# Assignment : 02.

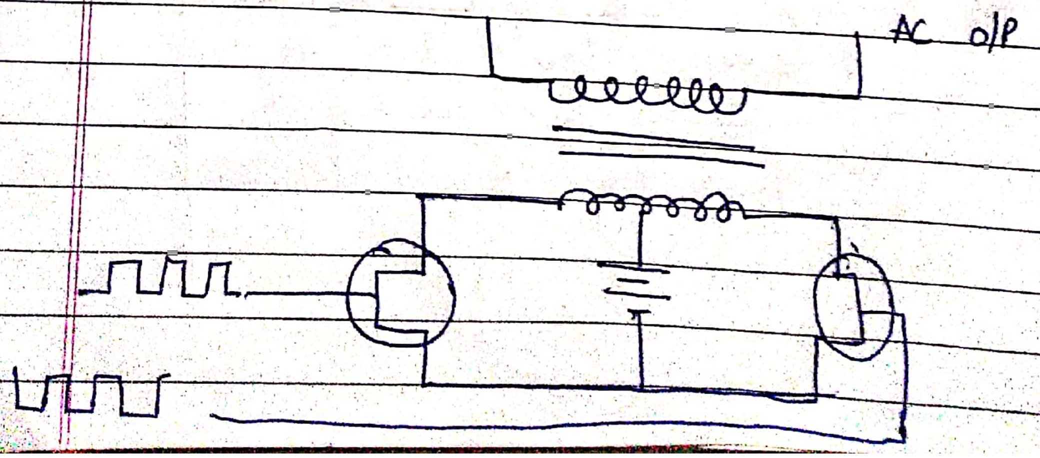
Que: 01 What is an inverter? List few industrial applications of it.

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 alternating power systems of the batteries can store only DC power.

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

Types of Inverter:

- Single phase Inverter
- Three phase Inverter



# Applications:

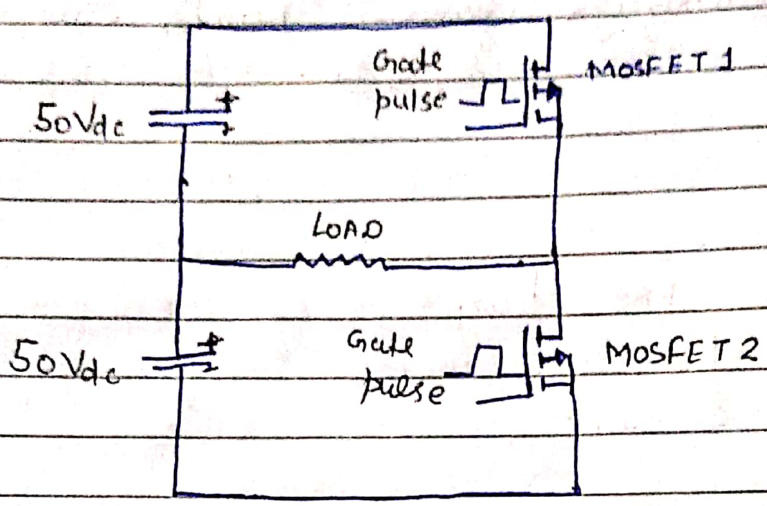
- used as an UPS (uninterruptible power supplies)
- used as standalone inverters.
- used in Solar power systems
- used in Centrifugal fans, pumps, mixers, extruders, test stands and web handling equipment.

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.

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

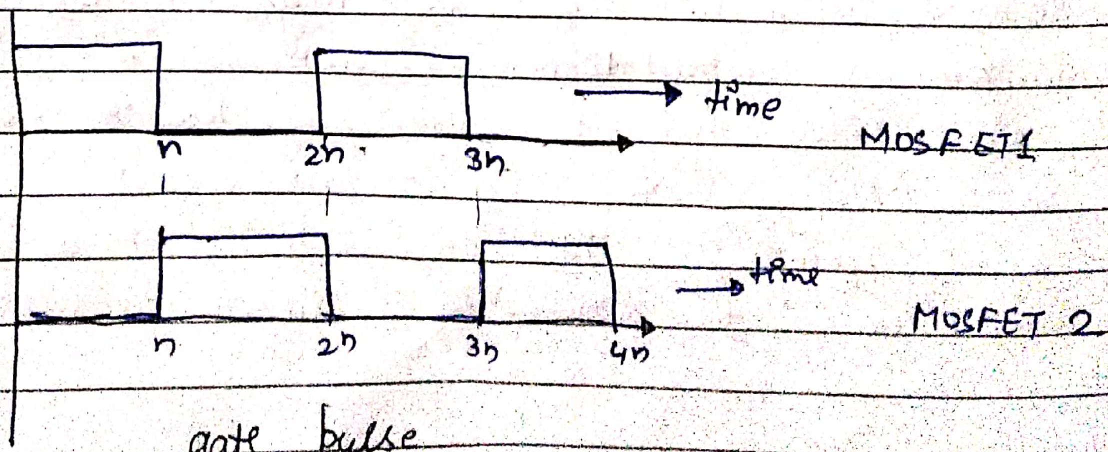
⇒ Ans:




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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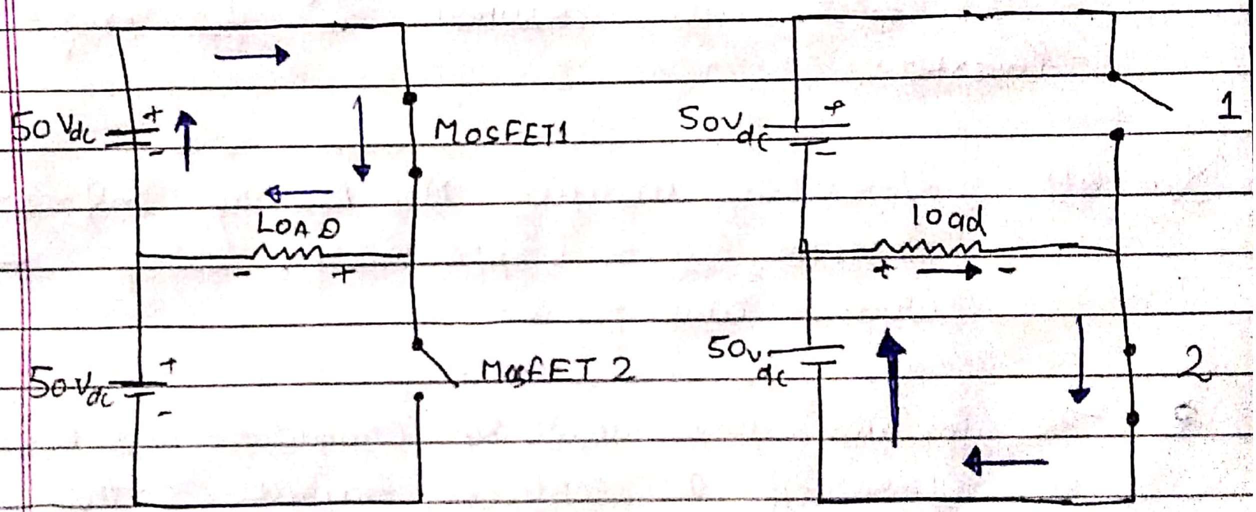
Acc" to o/p freq., ON time and OFF time of MOSFET is decided & gate pulse are generated. we need 50HZ AC power, so the time period of one cycle $(0 < t < 2\pi)$ is 20 msec. from fig., MOSFET-1 is triggered for first half cycle $(0 < t < \pi)$ and during this time period, current will flow in dir^n of 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 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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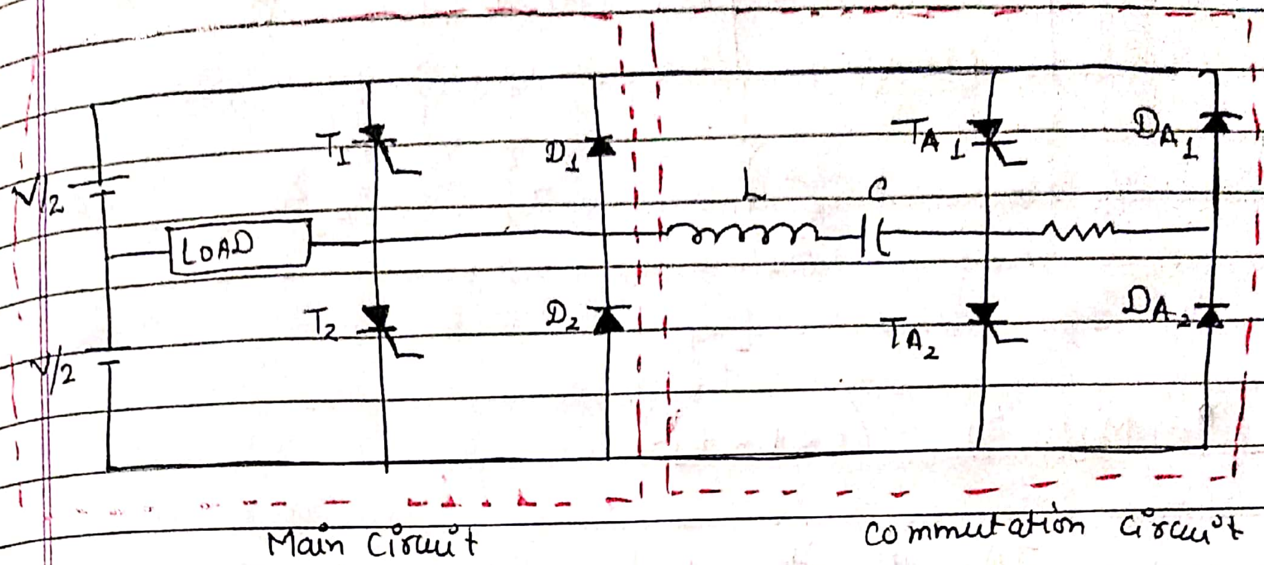
$T_2$ to $T_1$ $T_{A21}$ is triggered.



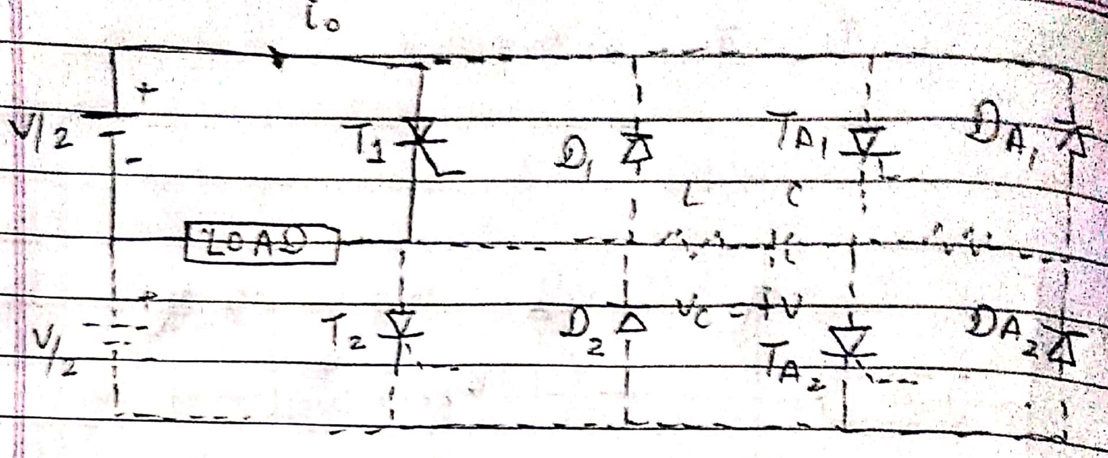

- Circuit of modified Mc Murray half-bridge Inverter.

For the sake of simplification, 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-conduction parts are shown by dotted lines.

- Mode : 01 ($t < 0$)

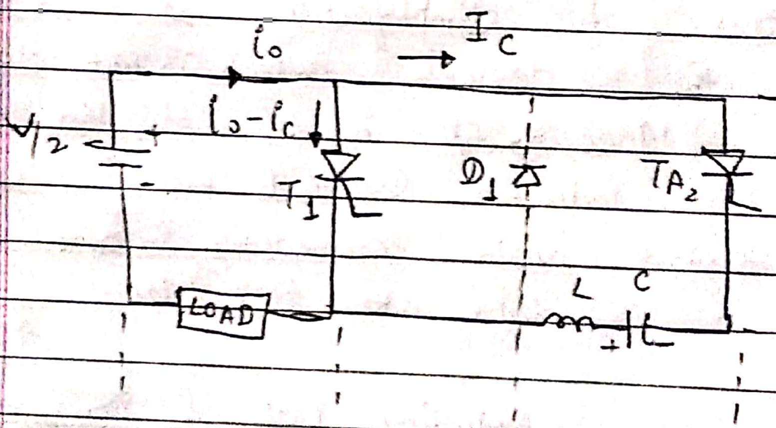
In this mode main thyristor T conducts and a constant positive load current ($I_o$) flows. The load voltage is +ve & the capacitor is charged up to +V.




- 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 $D_1$.

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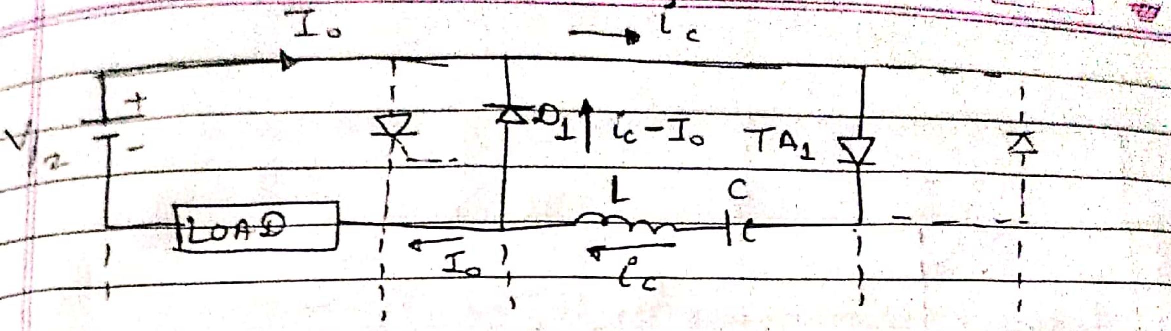
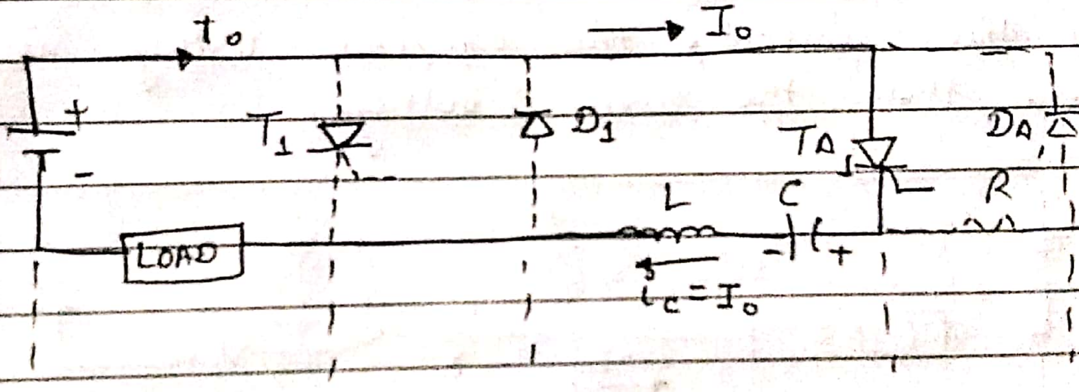


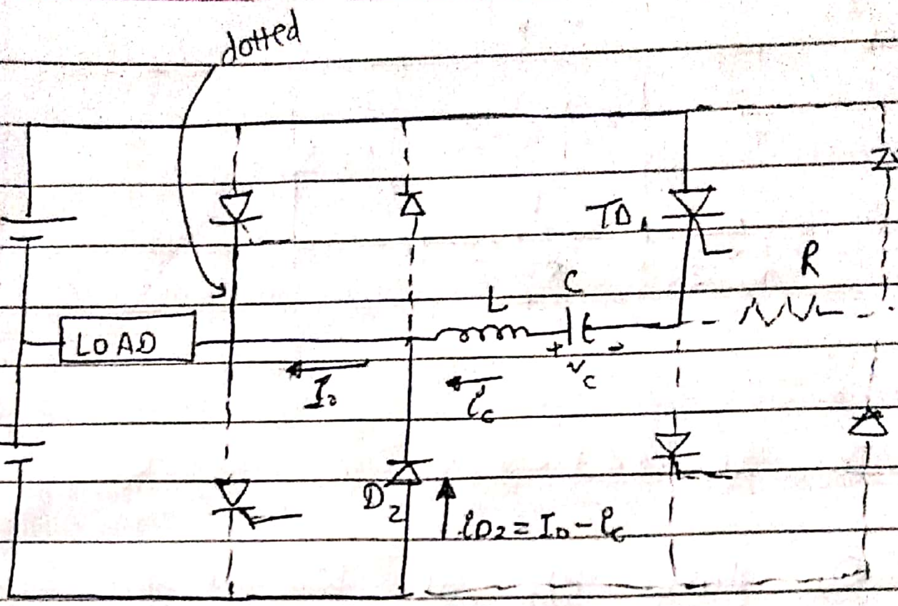

- Mode - IV ($t_2 < t < t_3$)

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



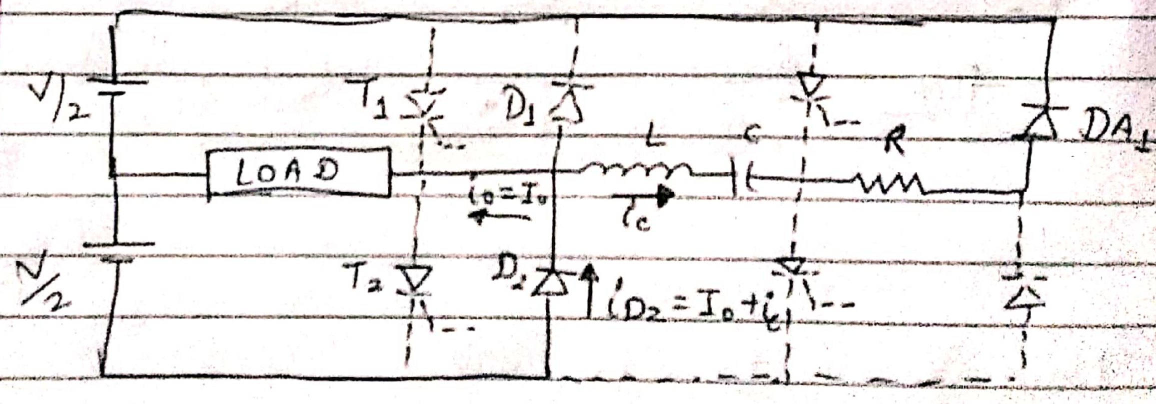

- Mode V ($t_3 < t < t_4$)

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 $I_0 - i_c$



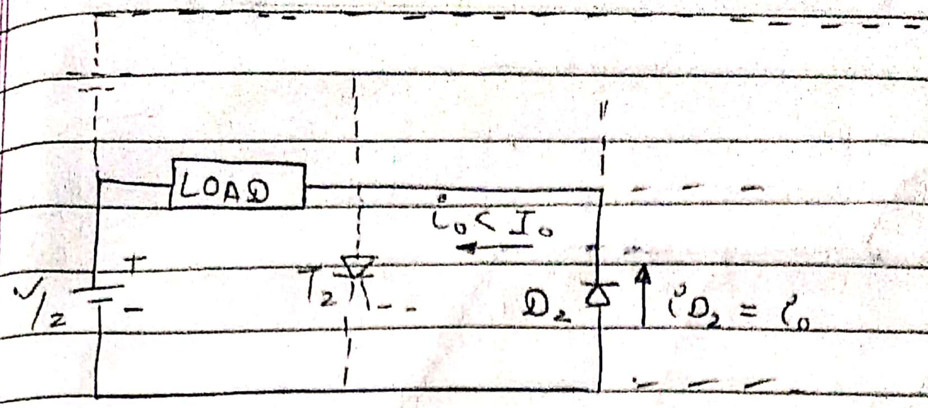

- Mode: VI ($t_4 < t < t_5$)

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.



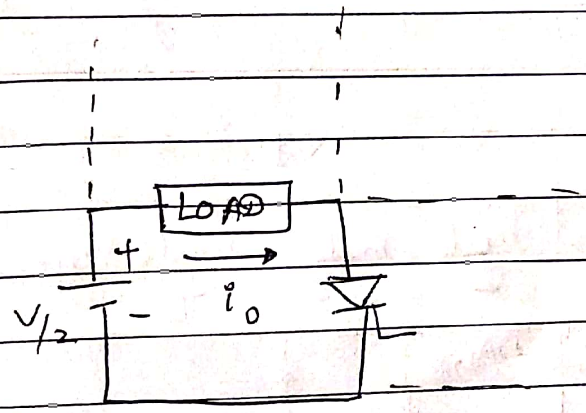

Mode VII ($t_5 < t < t_6$)

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

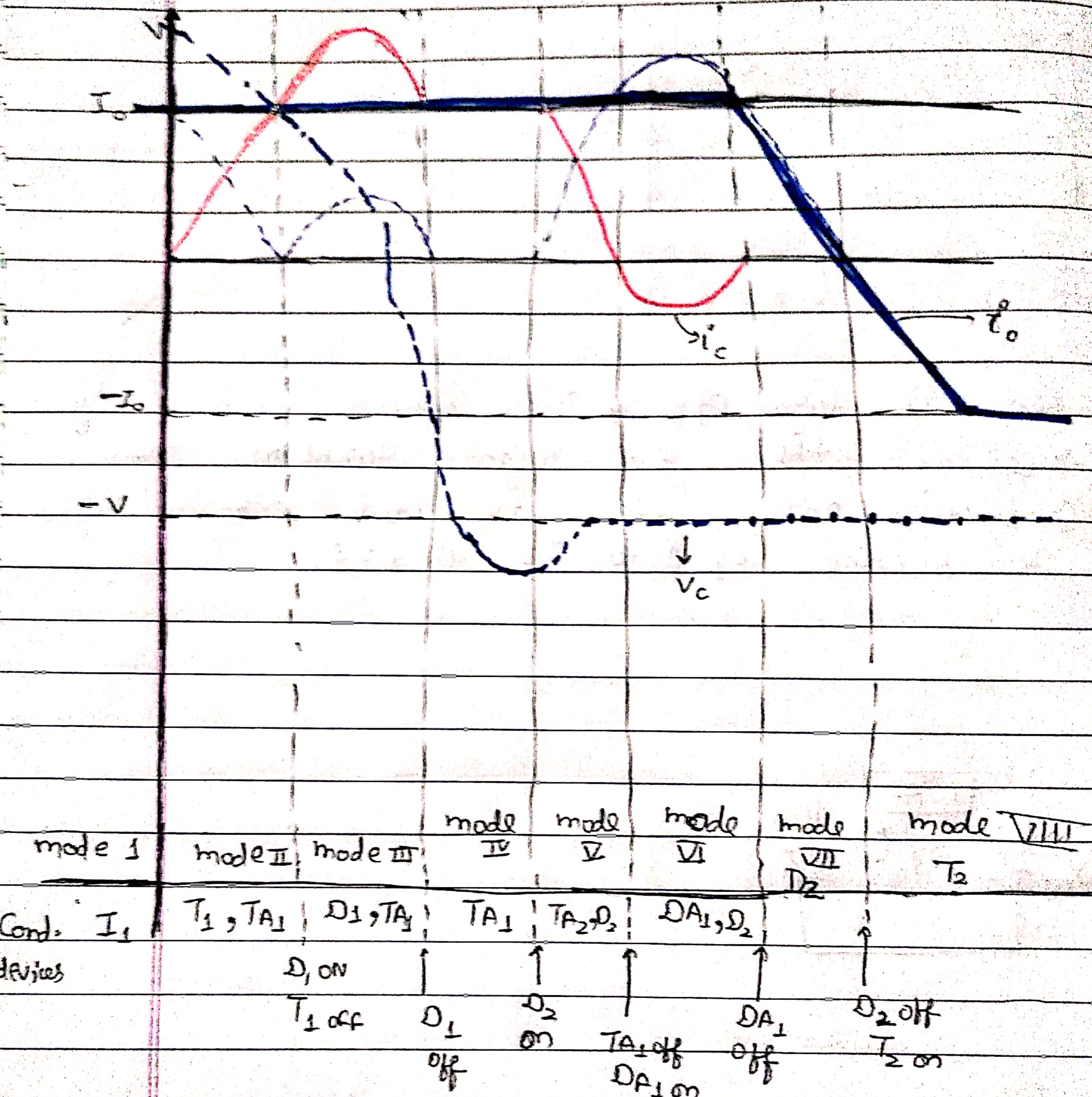



- Mode VIII ($t > t_6$)

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 $I_o$ at $t = t_7$

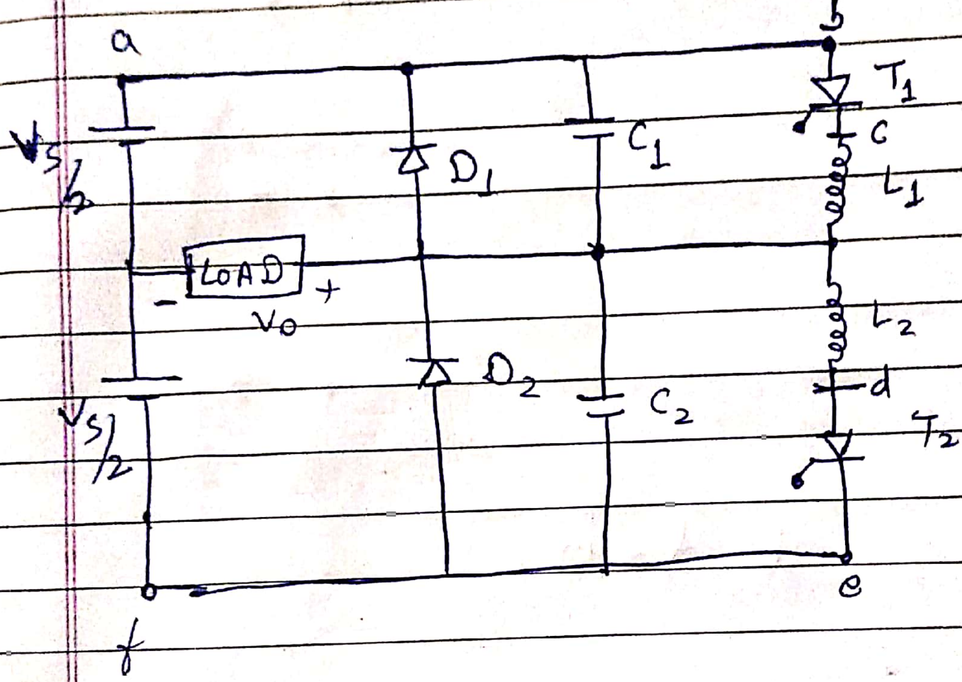


# Waveforms

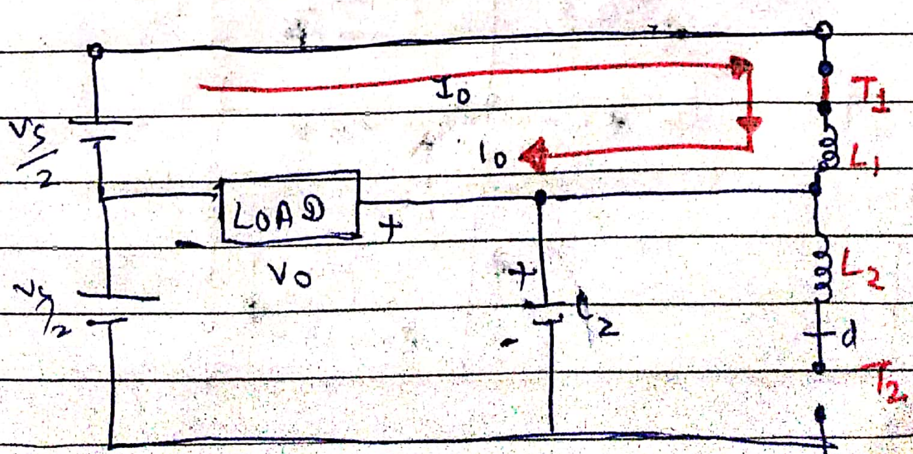


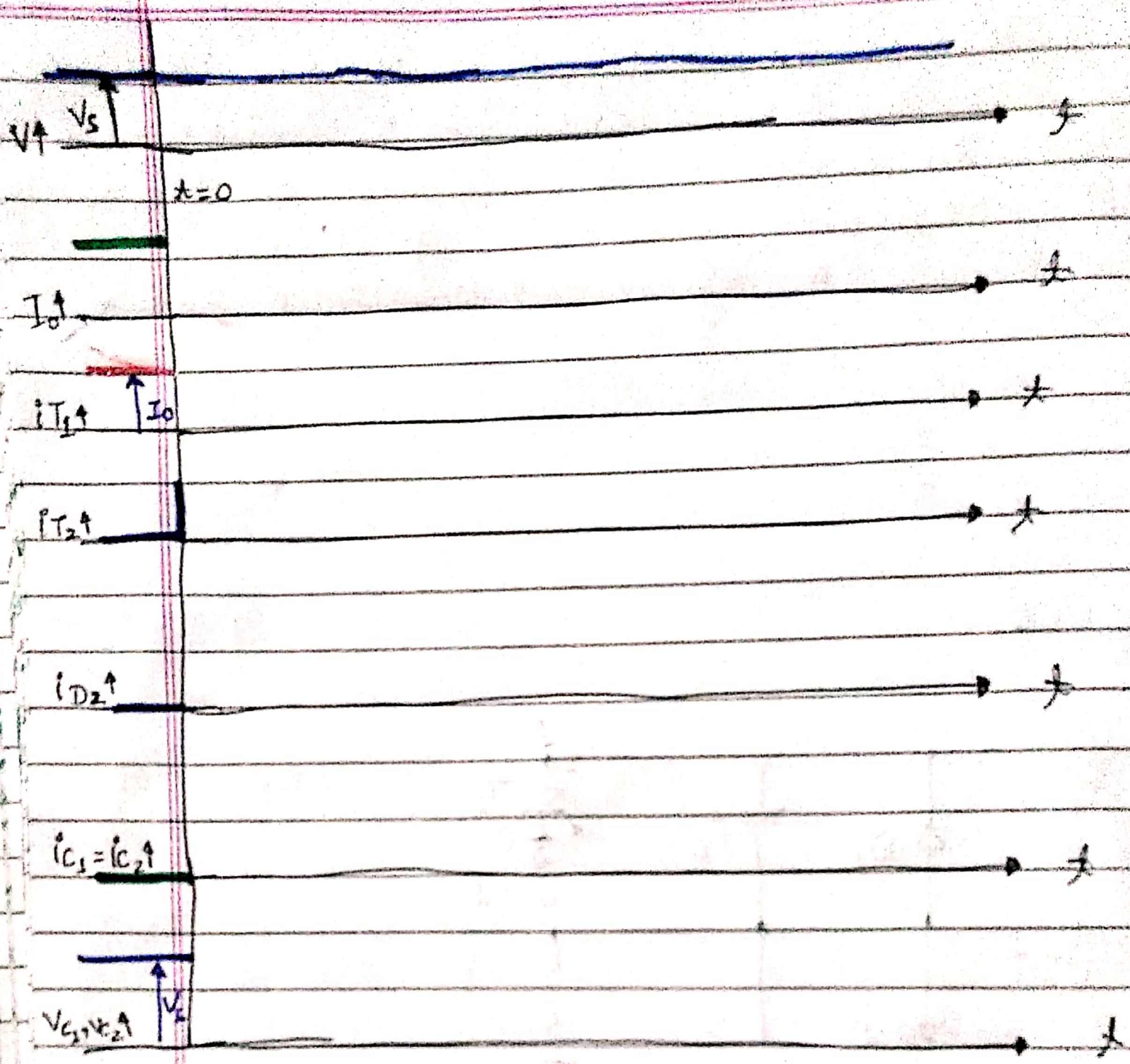
V
$I_o$
$i_c$
$i_o$
$-I_o$
$-V$
$v_c$
mode 1
mode II
mode III
mode IV
mode V
mode VI
mode VII
$D_2$
mode VIII
$T_2$
Cond. devices
$I_1$
$T_1$, $TA_1$
$D_1$, $TA_1$
$TA_1$
$TA_2$, $D_2$
$DA_1$, $D_2$
$D_1$ ON
$T_1$ off
$D_1$ off
$D_2$ on
$TA_1$ off
$DA_1$ on
$DA_1$ off
$D_2$ off
$T_2$ on

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.

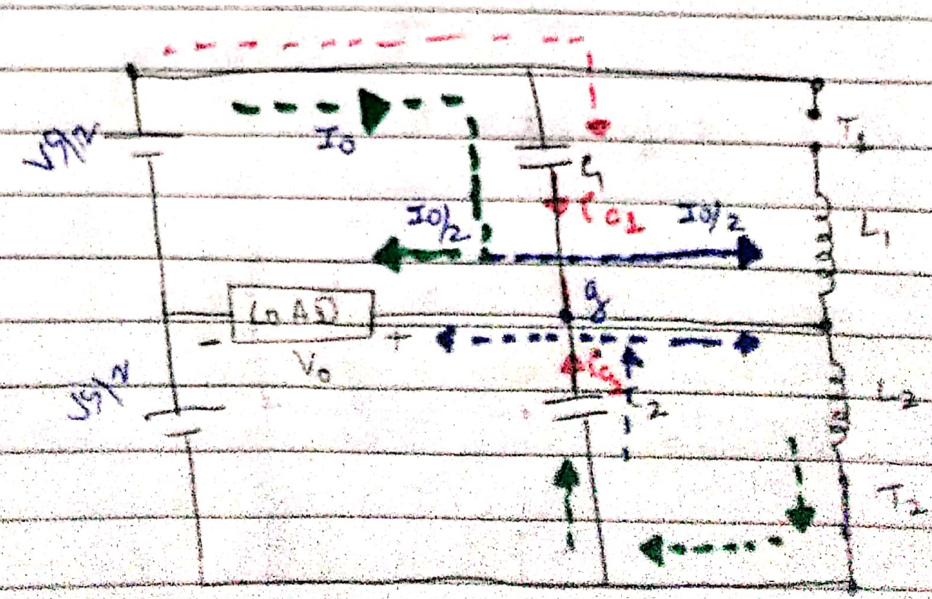



Mode 1 : befor t = 0



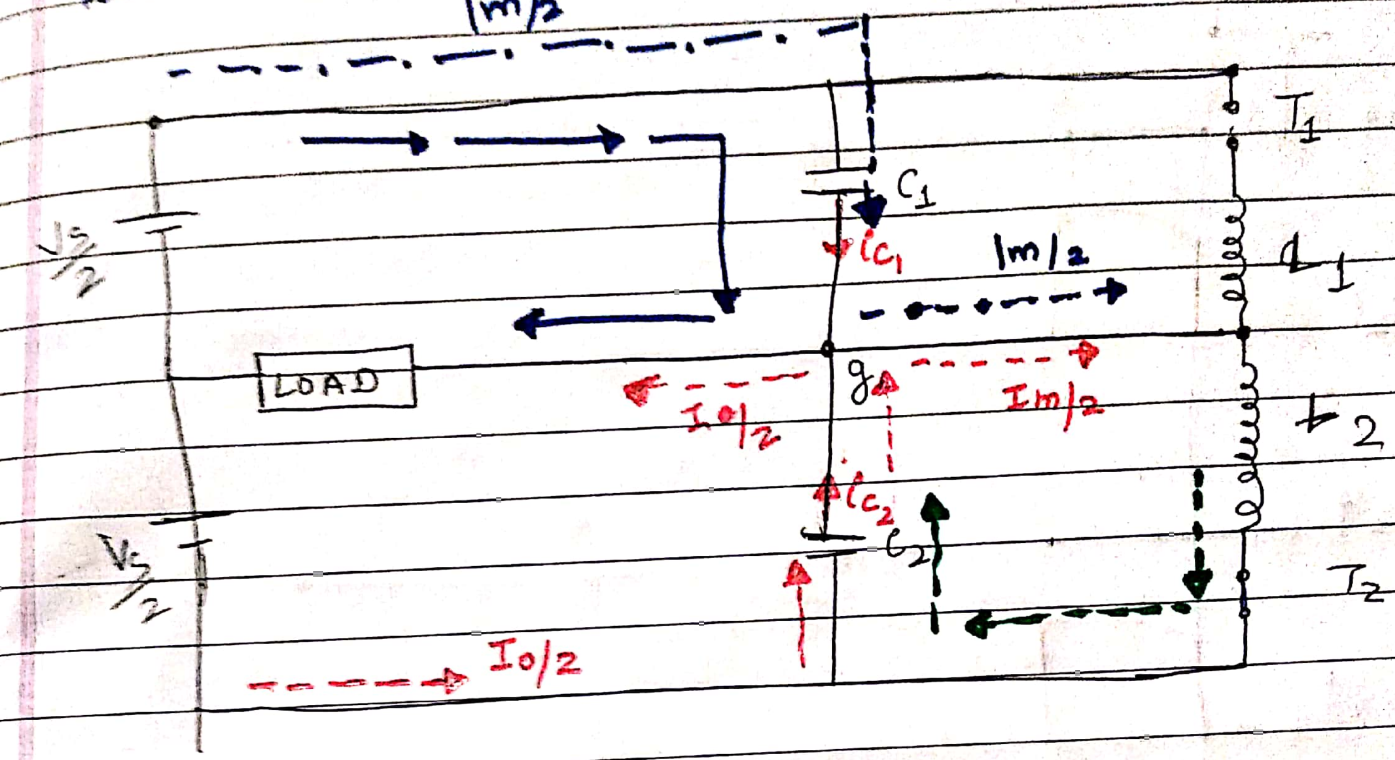

$V_s$
V
$t=0$
t
$I_0$
$i_{T_1}$
$I_0$
$i_{T_2}$
$i_{D_2}$
$i_{C_1}=i_{C_2}$
$V_c$
$V_{C_1}, V_{C_2}$

Mode : 02 at $t = 0$


$V_s/2$
$I_0$
$C_1$
$i_{C_1}$
$I_0/2$
$I_0/2$
$T_1$
$L_1$
LOAD
$V_0$
a
$i_{C_2}$
$C_2$
$L_2$
$T_2$
$V_s/2$

~~KVL at node g~~
~~$i_{C1} + i_{C2} = I_0 + I_0$~~ , $i_{C1} = i_{C2} = I_0$

→ At $t < t_1$




KCL at node g

$i_{C_1} + i_{C_2} = I_0 + I_m$ , $i_{C_1} = i_{C_2} = I_0 + I_m/2$

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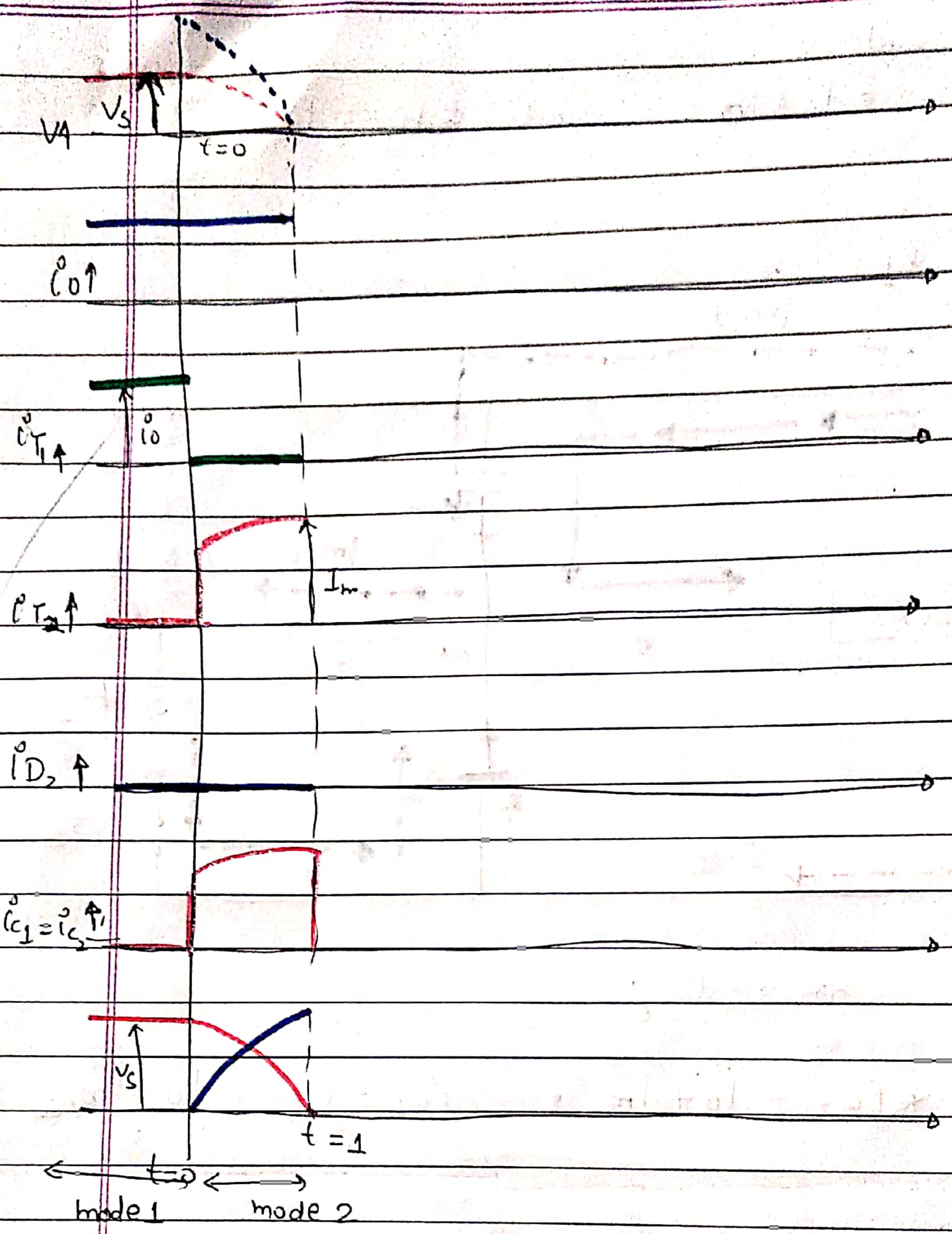
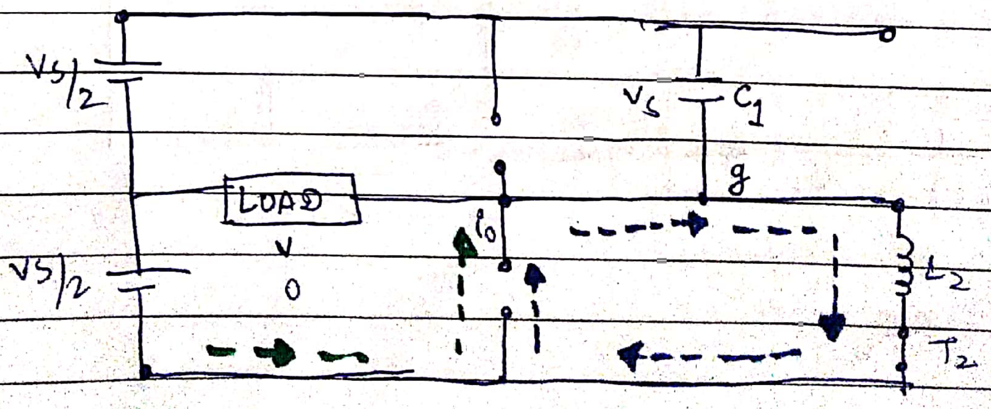
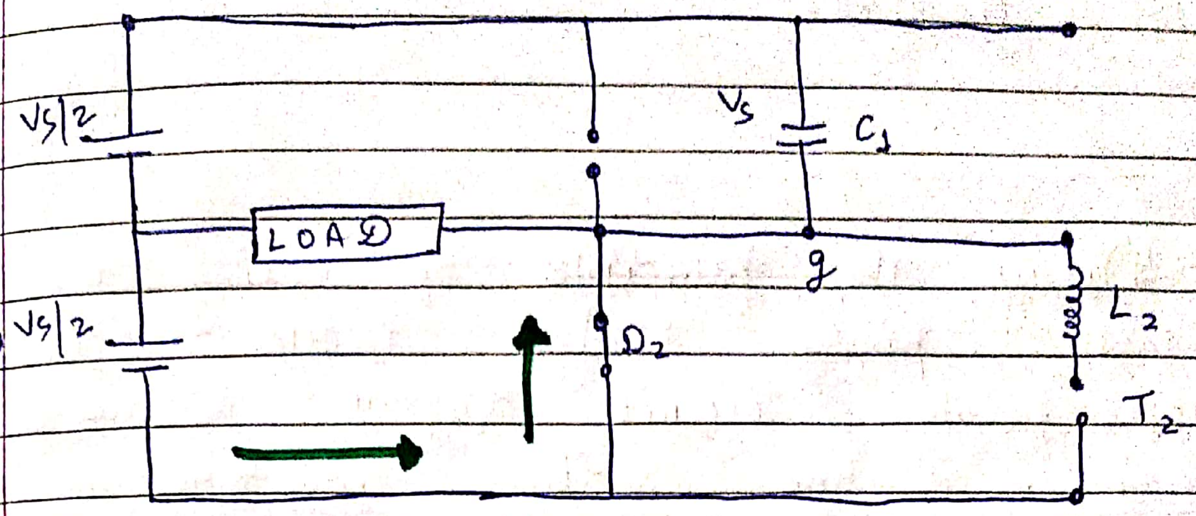
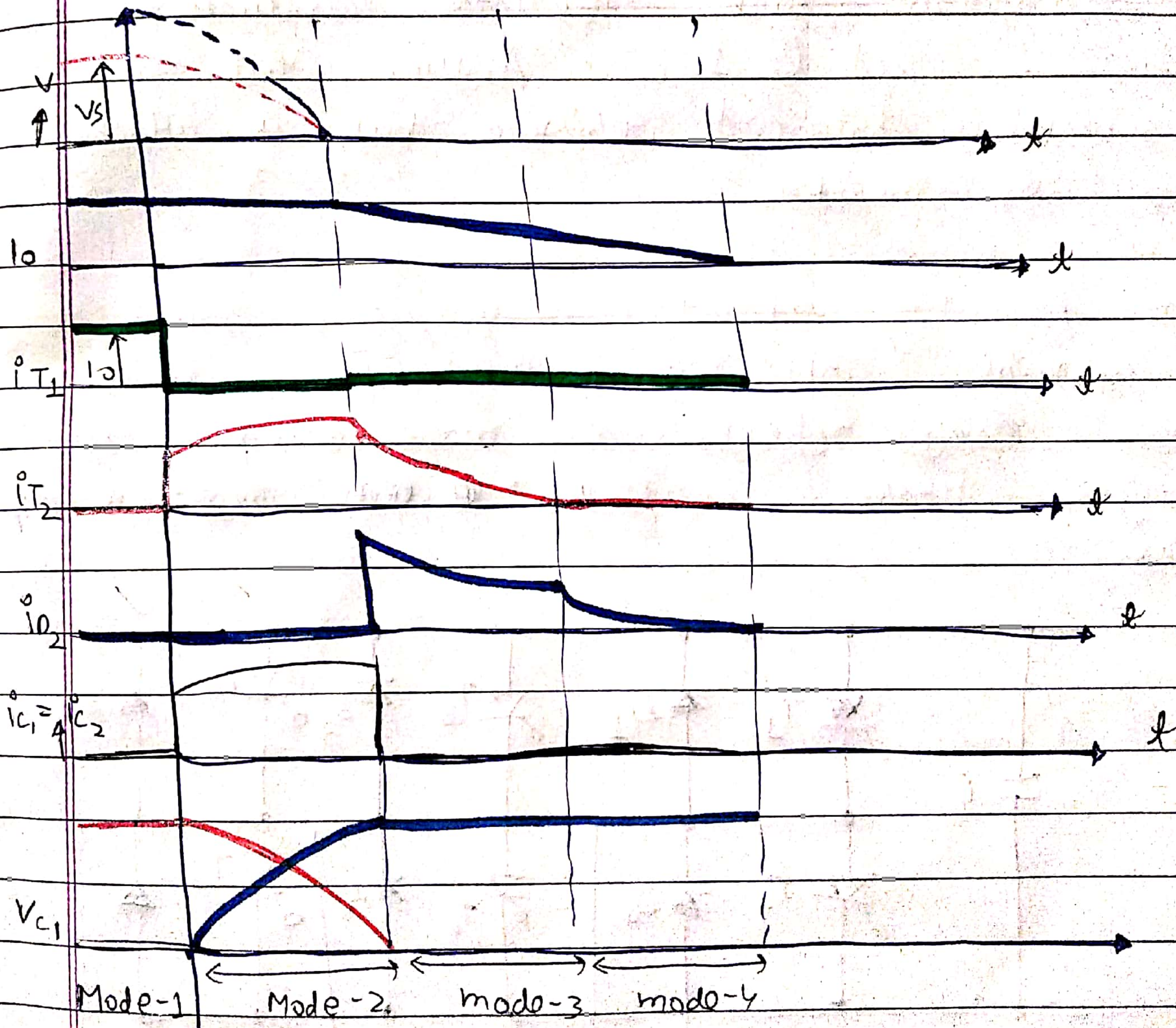



• Mode : 3 at $t_1$



- Mode : 04

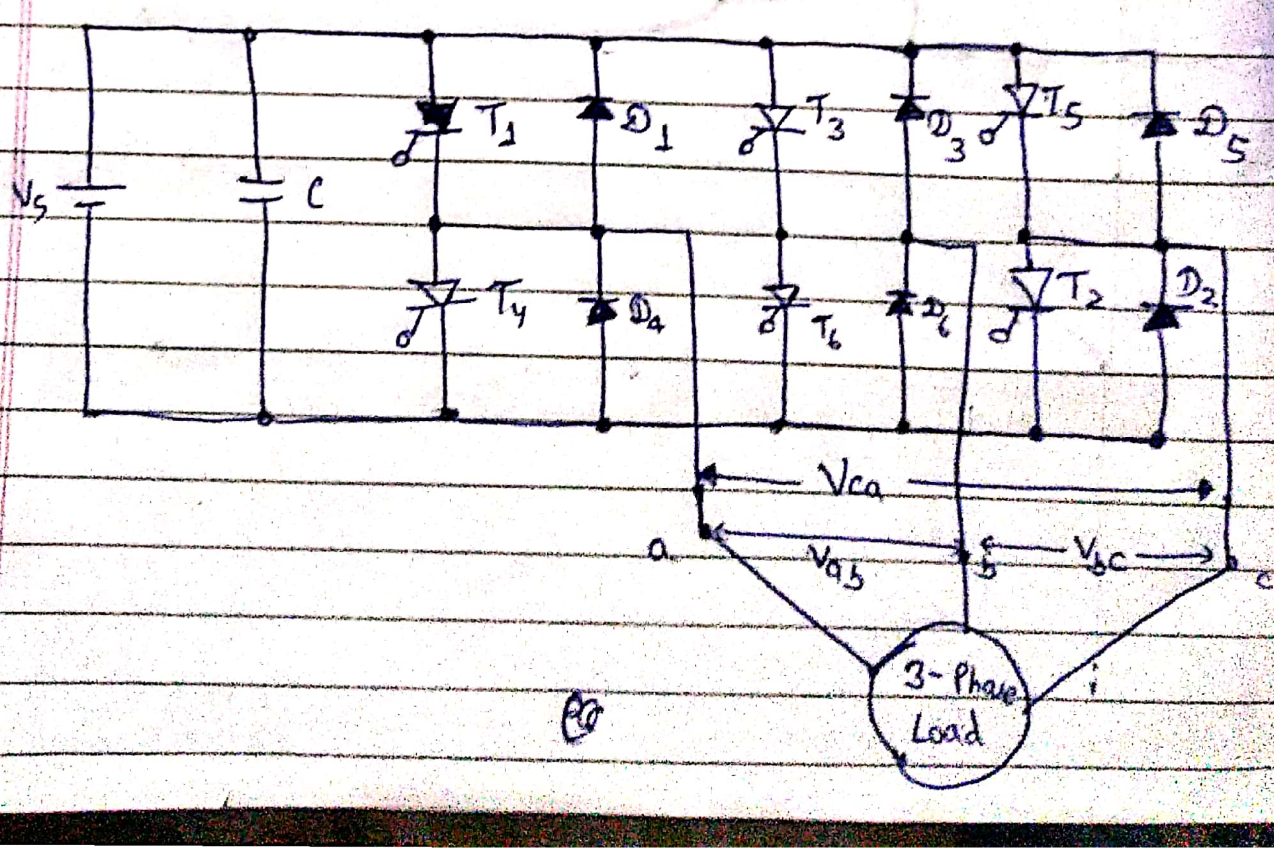

Vs|2
Vs|2
LOAD
Vs
C1
g
D2
L2
T2


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

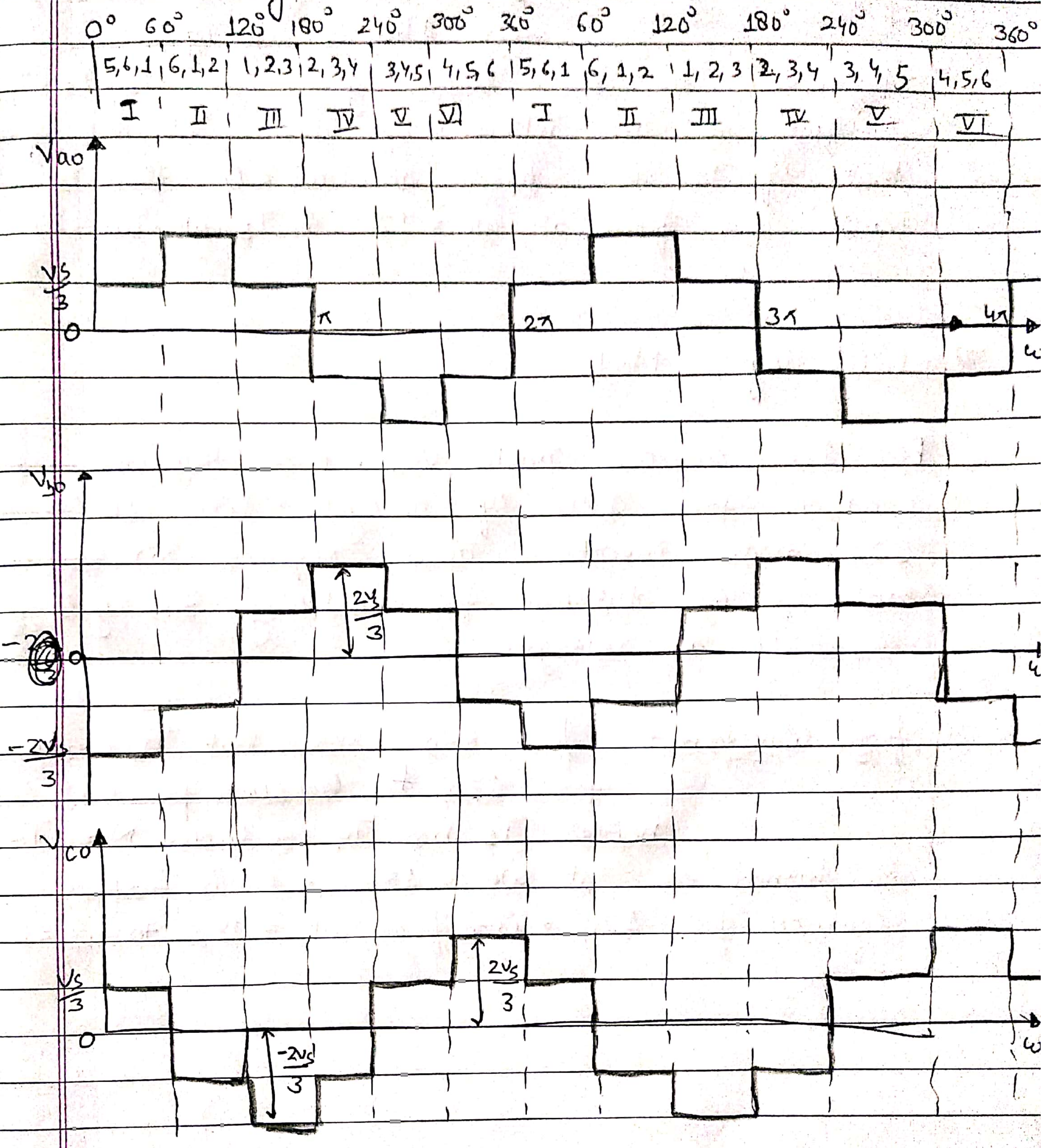
- It uses less number of thyristors & diodes as compared to modified McMurray half bridge inverter

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~~ are more common than single phase inverters.



# 180° degree



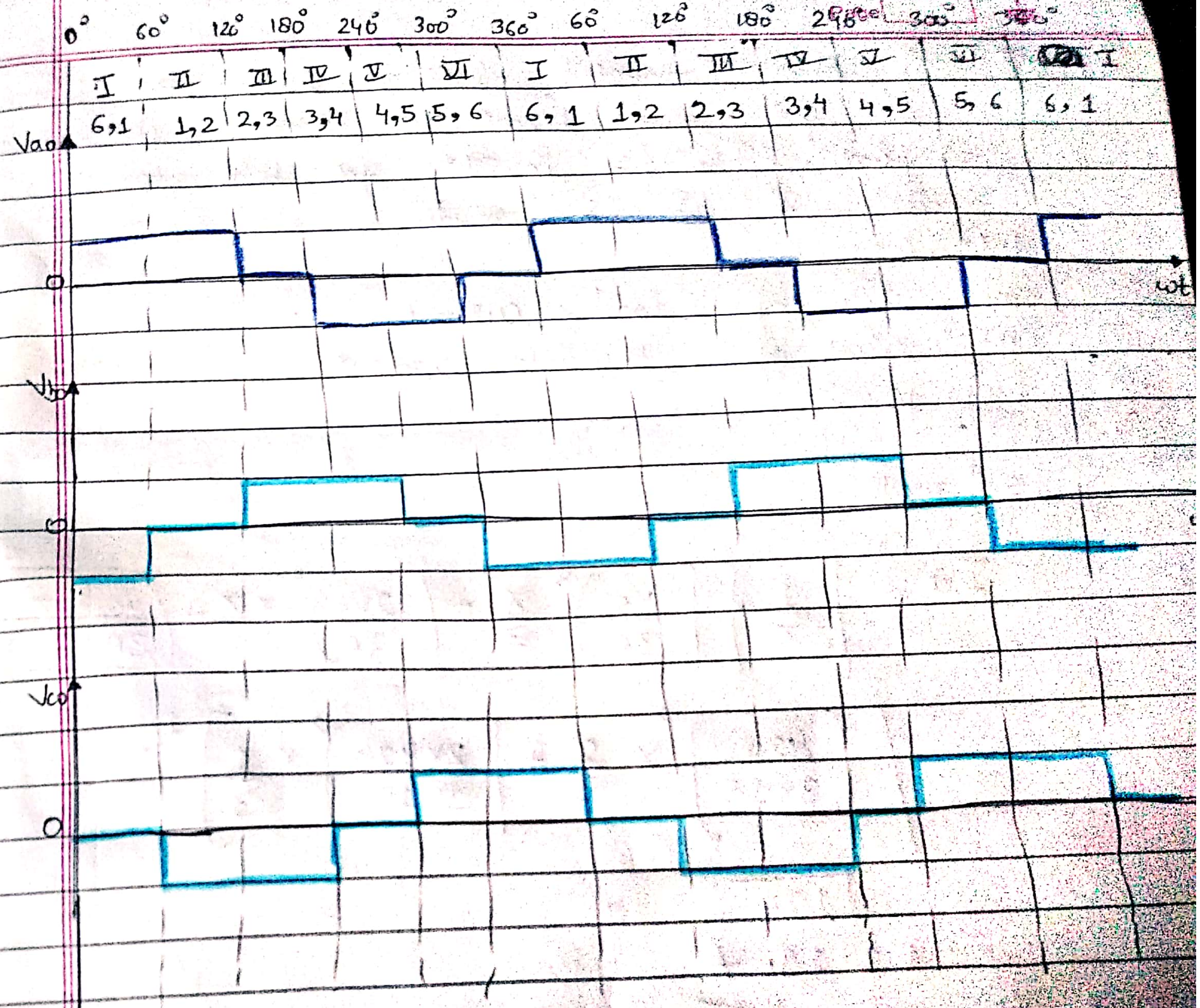

In three phase inverter, each SCR conducts for 180° of a cycle. Thyristor pair in each arm i.e. $T_1, T_4$; $T_3, T_6$ & $T_5, T_2$ are turned on with a time interval of 180°

from waveform: $T_1$ conduct for 180° & $T_4$ for next 180° of a cycle.
Thyristors 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° 360°
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
Vbo
Vco
0
ωt

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

$58.08 + 116.14$

Que: 07 A star connected load of 15 Ω per phase is fed from 420V 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

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

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

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

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

522.4

$= \sqrt{87}$

$= 9.327 A$

Power delivered to Load :

$= 3 I_{or}^2 R$

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

$= 7.83 \text{ KW}$

(b) $120^\circ$ mode :

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

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

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

$\cancel{= 3.055 A}$

Rms value of thyristor current

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

$= \sqrt{65.33}$

$= 8.082 A$

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(c) Load power

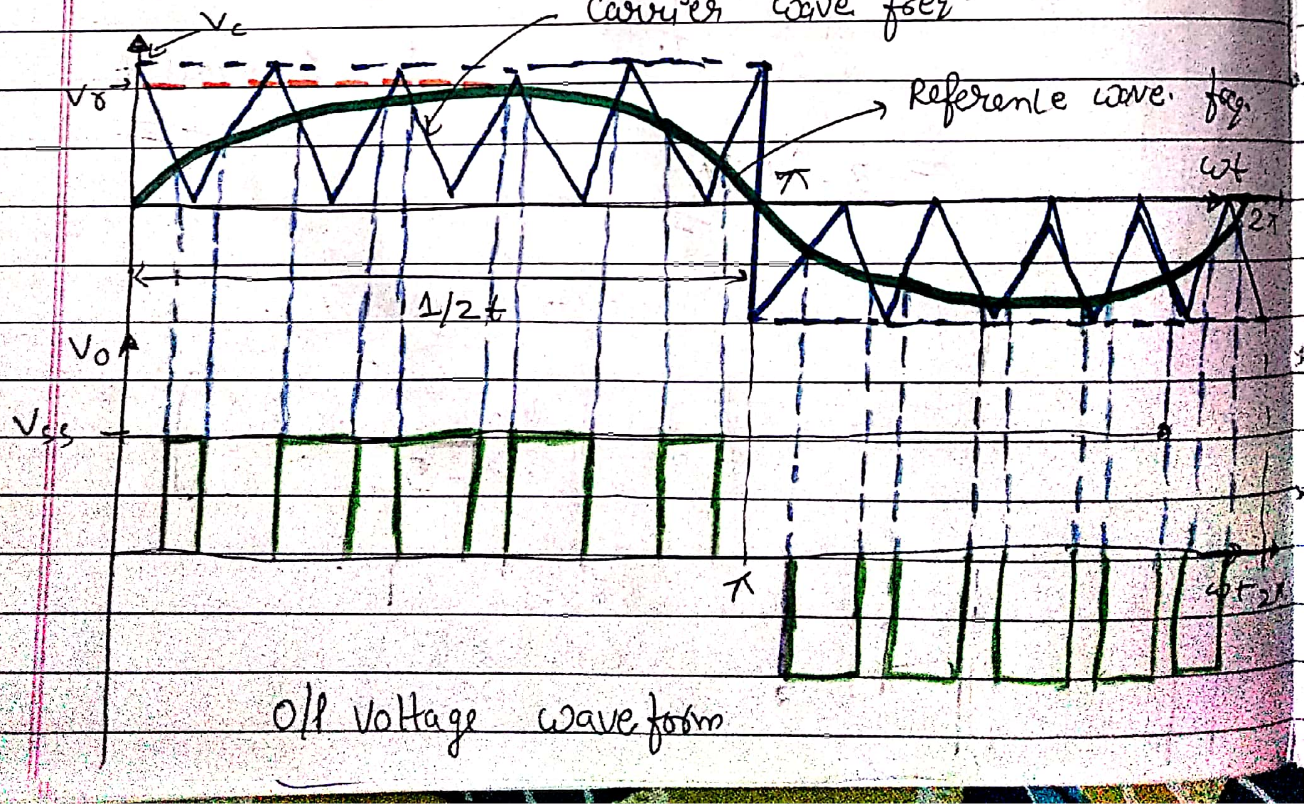
$= 3 I_{or}^2 R$

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

$= 5.877$ 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 wave form

for realizing SinM, 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