Assignment : 02 (By Manan Madan
2018U1C3087)

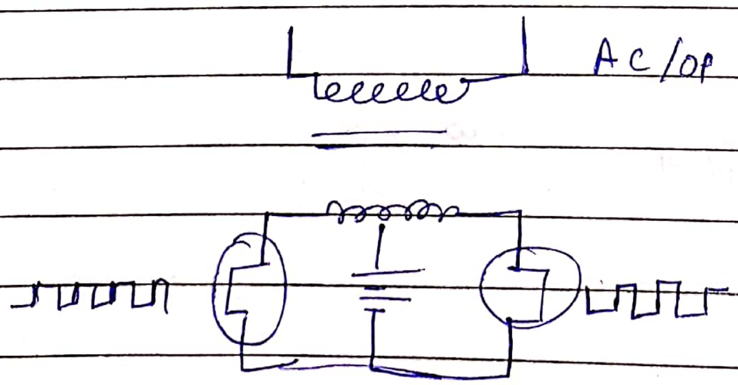
Que: 01 What is an inverter ? List few industrial applications of it.

Ans: An inverter is an electrical device, & it is capable of changing a DC current to an AC current at a given frequency as well as voltage. The AC power can be supplied to homes & industries using the public utility otherwise power grid, the alternatic power system of the batter can store only DC power.

In some situtions like when the DC voltage is low, then we cannot use the low DC voltage in home appliance. So due to this reason, an inverter can be used whenever we utilize solar power pannel.

Types of Invertor :

- Single phase Inverter
- Three phase Inverter



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Applications:

- used as an UPS (uninterruptible power supplies)
- used as standalone inverters.
- used in Solar power systems
- used in Centrifugal fans, pumps, mixers, extruders, test stands and web handling equipment.

Que: 02 what are the purpose of connecting diodes in antiparallel with thyristors in inverter circuits?

Ans: when a diode got connected with thyristor or SCR then it became unipolar switch.
whenever a diode placed antiparallel to any switching device it became unipolar so when diode connected its voltage drop on forward biased will became reverse voltage drop for SCR during its off-time & voltage drop for power diode is between 0.8 - 1 volt so reverse power loss become less for SCR as initially we may considering some bulky commutation circuit with voltage drop more then 1 volt so power loss more in other then antiparallel diode.
by using antiparallel diode power loss decreases & turn-off time increases.

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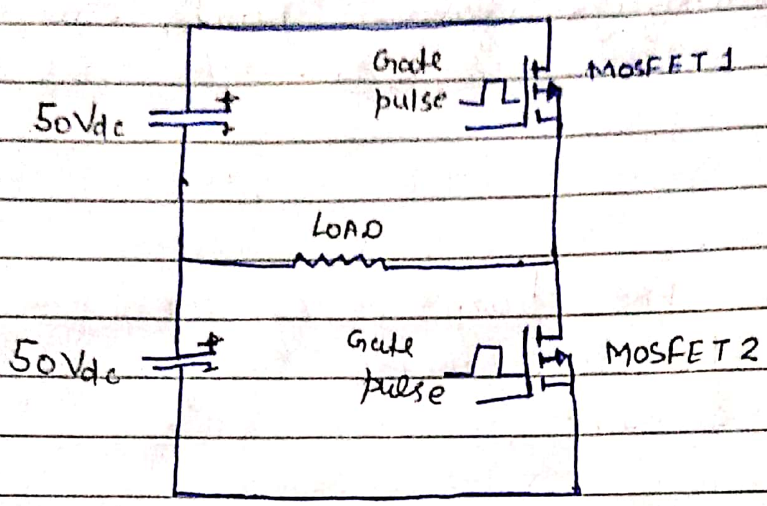
Que:03 Describe the working of a single phase half bridge inverter, what is its main drawback? Explain how this drawback is overcome.

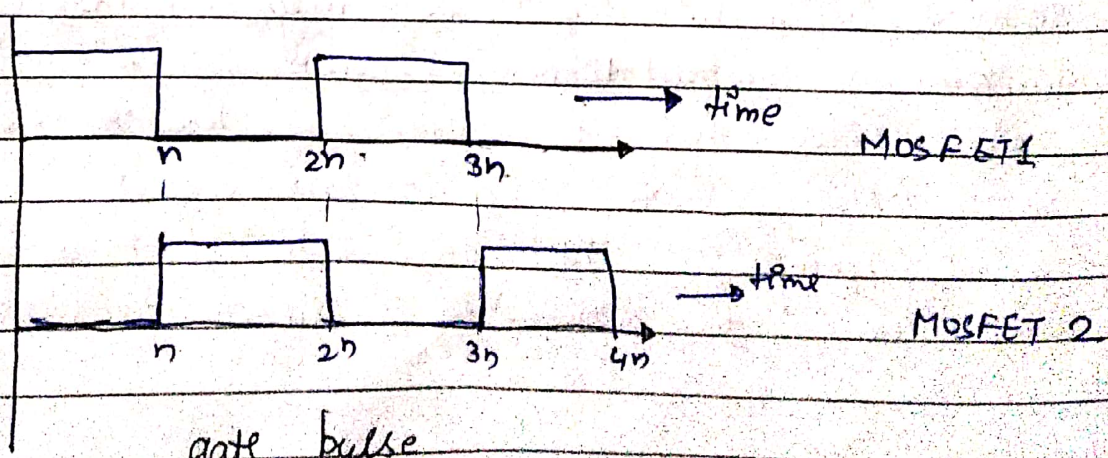
⇒ Ans:



Half Bridge inverter

This type of Inverter requires two power electronics switches (MOSFET). The MOSFET or IGBT is used for switching purpose.

As shown in circuit diagram, I/P DC voltage is $V_{dc} = 100V$. This source is divided into two equal parts.



gate pulse

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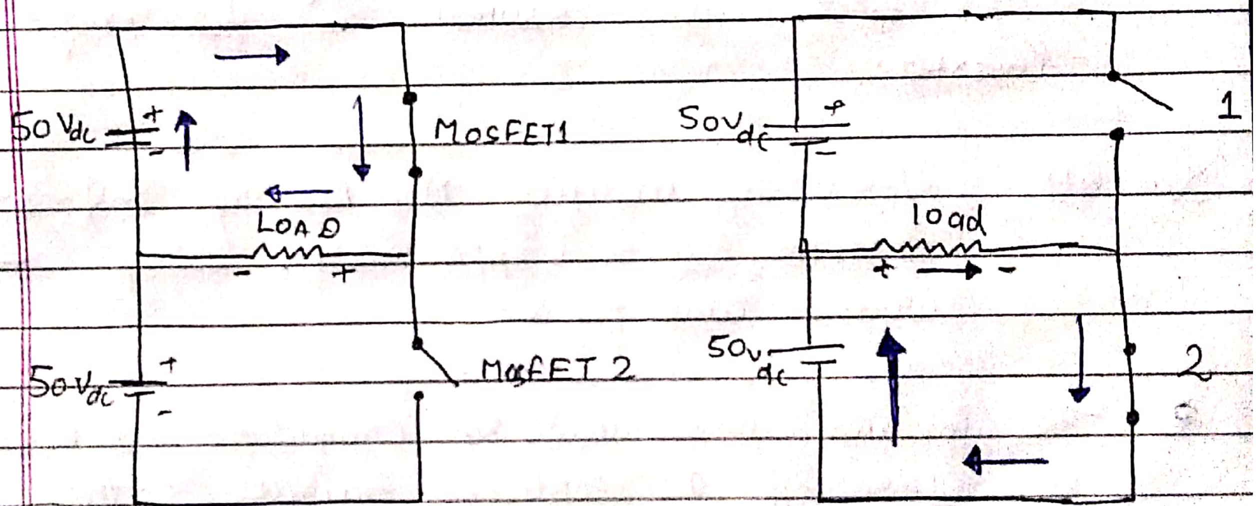
Acc" to o/p freq., ON time and OFF time of MOSFET is decided & gate pulse are generated. we need 50Hz AC power, so the time period of one cycle $(0 < t < 2\pi)$ is 20 msec. from fig., MOSFET-1 is triggered for first half cycle $(0 < t < \pi)$ and during this time period, current will flow in dir^n of arrow as shown in below figure & half cycle of AC o/p is completed. The current from the load is right to left & load voltage is equal to $+V_{dc}/2$.



In second half cycle $(\pi < t < 2\pi)$, the MOSFET-2 is triggered and lower voltage source is connected with the load. The current from the load is left to right dir^n & load voltage is equal to $-V_{dc}/2$.

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Drawbacks :

The main drawback is source utilization factor when compared to full bridge inverter.

It don't utilise the total source voltage at a time.

In every half cycle, voltage across the load is only half of source voltage i.e., $V_S/2$. whereas in full bridge inverter in every half cycle total voltage V_S appears across the load. So the power consumed by load is half of what is consumed in full bridge inverter.

Que:04 Describe modified Mc Murray half-bridge inverter with appropriate voltage & current wave forms.

⇒ The inverter uses auxiliary commutation scheme to turn off a conducting thyristor. The main inverter circuit is similar to the half-bridge circuit, except that it uses Thyristors T_1 & T_2 in place of commutated switches S_1 & S_2. The commutation circuit consists of ~~two~~ auxiliary thyristors TA_1 & TA_2 along with anti-parallel diodes DA_1 & DA_2 commutating elements L & C, and damping resistance R. To transfer current from T_1 to T_2, TA_1 is triggered and to transfer cur from

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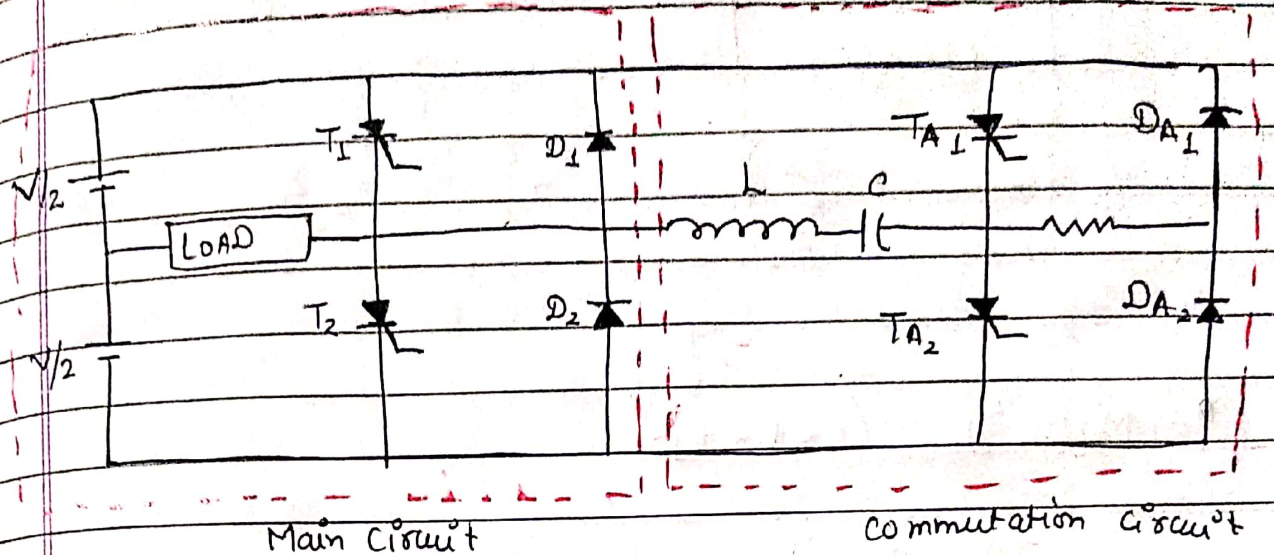
T_2 to T_1 TA_{21} is triggered.



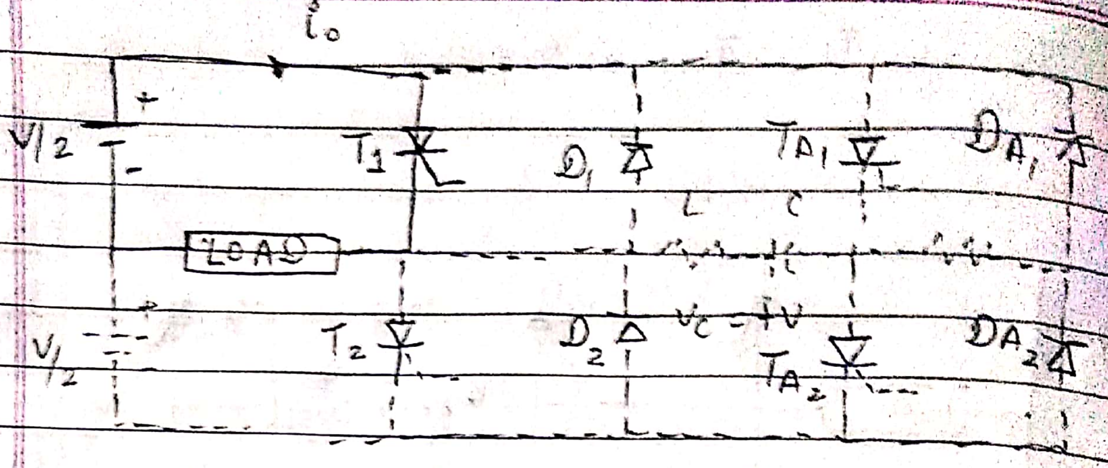
• Circuit of modified Mc Murray half-bridge Inverter.

For the sake of simplifaction, it is assumed that all the devices and circuit elements are Ideal. Moreover, it is assumed that the load is highly Inductive so that the load current remains Constant during commutation interval. the operation is divided into 8-modes.

thick lines show conducting part & non-conduc^n parts are shown by dotted lines.

• Mode: 01 ($t < 0$)

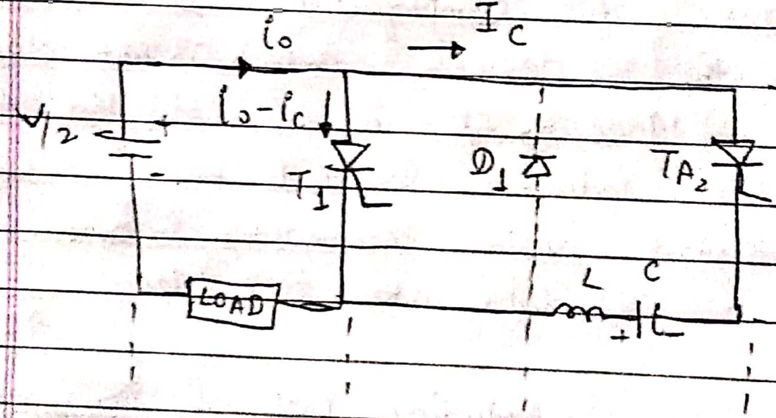
In this mode main thyristor T conducts and a constant positive load current (I_o) flows. The load voltage is +ve & the capacitor is charged up to +V.



- Mode II $(0 < t < t_1)$

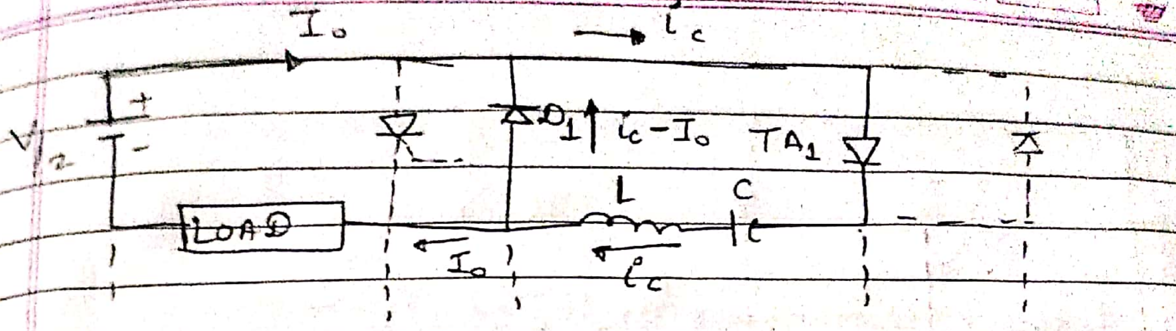
TA_1 is triggered at $t = 0$ to commutate T_1

$i_{T_1} = I_o - i_c$



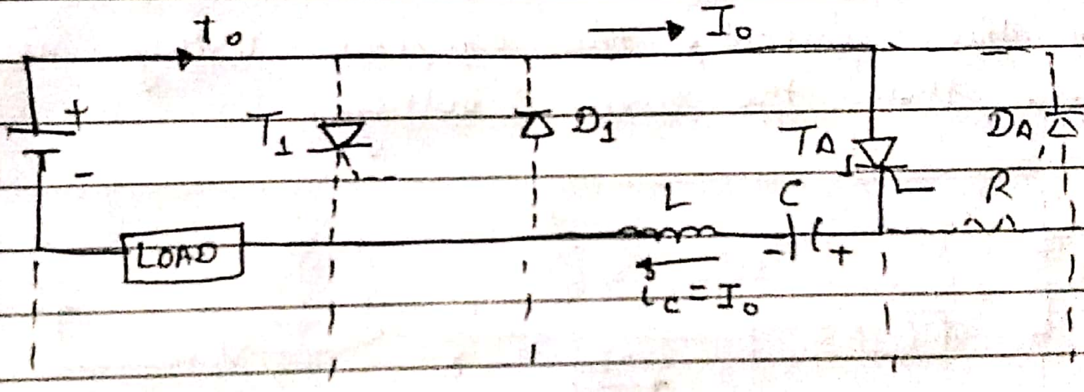
- Mode III $(t_1 < t < t_2)$

As the resonating current i_c becomes higher than the load current (I_o), the surplus current $(i_c - I_o)$ flows through the diode D_1.



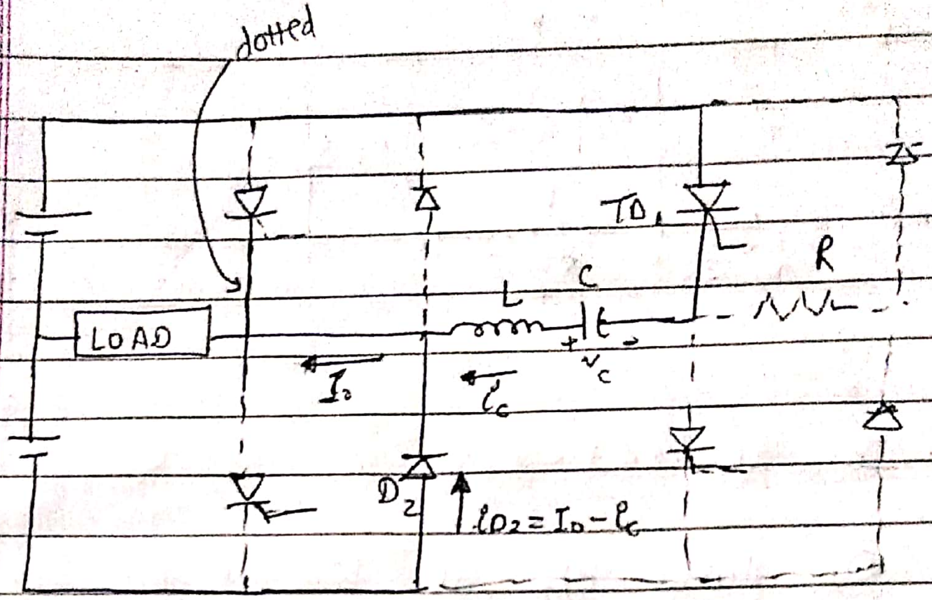
Mode - IV ($t_2 < t < t_3$)

when D_1 turns off at the end of mode - III, the capacitor is charged in reverse dir^n by the const. load current I_0 during this Interval, the voltage across diode D_2, v_{D_2} is equal to $(v_c - V)$.



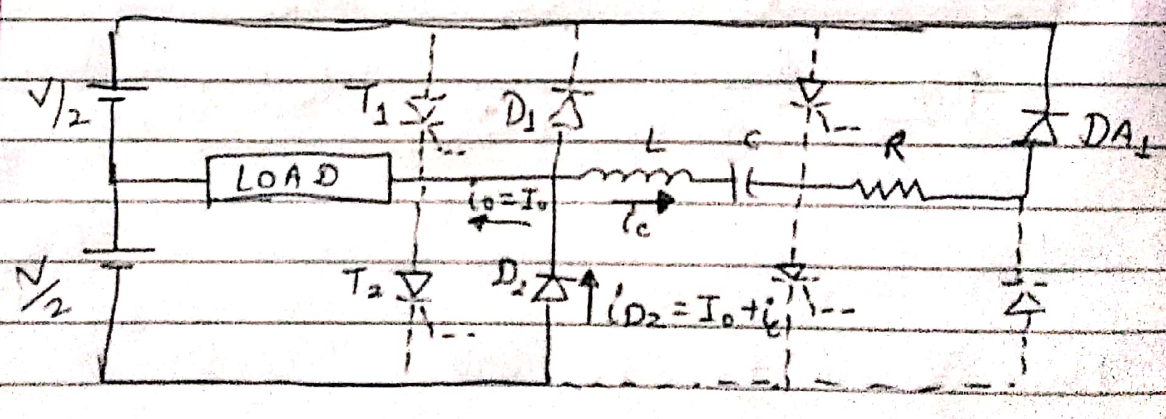
Mode V ($t_3 < t < t_4$)

when D_2 turns on, I_0 is shared by D_2 & i_c. as i_c ↓es, i_{D_2} ↑es which is equal to $I_0 - i_c$



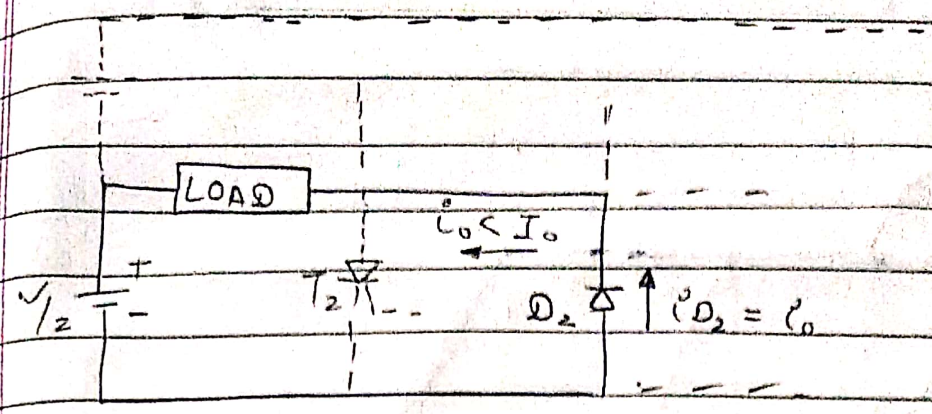
• Mode: VI ($t_4 < t < t_5$)

As i_c tries to reverse at t_4, DA_1 turns on. At this instant, the capacitor voltage is more than the source voltage.



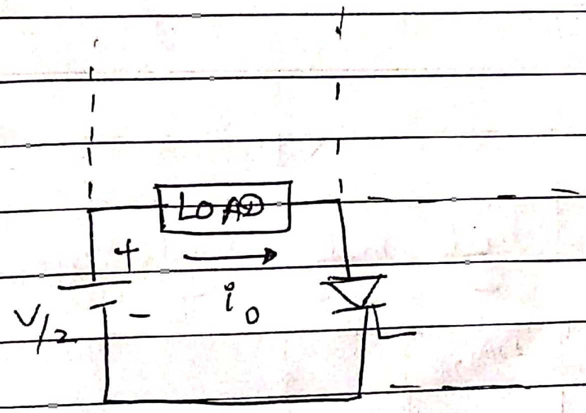
Mode VII ($t_5 < t < t_6$)

During this interval, i_0 flows through D_2 and the lower source.

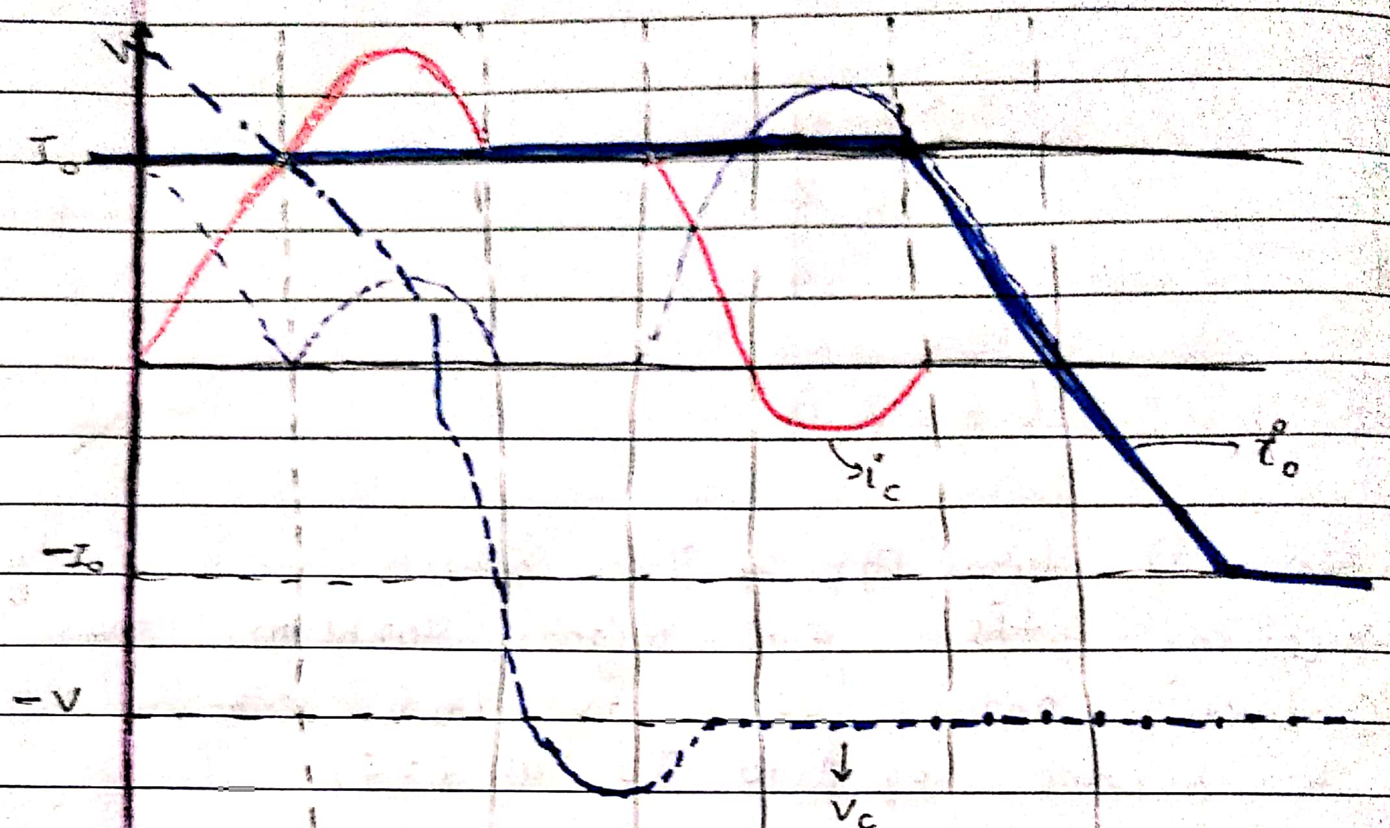


- Mode VIII $(t > t_6)$

When D_2 turns off, T_2 which is already receiving the gate signal turns on. It conducts and the -ve load current raises to become equal to I_0 at $t = t_7$



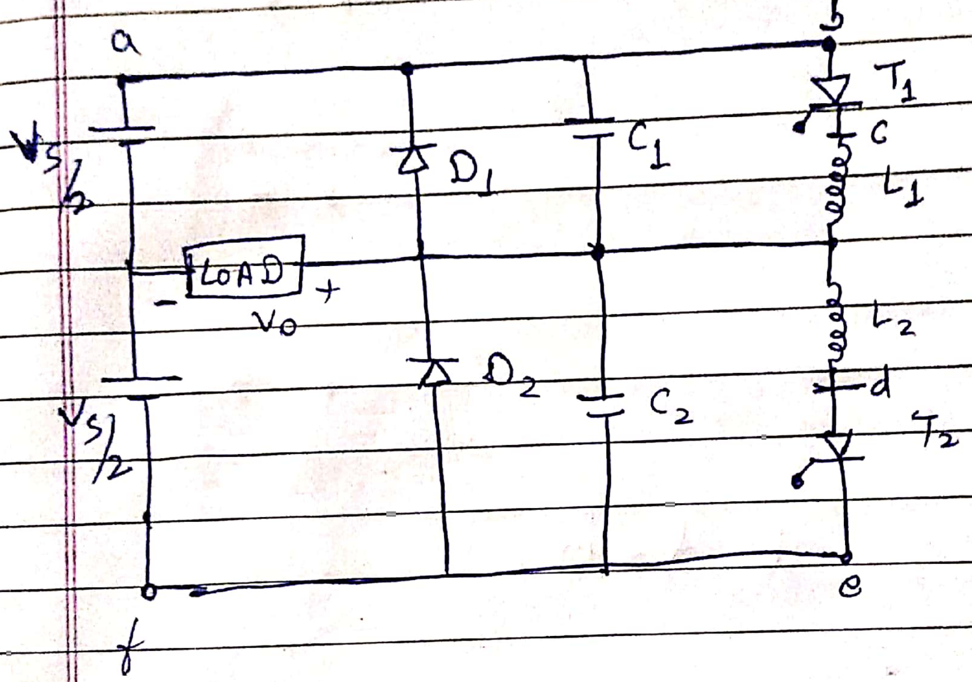
Waveforms



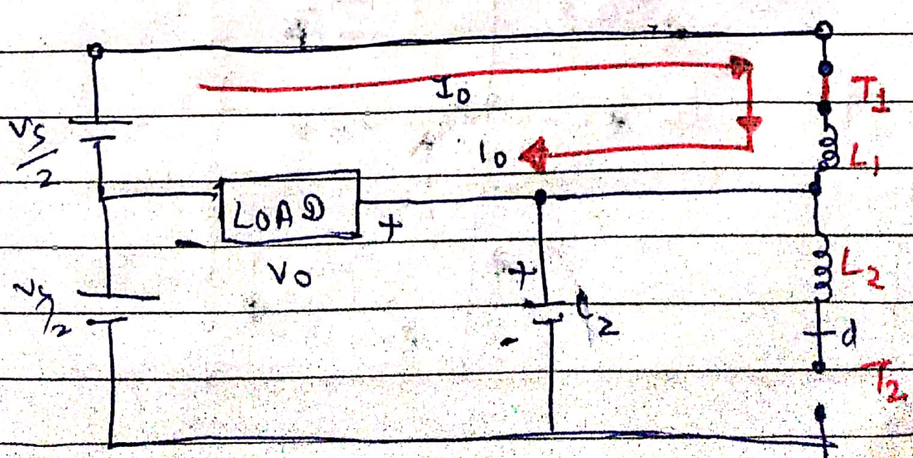
	mode 1	mode II	mode III	mode IV	mode V	mode VI	mode VII	mode VIII
Cond. devices	I_1	T_1, TA_1	D_1, TA_1	TA_1	TA_2, D_2	DA_1, D_2	D_2	T_2

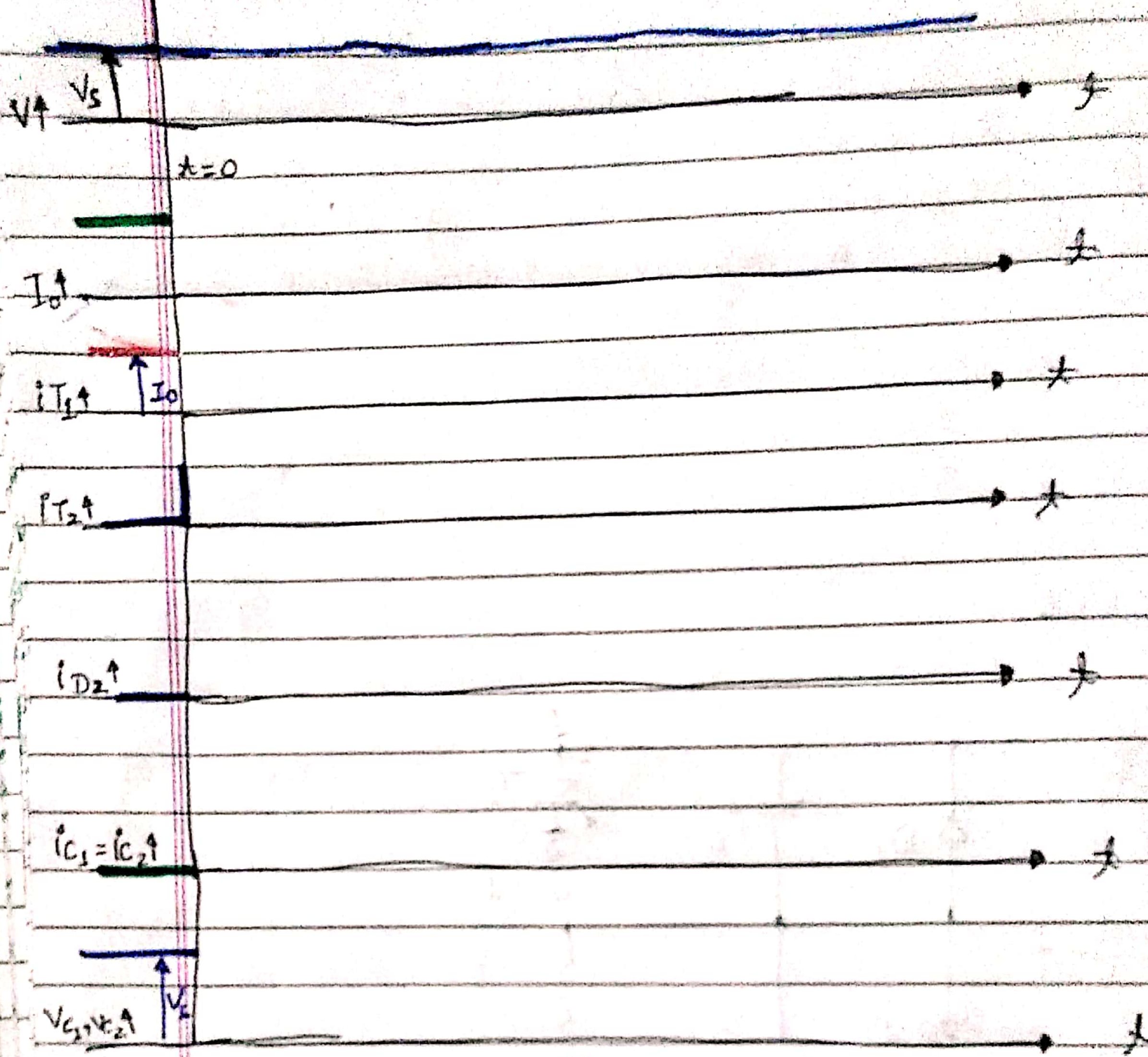
D_1 on, T_1 off; D_1 off; D_2 on; TA_1 off, DA_1 on; DA_1 off; D_2 off, T_2 on

Que:05 Describe the modified Mc Murray Bedford half bridge single phase inverter with relevant voltage & current waveforms. Also, explain advantages of it over modified Mc Murray half bridge inverter.



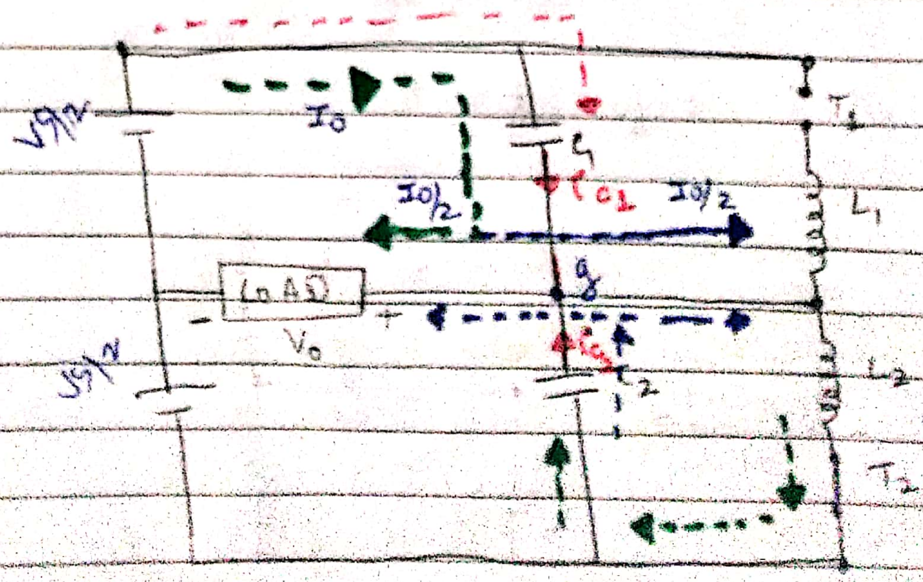
Mode 1 : befor $t=0$





V_s
V
$t=0$
t
I_o
i_{T_1}
I_o
i_{T_2}
i_{D_2}
$i_{C_1}=i_{C_2}$
V_c
V_{C_1}, V_{C_2}

Mode : 02 at $t = 0$

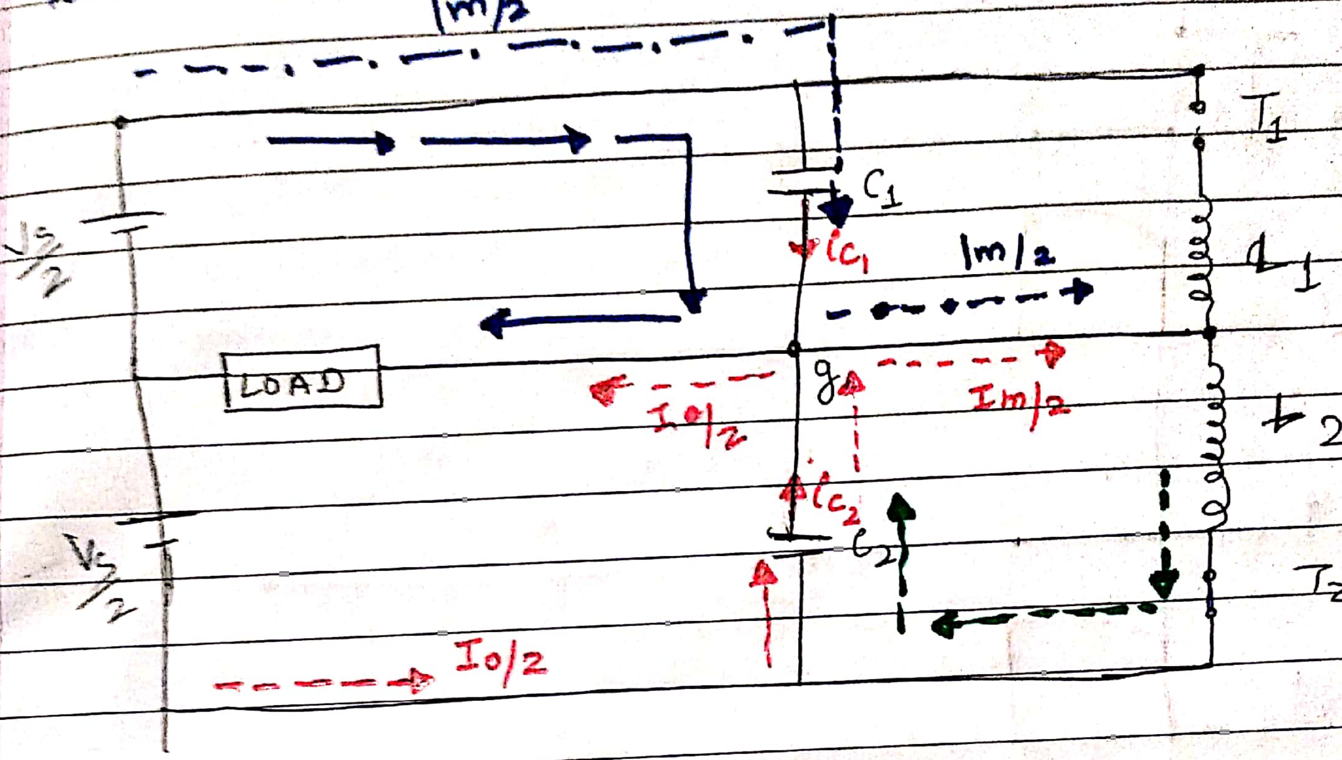


$V_s/2$
I_o
C_1
i_{C_1}
$I_o/2$
$I_o/2$
T_1
L_1
LOAD
V_o
g
i_{C_2}
C_2
L_2
$V_s/2$
T_2

~~KVL at node g~~

~~$i_{C1} + i_{C2} = I_o + I_o$~~ , $i_{C1} = i_{C2} = I_o$

→ At $t < t_1$



KCL at node g

$i_{C_1} + i_{C_2} = I_o + I_m$, $i_{C_1} = i_{C_2} = I_o + I_m/2$

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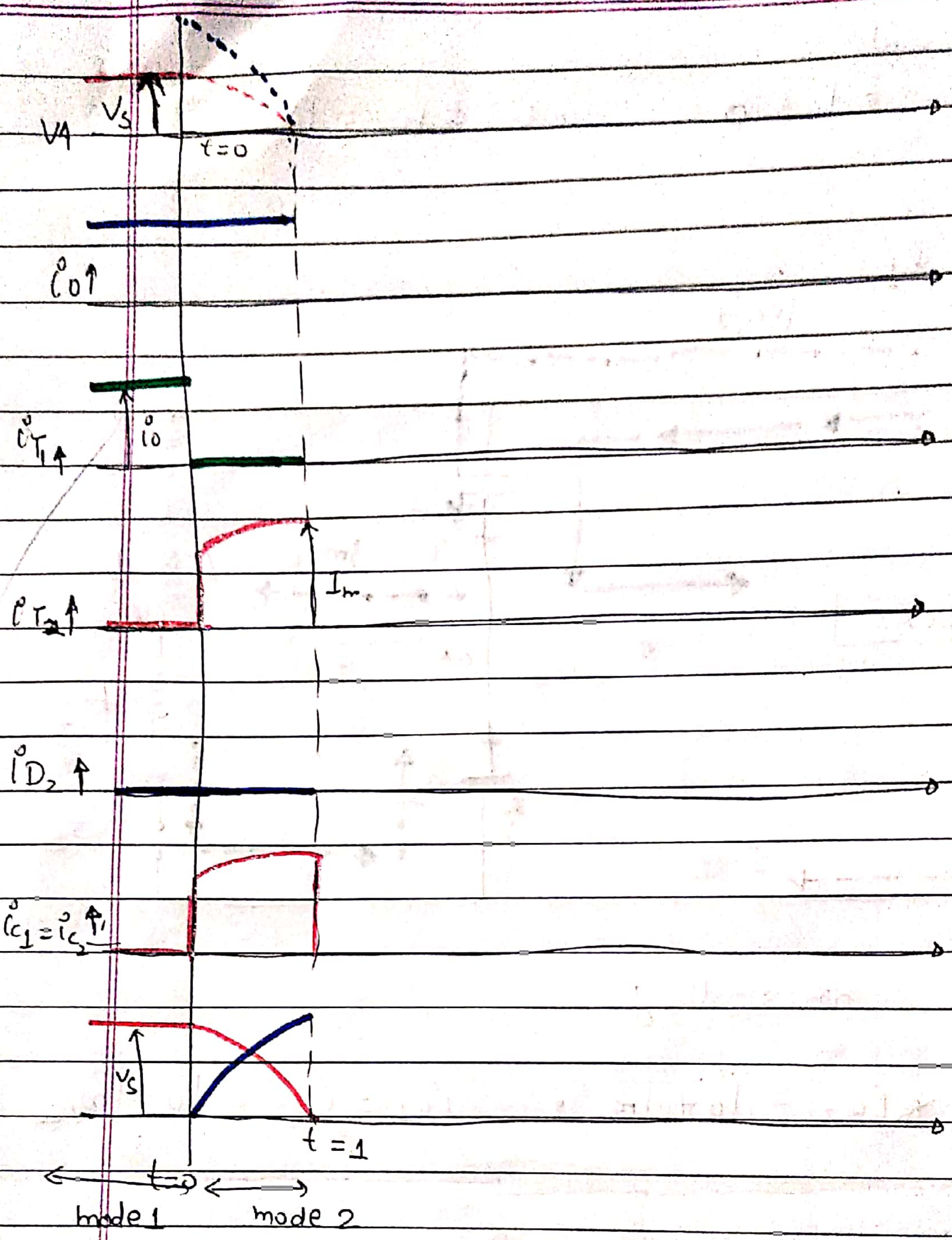
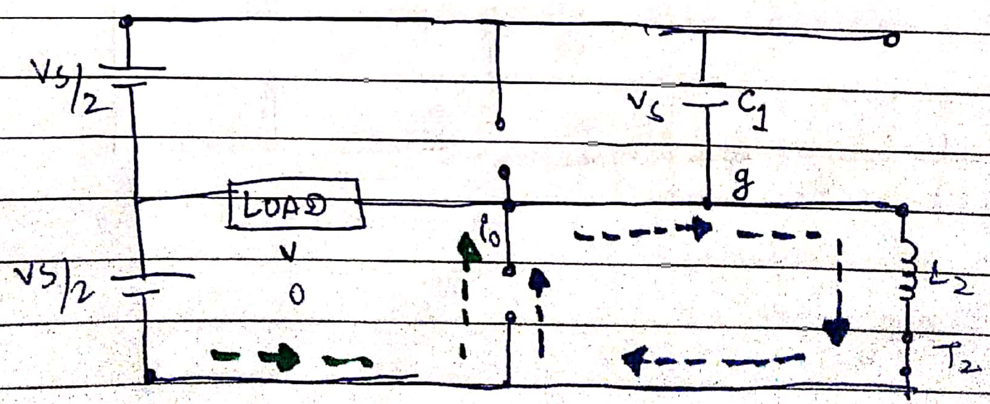
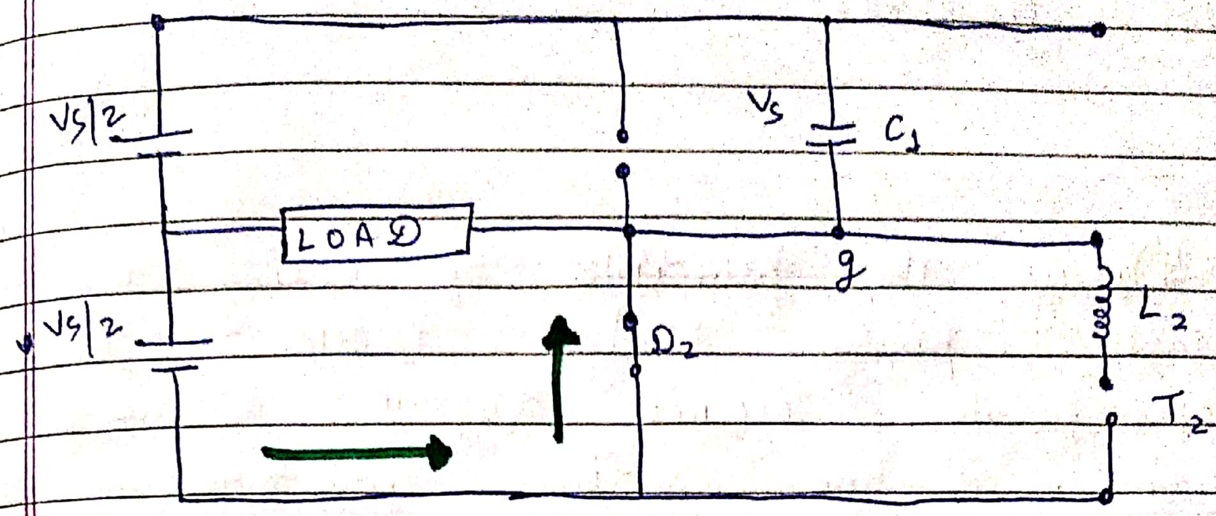


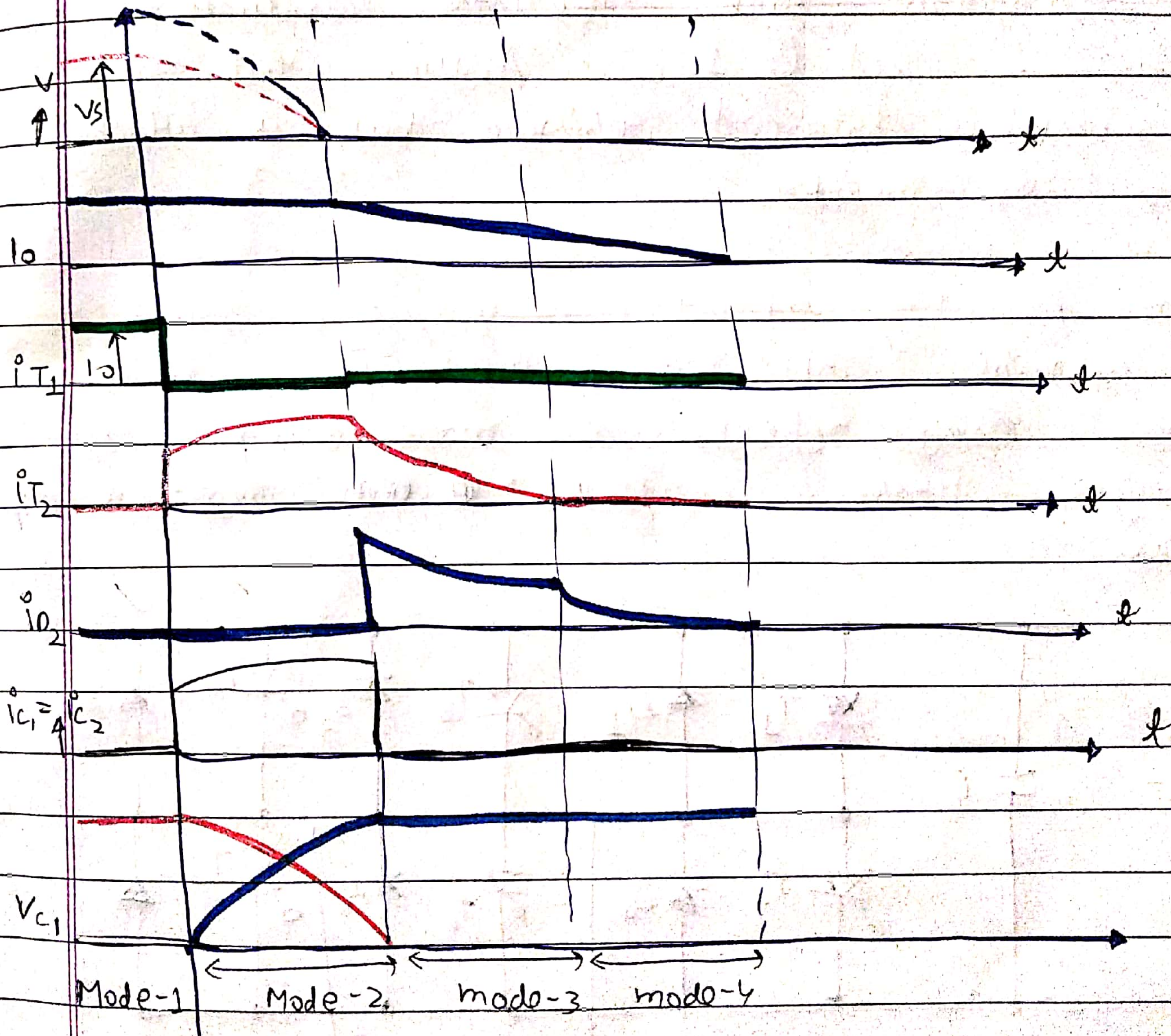
• Mode : 03 at t_1



• Mode : 04



Vs/2
Vs
C1
LOAD
g
Vs/2
D2
L2
T2

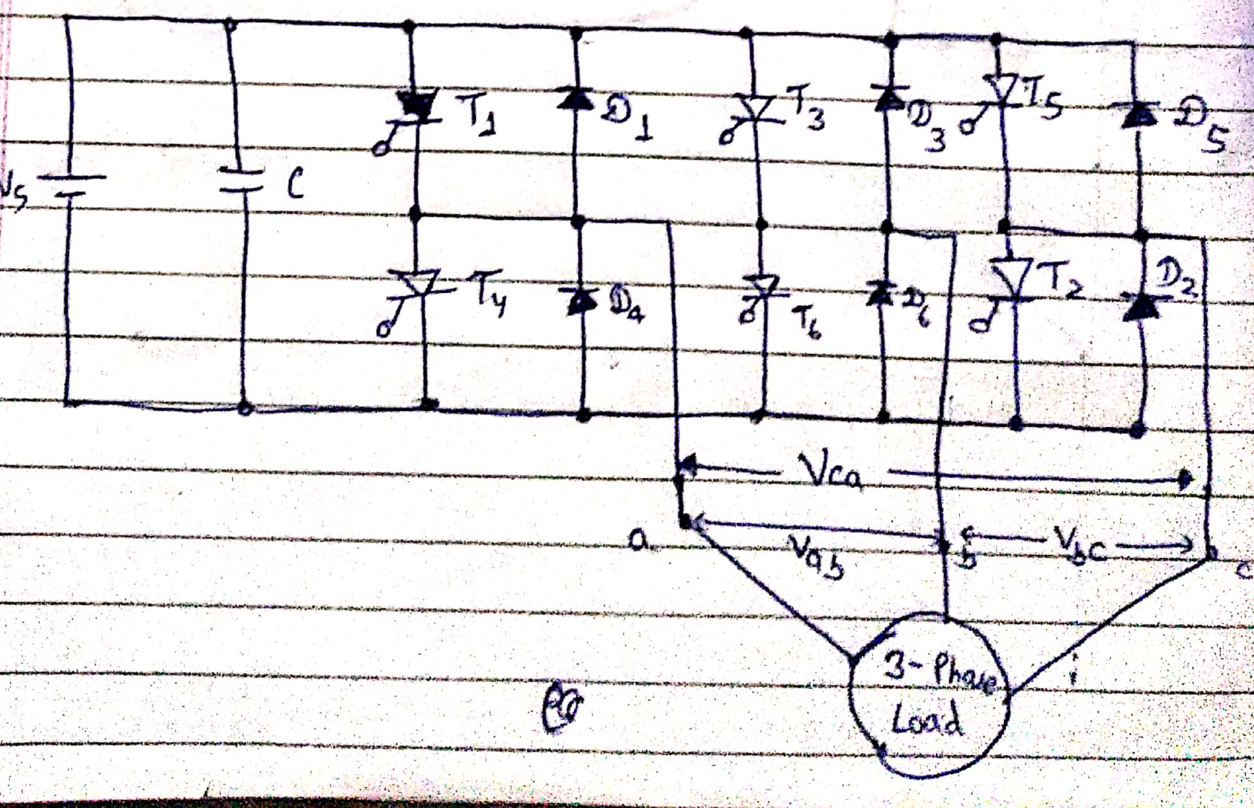


V
Vs
t
Io
t
iT1
Io
t
iT2
t
iD2
t
iC1 = iC2
t
VC1
Mode-1
Mode-2
mode-3
mode-4

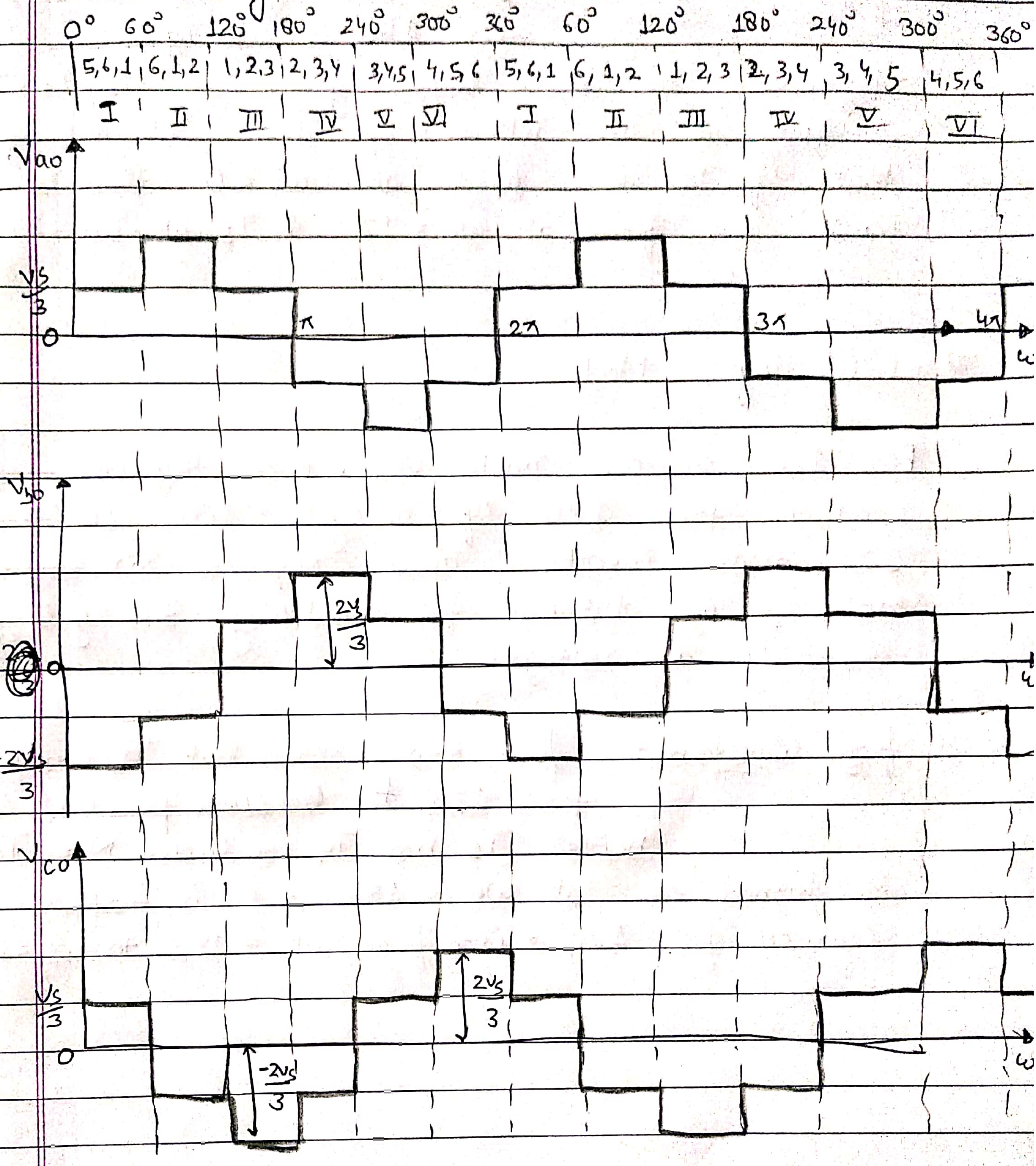
- It uses less number of thyristors & diodes as compared to modified McMurray half bridge inverter

Que 06 Discuss the principle of working of three phase bridge inverter with appropriate circuit diagram. Draw phase & line voltage waveforms on the assumption each thyristor conducts for (a) 180° and (b) 120°. Assume that star connected balanced resistive load is attached to the inverter.

Ans For providing adjustable - frequency power to industrial applications, three phase inverters are more common than single phase inverters.



180° degree



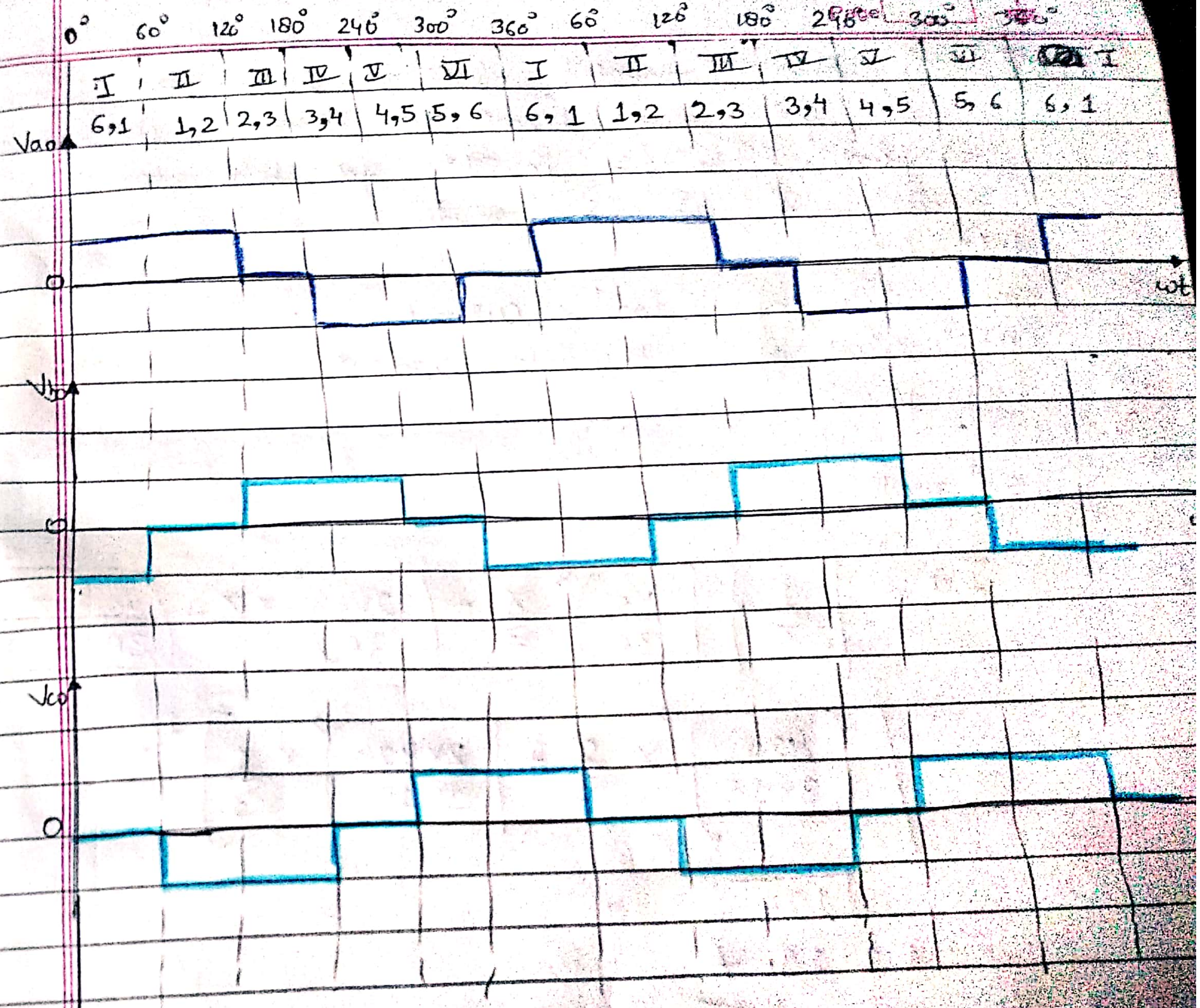
In three phase inverter, each SCR conducts for 180° of a cycle. Thyristor pair in each arm i.e. T_1, T_4; T_3, T_6 & T_5, T_2 are turned on with a time interval of 180°

from waveform: T_1 Conduct for 180° & T_4 for next 180° of a cycle. Thyristor in the upper group i.e. T_1, T_3, T_5 Conducts at an interval of 120°. It implies that if T_1 is fired at $\omega t = 0°$ then T_3 must be fired at $\omega t = 120°$ & T_5 at $\omega t = 240°$

⇒ 120° degree Mode:

For 120° degree mode VSI, each thyristor conducts for 120° of a cycle. Like 180° mode, 120° mode inverter also requires six steps, each of 60° duration for completing one cycle of the o/p ac voltage.

from Waveform: first rows shows that T_1 conducts for 120° & ~~conducts~~ for next 60°, neither T_1 nor T_4 conducts. Now T_4 is turned on at $\omega t = 180°$ and it further Conducts for 120°, i.e from $\omega t = 180°$ to $\omega t = 300°$



0° 60° 120° 180° 240° 300° 360° 60° 120° 180° 240° 300°
I II III IV V VI I II III IV V VI I
6,1 1,2 2,3 3,4 4,5 5,6 6,1 1,2 2,3 3,4 4,5 5,6 6,1
Vao
0
ωt
Vbo
0
Vco
0

$87.12 \times \frac{2}{3} + 348.4 \times \frac{1}{3}$

$58.08 + 116.14$

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Que: 07 A star connected load of 15 Ω per phase is fed from 420 V dc source through 3-phase bridge inverter for both (a) 180° mode & (b) 120° mode

determine:

(i) rms value of load current

(ii) rms value of thyristor current

(iii) load power

(a) 180° mode

$$I_{or} = \left[\frac{1}{\pi}\left\{\left(\frac{V_s}{3R}\right)^2 \frac{\pi}{3} + \left(\frac{2V_s}{3R}\right)^2 \times \frac{\pi}{3} + \left(\frac{V_s}{3R}\right)^2 \frac{\pi}{3}\right\}\right]^{1/2}$$

$$= \left[\left(\frac{420}{3\times 15}\right)^2 \times \frac{2}{3} + \left[\frac{2\times 420}{3\times 15}\right]^2 \times \frac{1}{3}\right]^{1/2}$$

$$= \sqrt{174}$$

$$= 13.190\,A$$

Rms value of thyristor current

$$I_{T_1} = \left[\frac{1}{2\pi}\left\{\left(\frac{420}{3\times 15}\right)^2 \times \frac{2\pi}{3} + \left(\frac{2\times 420}{3\times 15}\right)^2 \times \frac{\pi}{3}\right\}\right]^{1/2}$$

$$= \left[\frac{1}{2\pi}\cdot\frac{\pi}{3}\left\{\left(\frac{420}{3\times 15}\right)^2 \times 2 + \left(\frac{2\times 420}{3\times 15}\right)^2\right\}\right]^{1/2}$$

$$= \left[\frac{1}{6}\left\{\left(\frac{420}{45}\right)^2 \times 2 + \left(\frac{840}{45}\right)^2\right\}\right]^{1/2}$$

$$= \left[\frac{1}{6}\left\{87.12 \times 2 + 348.4\right\}\right]^{1/2}$$

$= \sqrt{87}$

$= 9.327 A$

Power delivered to Load :

$= 3 I_{or}^2 R$

$= 3 \left(\sqrt{174}\right)^2 \times 15$

$= 7.83$ KW

(b) 120° mode :

$$I_{or} = \left[\frac{1}{\pi} \left(\frac{\overset{210}{\cancel{420}}}{2 \times 15} \right)^2 \times \frac{2\pi}{3} \right]^{1/2}$$

$= \cancel{\left\{ (14)^2 \times \frac{2}{3} \right\}^{1/2}}$ $= \sqrt{130.66}$

$= \cancel{\sqrt{9.333}}$ $= 11.430 A$

$\cancel{= 3.055 A}$

Rms value of thyristor current

$$I_{T1} = \left[\frac{1}{2\pi} \left(\frac{\overset{210}{\cancel{420}}}{2 \times 15} \right)^2 \times \frac{2\pi}{3} \right]^{1/2}$$

$= \sqrt{65.33}$

$= 8.082 A$

(b) Load power

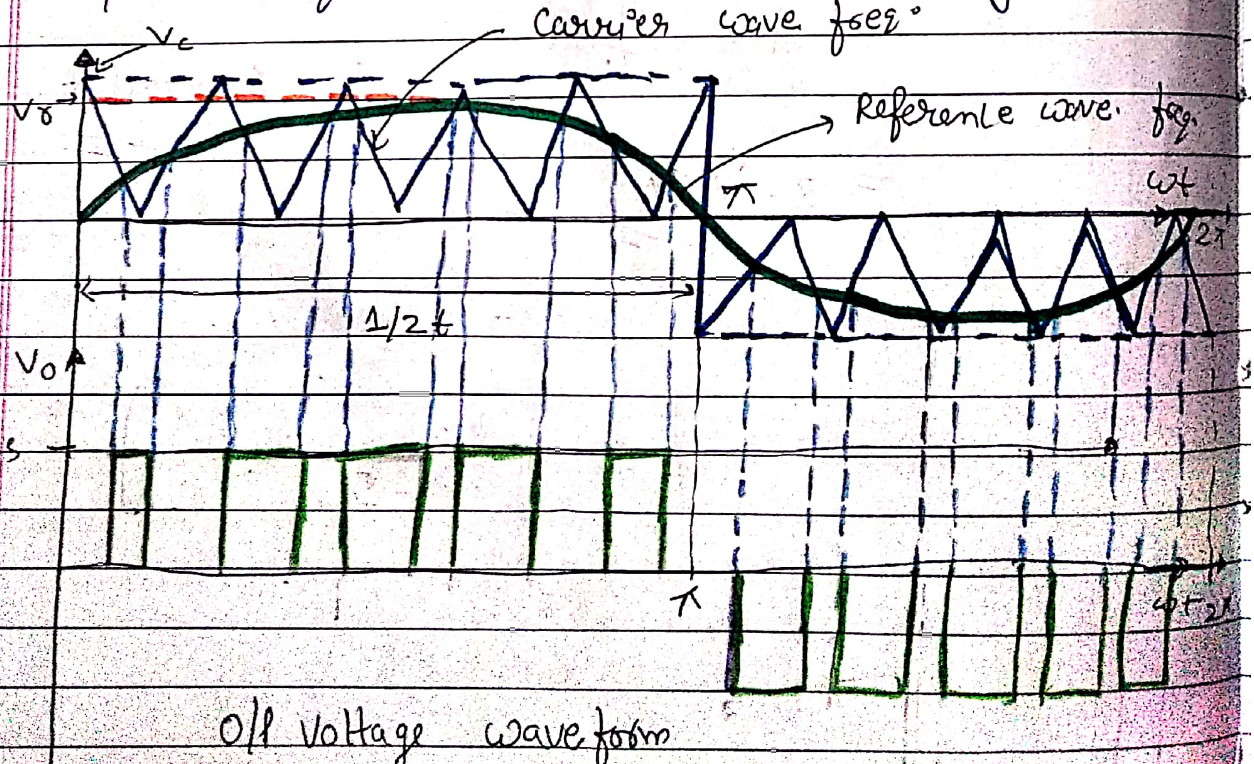
$= 3 I_{or}^2 R$

$= 3(\sqrt{130.6})^2 \, 15$

$= 5.877$ kW

Que: 08 Discuss Sinusoidal pulse modulation as used in PWM Inverters?

Ans In this method of modulation, several pulses per half cycle are used as in the case of multiple-pulse modulation (MPM). In MPM, the pulse width is equal for all the pulses. But in SinM, the pulse width is a sinusoidal func^n of the angular position of the pulse in a cycle.



O/P voltage waveform

for realizing Sin M, a high-freq. triangular carrier wave V_c is compared with a sinusoidal reference wave V_r of desired freq.

The intersection of V_c & V_r waves determines the switching instants and commutation of the modulated pulse. V_c is the peak value of triangular carrier wave and V_r that of the reference, or modulating signal.

The carrier & reference waves are mixed in a comparator. when sinusoidal wave has magnitude higher than the triangular wave, the comparator o/p is high, otherwise it is low