IAT4 PW NAN12014

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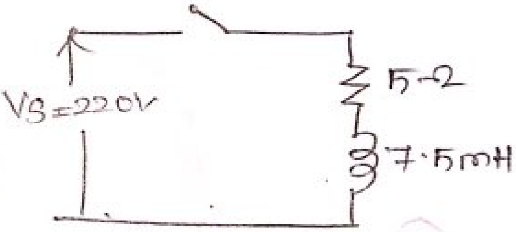
Internal Assesment Test III –Oct 2018								
Sub:	POWER ELECTRONICS						Code:	
Date:	22-[illegible]/11/2018	Duration:	90 mins	Max Marks:	50	Sem:	5	Section:

Note: Answer any five FULL Questions

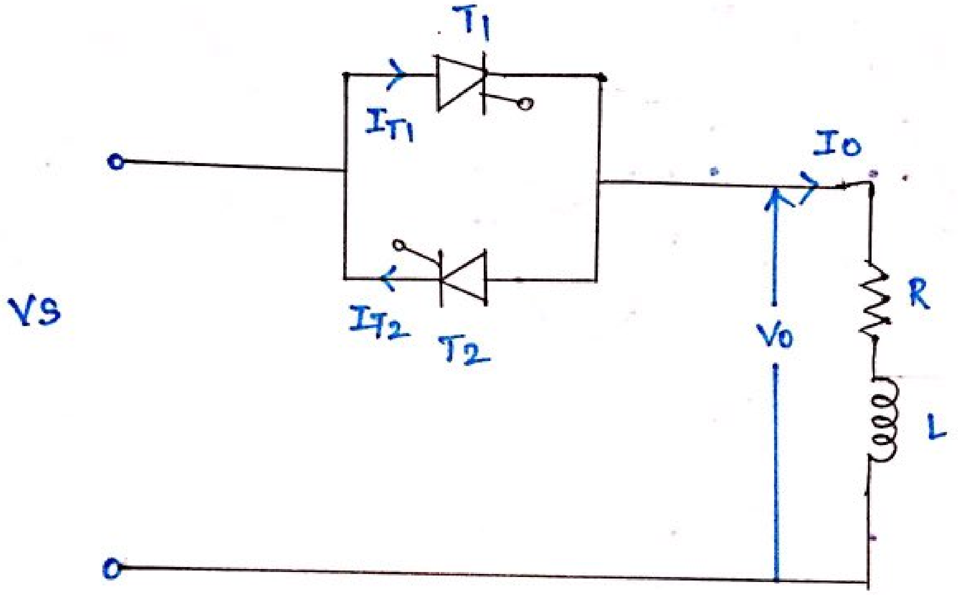
Sketch neat figures wherever necessary. Answer to the point. **Good luck!**

		Mark
1 (a)	With necessary waveforms, explain the operation of a single phase ac voltage controller with RL load. Derive the expression for rms output voltage	[8]
(b)	A single phase full wave ac voltage controller has an input voltage of 230V and a load resistance of 10Ω. The firing angle is 45° . calculate i) RMS output voltage and ii) output power and input power factor	[2]
2 (a)	With circuit diagram and waveforms explain the operation of single and three phase dual converters	[10]
3 (a)	Classify the different types of choppers with the help of circuit and quadrant diagram. Explain the operation of four quadrant chopper.	[10]
4 (a)	The single phase dual converter is operated from a 120V, 60Hz supply and the load resistance is 10 Ω. The circulating inductance is Lr = 40mH, delay angles are α1 = 60° and α2 = 120°. Calculate the peak circulating current and the peak current of converter 1	[5]

(b)	For the chopper circuit shown in the figure , the duty cycle is 0.5 and chopping frequency is 5kHz. Determine : i) Minimum instantaneous load current ii) Peak instantaneous load current iii) Maximum peak to peak current in load iv) Average and rms load current  	[5]	CO5
5 (a)	With a neat circuit diagram and waveforms explain 180 mode of operation of a three phase inverter. Give the expression for line and phase voltages for one cycle	[8]	CO5
(b)	Discuss the advantages of current source inverter over voltage source inverter	[2]	CO5
6 (a)	Explain the working of step-up chopper. Draw the relevant waveforms. Derive an expression for average output voltage.	[6]	CO5
(b)	A step down chopper has an input voltage of 200v and a load of 8Ω resistance. The voltage drop across thyristor is 2v and the chopping frequency is 800Hz. The duty cycle is 0.4. find i) average and rms output voltage ii) chopper efficiency	[4]	CO4
7	With the help of circuit diagram and waveforms, explain the working of single phase full converter with RL load.	[10]	CO4

1ϕ AC Voltage controller with RL load:-

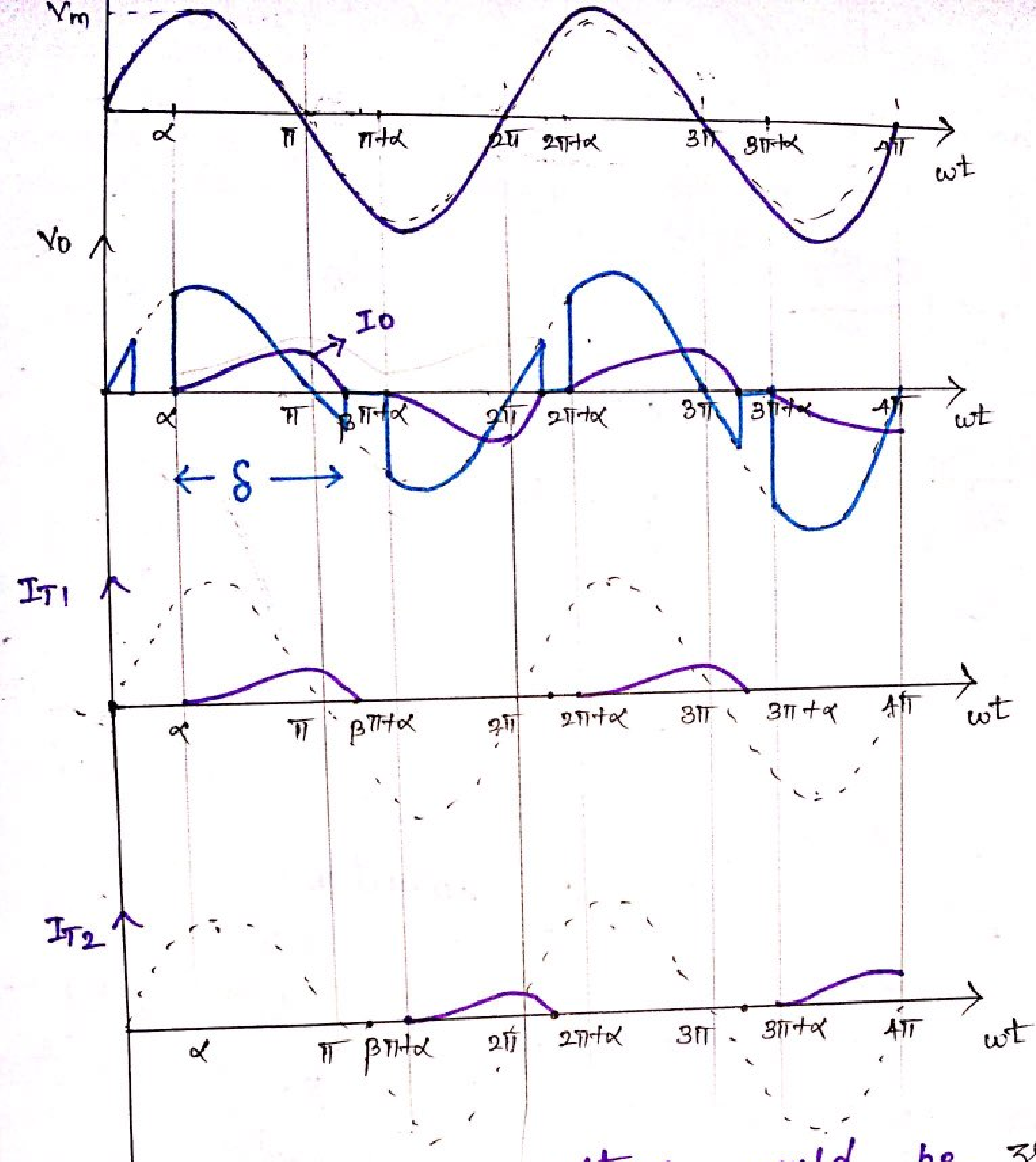
In practice most of the load are inducti in nature. ac voltage controller with RL load is shown in the below figure.



* Thyristor T_1 is fired during +ve half cycle carries the load current. Due to **inductance** in the load circuit, the thyristor T_1 would not fa zero at $\omega t = \pi$, instead **continues** to conduct inductor current falls to zero at $\omega t = \beta$.

* The conduction angle of the thyristor is $\delta = \beta - \alpha$

β - is termed as **extinction angle**.



* The avg o/p voltage would be zero, since voltage is symmetrical.

RMS Value of o/p voltage:

$$V_{o\,rms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} V_m^2 \sin^2 \omega t \; d\omega t}$$

$\because \beta$ to $\pi+$

$V_o \to 0$

$$V_{o\,rms}^2 = \frac{V_m^2}{\pi} \int^{\beta} \left(\frac{1-\cos 2\omega t}{2}\right) d\omega t$$

$$V_{oRMS}^2 = \frac{V_m^2}{2\pi}\left(\omega t - \frac{\sin 2\omega t}{2}\right)_\alpha^\beta$$

$$= \frac{V_m^2}{2\pi}\left[\beta-\alpha - \frac{\sin 2\beta}{2} + \frac{\sin 2\alpha}{2}\right]$$

$$= \frac{V_m^2}{2\pi}\left[\beta-\alpha + \frac{\sin 2\alpha}{2} - \frac{\sin 2\beta}{2}\right]$$

$$V_{oRMS} = V_m\left[\frac{1}{2\pi}\left(\beta-\alpha+\frac{\sin 2\alpha}{2} - \frac{\sin 2\beta}{2}\right)\right]^{1/2}.$$

~~The RMS load current :-~~

$$\cancel{I_{o_{RMS}}} = \cancel{\frac{V_{oRMS}}{}}$$

$$\frac{V_m}{\sqrt{2}}$$

$$i/p\ PF = \sqrt{\frac{(\pi-\alpha) + \frac{\sin 2\alpha}{2}}{\pi}}$$

6.5 A 1φ full-wave ac voltage controller has $R_L = 5\Omega$ and the i/p voltage is 120 V (rms), 60Hz. The delay angles of T_1 and T_2 are equal $\alpha_1 = \alpha_2 = \frac{2\pi}{3}$. ⇒

Calculate
- a) the rms o/p voltage
- b) the i/p PF
- c) the average current of thyristor I_T
- d) rms current of thyristor. current

$\alpha = 120^\circ$

$= 2.094$

$$a)\quad V_{o\,rms} = V_m \sqrt{\frac{(\pi-\alpha) + \frac{\sin 2\alpha}{2}}{2\pi}}$$

$$= \sqrt{2} \times 120 \sqrt{\frac{(\pi - 2.094) + \frac{\sin 2\times 120}{2}}{2\pi}}$$

$$\boxed{V_{o\,rms} = 53.07}$$

$P = VI\cos\phi$

b) Input PF $= \sqrt{\dfrac{(\pi - \alpha) + \dfrac{\sin 2\alpha}{2}}{\pi}}$

$= \sqrt{\dfrac{(\pi - 2.094) + \dfrac{\sin 240}{2}}{\pi}}$

$= 0.4423$ (lag)

c) $I_T = \dfrac{V_m}{2\pi R}(1 + \cos\alpha)$

$= \dfrac{\sqrt{2} \times 120}{2\pi \times 5}(1 + \cos 120)$

$= 2.7$ A

d) $I_{T\,rms} = \cancel{\dfrac{53.07}{2\pi\, 5}} \cancel{= 1.7}\ \cancel{16.61A} = \dfrac{\sqrt{2} \times 120}{5}\sqrt{\dfrac{(\pi - 2.094) + \dfrac{\sin 240}{2}}{4\pi}}$

$= 7.506$ A

② Repeat above prob with $V_S = 200V$, $\alpha = \pi/2$

$V_{o(rms)} = 141.38V$

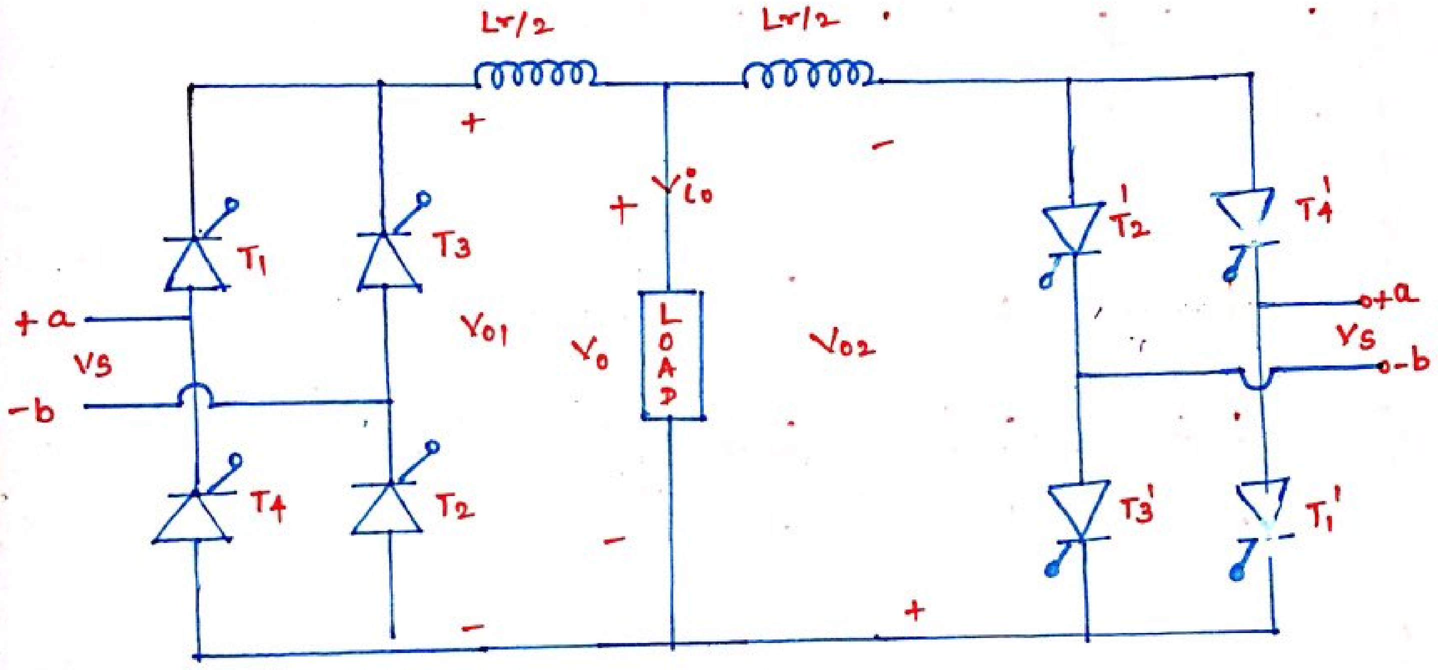
PF $= 0.707$

$I_T\,(avg) = 4.5A$

$I_T\,(rms) =$

Single-phase Dual Converters

- * Single phase full converters with inductive loads two-quadrant operation is possible.
- * If these two converters are connected back to back then both voltage and current can be reversed i.e four-quadrant operation is possible.
- * Such a converter is called dual converter

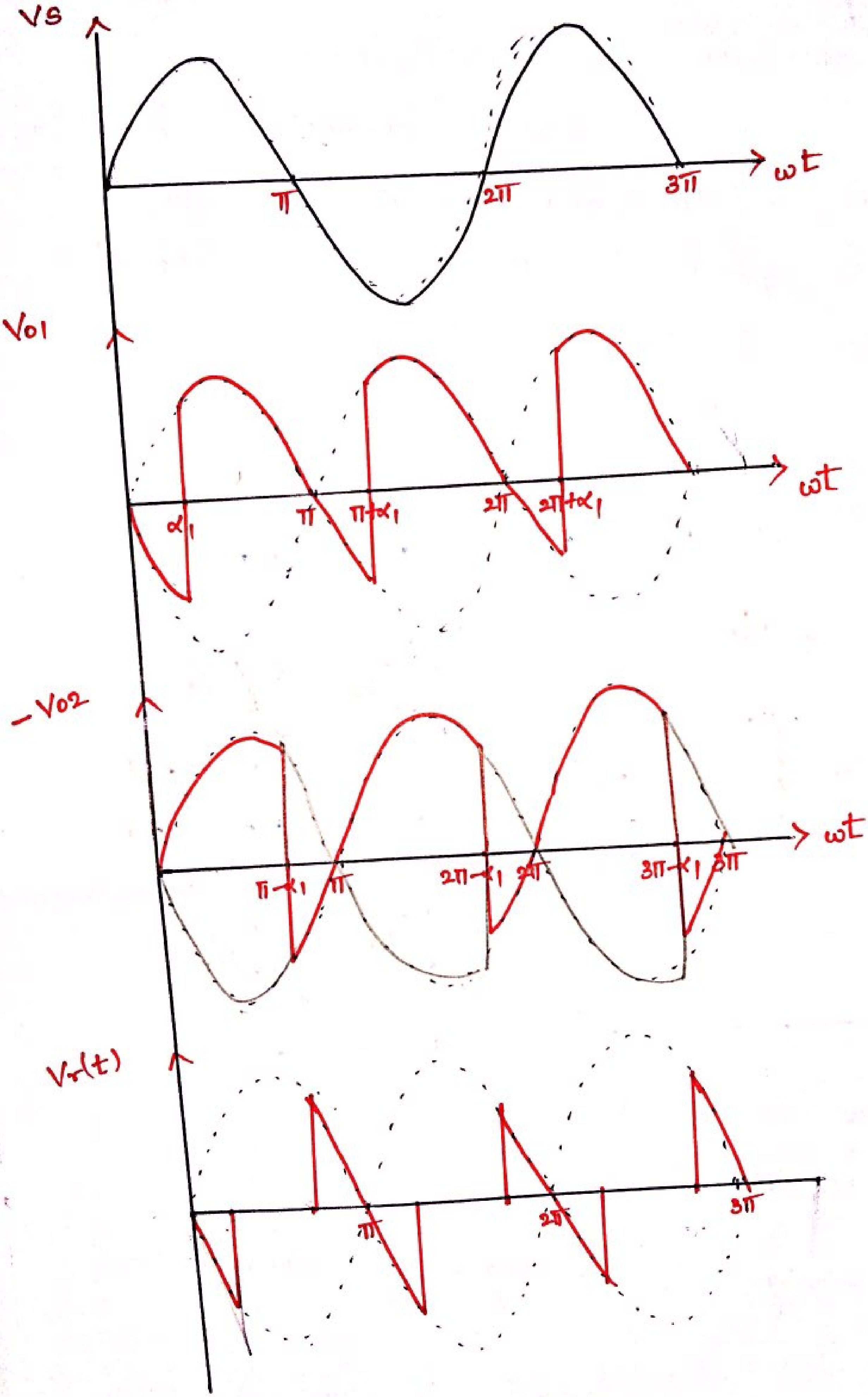


α_1 - firing angle of converter 1

α_2 - firing angle of converter 2

V_{d1} and V_{dc2} - average o/p voltages of converter 1 and converter 2.

- * The firing angles are adjusted in such a wa that one converter acts as rectifier and the other converter operates as an inverter


Vs
ωt
π
2π
3π
Vo1
ωt
α1
π
π+α1
2π
2π+α1
-Vo2
ωt
π-α1
π
2π-α1
2π
3π-α1
3π
Vr(t)
π
2π
3π

$$V_{dc_1} = \frac{2V_m}{\pi}\cos\alpha_1 \quad \text{and} \quad V_{dc_2} = \frac{2V_m}{\pi}\cos\alpha_2$$

Since one converter is rectifying and the other one is inverting,

$$V_{dc_1} = -V_{dc_2}$$

$$\frac{2V_m}{\pi}\cos\alpha_1 = -\frac{2V_m}{\pi}\cos\alpha_2$$

$$\cos\alpha_1 = -\cos\alpha_2$$

$$= \cos(\pi-\alpha_2)$$

$$\text{i.e}\quad \alpha_1 = \pi-\alpha_2$$

or

$$\alpha_2 = \pi-\alpha_1$$

$$\alpha_1+\alpha_2 = \pi.$$

Bcoz of difference in the instantaneous o/p voltages of conv1 and con 2, circulating current flows b/w two converters - therefore current limiting reactor or inductor Lr is used as shown in the figure.

The dual converters are operated in two modes,

⇒ Circulating current mode

⇒ Non-circulating current mode.

Non-circulating current mode - only one converter perates at a time (which carries the load current) nd other converter remains in non-conducting state gate pulses are blocked.

3) the reversal of load current is natural and smooth procedure.

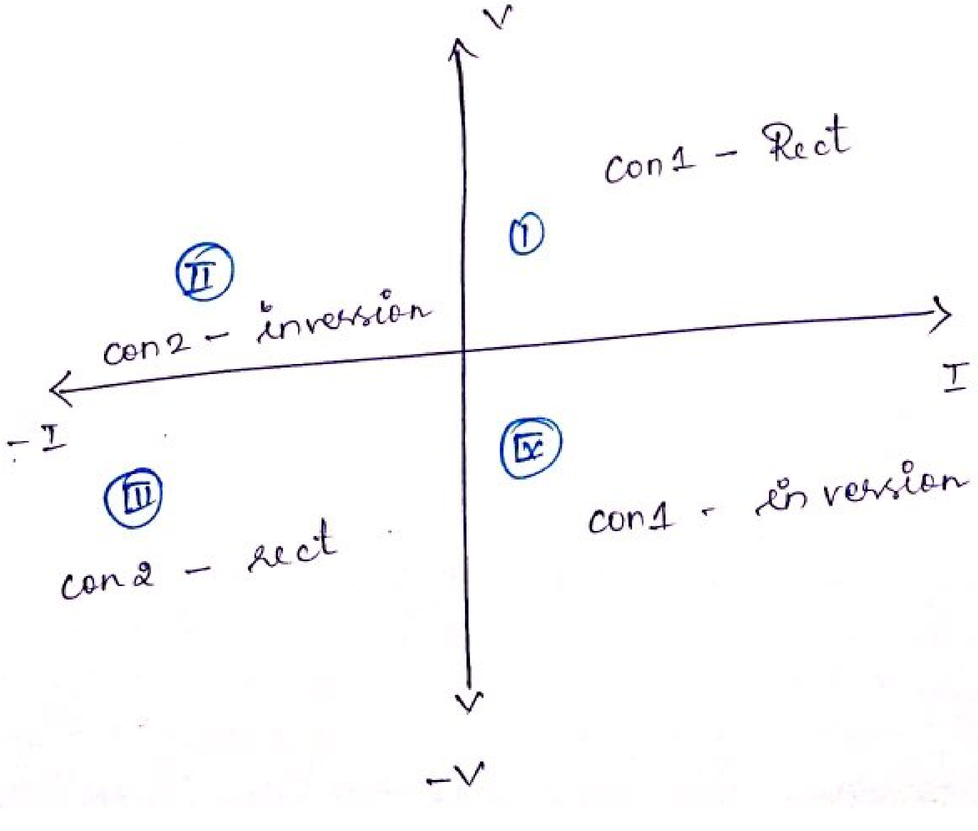
4) current sensing is not required and also the normal delay time of . 10 to 20ms is eliminated.

Dis-advantages:-

1) current limiting reactor is required, whose size and cost increases with increasing high power applications.

2) Thyristors with high current ratings are required ~~as~~ since converters should handle load as well as circulating current.

3) With circulating current η and PF are low.



$= 16.97 + 9 \Rightarrow 25.97\ A$.

② 1ϕ circulating dual converter is fed by 230V, supply. The load is resistive. The peak curre converter 1 is 39.7 A. $\alpha_1 = 45$ and $\alpha_2 = 135$. if peak circulating current is 11.5 A. Find

i) inductance of current limiting reactor

ii) load resistance.

$f = 50Hz$, $V_{rms} = 230V$. con 1 peak current 39.7 A.

$\alpha_1 = 45$, $\alpha_2 = 135$. $i_{r\,max} = 11.5\ A$.

W.K.T con 1 peak current $= I_p + i_{r(max)}$

$\therefore I_p$ (peak load current) = con 1 peak current $- i$

$= 39.7 - 11.5 \Rightarrow 28.2$

$$I_p \Rightarrow 28.2 \Rightarrow \frac{V_m}{R}$$

$$R \Rightarrow \frac{V_m}{I_p} \Rightarrow \frac{\sqrt{2} \times 230}{28.2} \Rightarrow 11.53\Omega .$$

$$i_{r\,max} = \frac{2V_m}{\omega L_r}\left[1 - \cos\alpha_1\right]$$

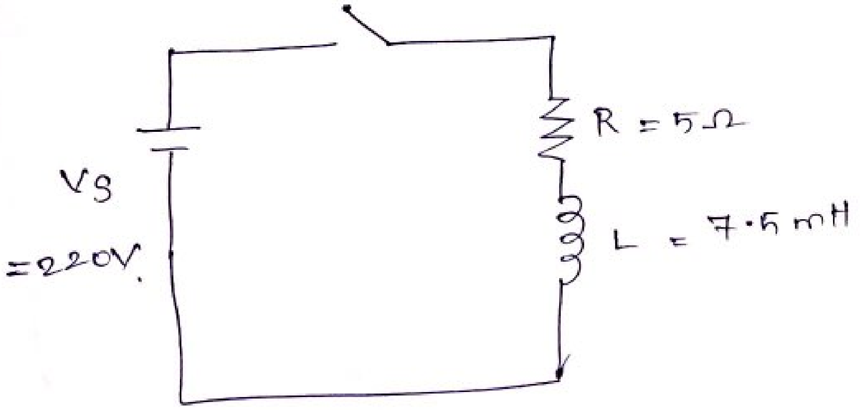
$$L_r = \frac{2V_m}{\omega i_{r max}}\left[1 - \cos 45\right]$$

$$= \frac{2 \times \sqrt{2} \times 230}{2\pi \times 50 \times 11.5}(0.2928) \Rightarrow 52.73\ mH .$$

① For the given chopper ckt ⑧.

calculate
i) the min instantaneous load current
ii) the peak 〃
iii) the max peak to peak ripple current
iv) average load current
v) rms load current.
vi) Ri.

f = 1KHz.
K = 0.5.



$$I_1 = I_2 e^{-\frac{R}{L}t_2} - \frac{E}{R}\left(1-e^{-R/L\, t_2}\right)$$

$$I_1 = I_2 e^{-R/L\, t_2} \quad — ①$$

$\boxed{\because E = 0}$.

$$I_2 = I_1 e^{-R/L\, t_1} + \frac{Vs}{R}\left(1-e^{-R/L\, t_1}\right) \quad —②$$

$f = 1KHz$, $T = \frac{1}{1\times10^{3}} \Rightarrow 1ms$.

$K = 0.5$, $t_1 = t_2 = 0.5ms$.

$$I_1 = I_2\, e^{-\left(\frac{5\times0.5\times10^{-3}}{7.5\times10^{-3}}\right)} \Rightarrow$$

$$\boxed{I_1 = 0.7165 I_2} \quad — ①.$$

Three Phase Bridge Inverters :-

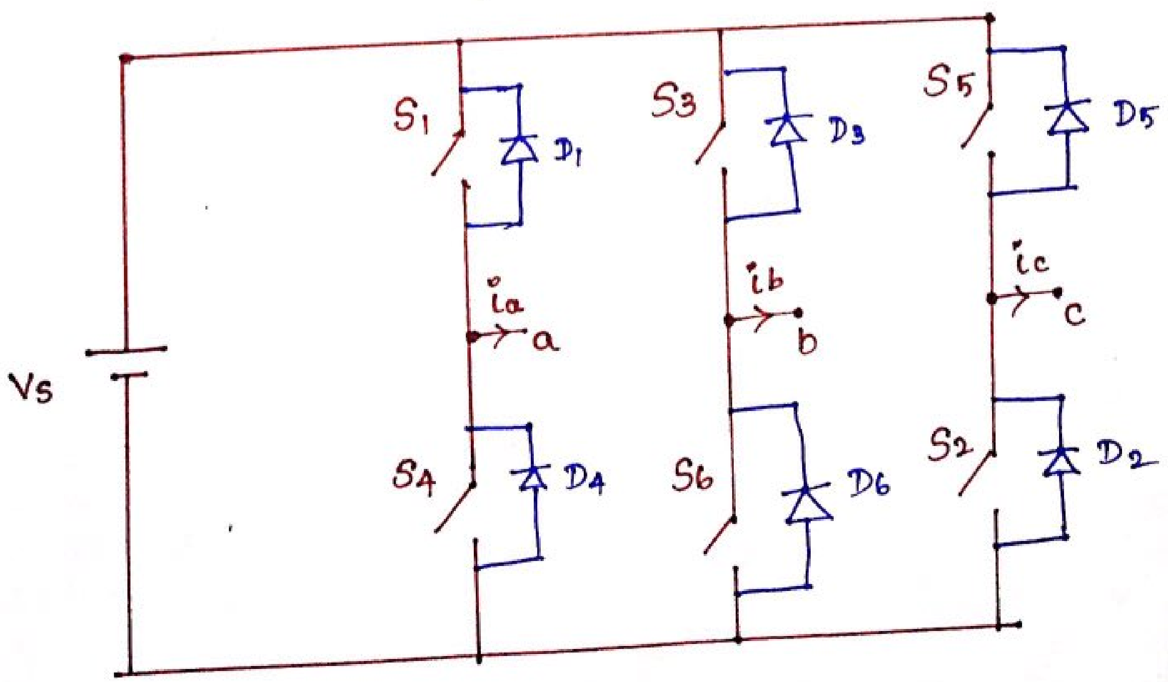
Three phase inverters are used for h
applications

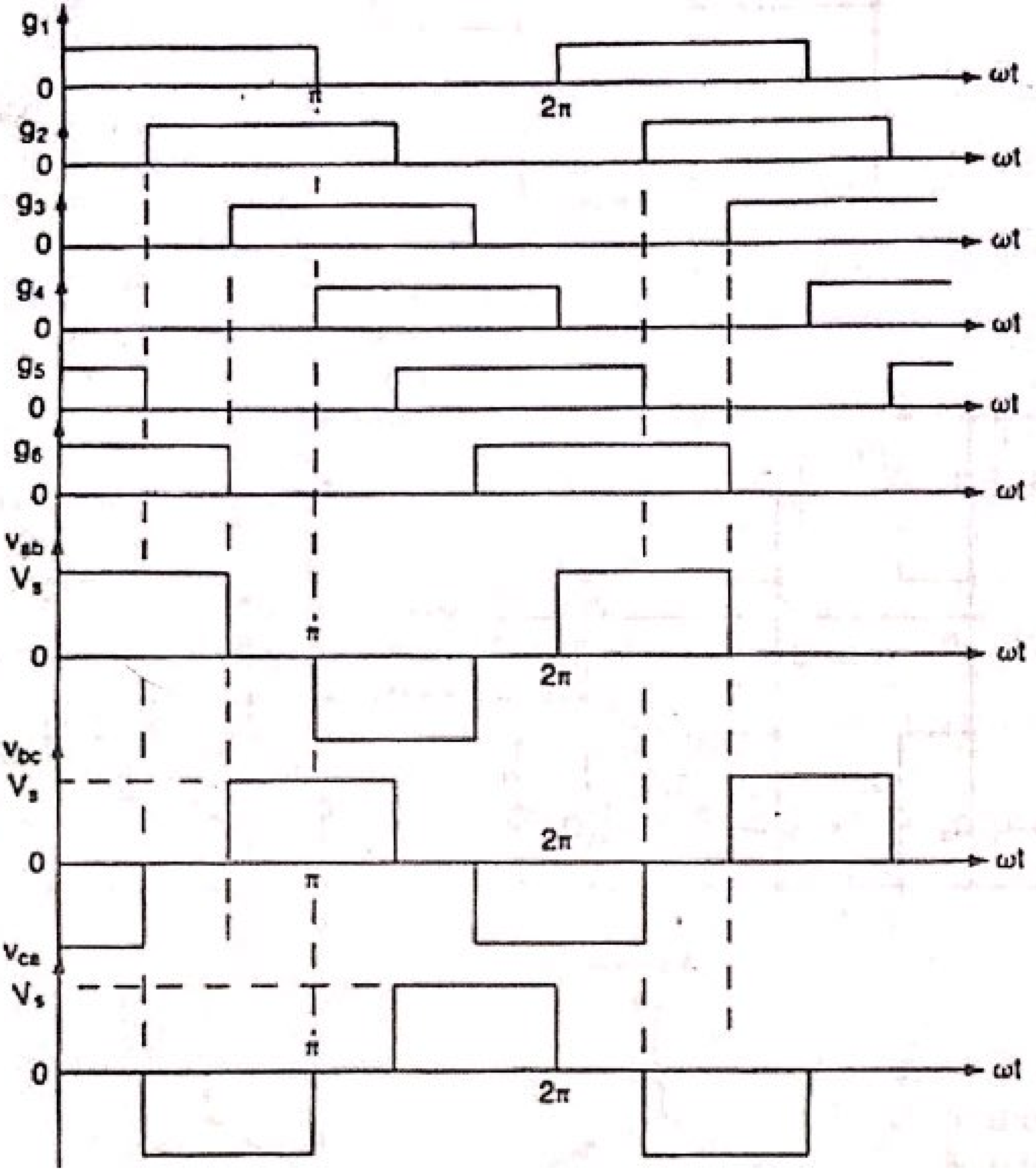
Two types of control signals can be applied
switches, accordingly two modes are there,

i) 180° conduction

ii) 120° conduction

3ϕ BRIDGE INVERTER



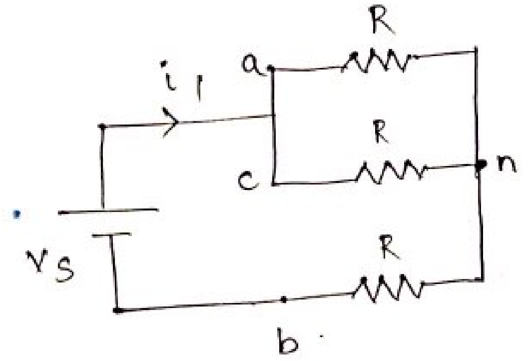


g₁
0
π
2π
ωt
g₂
0
ωt
g₃
0
ωt
g₄
0
ωt
g₅
0
ωt
g₆
0
ωt
vab
Vs
π
0
2π
ωt
vbc
Vs
2π
0
π
ωt
vca
Vs
π
0
2π
ωt

For star-connected load, the phase voltages can be drawn as shown below.

There are three modes during first half cycle (180°).

Mode 1:- 0 - 60°,



equivalent circuit

conducting devices, 1, 5, 6.

$$R_{eq} = R + \frac{R}{2} = \frac{3R}{2}$$

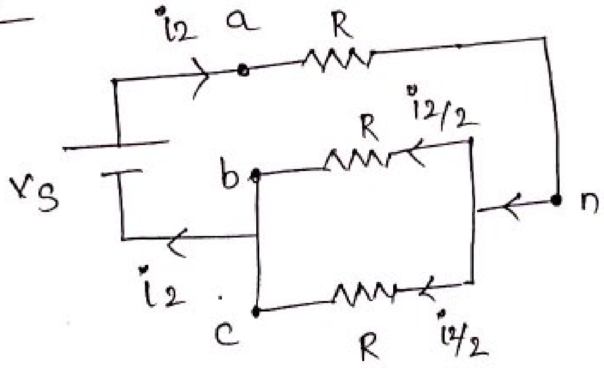
$$i_1 = \frac{V_S}{R_{eq}} = \frac{2V_S}{3R}$$

$$V_{an} = V_{cn} = \frac{i_1 R}{2} \Rightarrow \frac{\cancel{2} V_S R}{3R \times \cancel{2}} \Rightarrow \frac{V_S \cancel{R}}{3\cancel{R}}$$

$$= \frac{V_S}{3}.$$

$$V_{bn} = -i_1 R \Rightarrow -\frac{2V_S}{3R} \times R \Rightarrow \frac{-2V_S}{3}.$$

Mode 2:- 60° - 180° - conducting devices 6, 1, 2.



$$R_{eq} = \frac{3R}{2}$$

$$i_2 = \frac{2V_S}{3R}$$

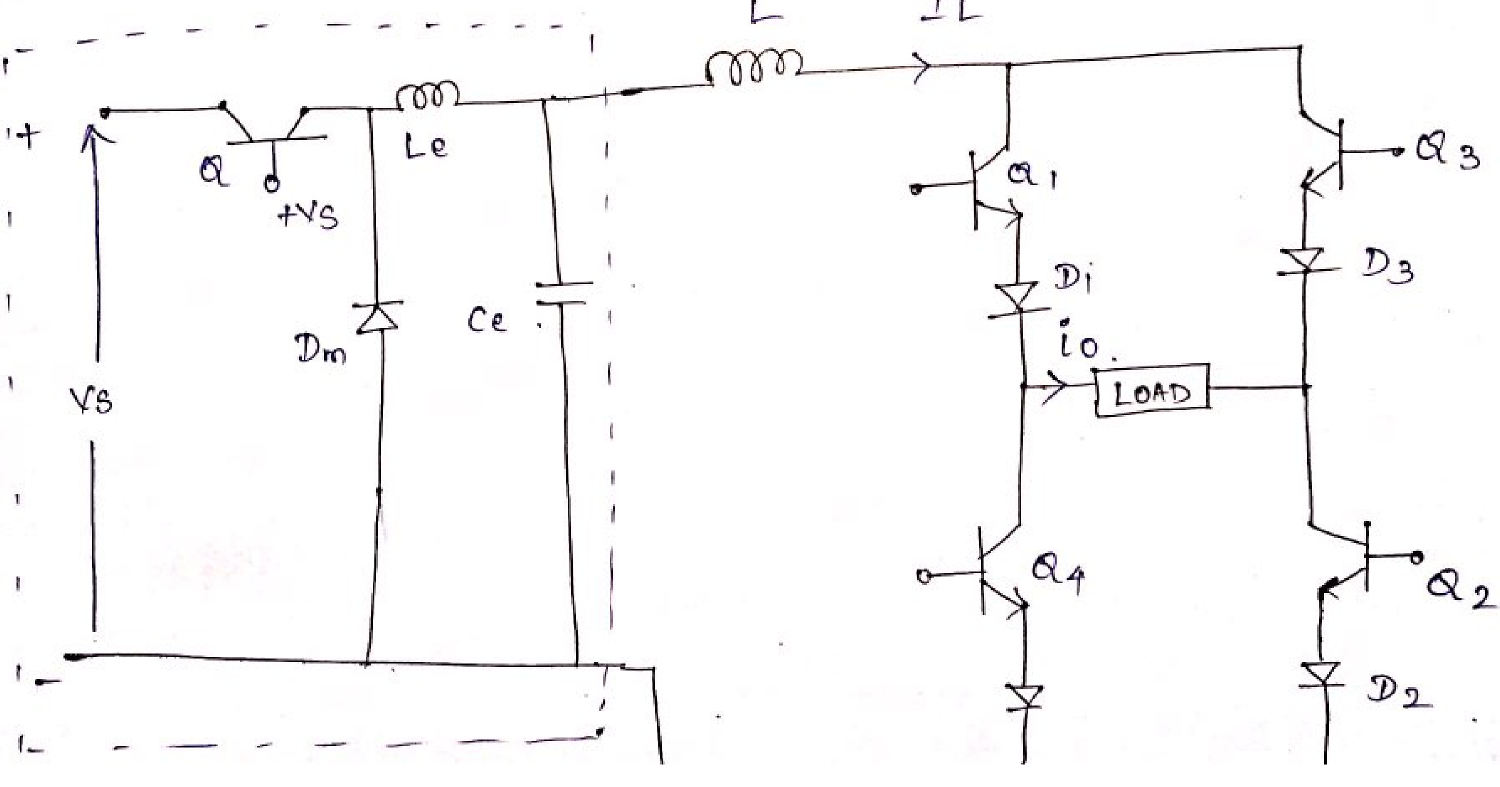
$$V_{an} = i_2 R = \frac{2V_S}{3}.$$

$$V_{bn} = V_{cn} = -\frac{i_2}{\ } R \Rightarrow \frac{-V_S}{3}.$$

* In voltage source inverters VSI , i/p voltag is maintained const and the amplitude of o/p voltage doesnot depend on the load. but nature and magnitude of load current depends on load impedance.

* In current source inverters CSIs, i/p curren is const but adjustable and the amplitude of o/p current is independent of load. i.e the magnitude of o/p voltage is dependent on load impedance.

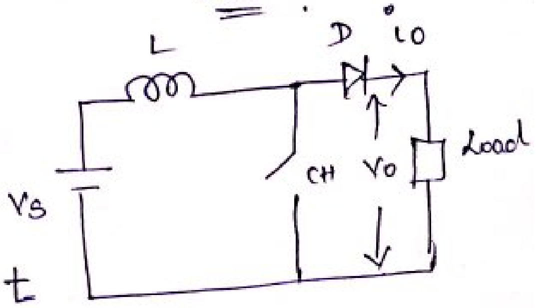
1ϕ CSI using Transistor

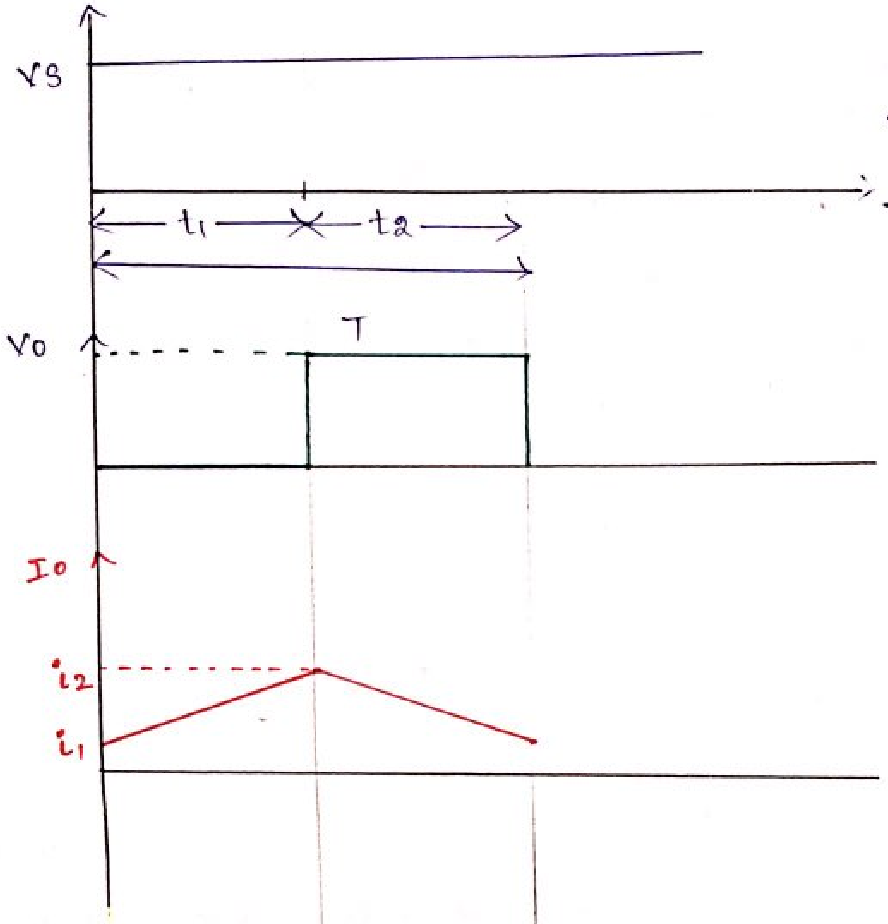


STEP UP CHOPPER :-

Using choppers, dc voltage can be stepped up. The arrangement for step-up chopper is shown below.

ckt





* When the switch is ON for time period t_1, the inductor current rises and energy is stored in the inductor

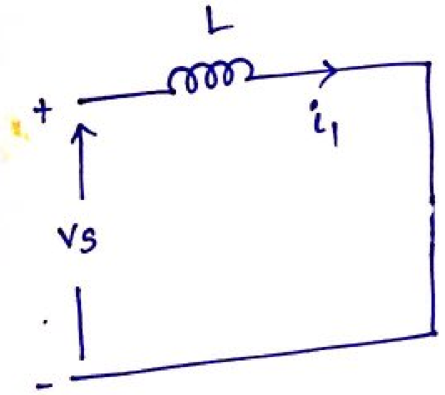
* When the switch is OFF for time period t_2, the energy stored in the inductor is transfered to load thro D_1 and the current falls.

when $K = 0$, $v_o = V_S$

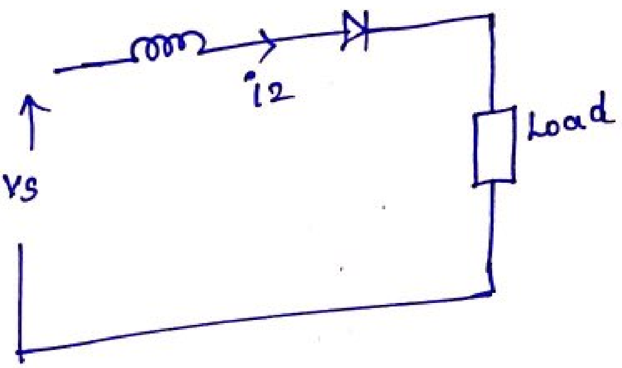
$K = 0.5$, $v_o = 2V_S$

$K = 1$, $v_o = \infty$ (which is not practically feasible)

The equivalent ckts for mode 1 (switch ON) and mode 2 (switch OFF) is shown below.



Mode 1



Mode 2

Numerical Probs (from VTU QP).

① For the given chopper circuit, the duty cycle is 0.5 and chopping frequency 5KHz. Determine

i) minimum instaneous load current

ii) peak instaneous load current

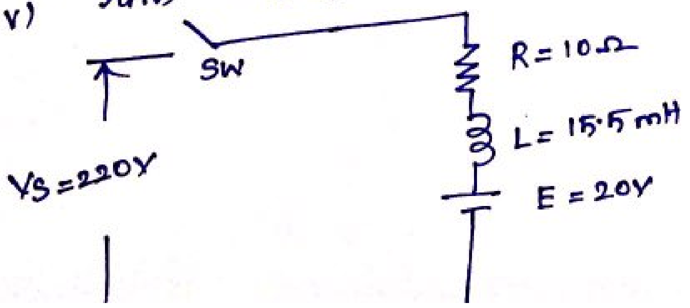
iii) Max peak to peak current in load

and rms load current.

iv) average chopper current.

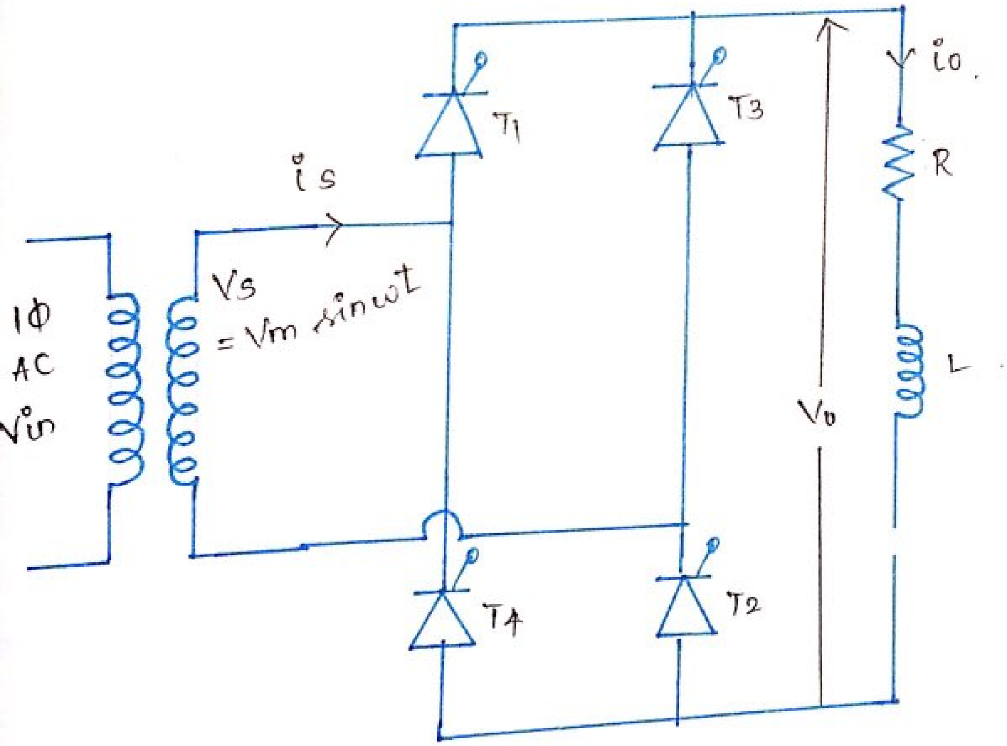
v) rms

X Practice prob -X.



Single phase full-wave rectifier with RL(E) load

(Highly inductive load - current is continuous and ripple free)

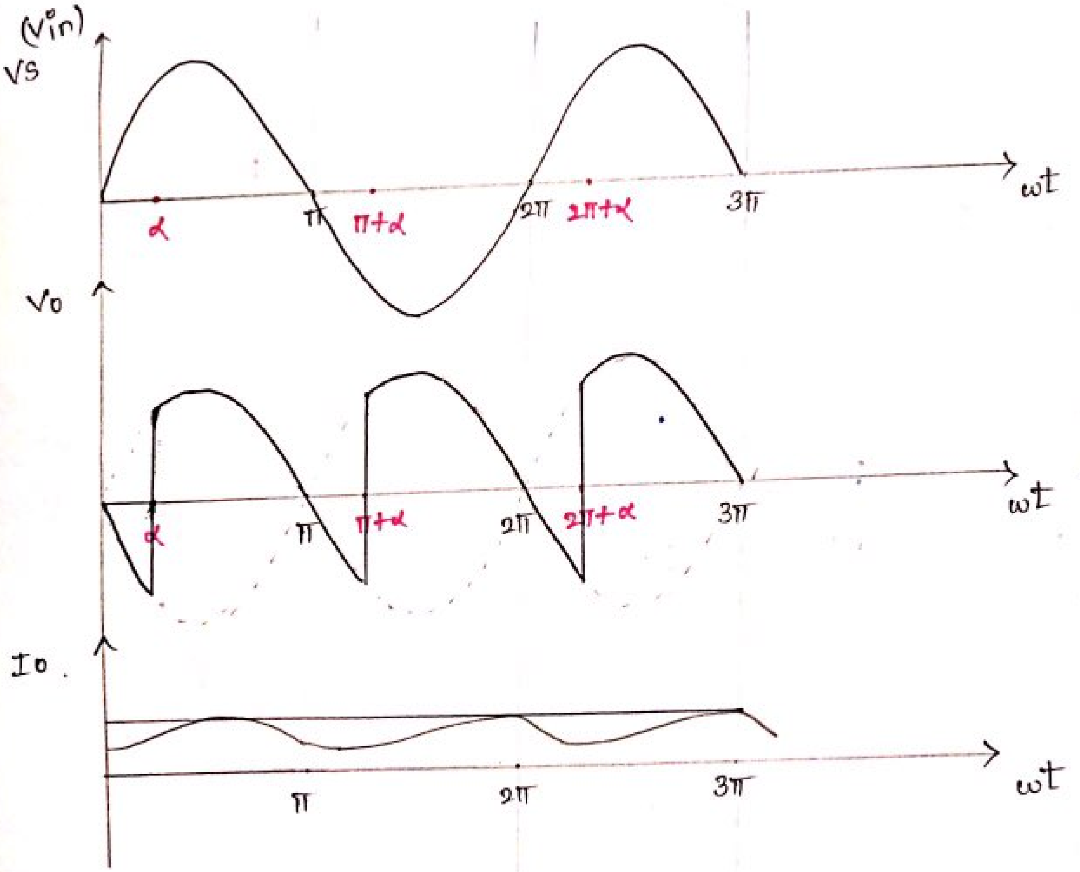


- During +ve half-cycle of i/p, T_1 and T_2 are forward biased and when they are fired simultaneously at $\omega t = \alpha$, load gets connected to the source and follows the supply voltage.

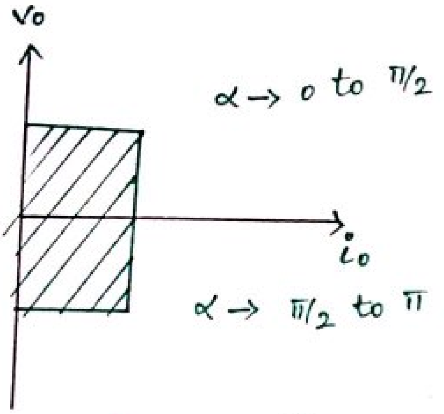
- T_1 and T_2 continue to conduct beyond $\omega t = \pi$ due to inductive load, even though i/p voltage is -ve.

- Similarly, during -ve half-cycle, T_3 and T_4 comes into conduction i.e T_1 and T_2 will be turned off due to line or natural commutation

- Single-phase full converter with inductive load can be operated in two-quadrant.



⇒ depending on the value of α, the o/p voltage could be either +ve or -ve



Average o/p voltage :- $V_{o\,avg} = \frac{1}{T}\int_0^T v_o \, dt \rightarrow V_{dc}$

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

$\because -\cos(\pi+\theta) = \cos\theta$.

$$= \frac{V_m}{\pi}\left(-\cos \omega t\right)_{\alpha}^{\pi+\alpha}$$

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

$$= \frac{2V_m}{\pi}\cos\alpha$$

$$V_o(avg) = \frac{2V_m}{\pi}\cos\alpha .$$

$V_{dc} = \frac{2V_m}{\pi}\cos\alpha$

V_{dc} can be varied from $\frac{2V_m}{\pi}$ (when $\alpha = 0$) to $-\frac{2V_m}{\pi}$ (when $\alpha = 180$).

i e max average o/p voltage $= V_{dm} \Rightarrow \frac{2V_m}{\pi}$

$\therefore$ normalized o/p voltage $= \frac{V_{dc}}{V_{dm}} \Rightarrow \frac{\frac{2V_m}{\pi}\cos\alpha}{2V_m/\pi}$.

$= \cos\alpha$.