_{do}\cos\alpha$

RL, RLE

R ($\alpha \le \pi/6$)

For R also Here if $\alpha \le \pi/6$ we get continious wavefom

when $\alpha \ge \frac{\pi}{6}$, $U \ge \pi$

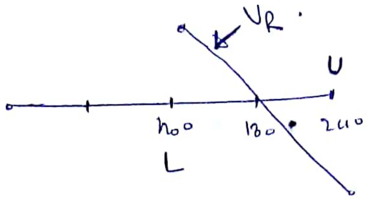
3pulse $\left(\frac{\pi}{6}+\alpha\right)$ $\underbrace{\qquad}_{T}$ π FD $\underbrace{\left(\frac{5\pi}{6}+\alpha\right)}_{\text{Discontinious}}$

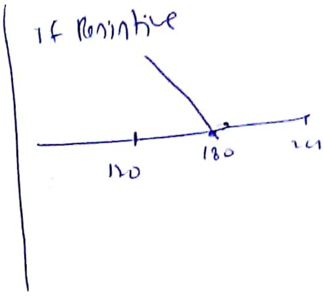
$\therefore V_0 = \int_{\pi/6+\alpha}^{\pi} V_{mph} \sin\omega t \, d\omega t = \frac{V_{mph}}{2\pi/3}\left[1+\cos\left(\frac{\pi}{6}+\alpha\right)\right]$

in b/w π to $\left(\frac{5\pi}{6}+\alpha\right)$ FD will conduct {If it is a 3 pulse + Free Wheel Diode}

Q For 3 pulse $\alpha = 90^\circ$ draw wave form fro inductive load

L	U
$\left(\frac{\pi}{6}+\alpha\right)$	$\left(\frac{5\pi}{6}+\alpha\right)$
$(30+90)$	$(150+90^\circ)$
120°	240

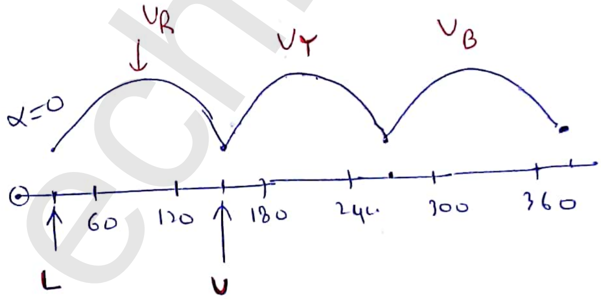




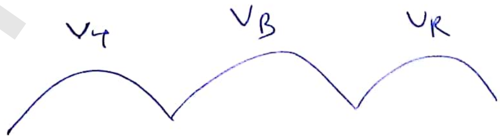
we use short cut for Reference waveform V_R.

Q Draw the wave form for $\alpha = 0$, 3 pulse, inductive load.

L	U
$\left(\frac{\pi}{6}+\alpha\right)$	$\left(\frac{5\pi}{6}+\alpha\right)$
$(30+0)$	$(150+0)$

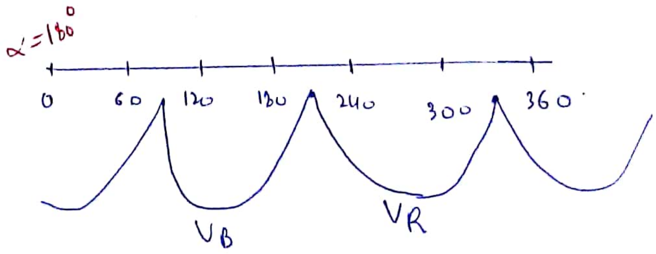


if in exam $V_Y = V_m \sin\omega t$ (given)



Q $\alpha = 180^\circ$,

L	U
$(30+180^\circ)$	$(150+180)$
210°	(330)



at $\alpha = 0$ max^m avg voltage.

at $\alpha = 180^\circ$ max^m −ve avg voltage.

For inductive load

$0 \leq \alpha \leq 180$

$V = \frac{3V_{ml}}{2\pi} \cos\alpha$

max^m +ve avg voltage

$+\frac{3V_{ml}}{2\pi}$

max^m -ve avg voltage

$-\frac{3V_{ml}}{2\pi}$

For resistive load

$0 \leq \alpha \leq 150$

$V = \frac{3V_{ml}}{2\pi} \cos\alpha$

$(V_o)_{max}$

$\frac{3V_{ml}}{2\pi}$

$\underline{\underline{0V}}$

draw wave fm $\alpha = 150^\circ$ for Induct for 3 pul.

$\left(\frac{\pi}{6} + \alpha\right)$

L

$(30 + 150)$

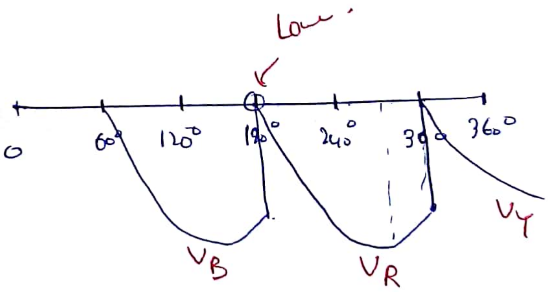
180°

$\left(\frac{5\pi}{6} + \alpha\right)$

U

$(150 + 150)$

300°



For $\alpha = 150^\circ$ For Resistive remove -ve voltage i.e we will get no voltage

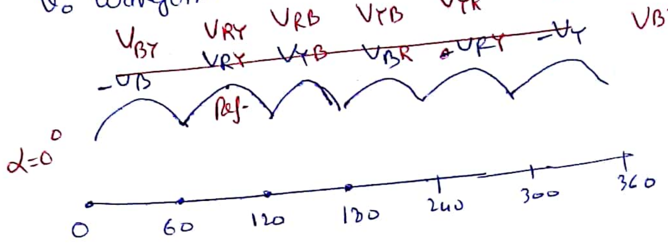
draw back of 3 pulse is that source current contain dc which saturate Xmer. core.

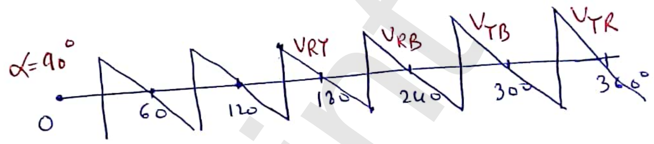
6 pulse

Let $V_{RY} = V_{mL} \sin\omega t$

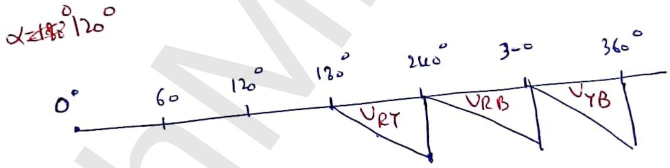
α	L $\left(\frac{\pi}{3}+\alpha\right)$ $L = 60+\alpha$	U $\left(\frac{2\pi}{3}+\alpha\right)$ $U = 120+\alpha$
$\alpha = 0$	$L = 60+0 = 60$	$U = 120$
$\alpha = 90^\circ$	$L = 60+90 = 150$	$U = 120+90 = 210^\circ$
$\alpha = 120^\circ$	$L = 60+120^\circ = 180^\circ$	$U = 120+120 = 240$
$\alpha = 120^\circ$	$L = 240^\circ$	$U = 300^\circ$

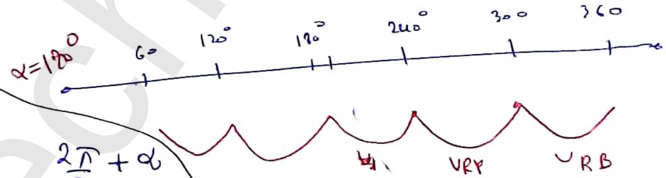
V_o waveform





at $\alpha = 90^\circ$ $V_o = 0$





for $\alpha > 60^\circ$

$\frac{\pi}{3}+\alpha$ $\qquad$ π $\qquad$ $\frac{2\pi}{3}+\alpha$

Discont : R ($\alpha > 60^\circ$)

$$V_o = \frac{V_{mL}}{\pi/3}\left[1+\cos\left(\frac{\pi}{3}+\alpha\right)\right]$$

$0 \leq \alpha \leq 180^\circ$

$+(V_o)_{max} = \frac{3V_{ml}}{\pi}$ $\qquad$ $= \frac{-3V_{ml}}{\pi}$

For Resistive Load α (ranges b/w 0 to 120°)

$0 \leq \alpha \leq 120^\circ \longrightarrow$ R Load

$0 \rightarrow +(V_o)_{max} = \frac{3V_{ml}}{\pi}$

$120^\circ \rightarrow 0V$

$$V_o = \frac{3V_{ml}}{\pi}\cos\alpha$$

at $\alpha = 90$, $V_o = 0$

$\alpha < 90^\circ$, V_o, +ve, I_o +ve

P+

$AC \xrightarrow{P} DC$ (Rectification mode)

$V_o = E_b + IR$

used for charging of battery and dc motors.

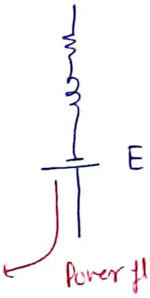
$\alpha > 90^\circ$

V_o^-, I_o+ $\therefore$ P−

$AC \xleftarrow{P} DC$ (Inv)

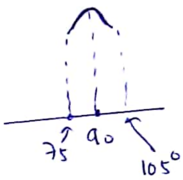
$V_o = -E + I_o R$

used in Solar cells.



Power flow from DC to AC

For 12 pulse



6 pulse

For inductive Load $V_o = \frac{3V_{ml}}{\pi}\cos\alpha$

$0 \leq \alpha \leq 180^\circ$

max^m avg voltage $= \frac{3V_{ml}}{\pi}$

min^m avg voltage $-\frac{3V_{ml}}{\pi}$

~~Here α is less than 60°~~

6 pulse

For Resistive Load

if $\alpha < 60^\circ$ $V_o = \frac{3V_{ml}}{\pi}\cos\alpha$

if $\alpha > 60^\circ$ $V_o = \frac{V_{ml}}{\pi/3}\left[1+\cos\left(\frac{\pi}{3}+\alpha\right)\right]$

$0 < \alpha \leq 120$

+ (V) max ~~max avg~~ $\frac{3V_{ml}}{\pi}$

0V.

Soln :- 3 pulse

R load

	L	U
	$\frac{\pi}{6}+\alpha$	$\frac{5\pi}{6}+\alpha$
$\alpha=15^\circ$	$30+\alpha$	$150+\alpha$

$$V_{or} = \frac{V_{mph}}{\sqrt{2 \cdot \frac{2\pi}{3}}} \left\{ \frac{4\pi}{6} + \frac{1}{2}\left[\sin\left(\frac{\pi}{3}+2\alpha\right) - \sin\left(\frac{5\pi}{3}+2\alpha\right)\right]\right\}^{1/2}$$

$$= V_{ml} \left\{ \frac{\qquad}{4\pi} \right\}^{1/2}$$

$$V_{or} = V_{mL} \left\{ \frac{1}{6} + \frac{1}{8\pi} \sqrt{3} \cos\alpha \right\}^{1/2}$$

$$P = I_{or}^2 R = \frac{V_{or}^2}{R}$$

for $\alpha = 15^\circ$ $\boxed{7.243 \text{ KW}}$

$\alpha = 60^\circ$

$\alpha > 30^\circ$ means Upper limit $\int 180^\circ$

For Resistive Load

Upper limit always don't go above 180° i.e. 180°

$$V_{or} = \frac{V_{mL}}{2\sqrt{\pi}} \left\{ \left(\frac{5\pi}{6} - \underset{\uparrow \pi/3}{\alpha} \right) + \frac{1}{2} \sin\left(\frac{\pi}{3} + 2\alpha \right) \right\}^{1/2}$$

$$\boxed{P = \frac{V_{or}^2}{R} = 4\ KW}$$

Q A

Q A 3Φ Half wave controlled rectifier is operated from a 3Φ 230V, 50Hz supply with load resistance of 10Ω an avg o/p voltage is 25% max possible o/p voltage (a) determine the Firing angle α

(b) determine the avg and rms value of load current

Sol^n : 3 pulse max^m o/p voltage

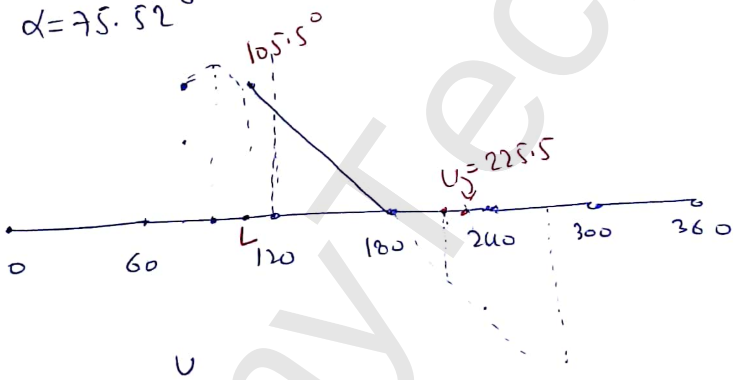
$$V_0 = \frac{3V_{ml}}{2\pi} \cos\alpha =$$

at $\alpha = 0$

$$V_{omax} = \frac{3V_{ml}}{2\pi}$$

$$0.25 \; \frac{3V_{ml}}{2\pi} = \frac{3V_{ml}}{2\pi} \cos\alpha \times \cancel{0.25}$$

$$\alpha = 75.52^\circ$$



L	U
$\left(\frac{\pi}{6}+\alpha\right)$	$\left(\frac{5\pi}{6}+\alpha\right)$
$(30+75.5)$	$(150+75.5)$
105.5	225.5

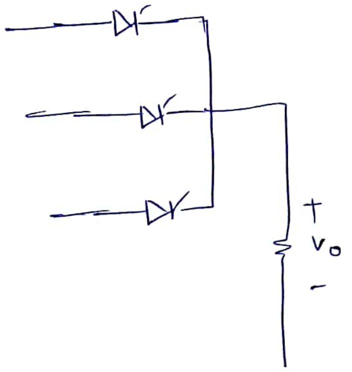
$$V_{oavg} = \frac{3}{2\pi}\left[\int_{105.5^\circ}^{180^\circ} V_m \sin\omega t\right]$$

By Sir.

$0 \le \alpha \le 150$ ← R load

$\downarrow$ $(V_o)_{max}$ $\downarrow$ 0V

L $\left(\frac{\pi}{6}+\alpha\right)$ U $\left(\frac{5\pi}{6}+\alpha\right)$ when $\alpha < \frac{\pi}{6}$



when $\alpha > \pi/6$

L $\left(\frac{\pi}{6}+\alpha\right)$ U (π)

L $\frac{\pi}{6}+\alpha$ U $\frac{5\pi}{6}+\alpha$ $\left(\alpha \le \frac{\pi}{6}\right)$ R load

$$V_o = \frac{3V_{ml}}{2\pi}\cos\alpha$$

$\alpha > \frac{\pi}{6}$, $U > \pi$. R load $\alpha > \frac{\pi}{6}$

L $\left(\frac{\pi}{6}+\alpha\right)$ U π

$$V_o = \frac{V_{mph}}{2\pi/3}\left[1+\cos\left(\frac{\pi}{6}+\alpha\right)\right]$$

Doubt Here: (wow).

I don't know α so which formula to use.

So trial w/ from left side formula

$$V_o = 25\% \text{ of } (V_o)_{max}$$

$$V_o = \frac{1}{4}\cdot\frac{3V_{ml}}{2\pi}$$

$$\frac{3V_{ml}}{2\pi}\cos\alpha = \frac{1}{4}\cdot\frac{3V_{ml}}{2\pi}$$

$\alpha = 75.5$ ✗. if we use above formula then α should come less than 30°. but it came 75.5°.

$\sqrt{3}\times V_{mph}$

$$V_o = \frac{3V_{mph}}{2\pi}\left[1+\cos\left(\frac{\pi}{6}+\alpha\right)\right] = \frac{1}{4}\cdot\frac{3V_{ml}}{2\pi}$$

$$1+\cos(30+\alpha) = \frac{\sqrt{3}}{4}$$

$$\alpha = 94.5^\circ$$

$$I_0 = \frac{V_0}{R}$$

$V_0 =$ 25% of $(V_0)_{max}$

$$= \frac{1}{4} \cdot \frac{3V_{ml}}{2\pi}$$

$$= \frac{1}{4} \cdot \frac{3 \cdot 230\sqrt{2}}{2\pi}$$

$$= 38.8\, V$$

$$V_{or} = \frac{V_{mL}}{2\pi} \left\{ \left(\frac{5\pi}{6} - \alpha \right) + \frac{1}{2} \cdot \sin\left(\frac{\pi}{3} + 2\alpha\right) \right\}^{1/2}$$

$94.5 \times \frac{\pi}{180°}$

$$I_{or} = \frac{V_{or}}{R}$$

Find the rectification η for the above Problem

$$\text{Rectification } \eta = \frac{P_{dc}}{P_{ac}} = \frac{V_o \cdot I_o}{V_{or} \cdot I_{or}} \times 100$$

$$TUF = \frac{P_{dc}}{\text{KVA rating of T/F}}$$

$$= \frac{V_o \cdot I_o}{V_{sr} \cdot I_{sr}}$$ ← secondary rms voltage and current of Xmer.

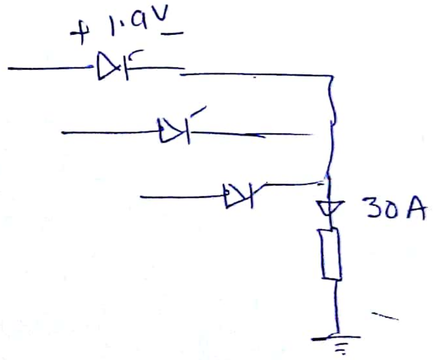
Q A 3ϕ Half wave phase controlled rectifier is fed from a 3ϕ, 400 volts 50Hz source and is connected to a load taking a const current of 30 A SCR's are having a v. drop of 1.9 volt during their conduction calc

(a) Avg load voltage at Firing angle of $\alpha = 30°$ and $\alpha = 60°$

(b) avg and rms current ratings of thyristors and as well as PIV

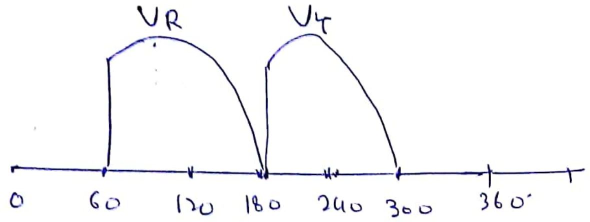
(c) Power loss in each SCR

(d) if free wheeling diode is connected across the load Find the avg value of o/p voltage, avg and rms value of free wheeling diode current for firing angles of 30° and 60°.



$\alpha = 30^\circ$

L	U
$\left(\frac{\pi}{6}+\alpha\right)$	$\left(\frac{5\pi}{6}+\alpha\right)$
$(30+30)$	$(150+30^\circ)$
60	180°



$$V_0 = \frac{3V_{ml}}{2\pi}\cos\alpha$$

$$= \frac{3 \times 400\sqrt{2}}{2\pi}\cos 30^\circ$$

By sir — load current continuous conduction. (with 80)

for $\alpha = 30^\circ$ $\quad \frac{\pi}{6}+\alpha \qquad \frac{5\pi}{6}+\alpha$

$$V_0 = \frac{3V_{ml}}{2\pi}\cos\alpha - V_{drop}.$$

this formula derived for Ideal thyristor.

$$V_0 = \frac{3 \times 400\sqrt{2}}{2\pi}\cos 30^\circ - 1.9$$

$V_0 = 232$ volt

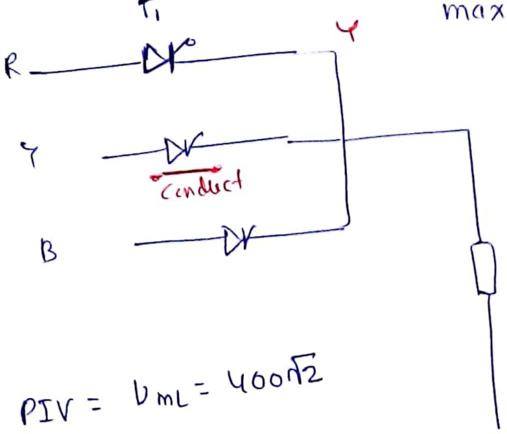
$\alpha = 60^\circ$ $\quad V_0 = \frac{3 \times 400\sqrt{2}}{2\pi}\cos 60^\circ - 1.9$

$V_0 = 133.15V$

(b) $(I_T)_{avg} = I_0\left(\frac{2\pi/3}{2\pi}\right) = \frac{I_0}{3} = \frac{30}{3} = 10\,A$

$(I_T)_{rms} = I_0\left(\frac{2\pi/3}{2\pi}\right) = \frac{I_0}{\sqrt{3}} = \frac{30}{\sqrt{3}} = \sqrt{3}\times 10\ A.$

PIV rating



max^m Rev^r voltage across thyristor = max^m ~~rev~~ ~~voltage~~ line voltage.

PIV = $V_{mL} = 400\sqrt{2}$

(c) Power loss in each thyristor = $(V_{drop})(I_{T\,avg}) = 1.9\times 10 = 19$ watt

(d) For 30° No role of ~~F D~~ free wheeling diode.

so $V_0 = 232$ Same as before. $(I_{FD})_{avg} = (I_{FD})_{rms} = 0.$

$\alpha \le 30°$, $U \le 180°$ | FD shown effect when $U > 180°$

For 60°.

when $\alpha > 30°$ $U > 180°$

$\frac{\pi}{6}+\alpha$ $\underbrace{\quad T \quad}$ π $\underbrace{\quad FD \quad}$ $\frac{5\pi}{6}+\alpha$

during Freewheeling

$V_0 = \frac{V_{mph}}{2\pi/3}\left[1+\cos\left(\frac{\pi}{6}+\alpha\right)\right] - V_{drop}$

L-limit

Time period.

$V_{mph} = \frac{400\sqrt{2}}{\sqrt{3}}$

$= \frac{3\cdot \cancel{400\sqrt{2}}}{2\pi}\left[1+\cos 90°\right] - 1.9$ $= 154$ volts.

$=$ ~~268.19 volt.~~

$\alpha \leq 30$ FD will not conduct.

$$\frac{\pi}{6}+\alpha \qquad\qquad \pi \qquad\qquad \frac{5\pi}{6}+\alpha$$

$$\underbrace{\qquad T \qquad}_{\left(\pi-\frac{\pi}{6}-\alpha\right)} \qquad \underbrace{\qquad FD \qquad}_{\left(\alpha-\frac{\pi}{6}\right)}$$

$$\frac{5\pi}{6}-\alpha$$

conduction angle of thyristor

$\alpha > 30$

$\alpha = 60 = \pi/3$

$$(I_{FD})_{avg} = I_0\left[\frac{\alpha-\pi/6}{2\pi/3}\right]$$

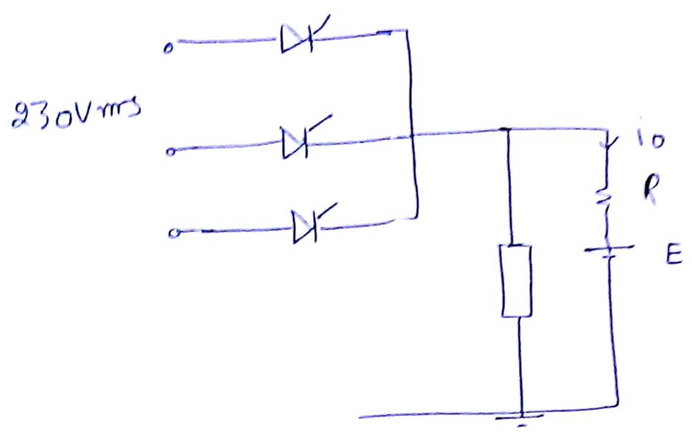
$$= 30\left[\frac{\frac{\pi}{3}-\frac{\pi}{6}}{2\pi/3}\right] = 30 \times \left(\frac{30}{120}\right)$$

$$= 30\left[\frac{\pi \; 3}{6 \; 2\pi}\right]^{\cancel{1/2}} = \frac{30}{4} = 7.5\text{ A}$$

$$(I_{FD})_{rms} = 30\left[\frac{\pi/3-\pi/6}{2\pi/3}\right]^{1/2} = 30\left(\frac{30}{120}\right)^{1/2} = 15\text{ A}$$

Q A battery consisting R=5Ω E=150 Volts is charging through a 3 ϕ Half wave phase controlled rectifier. I/P voltage to the converter is 230V (rms) from any line to neutral and firing angle for the SCR is 30° find the avg current flowing through the battery.

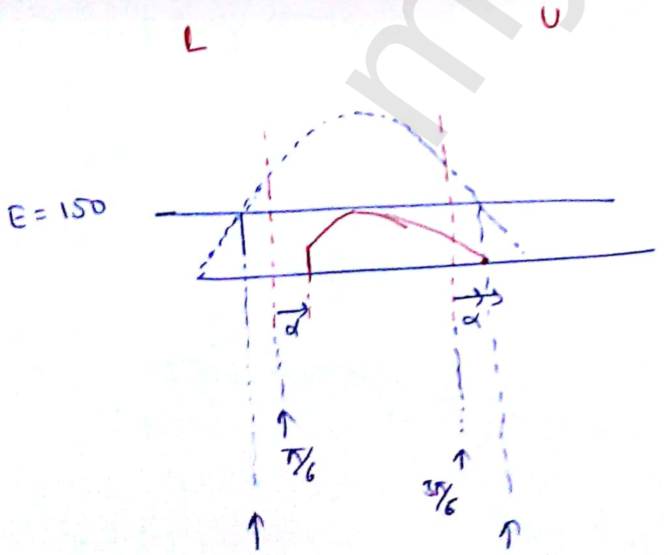
Sol^n 3 pulse



$230\ V(rms) = V_{ph\,rms}$

L $\left(\frac{\pi}{6}+\alpha\right)$ U $\left(\frac{5\pi}{6}+\alpha\right)$

$\theta_1 = \sin^{-1}\left(\frac{E}{V_m}\right) = \sin^{-1}\left(\frac{150}{230\sqrt{2}}\right) = 27.46$



$\theta_1 = 27.46$ $\theta_2 = \pi - 27.46° = 152.53° \times \frac{\pi}{180°}$

$$I_0 = \frac{1}{2\pi/3} \int_{\pi/6+\alpha}^{\theta_2} \left(\frac{V_{mph} \cdot \sin\omega t - E}{R} \right) d\omega t$$

$V_{mph} = 230\sqrt{2}$

$$I_0 = \frac{1}{2\pi/3} \left[\int_{60^\circ}^{152.53^\circ} \frac{230\sqrt{2}}{5} \sin\omega t - \int_{60^\circ}^{152.53^\circ} \frac{150}{5} \, d\omega t \right]$$

$$\frac{3}{2\pi} \left\{ \frac{230\sqrt{2}}{5} (\cos 60^\circ - \cos 152.53^\circ) - \left(\frac{150}{5}\right) \left(152.53 - 60^\circ \right) \times \frac{\pi}{180} \right\}$$

$$\frac{3}{2\pi} \left\{ 90.24 - 48.44 \right\}$$

$$\boxed{I_0 = 19.96 \text{ A}}$$

Date 20 August

Q A 3ϕ full controlled Bridge conv^r, 415 volt supply ~~Find~~ 0.04 Ω Resistance/phase and .25 Ω reactance per phase) A is operating in the inversion mode at a firing advance angle of 35°. the load is RLE load with R = 0.2 Ω and inductance is large enough to make load current constt at 80 Amp. and the load emf is E volts find the load emf E.

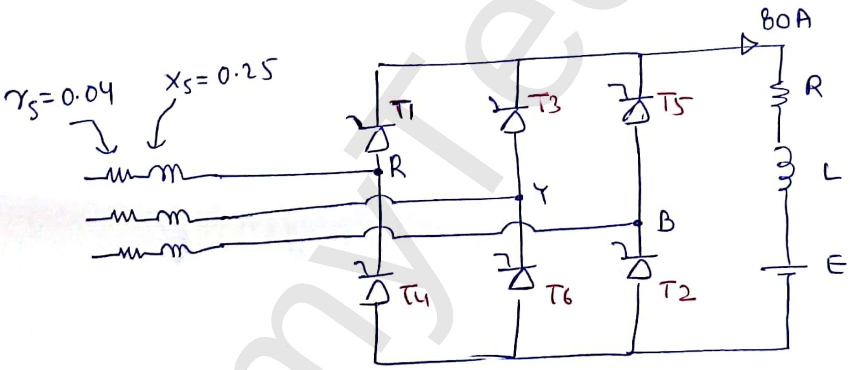
Sol^n 6 pulse.

source resistance and reactance given consider them.

$\alpha = 35^0$

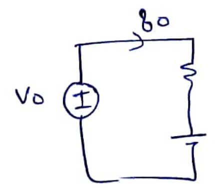
Inductive load.

$\left(\frac{\pi}{3}+\alpha\right)$ $\left(\frac{2\pi}{3}+\alpha\right)$



Some time they may given ~~Source~~ drop in thyristor.
Here not given

$V_o =$



ΔV_{do}

m = 6 $6fL_sI_o$

$\frac{V_o - E}{R} = I_o$

~~this Formula valid~~

$V_o = V_{do}\cos\alpha - \Delta V_{do}$

V_{do} → max^m avg o/p voltage

ΔV_{do} → reduction in o/p voltage

m	ΔV_{do}
1	fL_sI_o
2.	$4fL_sI_o$
3.	$3fL_sI_o$
6.	$6fL_sI_o$

← In bimbra this Formula using

$$\boxed{\begin{aligned} V_{do} &= (V_o)_{max} \\ &= \frac{2V_m}{\pi} \quad (m=2) \\ &= \frac{3V_{ml}}{2\pi} \quad (m=3) \\ &= \frac{3V_{ml}}{\pi} \quad (m=6) \end{aligned}}$$

$V_o = V_{do}\cos\alpha$ ← Formula applicable when every thing is ideal.

6 pulse

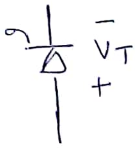
$V_o = V_{do}\cos\alpha - \underbrace{\Delta V_{do}}_{\text{source inductance drop}} - \{\text{source Resistance drop}\} - \{\text{drop in thyristor} \times 2\}$

$V_o = V_{do}\cos\alpha - 6fL_sI_o - 2r_sI_o - 2V_T$

I_o → the cont current which is flowing in load

$2r_sI_o$ → {bcz at a time any two thyristor will be in conduction}.

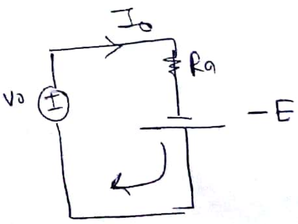
$2V_T$ → drop of two thyristors.



$V_o = \frac{3V_{ml}}{\pi}\cos\alpha - 6fL_sI_o - 2r_sI_o$

eqn for inversion mode =

$\boxed{V_o = -E + I_oR_a}$



$\alpha = 180 - \text{firing advance angle} = 180 - 35^\circ = 145$

$V_o = \frac{3 \times 415 \times \sqrt{2} \times (\cos 145^\circ)}{\pi} - 6 \times 50 \times \cancel{0.25} L_s \times 80 - 2 \times .04 \times 80$

$X_L = \omega L =$

$0.25 = 2\pi 50 \times L$

$L = \frac{0.25}{2\pi 50}$

$V_o = -459 - 19.09 - 6.4$

$V_o = -484.49$

$V_o = -E_b + I_o R_a$

$E_b = I_o R_a - V_o$

$E_b = 80 \times 0.2 - (-484.49)$

$\boxed{E_b = 500.5 \text{ V}}$

Q A 3ϕ full conv^r is fed from a 230 V 50Hz supply having source inductance of 4mH/phase the Load current 10 A & ripple free

(a) Calculate the voltage drop in the dc o/p voltage due to source inductance

(b) If dc o/p voltage is 210 volts find the firing angle and overlap period.

(c) In case the bridge is made to operate as line commutated inverter with dc voltage of 210 volts find the firing angle for the same load current.

Sol^n

only source inductance given

(a) 6 pulse

$V_o = V_{do} \cos\alpha - \Delta V_{do}$

$= \frac{3V_{ml}}{\pi} \cos\alpha - 6 f L_s I_o$

$= \frac{3 \times 230\sqrt{2}}{\pi} \cos\alpha -$

$\Delta V_{do} = 6 f L_s I_o$

$= 6 \times 50 \times 4 \times 10^{-3} \times 10$

$= 12$ volt.

② $V_o = 210$

$V_o = V_{do}\cos\alpha - 6fL_sI_o$

$210 = \dfrac{3V_{ml}}{\pi}\cos\alpha - 12$

$222 = \dfrac{3\times 230\sqrt{2}}{\pi}\cos\alpha$

$\alpha = 44.38^\circ$

overlap angle

③ $\boxed{\Delta V_{do} = \dfrac{V_{do}}{2}\left[\cos\alpha - \cos(\alpha+\mu)\right] = 6fL_sI_o}$

$= \dfrac{3V_m}{2\pi}\left[\cos 44.38 - \cos(\alpha+\mu)\right] = 12$

$\cos 44.38 - \cos(\alpha+\mu) = 0.0772675$

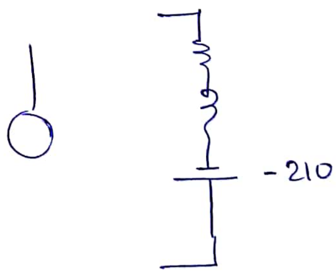
$\cos(\alpha+\mu) = 0.63744$

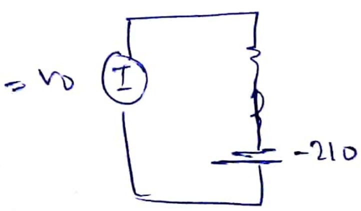
$\alpha+\mu = 50.398$

$\mu = 50.398 - 44.38 = 6.018^\circ$

③ we need to find α in inversion mode.

load current = same = ~~80 A~~ 10.





(7) inversion mode 80

** Imp

$\boxed{V_0 = -210}$ given.

$-210 = V_{do} \cos\alpha - 6 f L_s I_0$

$-210 = \frac{3 V_{ml}}{\pi} \cos\alpha - 12$

$-210 + 12 = \frac{3 V_{ml}}{\pi} \cos\alpha$

$\boxed{\alpha = 129.6^\circ}$

---

m	ΔV_{do}
1	$L I f$
2	$4 L I f$
3	$3 L I f$
4	$6 L I f$

same

$\Delta V_{do} = \frac{V_{do}}{2}\left[\cos\alpha - \cos(\alpha + u)\right]$ ← this Formula for 2, 3, 6 pulse.

$V_{do} = max^m$

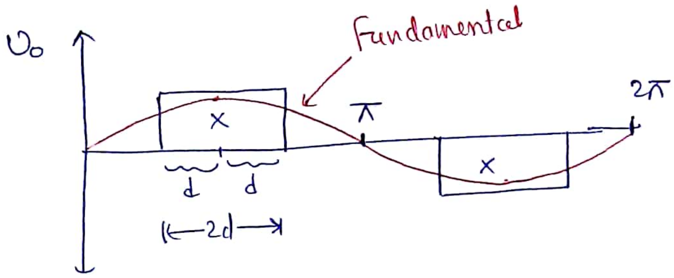
$4 L I f \rightarrow \frac{2 V_m}{\pi}$

$3 L I f \rightarrow \frac{3 V_{ml}}{2\pi}$

$6 L I f \rightarrow \cancel{6m}\ \frac{3 V_{ml}}{\pi}$

$V_0 = V_{do} \cos\alpha - \Delta V_{do}$

① Quasi- Squarewave.



$n = 1, 3, 5, 7 \ldots$ [Even harmonic are ~~redu~~ removed due to Halfwave Symmetry]

$$C_n = \frac{4X}{n\pi} \sin nd$$

$$V_o = a_o + \sum_{n=1,\cancel{2},3,\cancel{4},5}^{\infty} C_n \sin(n\omega t + \phi_n)$$

$$C_1 = \frac{4X}{\pi} \sin d$$

C_1 can be less than or more than x depends on pulse width

as pulse width more C_1 ↑es and more than x.

" " " less C_1 ↓es " less than x.

$$\underset{\text{DC}}{a_o} + \sum_{n=1}^{\infty} (a_n \cos n\omega t + b_n \sin n\omega t)$$

$$a_n = \frac{2}{T}\int_0^T f(t) \cos n\omega t \, dt$$

$$b_n = \frac{2}{T}\int_0^T f(t) \cdot \sin n\omega t \, dt$$

when x axis is in radian

let $T = 2\pi$ $\quad a_n = \frac{1}{\pi}\int_0^{2\pi} f(\omega t) \cdot \cos n\omega t \cdot d\omega t$

$$b_n = \frac{1}{\pi}\int_0^{2\pi} f(\omega t) \cdot \sin n\omega t \cdot d\omega t.$$

$C_n = \sqrt{a_n^2 + b_n^2}$, $\phi_n = \tan^{-1}\left(\frac{a_n}{b_n}\right)$

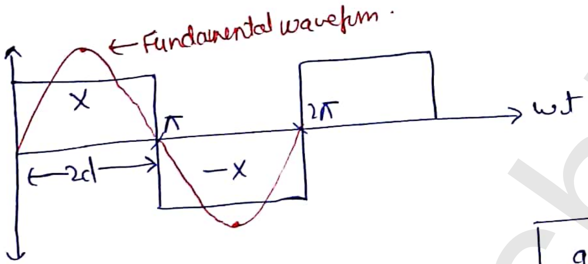
$$V_o = \underbrace{a_o}_{DC} + \sum_{n=1}^{\infty} \underbrace{C_n \cdot \sin(n\omega t + \phi_n)}_{\text{AC component}}$$

For Quasiwave $2d < \pi$

for square wave $2d = \pi$

(2) Square wave $2d = \pi$

$d = \pi/2$



$n = 1, 3, 5, 7 \cdots$

$$\boxed{g = \frac{V_{01}}{V_{0r}} =}$$

$C_n = \frac{4X}{n\pi}$

$g = \frac{2\sqrt{2}}{\pi} = 0.9$

$C_1 = \frac{4X}{\pi}$

$\boxed{THD = 48.34\%}$ For Square.

$C_1 > X$

**** Quasi is better bcz TDH for Quasi is less than the THD of square wave.

let in Quasi $2d = \frac{2\pi}{3} = 120°$

$d = \frac{\pi}{3}$

$C_n = \frac{4X}{n\pi} \sin \frac{n\pi}{3}$ d

Triplen Harmonic are eliminated.

So in Quasi - even Harmonic are already absent

so triplen also absent

So Quasi better than Square

Harmonic present in Quasi wave. when $\boxed{2d = \frac{2\pi}{3}}$

$n = 6K \pm 1$ Predominent Harmonic.

$n = 1, 5, 7, 11, 13, 17, 19 \ldots$

$g = \frac{3}{\pi}$, THD = 31%

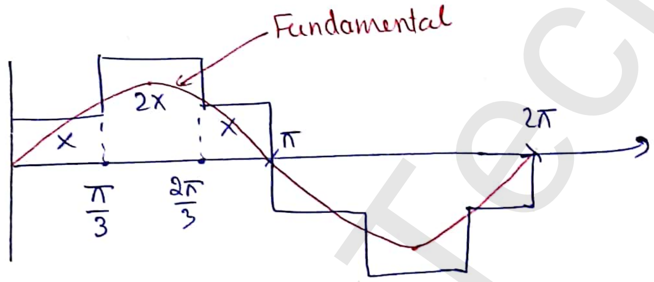
$g =$ THD $= \sqrt{\left(\frac{1}{g}\right)^2 - 1}$

$g = \frac{2\sqrt{2}\sin d}{\sqrt{(2d)}\cdot\pi}$

In rectifiers. generally fundamental frw = 50Hz so we can be asked to find the frq of Harmonic.

In ~~ed~~ Inv^r frq may not be 50Hz.

③ 6 step wave form



$\boxed{n = 6K \pm 1}$ $g = \frac{3}{\pi}$ THD = 31%.

$C_n = \frac{6X}{n\pi}$

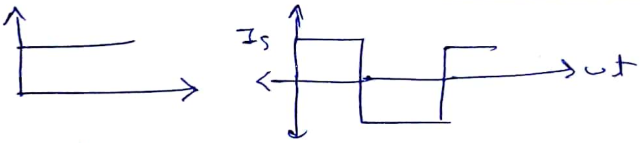
$C_1 = \frac{6X}{\cancel{2}\pi}$

$C_1 = \frac{3(2X)}{\pi}$

$C_1 > X$

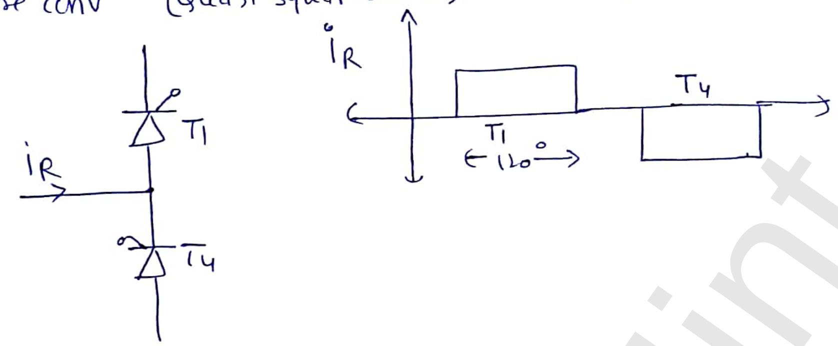
$C_1 < 2X$

2 pulse Rectifier



1ϕ Semi $conv^c$ for I_s — quasi Square wave

6pulse $conv^r$ {Quasi Square wave} Source phase current

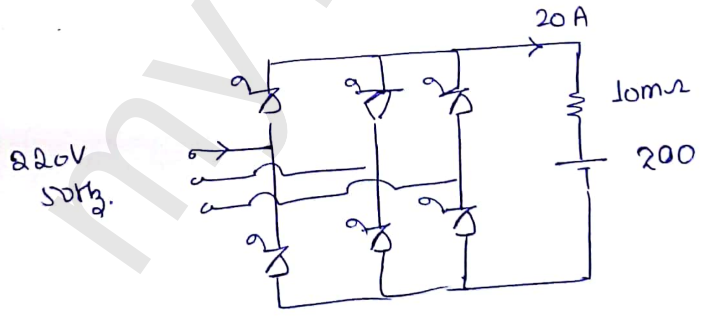


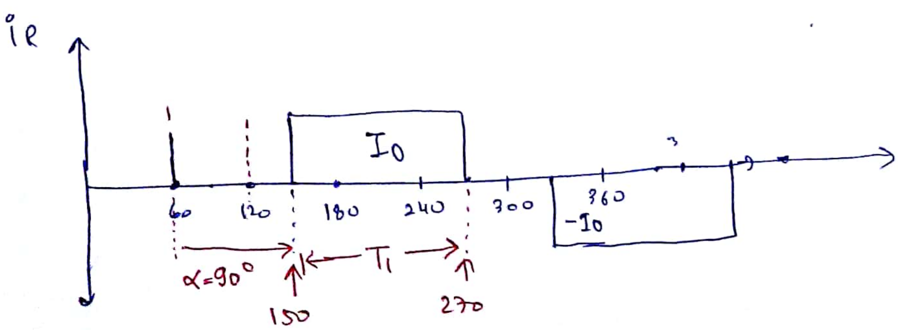
Q A Battery with a ~~normal~~ nominal voltage of 200 volts and internal resistance 10 mΩ has to be charged at constt current of 20 A. from a 3ϕ 220volts 50Hz ac supply. which of the following converter ckt will given better performance in terms of distortion factor in the source current and fundamental power factor. and total i/p power factor.

a) 3ϕ full $conv^r$

b) 3ϕ semi $conv^r$ (consider $\alpha > \pi/3$)

Soln





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Scanned by CamScanner

$\alpha_1 = 90^\circ$

$2d = \frac{2\pi}{3}$

$n = 6K \pm 1$

$g = \frac{3}{\pi}$ THD = 31%

$PF = g \cdot FDF$

$PF = \frac{3}{\pi} \cdot \cos\alpha$

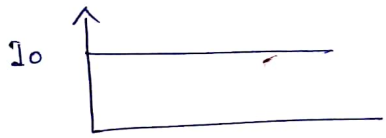
*** Active power

Fundamental angle

$P = \sqrt{3}\, V_{sr} \cdot I_{s1} \cos\alpha$

$= V_o \cdot I_o$

For Full Conv^r: High inductive load



no. of pulse.

AC side Harmonic (i_s) $\longrightarrow mK \pm 1$

2 pulse. $\longrightarrow 2K \pm 1 = 1, 3, 5, 7,$

6 pulse. $\longrightarrow 6K \pm 1$

12 pulse $\longrightarrow 12K \pm 1 = 1, 11, 13, 23, \ldots$

DC side Harmonic for o/p side waveform (V_o) $\rightarrow mK$

$\rightarrow 2K = 2, 4, 6 \ldots$

$\rightarrow 6K = 6, 12, 18$

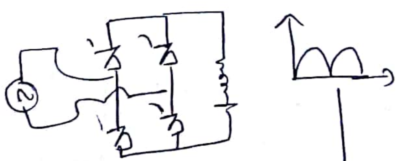
$\rightarrow 12K = 12, 24 \ldots$

In exam they can ask freq of Harmonics.

Ask? $m = 2$

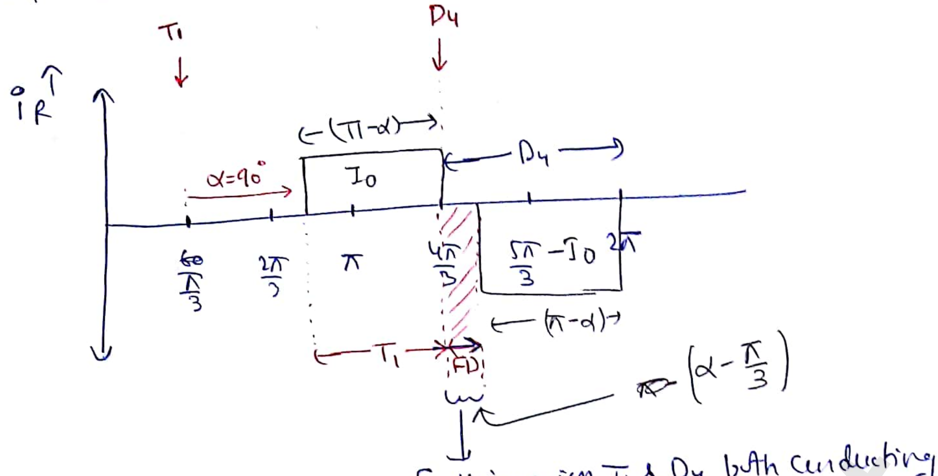
DC side Harmonic = $2K$

2, 4, 6,

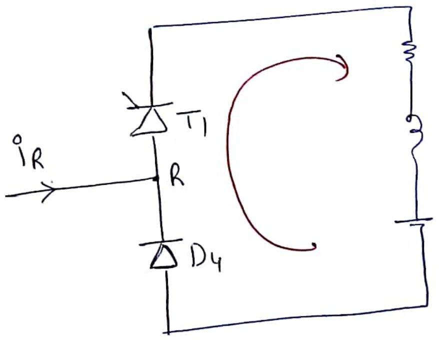


How we will know that this waveform contain 2, 4, 6 Harmonics.

(b) 3ϕ Full wave semiconv^r (drawing waveform for $\alpha=90°$)



For this region T_1 & D_4 both conducting so freewheeling.



this current waveform not Half wave symmetric so even and odd harmonic both present.

Rms value of fundamental source current is

Remb^r this →

$$\boxed{I_{S1} = \frac{\sqrt{6}}{\pi} I_o \cdot \cos\frac{\alpha}{2}}$$

$$\boxed{FDF = \cos\frac{\alpha}{2}}$$

$$I_{Sr} = I_o\left(\frac{\pi-\alpha}{\pi}\right)^{1/2} \qquad g = \frac{I_{S1}}{I_{Sr}} = \cancel{I_o\left(\frac{\pi-\alpha}{\pi}\right)^{1/2}}$$

$$g = \frac{\frac{\sqrt{6}}{\pi} I_o \cos\frac{\alpha}{2}}{I_o\left(\frac{\pi-\alpha}{\pi}\right)^{1/2}}$$

$$\boxed{g = \sqrt{\frac{6}{\pi(\pi-\alpha)}} \cdot \cos\frac{\alpha}{2}} \qquad \boxed{THD = \left(\frac{1}{g^2} - 1\right)^{1/2}}$$

↑ Here g is ~~more~~ reduced bcz here Harmonics are more.

$\uparrow PF = \downarrow g$ FDF$\uparrow$

FDF is $\uparrow$ed bcz $\cos\left(\frac{\alpha}{2}\right)$ this term is less than $\frac{\alpha}{2}$

as $g\downarrow$ THD$\uparrow$

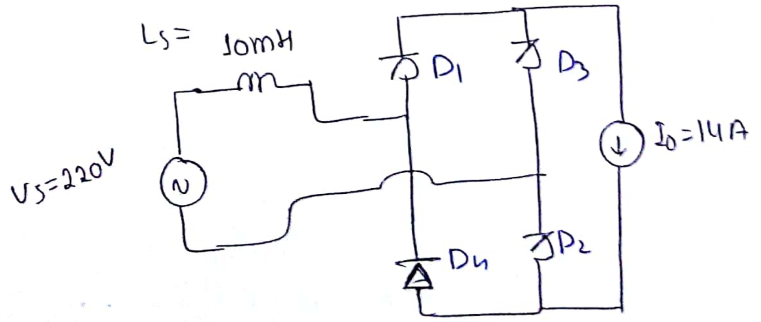
$\uparrow THD = \left(\frac{1}{g^2} - 1\right)^{1/2}$ THD$\uparrow$ bcz even Harmonic also present.

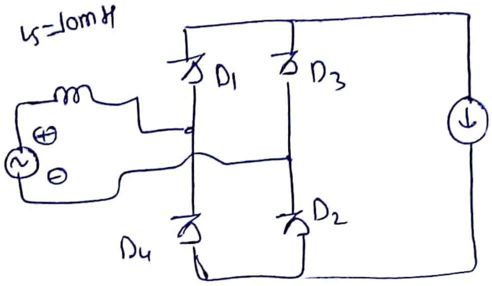
The supply current contains both even and odd harmonics except triplen harmonic (bcz multiple of 3rd Harmonic not there)

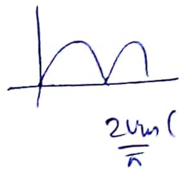
For same avg DC load current(I_0) and firing angle α 3ϕ semiconverter has better fundamental p.f., and power factor (PF) but the distortion factor is lesser (i.e. $g\downarrow$) when compared with the 3ϕ fully controlled rectifier. THD is more in 3ϕ semi conv^r

* 1ϕ semi conv^r is better in every aspect than 1ϕ full conv^r.

Q The Figure below is an uncontrolled diode bridge rectifier supplied from 220V, 50Hz 1ϕ ac source the load ~~co~~ draws a ctt current of 14 A. the cond^c angle of the diode D_1 in degrees is.







Con $\Delta U_{do} = \frac{U_{do}}{2}\left[\cos\alpha \mp \cos(\alpha+\mu)\right] = 4 f L_s I_o$

$= \frac{2V_m}{\pi \cdot 2}\left[\cos 0 - \cos\mu\right] = 4 \times 50 \times 10 \times 10^{-3} \times 14$

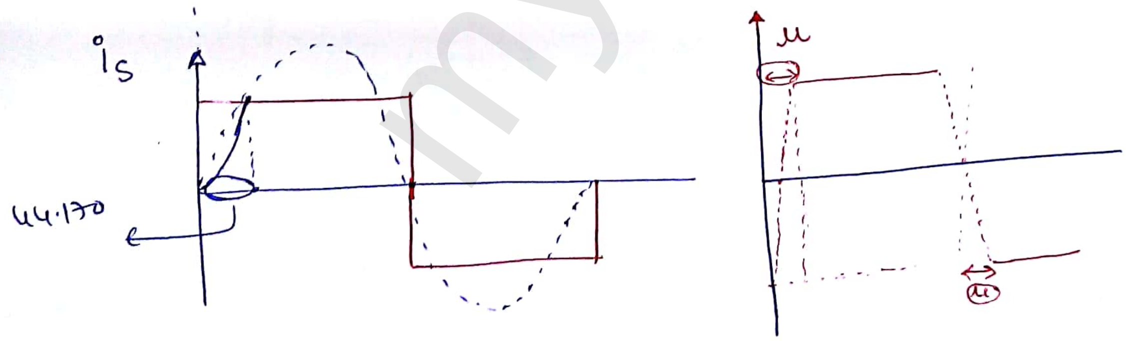
$\frac{V_m}{\pi}\left[1 - \cos\mu\right] = \frac{200 \times 10 \times 14}{1000} = 28$

$(1 - \cos\mu) = \frac{28 \times \pi}{220\sqrt{2}}$

$1 - \cos\mu = 0.2827$

$\cos\mu = 0.71727$

$\boxed{\mu = 44.170^\circ}$

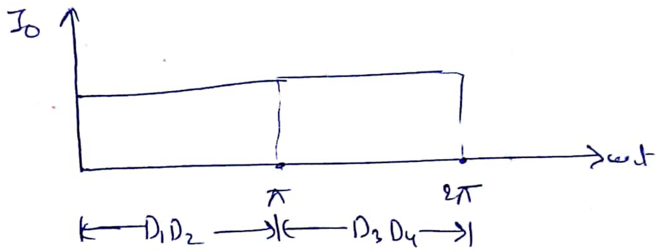


conduction angle of diode = $180 - 44.17$

$= 135.83^\circ$

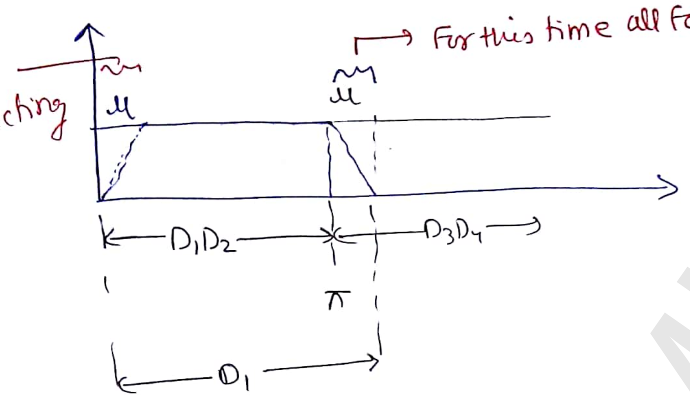
By Sir

when no source inductance.



Here all diode conducting

For this time all four Diode are conducting



$D_1 = 180 + \mu$

$D_1 \rightarrow 180 + 44.17$

Q the i/p voltage given to the conv^r and current drawn are expressed as.

$$v = 300 \sin(100\pi t) + 100 \sin\left(300\pi t + \frac{\pi}{4}\right)$$

$$i = 10 \cdot \sin\left(100\pi t - \frac{\pi}{3}\right) + 5 \sin\left(300\pi t + \frac{\pi}{4}\right) + 2 \cdot \sin\left(500\pi t - \frac{\pi}{6}\right)$$

find the i/p P.F of the converter =

$$PF = \frac{\text{active power}}{\text{Apparent power}}.$$

$$PF = \frac{\frac{300}{\sqrt{2}} \cdot \frac{10}{\sqrt{2}} \cos\left(\frac{\pi}{3}\right) + \frac{100}{\sqrt{2}} \cdot \frac{5}{\sqrt{2}} \cdot \cos\left(\frac{\pi}{4}\right)}{\frac{10}{\sqrt{2}} \times \frac{300}{\sqrt{2}} + \frac{5}{\sqrt{2}} \cdot \frac{100}{\sqrt{2}}}$$

$$PF = \frac{750 + 176.77}{1500 + 250} = 0.529$$

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By Sir

In voltage also Harmonic are present.

If $v = 300 \sin(100\pi t)$

$i =$ same as given

then we can use

$PF = g \cdot FDF$

but Here we can't use $pf = gFDF$

$$PF = \frac{\text{Active power}}{\text{Apparent power}} = \frac{P}{V_{sr} I_{sr}}$$

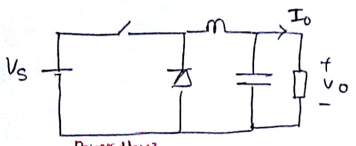
$$V_{sr} = \sqrt{\left(\frac{300}{\sqrt{2}}\right)^2 + \left(\frac{100}{\sqrt{2}}\right)^2} = 223.6067$$

$$I_{sr} = \sqrt{\left(\frac{10}{\sqrt{2}}\right)^2 + \left(\frac{5}{\sqrt{2}}\right)^2 + \left(\frac{2}{\sqrt{2}}\right)^2} = \sqrt{50 + 12.5 + 2} = 8.03$$

$$PF = \frac{926.78\,\omega}{223.606 \times 8.03} = 0.516$$

Choppers.

① Buck



HV $\xrightarrow{\text{Power flow}}$ LV

① Inductor ripple current

$$\Delta I_L = \frac{\alpha(1-\alpha)V_S}{FL}$$

→ Switch & diode block Vs (source voltage)

→ $\frac{V_O}{V_S} = \frac{I_S}{I_O} = \alpha$

→ $I_{max} = \underbrace{(i_L)_{Avg}}_{I_O} + \frac{\Delta I_L}{2}$

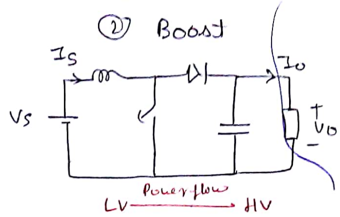
→ Ripple in o/p voltage ($\Delta V_O = \Delta V_C$)

$$\Delta V_O = \Delta V_C = \frac{\alpha(1-\alpha)V_S}{8f^2LC}$$

$$L_c = \frac{(1-\alpha)R}{2f}$$

C_c =

② Boost



LV $\xrightarrow{\text{Power flow}}$ HV

$$\Delta I_L = \frac{\alpha V_S}{FL}$$

→ Switch and diode block V_0 Voltage

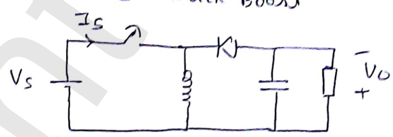
→ $\frac{V_O}{V_S} = \frac{I_S}{I_O} = \frac{1}{1-\alpha}$

$I_{max} = \underbrace{(i_L)_{Avg}}_{I_S} + \frac{\Delta I_L}{2}$

$$\Delta V_O = \frac{\alpha I_O}{FC}$$

$$L_c = \frac{\alpha(1-\alpha)^2 R}{2f}$$

③ Buck Boost



$$\Delta I_L = \frac{\alpha V_S}{FL}$$

→ Switch and diode block ($V_S + V_O$) voltage

→ $\frac{V_O}{V_S} = \frac{I_S}{I_O} = \frac{\alpha}{1-\alpha}$

$I_{max} = \underbrace{(i_L)_{Avg}}_{(I_O+I_S)} + \frac{\Delta I_L}{2}$

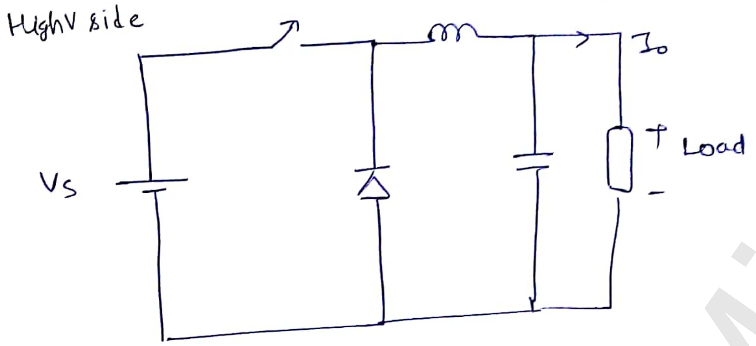
$$\Delta V_O = \frac{\alpha I_O}{fC}$$

$$L_c = \frac{(1-\alpha)^2 R}{2f}$$

Choppers

Buck Conv^r ($V_0 < V_s$)
↑
o/p voltg < i/p supply

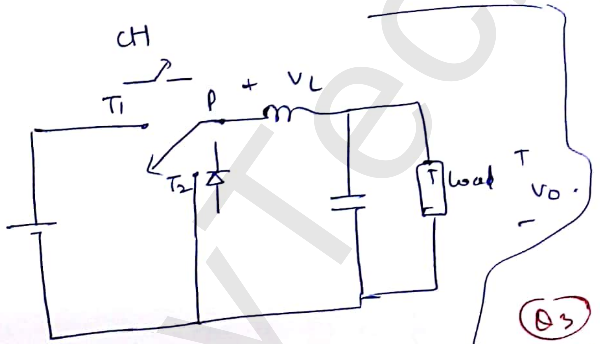
Power flow in Buck.
HV → LV
P. flow in Boost.
LV → HV



PIV of diode — V_s
Holding voltage of CH — V_s

or

Q.1 Ind^c current ripple - { 1st find indu. voltg by apply KVL (by ~~when~~ switch on) }
sol)



Switch ON [$0 < t < T_{on}$)

$-V_s + V_L + V_0 = 0$

$V_L = V_s - V_0$

$L\frac{di}{dt} = V_s - V_0$

⋮

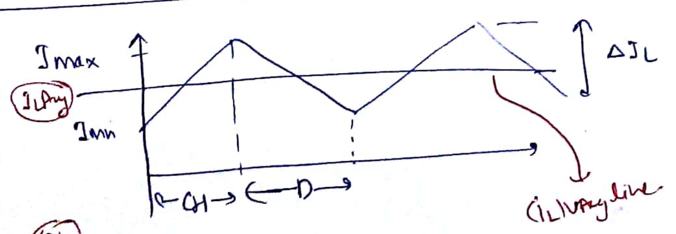
$\Delta I_L = \frac{V_s - \alpha V_s}{L} \cdot T_{ON}$

Q3 $\Delta I_L = \frac{\alpha(1-\alpha)V_s}{fL}$

in Boost and BB this term not present like this

~~Boost~~ * Q2 switch and diode block V_s

• In all 3 conv^r current waveform same.



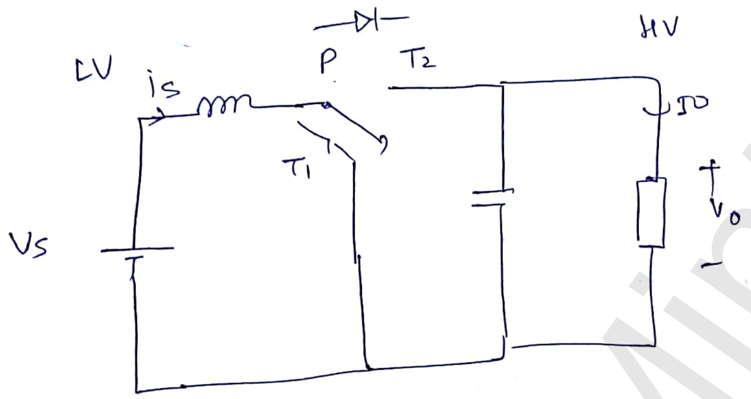
Q4 Tf func^c = $\frac{V_0}{V_s} = \frac{I_s}{I_0} = \alpha$

Q5 what max^m current the diode and switch will handle

$I_{mx} = (i_L)_{Avg} + \frac{\Delta I}{2}$
↓
I_0 → (Buck)
I_s → (Boost)
($I_s + I_0$) → (Buck Boost)

Q-6 if asked Iminimum just put -ve sign

Boost



switch and diode will block load voltage · V_0

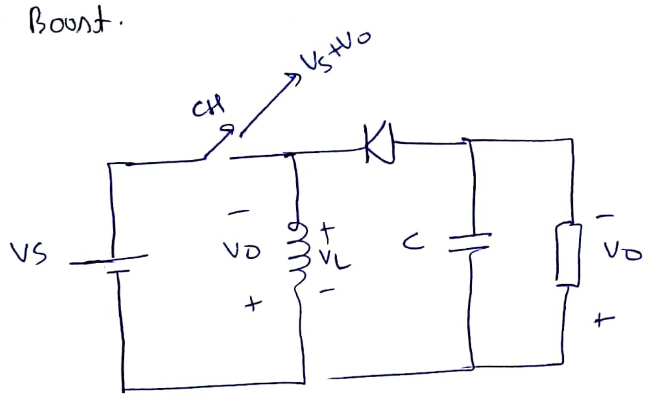
$\Delta I \qquad V_L = V_S$

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

$$di = \frac{V_s}{L}\int_0^{T_{on}} dt = \frac{\alpha V_s}{FL}$$

$$\frac{V_0}{V_s} = \frac{I_s}{I_0} = \frac{1}{1-\alpha}$$

Buck Boost.



Switch & diode will block (V_s+V_0) voltage.

Purchase a switch which block V_s+V_0

PIV of diode

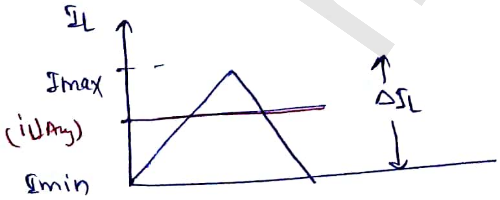
$$\frac{V_0}{V_S} = \frac{I_s}{I_0} = \frac{\alpha}{1-\alpha}$$

***

At last when we don't get any idea

Put $(V_L)_{avg} = 0$ {we may get any unknown}.

At the boundary



Q

$(i_L)_{avg} = \frac{\Delta I_L}{2}$ [this relation holds only at boundary]

I_0 (Buck) — i_L avg is I_0 for Buck

I_s (Boost)

$I_s + I_0$ (Buck Boost)

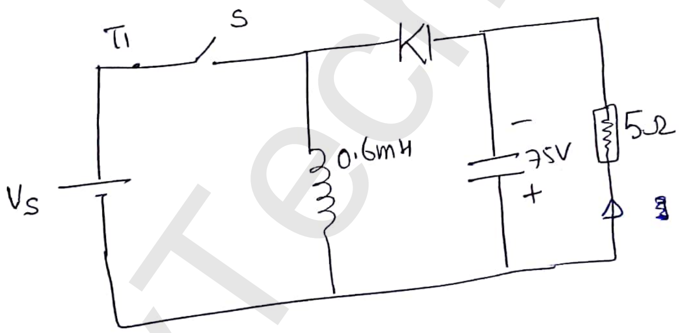
$\underline{\underline{\mathcal{S}}}$ $\Delta V_0 = \Delta V_c = \dfrac{\alpha(1-\alpha)V_s}{8f^2LC}$ (Buck)

Ripple in voltage

$\Delta V_0 = \dfrac{\alpha I_0}{fC}$ (Boost, Buck Boost)

Gate 2017

Q In the ckt shown all elements are ideal and the switch S is operated at 10kHz and 60% duty cycle the capr is large enough so that the ripple across it is negligible and at steady state acquires a voltage as shown in figure. Find the peak value of current drawn from the 50V dc source

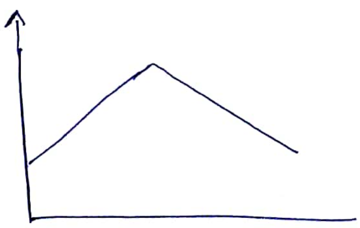


Soln $f = 10\,kHz$

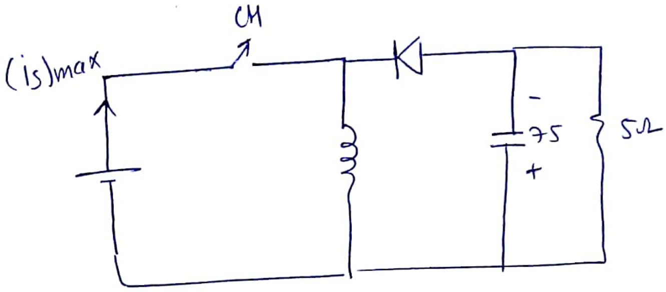
$\delta = 0.6$

$I_{max} = (i_L)_{avg} + \dfrac{\Delta I_L}{2}$

$(I_s + I_0) + \dfrac{\Delta I_L}{2}$



$I_0 = \dfrac{75}{5} = 15A$



$$I_{max} = (i_L)_{avg} + \frac{\Delta I_L}{2}$$

$$= (I_s + I_o) + \frac{\Delta I_L}{2}$$

$$I_o = \frac{75}{5} = 15A$$

$$I_s = \frac{\alpha I_o}{(1-\alpha)}$$

$$I_s = \frac{0.6 \times 15}{1-0.4} = \frac{6 \times 15}{4} = \frac{90}{4} = 22.5A$$

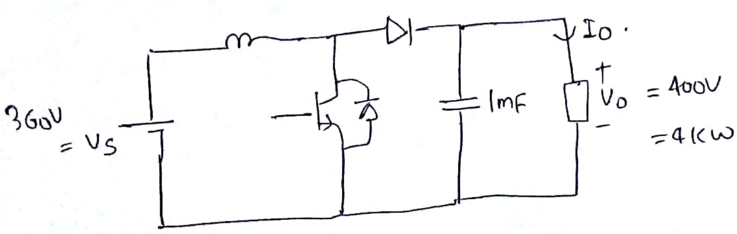
$\Delta I_L =$ for Buck Boost $= \frac{\alpha V_s}{fL} = 5A.$

$$= (22.5 + 15) + \frac{5}{2}$$

$$= 37.5 + 2.5$$

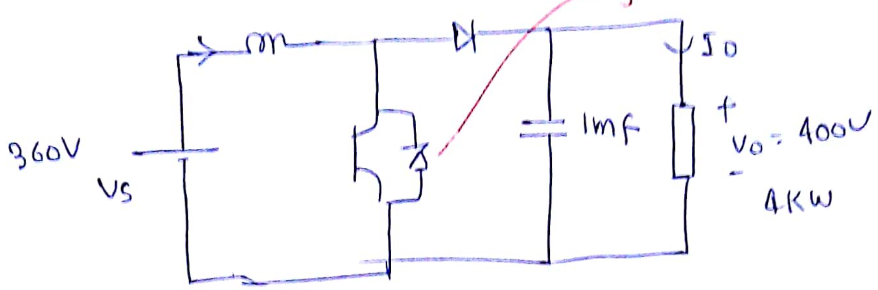
$$(\Delta I_L)_{max} = 40 \text{ A}$$

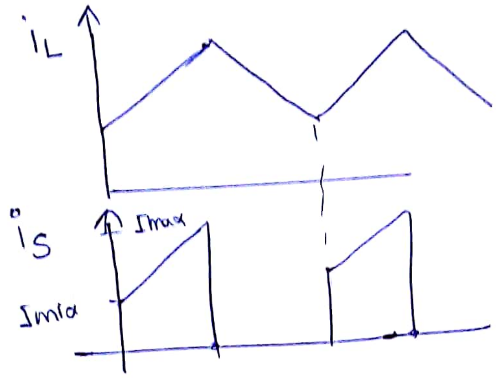
Q A DC–DC Boost converter as shown in the figure below is used to Boost 360V to 400 V. at a power of 4 KW. all devices are ideal. Considering continious inductor current the rms value of current in the switch is ____.



Sol^n Boost Chopper

it just given to confuse its not necessary





$$\cancel{\frac{V_0}{V_S} = \frac{\alpha}{1-\alpha}}$$

$$V_0 = \frac{V_S}{1-\alpha}$$

$\cancel{V_0} =$

$$1-\alpha = \frac{360}{400}$$

$$1 - \frac{360}{400}$$

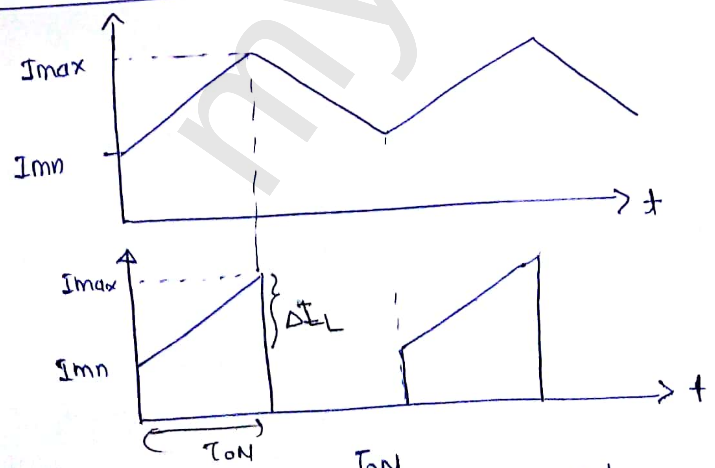
$$1 - 0.9 = \alpha$$

$$\alpha = 0.1$$

$$\left(\frac{I_{max} + I_{min}}{2}\right)$$

$$I_0 = \frac{4000}{400} = 10A.$$

By sig



$$I_{sw_{rms}} = \left\{ \frac{1}{T} \int_0^{T_{ON}} (i_{sw})^2 \cdot dt \right\}^{1/2}$$

$$m = \frac{di}{dt} = \frac{\Delta I_L}{T_{ON}}$$

$$i_{sw} = mt + I_{mn}$$

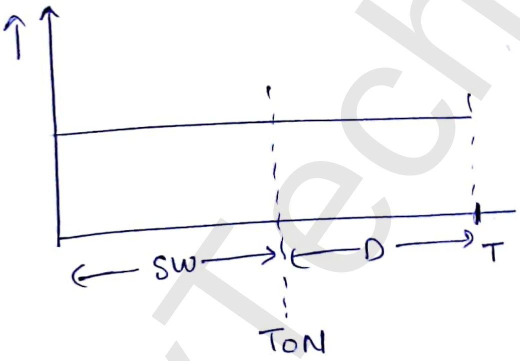
$$\Delta I_L \text{ for Boost} = \frac{\alpha V_S}{fL}$$

frq not given cant find ΔI_L

frq is not given choppers work for high frq assume very high frq

$$\Delta I_L = \frac{\alpha V_S}{fL} \simeq 0$$ } i.e no ripple.

i.e $i_s = i_L$



$$I_{sw_{rms}} = I_S \left(\frac{T_{ON}}{T}\right)^{1/2}$$

$$= \sqrt{\alpha} \cdot I_S$$

$$= \sqrt{0.1} \times 11.1$$

$$= 3.5 A$$

$$\frac{V_0}{V_S} = \frac{I_S}{I_0} = \frac{1}{1-\alpha}$$

$$I_S = \frac{I_0}{1-\alpha}$$

$$I_S = 11.1 A$$

* whenever asked rms draw waveform and if frq not given neglect ripple i.e frq very high.

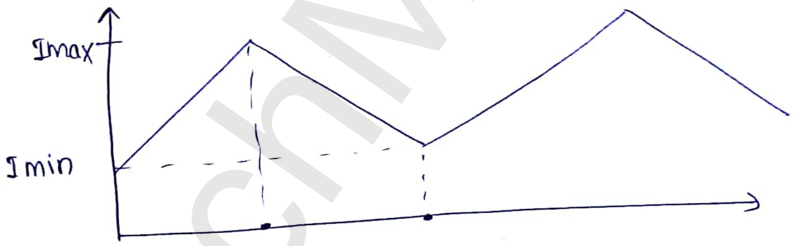
Q The i/p voltage to a boost converter is 8 volts the required avg o/p voltage is 16 volts and the avg load current is 0.5 amp. the ~~the value of~~ switching frq^c of the converter is 30 KHz if L = 160 μH C = 380 μF Calc

(a) peak to peak ripple in the inductor current
(b) Peak value of current in the switch
(c) Rms value of current in the switch
(d) Ripple in the cap^c voltage

Soln.

$V_S = 8$ $\quad V_0 = 16$ $\quad I_0 = 0.5$ $\quad f = 30\,KHz$ $\quad L = 160\,\mu H$ $\quad C = 380\,\mu F$

$$V_0 = \frac{V_S}{1-\alpha}$$



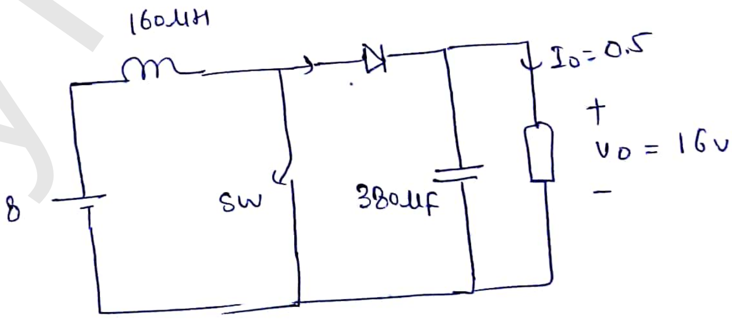
$$16 = \frac{8}{1-\alpha}$$

$$1-\alpha = \frac{8}{16} = \frac{1}{2}$$

$$1-\alpha = 0.5$$

$$\alpha = 0.5 = \frac{T_{ON}}{T}$$

$$T_{ON} = \frac{0.5 \times 1000}{30}$$



/ V

(1) $$\Delta I_L = \frac{\alpha V_S}{fL} = \frac{0.5 \times 8 \; 10^6}{30 \times 10^3 \times 160}$$

$\Delta I_L = 0.833\,A$

hen ripple current is more than avg load current

(2) $$i_{max} = (i_L)_{avg} + \frac{\Delta I_L}{2}$$

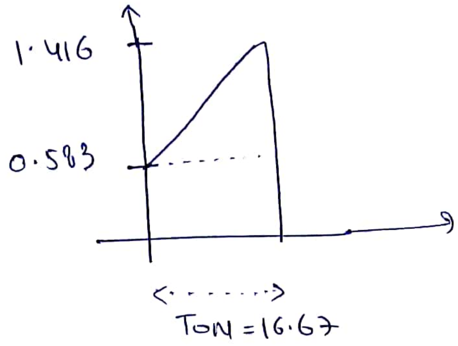
$$= I_S + \frac{0.833}{2}$$

$$\frac{V_o}{V_s} = \frac{I_s}{I_o} = \frac{1}{1-\alpha}$$

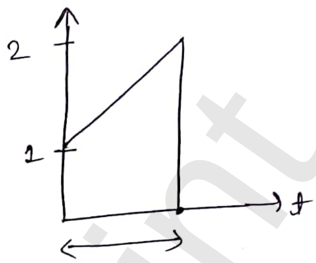
$$I_s = \frac{0.5}{1-0.5} = 1 \text{ amp}$$

$$I_{max} = 1 + \frac{0.833}{2} = 1.416\text{ A}$$

③ rms current in switch



check



Find rms.

$$\text{slope} = \cancel{0.05}\ \frac{0.833}{(\alpha/f)} = 49980$$

$$I_{sw\,rms} = \left\{ \frac{1}{T} \int_0^{T_{ON}} (49980\,t + 0.58)^2 \, dt \right\}^{\frac{1}{2}}$$

$$I_{sw\,rms} = 0.727\text{ A}$$

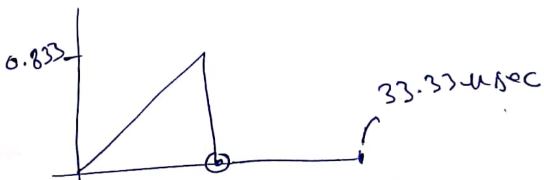
approximation

$$I_{sw_{Rm}} = \sqrt{\alpha} \cdot I_s$$

$$\sqrt{0.5} \times 1$$

$$= 0.717\text{ A}.$$

$$0.727 \simeq 0.717$$



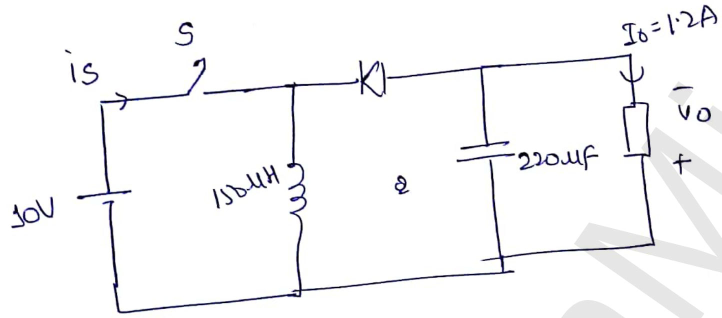
$$\left(\frac{0.833^2\, t^2}{2} \right)_0^{16.665\times10^{-6}}$$

$$\sqrt{\frac{\frac{1}{2}\left\{ (.833)^2 t^2 (16.65)^2 \times 10^{-12} \right\} + \left\{ (0.583)^2 \times (16.65)^2 \times 10^{-12} \right\}}{33.33 \times 10^{-6}}}$$

Q the i/p voltage to a buck-boost conv^r is 10V the switch is operating with a duty ratio of $\alpha = 0.3$ and switching freq' of 25 KHz the filter inductance is 150 μH and the filter cap' is 220 μF. avg load current is 1.2 amperes determine

① peak to peak ripple in the o/p voltage
② " " " " " " inductor current.
③ the peak and avg current of the switch.

Sol^n



$\alpha = 0.3$ $f = 25$ KHz

$$\Delta V_0 = \frac{\alpha I_0}{fC} = \frac{0.3 \times 1.2}{25 \times 10^3 \times 220 \times 10^{-6}} = 0.0654 = 65.45 mV$$

$$\Delta I_L = \frac{\alpha V_s}{fL} = \frac{0.3 \times 10}{25 \times 10^3 \times 150 \times 10^{-6}} = 0.8 \text{ Amp.}$$

peak value of Switch Cu.

$$i_{max} = (i_L)_{avg} + \frac{\Delta I_L}{2}$$

$$= (I_s + I_0) + \frac{\Delta I_L}{2}$$

$$= (0.514 + 1.2) + \frac{0.8}{2}$$

$$= 1.714 + 0.4$$

$$= 2.114 \text{ A}$$

$$\frac{V_0}{V_s} = \frac{I_s}{I_0} = \frac{\alpha}{1-\alpha}$$

$$I_s = \frac{0.3 \times 1.2}{1 - 0.3}$$

$$I_s = 0.514$$

avg value of switch current = value of supply current

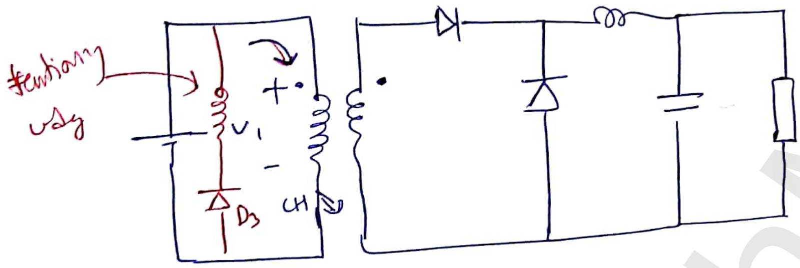
$I_{avg} = 0.514$.

Till now we used non-isolated Buck conv^r ⟵ Non Isolated DC $\xrightarrow{to}$ DC

In SMPS we use isolate Buck conv^r

$V_o = \alpha V_s$ [for non isolate]

Isolated Buck conv = Forward conv^r



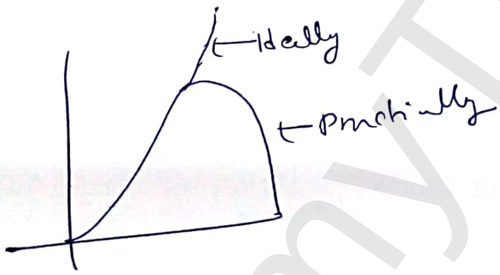
$\boxed{a = \frac{N2}{N1}}$

$V_o = a \cdot \alpha V_s$] ⟵ isolate

[as i on the switch Xmer draws magnetising current

in old Buck problem that differ b/w I/p and O/p less to less

we can't get high o/p voltage



In Buck we reduce o/p voltage i.e ↑ I_o

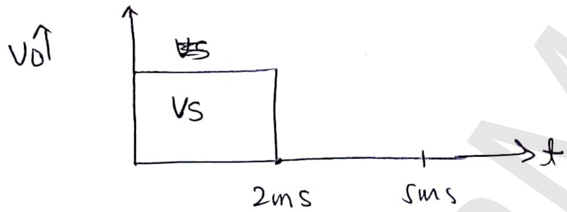
$\downarrow V_o I_o \uparrow = V_s \cdot I_s$

$\boxed{\text{So voltage Buck converter = Current Boost conv}^r}$

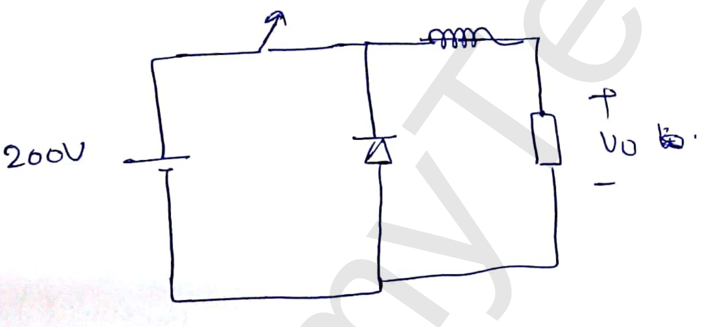
Vo $8f^2LC$

Q A battery with a terminal voltage of 200V is supplied with ~~a wat~~ Power to a type A Chopper the o/p voltage of the chopper consist of rectangular pulses of 2m sec duration in overall cycle time of 5 m sec internal resistance of battery is negligible. calc

(a) Ripple factor
(b) Avg and rms value of o/p voltage
(c) Rms value of fundamental component of o/p voltage
(d) Ac ripple voltage



Soln the waveform tells that the chopper is without filter.



$$\alpha = \frac{T_{ON}}{T} = \frac{2}{5} = 0.4$$

$$V_{ripple} = \sqrt{(FF)^2 - 1}$$

$$FF = \frac{V_{or}}{V_o} = \frac{\sqrt{\alpha} V_s}{\alpha V_s} = \frac{1}{\sqrt{\alpha}}$$

$$VRF\ (V_{ripple}) = \sqrt{\frac{1}{\alpha} - 1}$$

$$= \sqrt{\frac{1}{0.4} - 1}$$

$$VRF = 1.224$$

(b) $V_0 = \alpha V_S = 0.4 \times 200 = 80$

$V_{rm} = \sqrt{\alpha} V_s = 126.49$

(c) $$v_o = \underbrace{\alpha V_s}_{DC} + \underbrace{\sum_{n=1}^{\infty} \frac{2V_s}{n\pi} \sin \pi n \alpha \cdot \sin(n\omega t + \phi_n)}_{AC}$$

$$\phi_n = \tan^{-1}\left[\frac{\cos \pi n \alpha}{\sin \pi n \alpha}\right]$$

$$v_{on} = \underbrace{\frac{2V_s \sin \pi n \alpha}{n\pi}}_{\downarrow} \cdot \sin(n\omega t + \phi_n)$$

rms value of n^{th} Harmonic $= \frac{1}{\sqrt{2}} \frac{2V_s \sin \pi n \alpha}{n\pi}$

Fundamental RMS $= \frac{\sqrt{2} V_s \sin \pi \alpha}{\pi} = \frac{\sqrt{2} \times 200 \times 0.951}{\pi} = 85.6V$

(d) $V_{or}^2 = V_0^2 + V_{ac}^2$

$$V_{ac}^2 = V_{o1}^2 + V_{o2}^2 + V_{o3}^2 + \cdots$$

$$V_{ac} = \sqrt{V_{or}^2 - V_o^2}$$

$$V_{ac} = \sqrt{(126.49)^2 - (80)^2} = 97.98\ V$$

① An Ideal chopper at 500Hz feeds an RL load having load resistance R=30Ω and load inductance L=9mH from a 48 volts battery the load is shunted by a ~~F.D. Di~~ Free Wheeling diode. battery is lossless assuming duty cycle of the chopper is to be 50%. find.

ⓐ Peak value of load current.

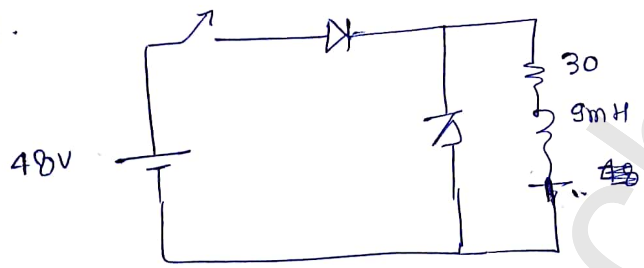
ⓑ min^m value of load current

ⓒ Avg load current, avg ~~load voltage~~

ⓓ Avg load voltage

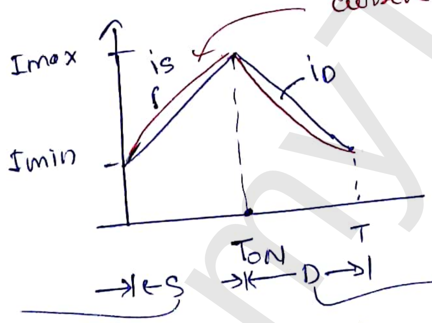
ⓔ Current excursion ~~of~~ in the load current or Ripple

Soln.



load is shunted across free wheel diode means LC filter is not there.

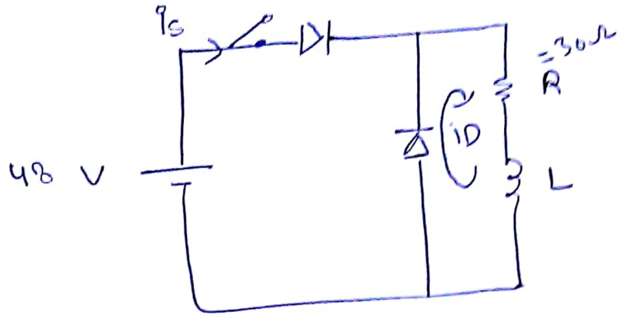
$\alpha = 0.5$ $f = 500Hz$.



$I_{max} = (\Delta I_L)_{avg} + \frac{\Delta I_L}{2}$ ← i can't apply this formula here

$$I_{mx} = \frac{V_s}{R_a}\left[\frac{1 - e^{-T_{ON}/\tau_a}}{1 - e^{-T/\tau_a}}\right] - \frac{E_b}{R_a}$$

← this formula was derived for RLE load and we have to use formula for RL load, we can't put $E_b = 0$ in above eqn to



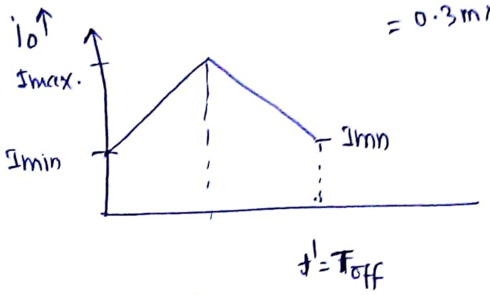
$$i_s = \frac{V}{R}\left(1 - e^{-t/\tau}\right) + I_{min}\, e^{-t/\tau}$$

$$i_s = \frac{48}{30}\left(1 - e^{-t/0.3}\right) + I_{mn}\, e^{-t/0.3}$$

$$I_{mx} = \frac{48}{30}\left(1 - e^{T_{ON}/0.3}\right) + I_{mn}\, e^{-T_{ON}/0.3}$$

$$\tau = \frac{L}{R} = \frac{9\times10^{-3}}{30} = 0.3 \times 3\times10^{-4}$$
$$= 0.3\,\text{msec}$$

$$i_D = I_{mx}\cdot e^{-t'/\tau}$$



$t = 0$ $\quad t' = 0$

$$I_{mn} = I_{mx}\cdot e^{-T_{off}/0.3}$$

$$I_{mx} = \frac{48}{30}\left(1 - e^{-T_{ON}/0.3}\right) + I_{mx}\, e^{-T_{off}/0.3}\cdot e^{-T_{ON}/0.3}$$

$$I_{mx} = \frac{\frac{48}{30}\left(1 - e^{-T_{ON}/0.3}\right)}{1 - e^{-T/0.3}} = \frac{1.5429}{0.998}$$

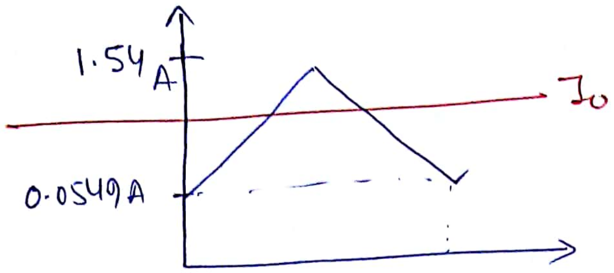
≈ 1.544 A.

$$T_{ON} = \frac{\alpha}{f} = \frac{0.5}{500} = 1\times10^{-3} \qquad I_{mx} = 1.54\ \underline{\underline{A}}$$

$$I_{mn} = I_{mx}\, e^{-T_{off}/0.3}$$
$$= 1.54 \times e^{-\frac{1\times10^{-3}}{0.3}} = 0.0549\ \underline{A}$$

RL e: $\boxed{I_{mx} = \frac{V_s}{R}\left[\frac{1 - e^{-T_{ON}/\tau_a}}{1 - e^{-T/\tau_a}}\right]}$ ← eqn for RL load.

$$\boxed{I_{mn} = I_{mx}\, e^{-T_{off}/\tau_a}}$$



$$I_0 = \frac{0.0549 \times T + \frac{1}{2} \times T \times (1.54 - 0.0549)}{T}$$

$$I_0 = 0.0549 + 0.74255$$

$$\boxed{I_0 = 0.79745\ A}$$

$V_0 = I_0 R$

$V_0 = 0.79745 \times 30$

$= 23.9235$

$V_0 = \alpha V_S$

$= 0.5 \times 48 = 24$

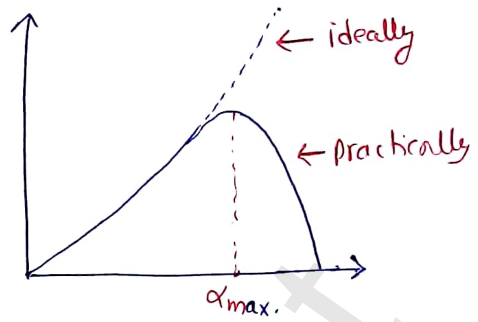
current ripple $\Delta I_L = 1.54 - 0.0549$

$= 1.4851\ A$

Till Now we have used non-isolated Buck converter means dc voltage source is directly connected to chopper.

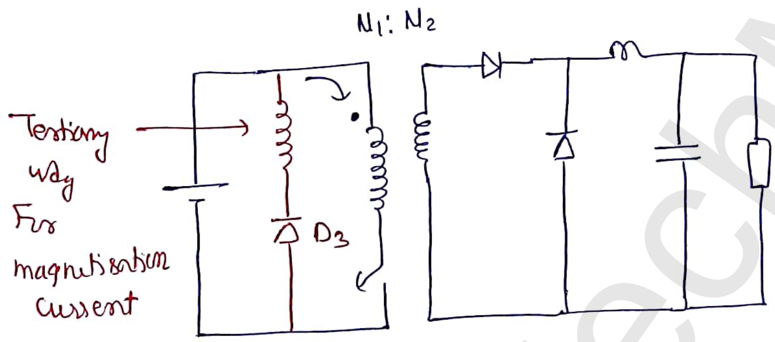
Disadvantage of this is that we can't get a large difference b/w i/p voltage V_s and O/p voltage V_o

because practically as we ↑ α



So we started concept of Isolated Buck conv^r or Forward converter.

→ Isolated Buck conv^r are used in SMPS.



$$\boxed{a = \frac{N_2}{N_1}}$$

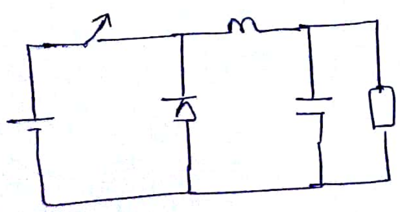
For Non Isolated conv^r $\boxed{V_0 = \alpha V_S}$

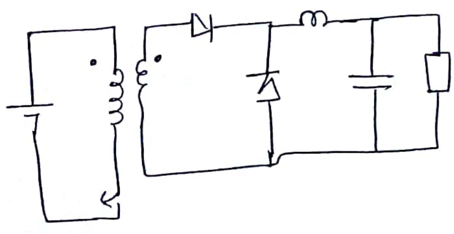
For Isolated Buck conv^r $\boxed{V_0 = a \cdot \alpha \cdot V_S}$

in Buck conv^r we reduce O/p voltage i.e ↑ I_o

$$\downarrow V_o I_o \uparrow = V_s I_s$$

$$\boxed{\text{Voltage Buck conv}^r = \text{Current Boost conv}^r}$$





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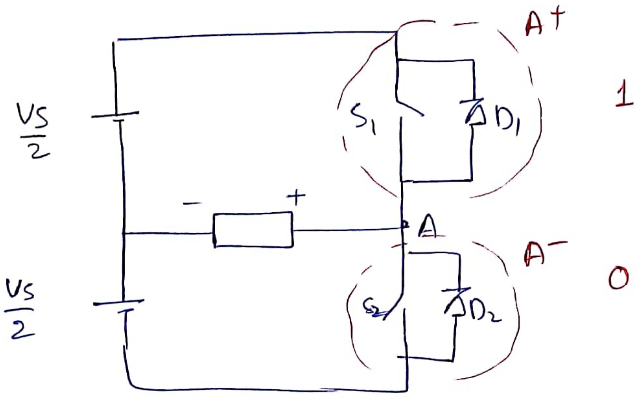
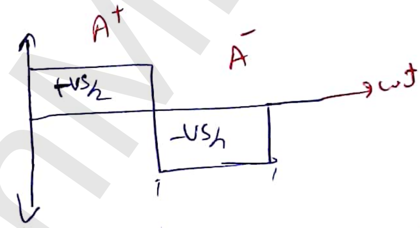
Inverters.

1Φ Half bridge

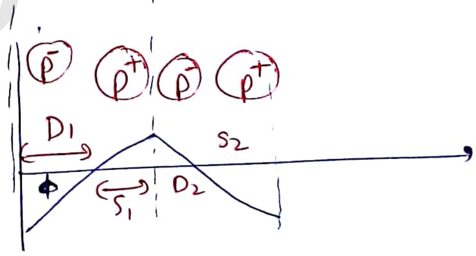




Switch allow the power

Diode " the power.

whatever load voltage waveform fixed



V_{AO} → pole voltage of A

A^+ (S_1 or D_1)

A^- (S_2 or D_2)

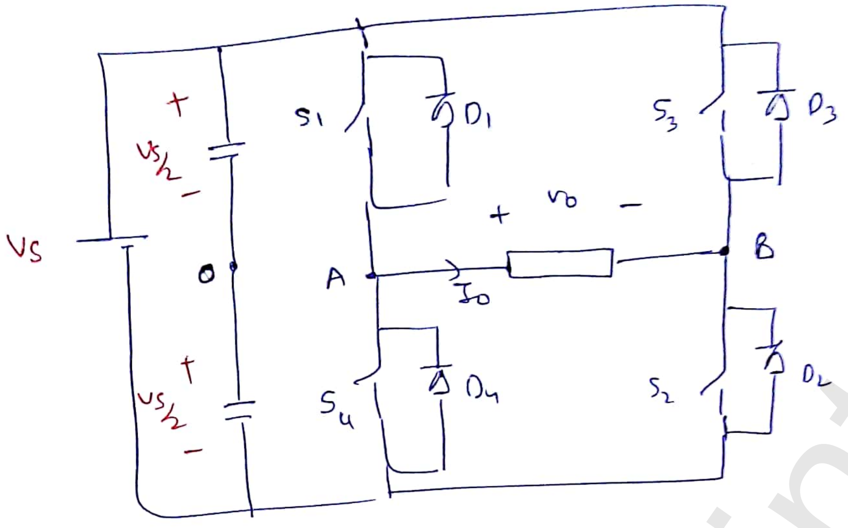
Diode angle = impedance angle

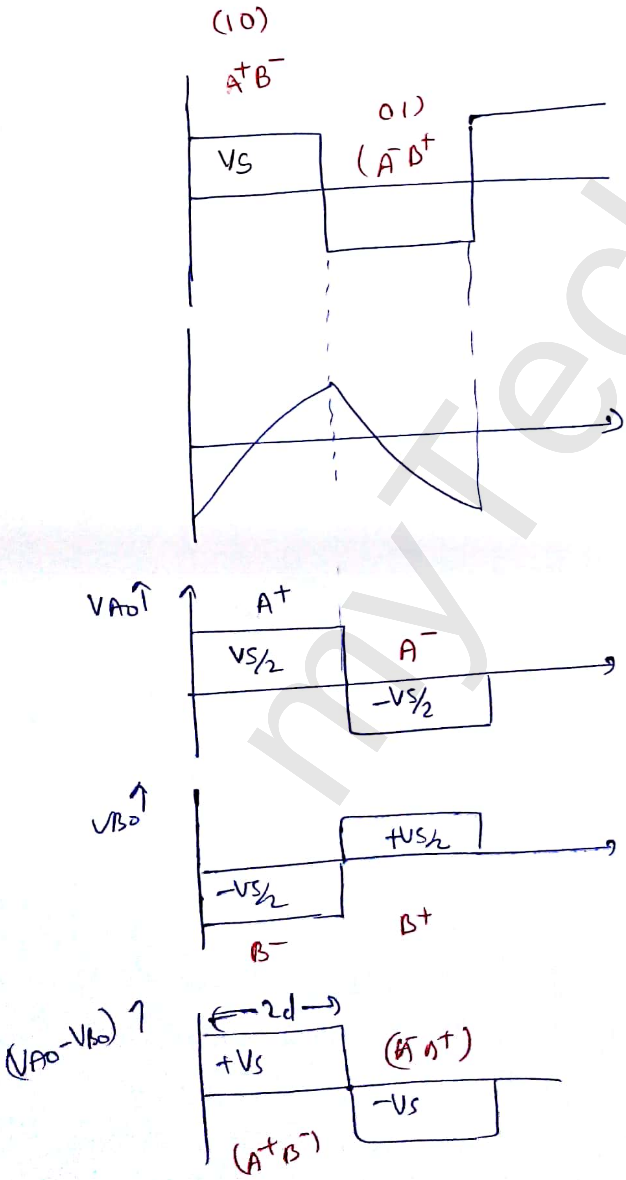
VSI ⟶ Vo (voltage waveform fixed)

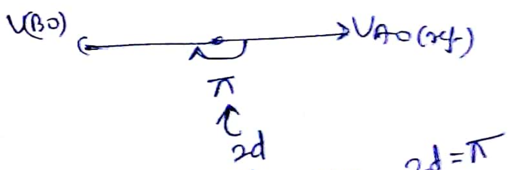
as load changes current waveform changes

CSI ⟶ opposite.

Inverters :



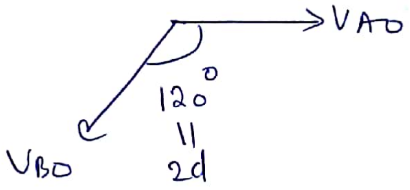


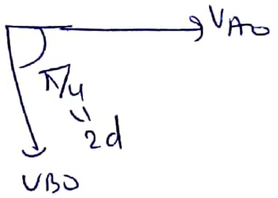


$\cancel{V_{or}} = V_s \left(\frac{2d}{\pi}\right)^{1/2}$

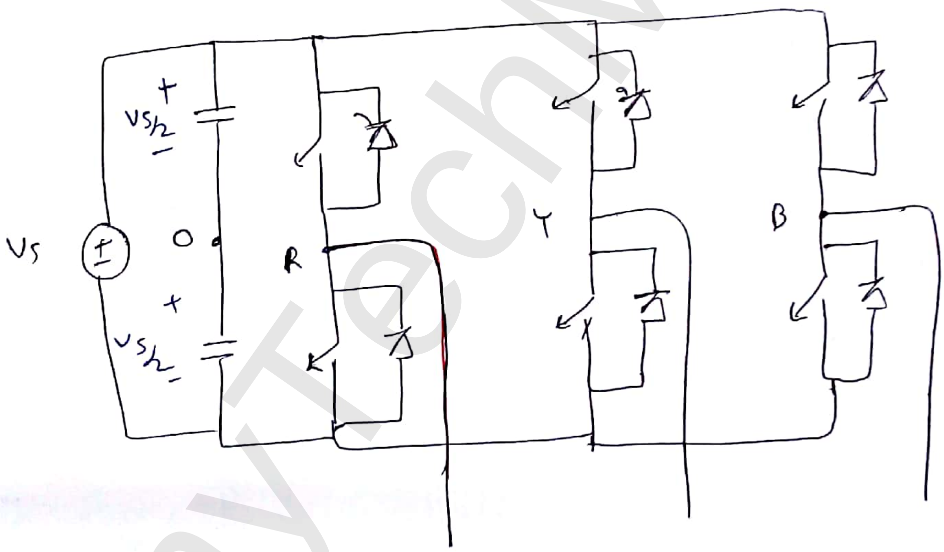
pulse width $= 2d = \pi$

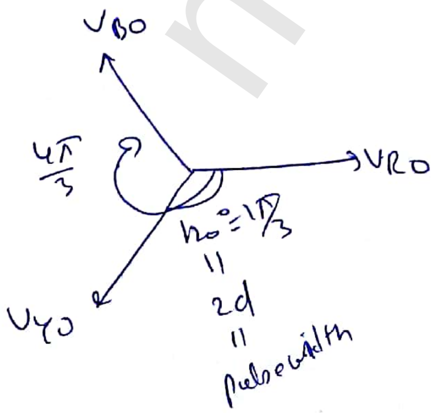
By varying phase angle diffre b/w pole A and pole B we can change pulse width and by changing pulse width we can change $V_{o\,rms}$

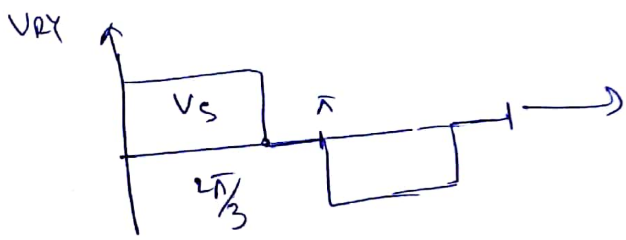


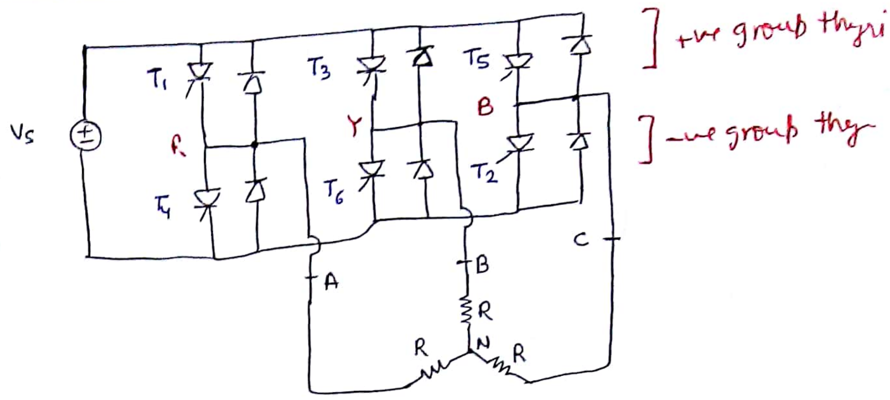


3 ϕ VSI

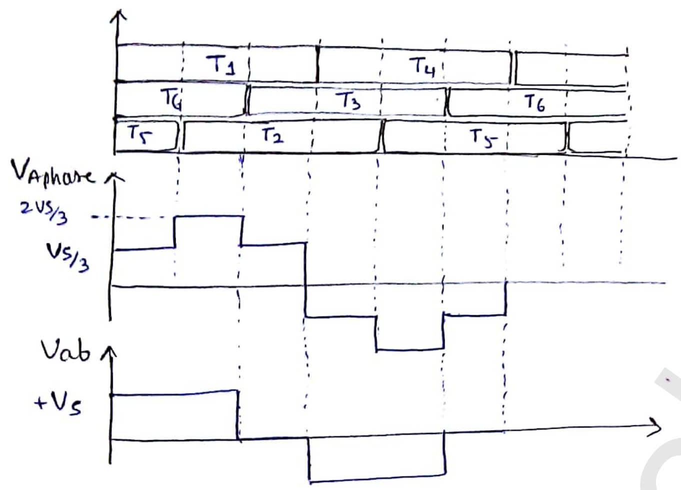








180° cond^c mode

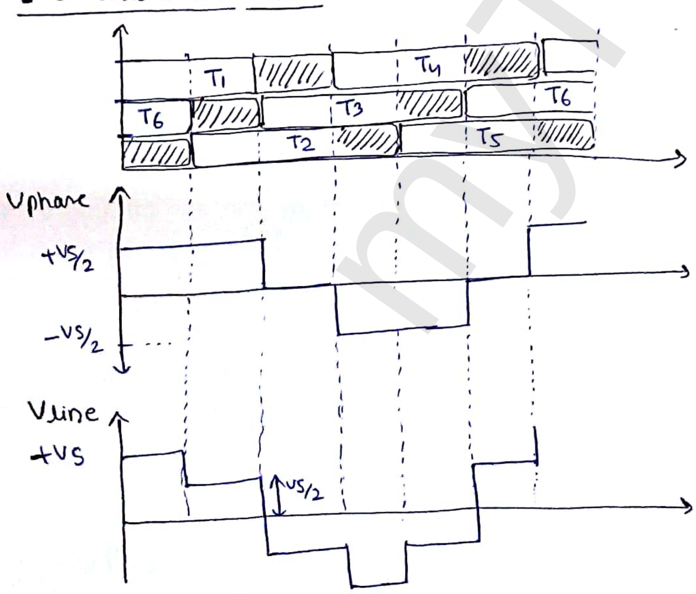


Each thyristor conduct for 180°
at a time 3 thyristor conduct

$V_{ph\,rms} = \sqrt{2}\,\frac{V_s}{3}$

	Phase		line
Total	$\sqrt{2}\,\frac{V_s}{3}$	$\xrightarrow{\sqrt{3}}$	
	$\downarrow \frac{3}{\pi}$		
fundam			

120° conduction mode



Each thyristor conduct for 120°
at a time 2 thyristor conduct

$V_{ph\,rms} = \frac{V_s}{\sqrt{6}}$

	Phase		line
Total	$\frac{V_s}{\sqrt{6}}$	$\xrightarrow{\sqrt{3}}$	
Fundam	$\downarrow \frac{3}{\pi}$		

180° की line की waveform
120° की phase जैसी थी है पर 120° की phase का mag
$+\frac{V_s}{2}$ था है पर यहां V_s थी है

Q A single phase full bridge VSI delivers power at 50Hz to RLC load with R = 5Ω, L = 0.3 H, C = 50μF. The dc I/P voltage is 220 volts determine

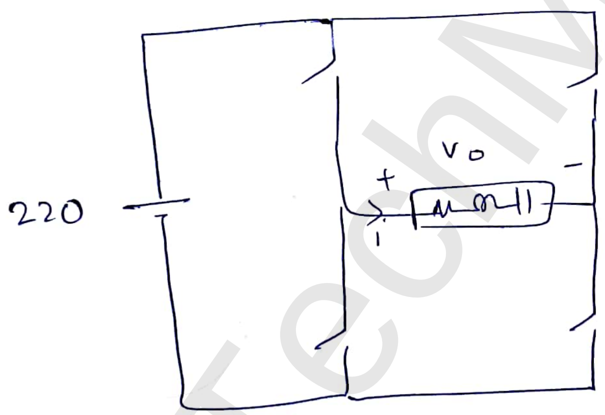
(a) expression for load current upto 9th harmonic.

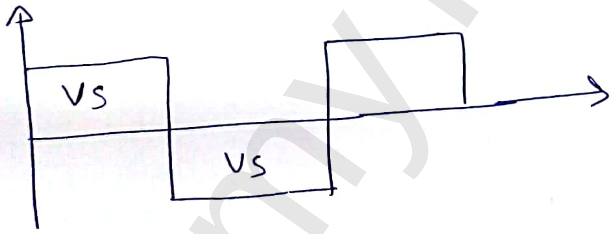
(b) Power delivered to the load and the fundamental power.

(c) Rms and peak values of current in each switch.

(d) Conduction time of switches and diodes. by considering only fundamental component.

Soln





$$V_0 = \frac{4V_s}{\pi}\sin\omega t + \frac{4V_s}{3\pi}\sin 3\omega t + \frac{4V_s}{5\pi}\sin 5\omega t + \frac{4V_s}{7\pi}\sin 7\omega t$$

$$I_0 = \frac{4V_s}{|Z_1|\pi}\sin(\omega t - \phi_1) + \frac{4V_s}{|Z_3|3\pi}\sin(3\omega t - \phi_3) + \frac{4V_s}{|Z_5|5\pi}\sin(5\omega t - \phi_5)$$

$$+ \frac{4V_s}{|Z_7|7\pi}\sin$$

By Sir

(a) $v_{on} = \frac{4V_s}{n\pi} \sin n\omega t$

$$i_{on} = \frac{\cancel{4V_s}\ V_{on}}{Z_n}$$

$$= \frac{v_{on}}{|Z_n| \angle \phi_n} = \frac{V_{on} \angle -\phi_n}{|Z_n|} = \frac{4V_s}{n\pi |Z_n|} \sin(n\omega t - \phi_n)$$

$$i_o = i_1 + i_3 + i_5 +$$

$$i_o = \frac{4V_s}{\pi |Z_1|} \sin(\omega t - \phi_1) + \frac{4V_s}{3\pi |Z_3|} \sin(3\omega t - \phi_3) + \frac{4V_s}{5\pi |Z_5|} \sin(5\omega t - \phi_5)$$

(b)

$$|Z_n| = \sqrt{R^2 + (X_{Ln} - X_{cn})^2}$$

$$|Z_1| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} \qquad \phi_1 = \tan^{-1}\left(\frac{\omega L - \frac{1}{\omega C}}{R}\right)$$

$$|Z_3| = \sqrt{R^2 + \left(3\omega L - \frac{1}{3\omega C}\right)^2} \qquad \phi_3 = \tan^{-1} \frac{\left(3\omega L - \frac{1}{3\omega C}\right)}{R}$$

$$|Z_5| = \sqrt{R^2 + \left(5\omega L - \frac{1}{5\omega C}\right)^2} \qquad \phi_5 = \tan^{-1}\left(\frac{5\omega L - \frac{1}{5\omega C}}{R}\right)$$

$R = 5\Omega$ $\quad L = 0.3H$ $\quad C = 50\mu f$ $\qquad \omega L = 314 \times 0.3 = 94.2$

$$\frac{1}{\omega C} = 63.69$$

$|Z_1| = 30.98\Omega$ $\qquad \phi_1 = 80.73$

$|Z_3| = 261.5\Omega$ $\qquad \phi_3 = 88.9$

$|Z_5| = 458.53\Omega$ $\qquad \phi_5 = 89.37$

$$\frac{4V_s}{\pi} = \frac{4 \times 220}{\pi} = 280.11$$

$$i_o = \frac{280.11}{30.98} \sin(\omega t - 80.73) + \frac{280.11}{3 \times 261.5} \sin(3\omega t - 88.9) + \frac{280.11}{5 \times 458.53} \sin(5\omega t - 89.37^\circ)$$

$$i_o = 9 \sin(\omega t - 80.73) + 0.357 \sin(3\omega t - 88.9) + 0.122 \sin(5\omega t - 89.37^\circ)$$

$$I_{or} = \sqrt{\left(\frac{9}{\sqrt{2}}\right)^2 + \left(\frac{0.357}{\sqrt{2}}\right)^2 + \left(\frac{0.122}{\sqrt{2}}\right)^2}$$

$I_{or} = 6.37$ Am

Fundamental power

$$V_{on} = \frac{2\sqrt{2}V_s}{n\pi}$$

$$P_1 = V_{01} \cdot I_{01} \cos\phi_1$$

$$V_{01} = \frac{2\sqrt{2}V_s}{\pi} = \frac{2\sqrt{2} \times 220}{\pi} = 198.07$$

$$= 198 \times \frac{9}{\sqrt{2}} \times \cos(80.73)$$

$$V_{03} = \frac{2\sqrt{3}V_s}{3\pi} = 66.02$$

$P_1 = 202.98$ watt

$$V_{05} = \frac{2\sqrt{2}V_s}{5\pi} = 39.61\,V$$

$$P_3 = 66.02 \times \frac{0.357}{\sqrt{2}} \times \cos 88.9$$

$$= 0.3199$$

$$P_5 = 39.61 \times \frac{0.122}{\sqrt{2}} \times \cos 89.37$$

$$= 0.0375$$

$$P = P_1 + P_2 + P_3$$

$$= 202.98 + 0.3199 + 0.0375$$

$$\underline{P = 203.3375}$$

2nd

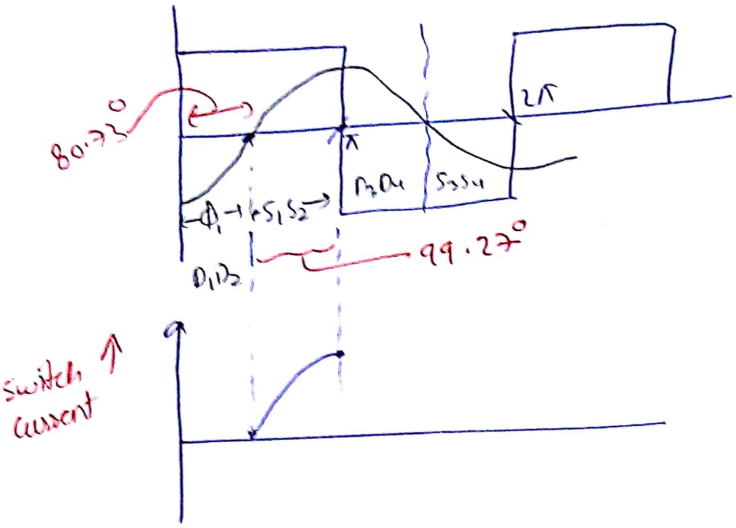
$$P = I_{or}^2 R$$

$$(6.37)^2 \times 5$$

$$= 202.8845$$

3

③



$$I_{rms}^2 = \left\{ \frac{1}{2\pi}\int_0^{99.27^\circ} 9^2 \sin^2\omega t \; d\omega t \right\}$$

$$= \frac{81}{2\pi}\int_0^{99.27^\circ} \frac{1-\cos 2\omega t}{2} \; d\omega t$$

$$= \frac{81}{2\cdot 2\pi}\left[\frac{(99.27-0)\times\pi}{180} - \left[\sin 2\omega t\right]_0^{99.27^\circ}\right]$$

$$= 6.445\left[1.7325 + 0.3179\right]$$

$$= 13.215$$

$$I_{rms} = \sqrt{13.215} = 3.635$$

④ Cond^c angle of Diode $= \phi_1 = 80.73^\circ$

$$\omega t = \frac{80.73 \times \pi}{180} = 1.409$$

Conduction time of diode $t = \dfrac{1.409}{2\pi f} = 4.48\,m\,sec$

Q A 3ϕ VSI operating in $120°$ mode feeds a star connected load of $R = 5\Omega$, DC source voltage is 230 volts and o/p freq is 50Hz

(a) Rms value of line to line o/p voltage and line to neutral o/p voltage and the line current in fourier series up to 11th Harmonic component

(b) Rms value of line to line and line to neutral voltage

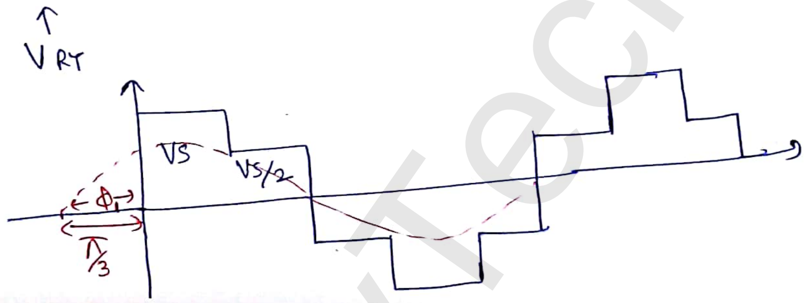
(c) Rms value of line to line and line to neutral voltages at fundamental frequency

(d) Total Harmonic distortion for line current

(e) Load power & avg value of source current

(f) avg and rms values of switch current.

Soln 3ϕ, $120°$ λ connected load.



$$C_n = \frac{6X}{n\pi} = \frac{6 \cdot V_s/2}{n\pi} = \frac{3V_s}{n\pi}$$

$$V_{RYn} = \frac{3V_s}{n\pi} \sin n(\omega t + \pi/3)$$

$$V_{RY_1} = \frac{3V_s}{\pi} \sin(\omega t + \pi/3)$$

$$V_{RY_5} = \frac{3V_s}{5\pi} \sin 5(\omega t + \pi/3)$$

$$V_{RY7} = \frac{3V_s}{7\pi} \sin 7(\omega t + \pi/3)$$

$$V_{RY11} = \frac{3V_s}{11\pi} \sin 11(\omega t + \pi/3)$$

$$V_{RY} = \frac{3V_s}{\pi} \sin(\omega t + \pi/3) + \frac{3V_s}{5\pi} \sin 5(\omega t + \pi/3) + \frac{3V_s}{7\pi} \sin 7(\omega t + \pi/3) + \frac{3V_s}{11\pi} \sin 11(\omega t + \pi/3)$$

$$\frac{3V_s}{\pi} = \frac{3 \cdot 230}{\pi} = 219.6$$

$$V_{RY} = 219.6 \sin(\omega t + \pi/3) + 43.92 \sin 5(\omega t + \pi/3) + 31.37 \sin 7(\omega t + \pi/3) + 19.9 \sin(11\omega t + 11\pi/3)$$

v_R

phase.

$$\hookrightarrow V_R = \frac{2V_s}{\pi} \sin\frac{\pi}{3} \sin(\omega t + \pi/6) + \frac{2V_s}{5\pi} \sin\frac{5\pi}{3} \sin 5(\omega t + \pi/6) + \frac{2V_s}{7\pi} \sin\frac{7\pi}{3} \cdot \sin 7(\omega t + \pi/6)$$

$$+ \frac{2V_s}{11\pi} \sin\frac{11\pi}{3} \sin 11(\omega t + \pi/6)$$

$$v_R = 126.7 \sin(\omega t + \pi/6) - 25.36 \sin\left(5\omega t + \frac{5\pi}{6}\right) + 18.15 \sin\left(7\omega t + \frac{7\pi}{6}\right)$$

$$\cancel{+} - 11.52 \sin(11\omega t + 11\pi/6)$$

$$i_R = 25.34 \sin(\omega t + \pi/6) - 5.072 \sin\left(5\omega t + \frac{5\pi}{6}\right) + 3.63 \sin(7\omega t + 7\pi/6)$$

$$- 2.304 \sin\left(11\omega t + 11\frac{\pi}{6}\right)$$

$$(I)_{rms} = \sqrt{I_{R1}^2 + I_{R5}^2 + I_{R7}^2 + I_{R11}^2} = \sqrt{}$$

(b) $V_L = \frac{V_s}{\sqrt{2}} = \frac{230}{\sqrt{2}} = 162.63$

$V_{pn} = \frac{V_L}{\sqrt{3}} = 93.89$

(c) $V_{RY1\,Rms} = \cancel{291.6}\ \frac{219.6}{\sqrt{2}} = 155.28$

$V_{R1\,Rms} = \frac{126.7}{\sqrt{2}} = 89.6$

(d) 31.1. bcz load is resistive

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(e) Load power

$3 I_{ph}^2 R$

$$I_{ph} = \frac{V_{ph}}{R} = \frac{93.89}{5} = 18.77$$

$P = 3 I_{ph}^2 R =$ ~~5.3 KW~~ 5.289 KW

(f) avg value of supply current.

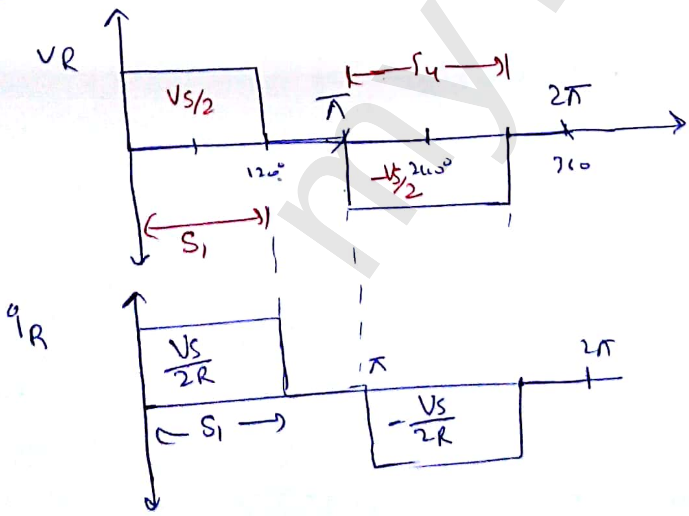
supply current will be dc.

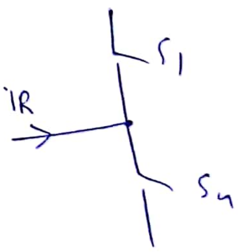
$V_s \cdot I_s = P_o = 5.289 \times 10^3$

$I_s = 22.9$ A

if in qu^n Is asked then first find Po then use Power balance eq^n.

(g) avg and rms value of switch current





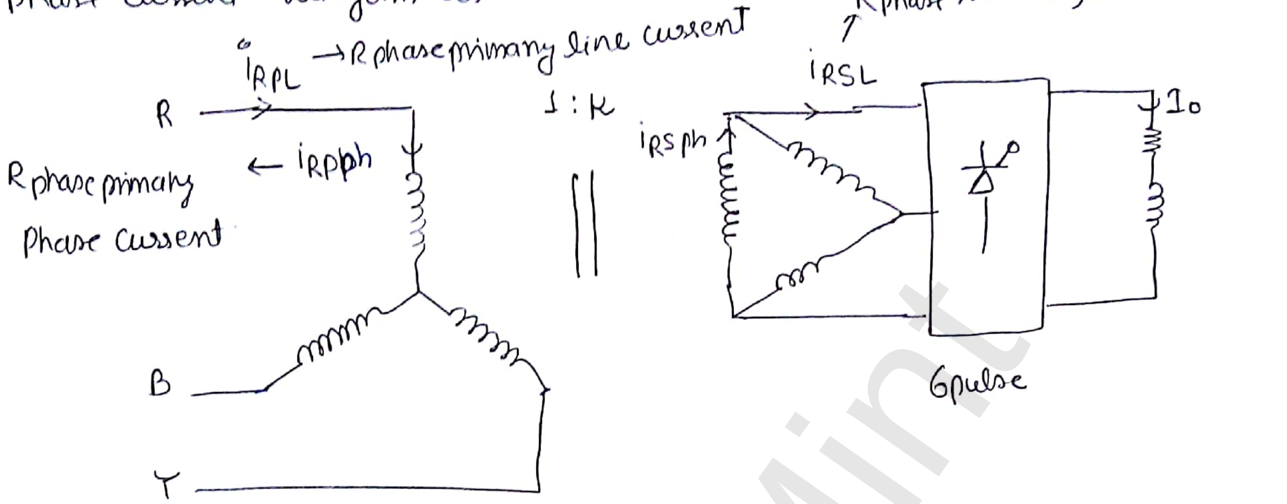
~~Iavg~~ $I_{sw\,avg} = \frac{V_s}{2R}\left(\frac{2\pi/3}{2\pi}\right) = \frac{V_s}{2R}\cdot\frac{1}{3} = \frac{230}{2\cdot 5\cdot 3} = 7.66$ A

$I_{sw\,rms} = \frac{V_s}{2R}\left(\frac{2\pi/3}{2\pi}\right)^{1/2} = \frac{V_s}{2R\cdot\sqrt{3}} = 13.279$ A.

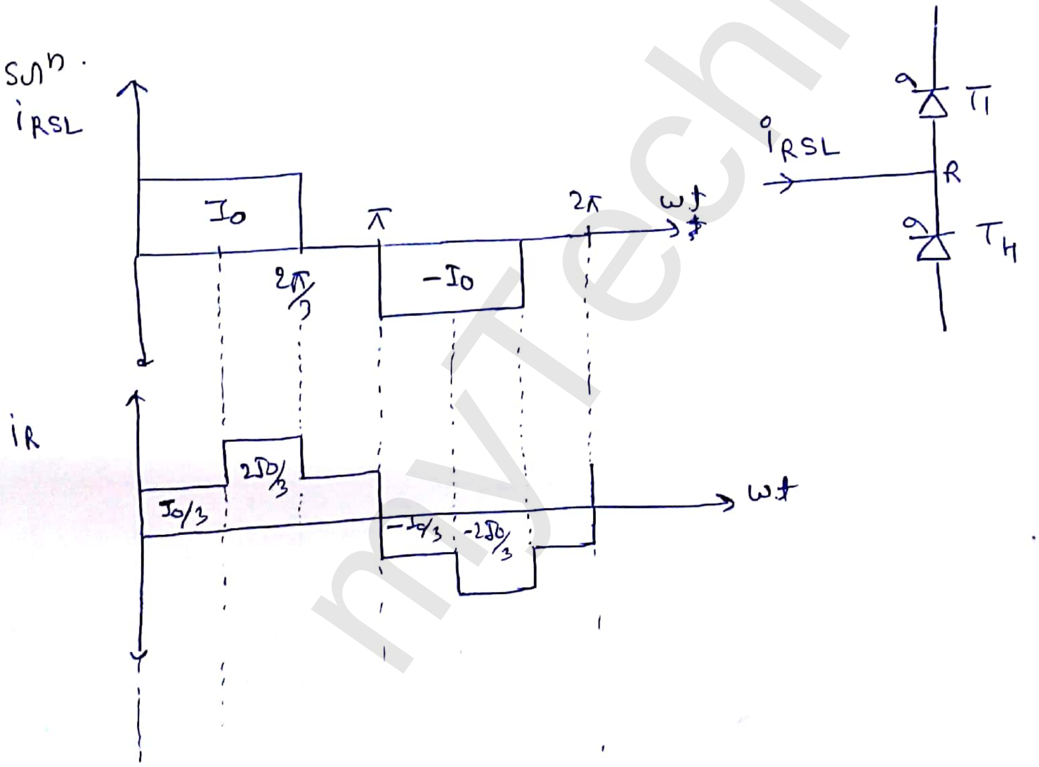
Date. 21 August

Q) A 3φ Full conv^r Bridge is fed to λΔ Xmer

the conv^r is operated at a firing angle of 30°. assuming the load current I_0 to be virtually contl at 1 pu and Xmer to be an ideal one, the i/p phase current waveform is

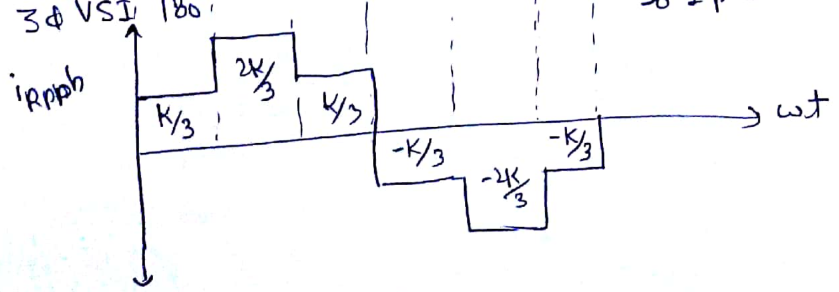


Sol^n.



Use analogy from 3φ VSI 180°

$I_0 = 1$ pu



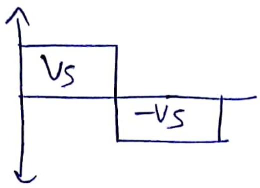
PWM Inverters

ONE ques^n PWM

Gate and IES

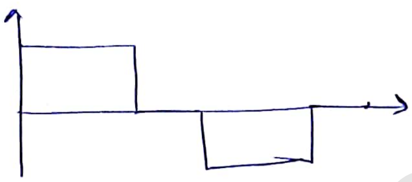
two types of VSI → Square wave Inv^r ; PWM

Square wave Inv^r (drawback we can vary freq^c N.A the rms



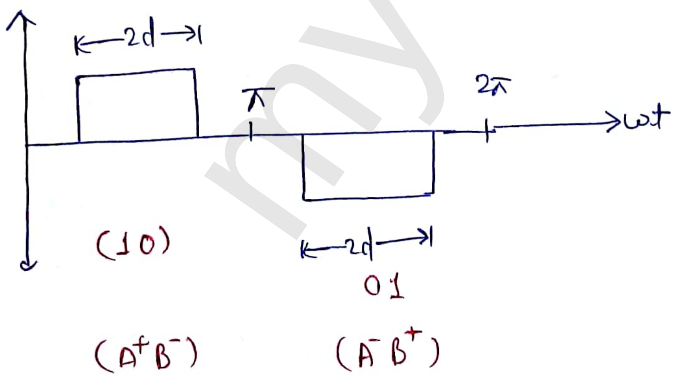
$V_{or} = V_s$

3Φ - VSI (180° mode) is also called $\boxed{\text{Square wave mode}}$



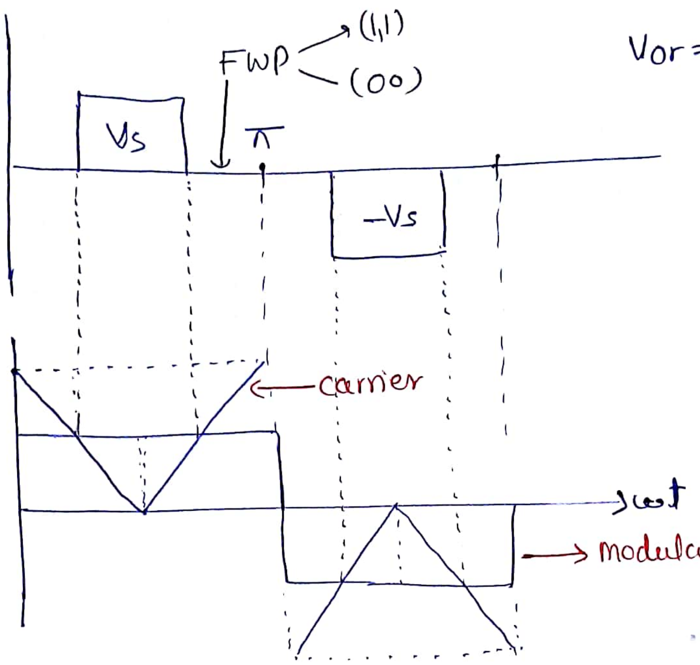
may be voltage waveform is Quasi wave but it's called square wave mode b/z we can't change the rms of the waveform.

① Single PWM Tech



we will control the gate sig pulse of A^+, A^-, B^+, B^-,
we have four switch here A^+ A^- B^+ B^- and every switch has one gate s/g pulse.

$V_{or} = V_s \left(\frac{2d}{\pi}\right)^{1/2}$



Power sig Vs is of KV's.

$v_{on} = \frac{4V_s}{n\pi} \sin n d \sin n\omega t$

FWP [Free wheeling period]

if $|A_m| > |a_c| \rightarrow (1,0)$ if a_c^+

$\rightarrow (0,1)$ if a_c^-

$|A|_m < |a_c| \longrightarrow$ FWP $\begin{cases} (11) \\ (00) \end{cases}$

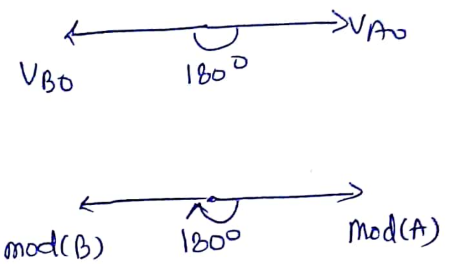
if i use (11) logic — upper switch used more

if " " (00) " — lower " " "

Remedy

1 modulating sig to control the switches of leg A

2nd " " " " " " leg B

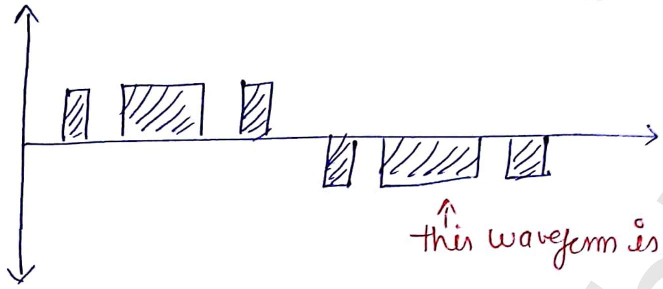


$mod(A) > a_c \rightarrow 1 \quad (A^+)$

$mod(A) < a_c \rightarrow 0 \quad (A^-)$

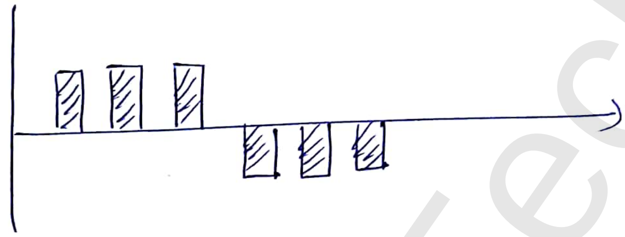
$mod(B) > a_c \rightarrow 1 \ (B^+)$

$mod(B) < a_c \rightarrow 0 \ (B^-)$



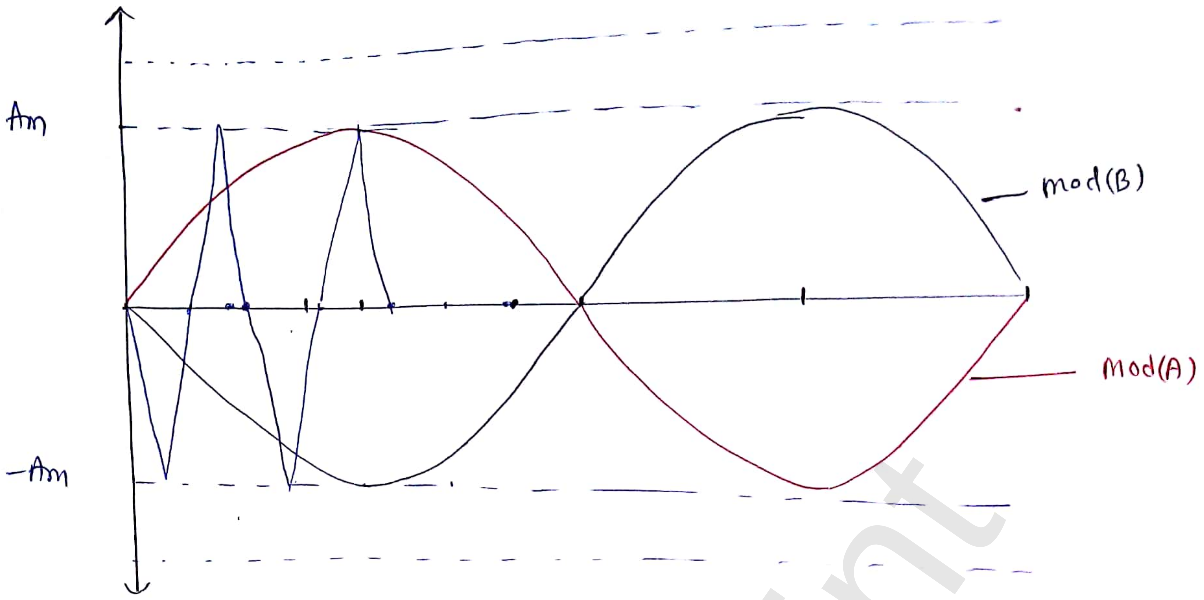
we will use sinosoidal moidal s/g

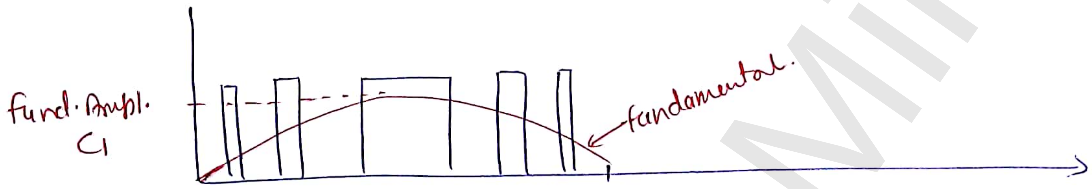
this waveform is better than below. bcz THD less.



Sin- Triangle unipolar PWM

~~we are~~ will use two modulating s/g one for leg A and one for leg B.





How many carrier we have b/w A and B that many pulses.

$\uparrow m_A = \frac{A_m \uparrow}{A_c}$

$V_{01} \rightarrow$ Funda rms

$\hat{V}_{01} \rightarrow$ Peak Funda i.e C_1

Amplitude modulation Index decides the mag. of Fundamental amplitude.

as $A_m \uparrow$, Fundamental Amp $\uparrow$es.

Rembr

$\uparrow \hat{V}_{01} = M_A \uparrow \cdot V_s \rightarrow$ 1 ϕ Full bridge Invr

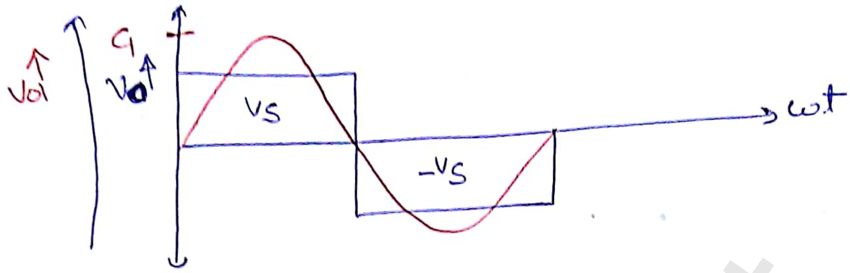
$\hat{V}_{01} = M_A \cdot \frac{V_s}{2} \rightarrow$ 1 ϕ Half bridge Invr

$\hat{V}_{L1} = M_A \cdot \sqrt{3} \frac{V_s}{2} \rightarrow$ 3 ϕ VSI

these all when $M_A \leq 1$ Linear Modulation

Peak value of Fundamental line voltage

1ϕ VSI Square wave mode



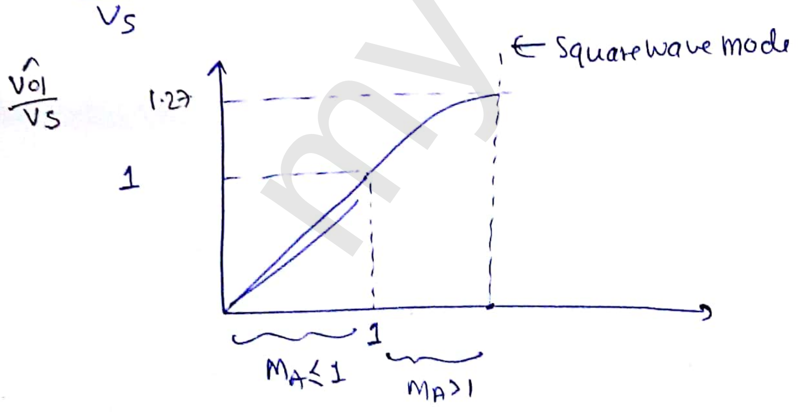
$$C_n = \frac{4V_s}{n\pi}$$

$$\hat{V}_{01\,max} = \frac{4V_s}{\pi} = 1.27V_s$$

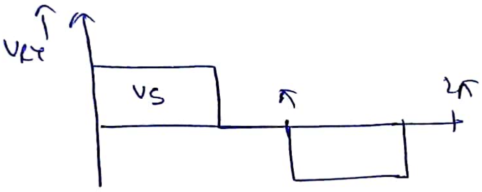
$$\left.\frac{\hat{V}_{01}}{V_s}\right|_{max} = 1.27$$

$\uparrow \hat{V}_{01} = m_A \uparrow V_s \rightarrow$ 1ϕ full bridge

$$\frac{\hat{V}_{01}}{V_s} = m_A$$



3Φ VSI - Squarewave mode (180°)



$J = 1$

First side band

frq

$n = M_F \pm K$

3Φ VSI : PWM mode ($M_A < 1$)

Frq modulation index

$$M_F = \frac{f_c}{f_m}$$

fm - modulating frq is decided by o/p frq

sig of ~~Inv~~ Inv sig

$f_m = f_{o/p} =$

$\uparrow M_F = \frac{F_c \uparrow}{f_m}$

M_F decides harmonic spectrum

Harmonic Spectrum : $n = JM_F \pm K$

If $J = 1, 3, 5 \ldots$ $\quad k = 0, 2, 4, 6$

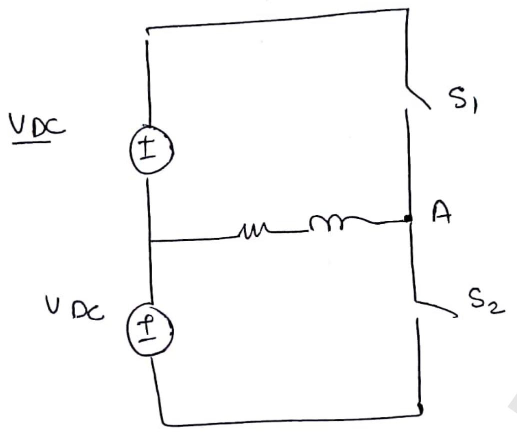
J can't be 0

If $J = 2, 4, 6 \ldots$ $\quad k = 1, 3, 5$

M_F should be multiple of 3 to

M_F should be an odd integer to satisfy HWSymm.

Imp ② The figure shows a Half Bridge VSI supplying an RL load with $R = 40\Omega$ & $L = \frac{0.3}{\pi} H$, The desired Fundamental frq of the load voltage is 50 Hz, the switch control sigs of the ~~contr~~ conv^r are generated using sinusoidal pwm with modulation index = 0.6 at 50 Hz RL load draws an active power of 1.44 kW Find the value of DC source voltage Vdc



Soln Diode absent is it ~~wrong~~ wrong → No bcz Switch S_1 & S_2 can be RCT and RCT contain inbuilt diode so ckt correct only

$R = 40\Omega$ $L = \frac{0.3}{\pi} H$

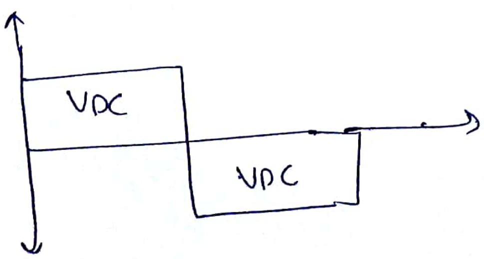
$F_1 = 50 Hz$

Sinusoidal pwm ; $m_A = 0.6$

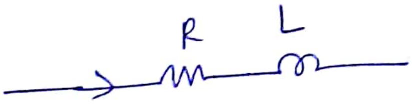
$= \frac{4X}{n\pi}$

At 50 Hz , $P = 1.44 kW$

& $\hat{V}_{01} = \frac{4 V_{DC}}{\pi}$



$m_A = \frac{A_m}{A_c}$ $m_A = \frac{\hat{V}_{01}}{V_s}$



$P = V_{01} I_{01} \cos\phi$

$$1.44 \times 10^{3} = \frac{4V_{DC}}{\pi\sqrt{2}} \times \frac{4V_{DC}}{\pi\sqrt{2}\,|Z_1|} \cos\phi_1$$

$$I_{01} = \frac{4V_{DC}}{\pi\sqrt{2}\,|Z_1|} \qquad \phi_1 = \tan^{-1}\frac{\left(\omega L - \frac{1}{\omega C}\right)}{R}$$

$$I_{01} = \frac{4V_{DC}}{\pi\sqrt{2}\times 50} \qquad \phi_1 = \tan^{-1}\left(\frac{314 \times 0.3}{40\ \pi}\right)$$

$$1.44 \times 10^{3} = \frac{16V_{DC}^{2}}{\pi^{2} \times 2 \times 50} \times \cos 36.86 \qquad \phi_1 = \tan^{-1}\left(\frac{2\pi \times 50 \times 0.3}{40\ \pi}\right)$$

$$\tan^{-1}\frac{100 \times 3}{400}$$

$$\phi_1 = \tan^{-1}\left(\frac{3}{4}\right) = 36.86^\circ$$

$$Z_1 = \sqrt{(40)^2 + \left(\frac{314 \times 0.3}{\pi}\right)^2}$$

$$|Z_1| = 50$$

By sir

$\hat{V}_{01} = M_A \cdot \frac{V_S}{2}$ ← use this formula when $(M_A \leq 1)$

$\frac{V_S}{2} = V_{DC}$

$V_{01} = \frac{0.6 \times V_{DC}}{\sqrt{2}}$

↑

Funda rms

$P_1 = V_{01} \cdot I_{01} \cdot \cos \phi_1$

$I_{01} = \frac{V_{01}}{|Z_1|} = \frac{V_{01}}{\sqrt{R^2 + X_1^2}}$

$\phi_1 = \tan^{-1}\left(\frac{\omega L}{R}\right)$

$\phi_1 = 36.86$

$P_1 = V_{01} \cdot I_{01} \cdot \cos \phi_1$

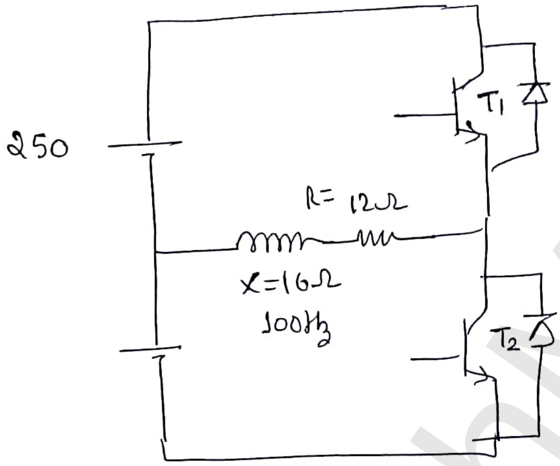
$1.44 \times 10^3 = \frac{V_{01} \cdot V_{01}}{|Z_1|} \cos \phi_1$

$= V_{01}^2 \cdot \frac{1}{50} \cdot \cos 36.86^\circ$

$1.44 \times 10^3 = \left(\frac{0.6}{\sqrt{2}} V_{DC}\right)^2 \times \frac{1}{50} \cdot \cos(36.86^\circ)$

$V_{DC} = 500\sqrt{2}$

Q The switches T_1 and T_2 are switched in a complementary fashion with sinusoidal pulse width modulation Technique the modulating voltage is $V_m(t) = 0.8 \sin(200\pi t)$ V and the triangular carrier voltage magnitude is $V_c = 1$ volt the Carrier freq is 5 kHz Find the peak value of 100 Hz component of load current



Sol^n $V_m(t) = 0.8 \sin(200\pi t)$

$$200\pi t = \omega t$$

$$200\pi = 2\pi f$$

$$f = 100 \text{ Hz}$$

$V_c = 1$ volt.

$f_c = 5$ kHz

$$M_f = \frac{f_c}{f_m} = \frac{5\times10^3}{100} = \frac{5000}{100} = 50$$

$$I_L = I_{01} + I_3 +$$

$$I_1 = \hat{I}_{01} \sin(\omega t - \phi_1)$$

$$\hat{I}_{01} = \frac{\hat{V}_{01}}{|Z_1|}$$

By Sir

$$V_m(t) = \overset{A_m}{0.8} \sin(200\pi t) \qquad f_m = 100\ Hz = \text{Fundamental freq}$$

modulation freq' = "

$A_c = V_c = 1V$

$$m_A = \frac{A_m}{A_c} = \frac{0.8}{1} = 0.8$$

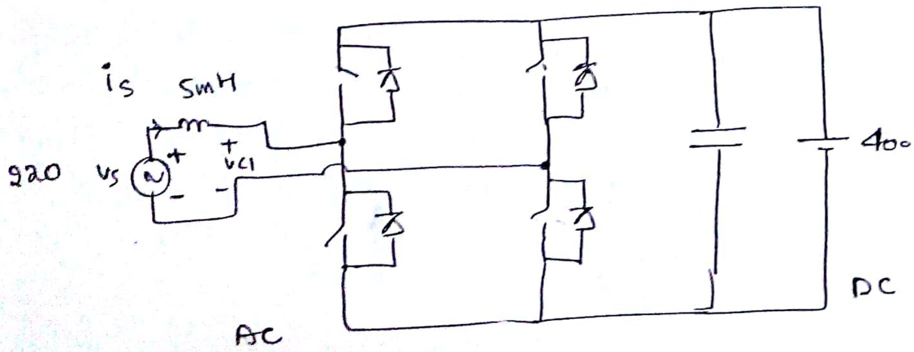
$$\hat{V}_{01} = m_A \cdot \frac{V_s}{2} \longleftarrow (m_A \le 1) \text{ we can use this formula.}$$

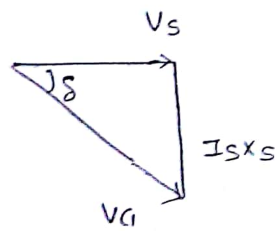
$$\hat{V}_{01} = 0.8 \times 250$$

$$\hat{V}_{01} = 200V$$

$$\hat{I}_{01} = \frac{\hat{V}_{01}}{|Z_1|} = \frac{200}{\sqrt{(12)^2 + (16)^2}} = 10A$$

Q A single phase bidirectional VSI voltage source conv^r VSC is shown in the figure given below all devices are ideal it is used to charge a battery at 400volts with power of 5000 watt from ac source of $V_s = 220V$ (rms) 50 Hz sinusoidal ac at unity p.f. if its ac side interfacing inductor is 5mH and the switches are operated at 20kHz then the phase shift angle (δ) b/w the ac mains voltage V_s and fundamental ac rms VSC voltage (V_{C1}) in degree is ___.





see on DC side - it is VSC

i can use VSC as Inv and conv

Supply is 50 Hz why we have to have to operate switch at $f_c = 20\,kHz$.

PF = 1 mean no harmonic

Power flowing from ac $\xrightarrow{\text{to}}$ DC

V_s is

i_s is ?

i will make i_s using 5 mH and CH switch (I am using PWM switches)

so i_s now almost

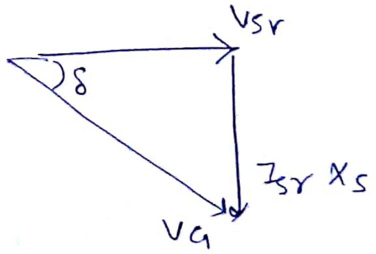
$P = V_{sr} \cdot I_{sr} \cdot PF$

$5 \times 10^3 = 220 \times I_{sr} \; (1)$

$I_{sr} = 22.7\,A$

$$\tan\delta = \frac{I_{sr} X_s}{V_{sr}} = \frac{22.7\,(2\pi f \cdot L_s)}{220}$$

50 ; 5×10^{-3}



$\delta = 9.2$

Q A DC chopper is used for regenerative breaking of a seperately excited dc motor the dc supply voltage is 400 V The motor has arm^r resistance $R_A = 0.5\Omega$, $K_m = 1.25$ V s/rad the avg arm^r current during regenerative breaking is kept constt at 300 A with negligible ripple for a duty cycle of 50%. determine ① Power return to the dc supply

② max^m and min^m permissible breaking speed.

© speed during regenerative breaking.

Soln.

2nd quadrant chopper is used in regenerative breaking

2nd " " use boost chopper concept not exactly Boost chopper.

1st quadrant chopper (i.e Buck) used in motoring mode.

By Sir regenerative power for II^nd quad chopper

$$P = V_0 I_0$$

$$= V_s(1-\alpha) I_0$$

$$= 400 (1-0.5) 300$$

$$= 60 KW$$

during breaking m/c behave as D' gen^r

so gen^r eq^n

$E_b = V_o + I_o R_a$

neqd (min^m) speed when $(E_b)_{min}$

$(E_b)_{min} = \cancel{0}\ I_o R_a$

$K_m \omega_{min} = \frac{I_o R_a}{K_m} = \frac{300 \times 0.2}{1.2\ Vs/rad} = 50\ rad/sec$

neqd max^m speed when $V_o =$ max^m i.e $V_o =$ Supply voltage $= V_s$

" " " " " $(E_b)_{max}$

$(E_b)_{max} = V_s + I_o R_a$

$= 400 + (300 \times 0.2)$

$$\omega_{max} = \frac{400 + (300 \times 0.2)}{1.2\ Vs/rad}$$

$\omega_{max} = 383.33$ Rad/sec

(c) $E_b = V_o + I_o R_a$

$K \cdot \omega = V_s(1-\alpha) + I_o R_a$

$$\omega = \frac{400(1-0.5) + (300 \times 0.2)}{1.2\ Vs/rad}$$

$\omega = 216.67$ rad/sec

Q
The speed of a seperately excited dc motor is controlled through a 1Φ HWave controlled converter from 230 volts mains the motor arm^r resistance is 0.5Ω and motor const is K = 0.4 Vs/rad for load torque of 20 Nm at 1500 rpm and for const arm^r current calc

ⓐ Firing angle delay of a conv^r

ⓑ Rms value of thyristor current.

ⓒ i/p power factor of the motor

Sol^n 1Φ Half wave — means 1 pulse

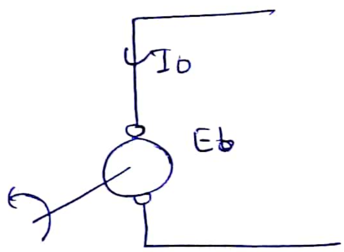
1Φ Half controlled — means 2 pulse semiconv^r

$$230 = E_b + I_o R_a$$

$$230 = 0.4 \times \omega + I_o \times 0.5\Omega$$

$$P = T\omega$$

$$T_L = 20\,Nm = \frac{P}{\omega} = \frac{V_o I_o}{}$$



$$T_L = E_b \times I_o$$

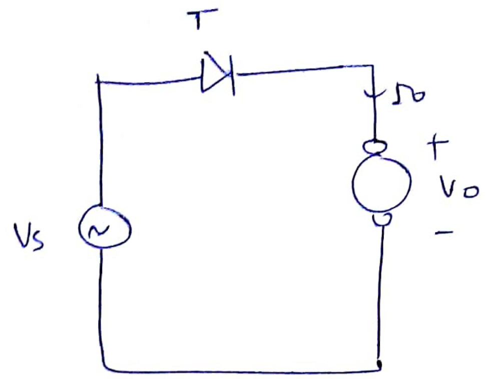
$$E_b = 230 - I_o R_a$$

$$\omega_m = \frac{230}{K} - \frac{I_o R_a}{K}$$

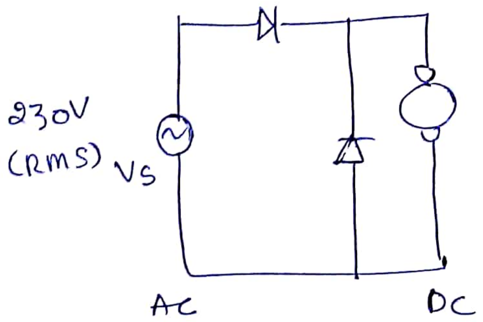
$$= \frac{230}{0.4} - \frac{20 \cdot R_a}{K\omega_m \cdot K}$$

$$T_L = 20 = E_b \times I_o$$

$$20 = 0.4 \times \frac{2\pi 1500}{60} \times I_o$$



⇓



$T_a = K I_o$

$20 = 0.4 I_o$

$I_o = \frac{20}{0.4} = 50A$

$V_o = \frac{V_m}{2\pi}(1+\cos\alpha) = E_b + I_o R_a$

$\frac{230\sqrt{2}}{2\pi}(1+\cos\alpha) = \frac{K \cdot 2\pi N}{60} + I_o R_a$

$= \frac{0.4 \times 2\pi(1500)}{60} + (50 \times 0.5)$

$\alpha = 45.84^\circ$

$(I_T)_{rms} = I_o \left(\frac{\pi-\alpha}{2\pi}\right)^{1/2}$

$= I_o \left(\frac{180-\alpha}{360}\right)^{1/2}$

$= 50\left(\frac{180-45.84}{360}\right)^{1/2}$

$= \cancel{21.5\ A} = 30.52$

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using power balance eqn

$P_{in} = P_o$

$V_{sr} \cdot I_{sr} \cdot PF = V_o I_o$

$V_o = \frac{\cancel{2\pi} V_m}{2\pi}(1 + \cos\alpha)$

$V_o = 87.83\,V$

$$PF = \frac{87.83 \times 60}{\underset{230}{\underset{\uparrow}{V_{sr}}} \times \underset{30.52}{\underset{\uparrow}{I_{sr}}}}$$

=

$PF = 0.625$

Find rectification efficiency

Rectification efficiency $= \frac{P_{DC}}{P_{ac}} = \frac{V_o \cdot \cancel{I_o}}{V_{or} \cdot \cancel{I_{or}}}$

$$V_{or} = \frac{V_m}{\sqrt{2 \cdot 2\pi}} \left\{ \underset{45.84 \times \frac{\pi}{180}}{\underset{\uparrow}{(\pi - \alpha)}} + \underbrace{\frac{1}{2} \sin 2\alpha}_{0.497} \right\}^{1/2}$$