		OR			
9		The buck-boost regulator has input voltage of 12V DC. The duty cycle is 0.25 and switching frequency is 25KHz. The inductance is 150 μH and filter capacitance is 220 μF. The average load current is 1.25A. Determine : a) average output voltage, b) peak to peak output ripple voltage, c) peak to peak ripple current of inductor, d) Critical value of inductor, e) critical value of capacitor.	L4	CO4	10 M
		UNIT-V			
10	a)	Describe current source inverter with the help of circuit diagram and waveforms.	L4	CO3	5 M
	b)	Explain about unipolar and bipolar PWM methods.	L4	CO5	5 M
		OR			
11	a)	Analyze the performance of three phase inverter with 180° conduction mode of operation for star connected load and derive output voltage expression.	L4	CO4	6 M
	b)	A Single phase full bridge inverter is fed from a 500Volts DC source, it is supplying a purely resistive load of 100 Ω. Determine the RMS value of the output voltage and current.	L4	CO4	4 M

Code: 23EE3501

III B.Tech - I Semester - Regular Examinations - NOVEMBER 2025

POWER ELECTRONCIS
(ELECTRICAL & ELECTRONICS ENGINEERING)

Duration: 3 hours Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

PART – A

		BL	CO
1. a)	What are the advantages of UJT firing circuit?	L2	CO1
b)	Draw circuit symbols of SCR and MOSFET.	L1	CO1
c)	Write applications of phase controlled converters.	L2	CO3
d)	Interpret the significance of circulating current mode in dual converter operation.	L3	CO3
e)	Illustrate the reason why ripple content is very less in three phase rectifier circuits.	L3	CO3
f)	What is cyclo-converter and write its classification?	L1	CO1
g)	Write applications of choppers.	L2	CO3
h)	What is current limit control of a chopper?	L2	CO5
i)	What are the applications of inverters?	L2	CO4
j)	Demonstrate the advantages with PWM control in the inverters.	L3	CO5

PART – B

			BL	CO	Max. Marks
		UNIT-I			
2	a)	Analyze and draw steady state characteristics of SCR.	L4	CO1	5 M
	b)	Draw and explain switching characteristics of SCR.	L3	CO1	5 M
		OR			
3	a)	Demonstrate the RC triggering circuit for SCR.	L3	CO1	5 M
	b)	Write detailed comparison between MOSFET and IGBT.	L3	CO1	5 M
		UNIT-II			
4	a)	A single Phase fully controlled converter is operated from a 220V, 50Hz supply. The load current is 10A continuous with negligible ripple content. The delay angle of Thyristor is 30^0. Determine. a) Input displacement factor, b) Input power factor, c) Output DC voltage, d) Output RMS voltage, e) Input distortion factor, f) Input harmonic factor.	L4	CO4	10 M
		OR			
5	a)	Explain the working operation of a single phase half controlled bridge converter with resistive load and draw output voltage waveforms. Also derive output voltage expression.	L4	CO3	6 M
	b)	A single phase half controlled bridge rectifier supplies a resistive load. Assume that the transformer secondary voltage is	L4	CO4	4 M

		15V and load is 0.013 ohms. Neglecting transformer leakage and device voltage drops. Find the rectifier average value of the load voltage and current when firing angle is 90^o.			
		UNIT-III			
6	a)	Analyze the performance of a three phase half-wave mid-point converter operating with RL load and draw output voltage waveforms.	L4	CO3	6 M
	b)	Derive the output voltage expression for the three phase half-wave mid-point converter operating with RL load.	L4	CO3	4 M
		OR			
7	a)	Describe the operating principle of midpoint type step down cyclo-converter with related wave forms for output frequency of $f_s/4$ in continuous and discontinuous conductions modes of operation.	L4	CO4	6 M
	b)	List out applications of cyclo-converters.	L3	CO4	4 M
		UNIT-IV			
8	a)	Explain the operation of buck converter with neat waveforms.	L4	CO3	5 M
	b)	The buck regulator has input voltage of 12V DC. The required average output voltage is 5V for R Load of 500Ω and peak to peak output ripple voltage is 20mV. The switching frequency is 25KHZ. If the peak to peak ripple current of inductor is 0.8A. Determine duty cycle k, Required value of inductor (L) and capacitor(C).	L4	CO4	5 M

III B.Tech. I-SEM Regular
November 2025
Power electronics (23EE3501)
PVP23 Regulations
Scheme of Evaluation.

PART A

1a) Any 2 advantages 2×1M = 2M

b) SCR – 1M } 2M
MOSFET – 1M

c) Any 2 applications 2×1M – 2M

d) significance – 2M

e) Any one reason 1×2M – 2M

f) Definition – 1M } 2M
classifications – 1M

g) Any 2 application 2×1M – 2M

h) Diagram – 1M } 2M
Definition – 1M

i) Any 2 applications 2×1M – 2M

j) Advantages – 2M

PART B

2a) Diagram – 2M
characteristics – 2M
explanation – 1M
5M

2b) characteristics – 3M
Explanation – 2M.
5M

3a) circuit – 3M
Explanation & waveforms – 2M
5M

3b) Any Four comparisions – 5M

4a) Given data – 2M
Formula – 3M
Calculation & Answers – 5M
10M

5a) Diagram – 3M
waveforms & Explanation – 2M
Derivation – 1M
6M

5b) Data – 1M
Formula – 1M
Calculation & Answer – 2M
4M

6a) Diagram – 3M
Explanation – 1M
waveform for any one angle – 2M
6M

6b) Derivation – 4M.

7a) Diagram – 3M
Explanation & waveform – 3M

7b) Any 3 applications – 4M

8a) Circuit Diagram - 3 M
waveforms & Explanation - 2 M
5 M

8b) Data - 1 M
Formula - 2 M
Calculation & Answer - 2 M
5 M

9) Data - 2 M
Formula - 3 M
Calculation & Answers - 5 M
10 M

10a) Diagram - 3 M
Explanation & waveforms - 2 M
5 M

10b) Unipolar PWM - 3 M
Bipolar PWM - 2 M
5 M

11a) Diagram - 3 M
Mode of operation with waveforms - 3 M
6 M

11b) Data - 1 M
Formula - 2 M
Answer - 1 M
4 M

III B.Tech. I-SEM
Regular Examinations
November 2025
Power Electronics (23EE3501)
PVP23 Regulations
Detailed key.

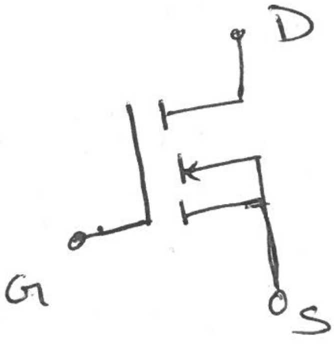
PART - A

1a. 1. Simple and low-cost design
2. Low power consumption
3. Power dissipation in the gate ~~drive~~ circuit is less.
4. Isolation of Gate circuit and main power circuit

Any two × 1M = 2M.

b.

SCR



MOSFET.

2 + 1M = 2M

c. 1. DC Motor speed Control
2. HVDC transmission
3. Industrial Heating & welding
4. UPS

5. Tranction and Electric Locomotive

6. Renewable Energy systems

Any two × ½ M = 2M.

d. Dual converter in circulating current mode.

→ Both converters are active, the output voltage polarity can change immediately without delay, ensuring fast and smooth operation (speed reversal of the motor).

e. 1. The ripple frequency of the converters output voltage is higher than in single-phase converters.

2. 3-φ rectifier produces 6 pulses (for a 3-φ full-wave rectifier). More pulses mean the output voltage is smoother, so ripple is naturally lower.

Any one × 2M - 2M

f. Cyclo-Converter:-

A device which converts input power at one frequency to output power at a different frequency with one-stage conversion is called a cycloconverter.

classification of cycloconverters

1. step-up
2. step-down.

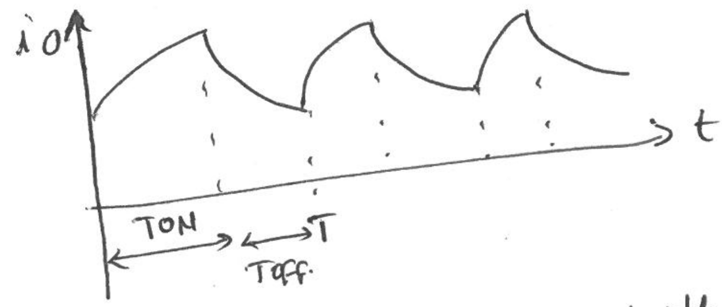
Def - 1M
classification - 1M.

g) Applications of choppers

1. Battery-operated vechicles
2. Subway Cars
3. Trolley Buses
4. Battery charging
5. speed control of DC drives etc

Any two × 1M = 2M.

h. current limit control of chopper.



The ON and OFF of the chopper circuit guided by the previous set value of load current. The two set values are maximum load current and minimum load current.

i. Application of Inverters.

1. Adjustable speed drives
2. Induction Heating
3. UPS
4. HVDC transmission etc..

Any two × 1M = 2M

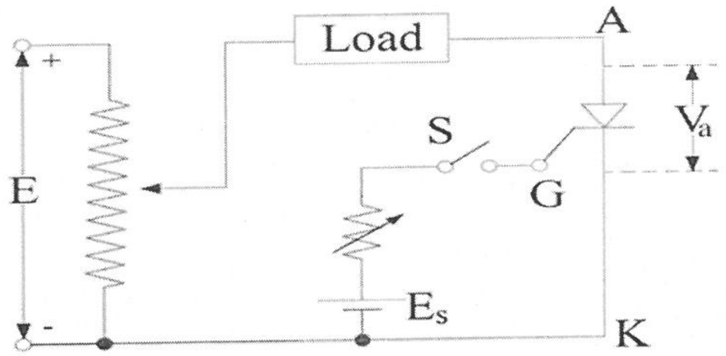
j. Advantage of PWM.

1. o/p voltage control with this method can be obtained without any additional components.
2. Lower order harmonic can be eliminated. Higher order harmonics can be filtered easily.

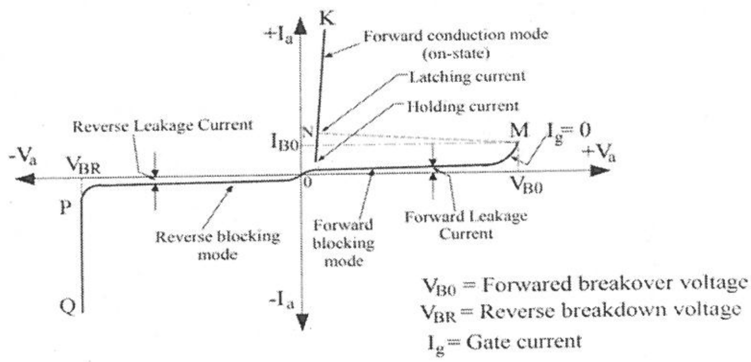
PART-B

2a) <u>*Static V-I characteristics of a Thyristor*</u>

To obtain V-I characteristics of SCR, its anode and cathode are connected to the source through the load. The Gate and cathode are fed through a separate source which is meant to provide positive gate current from gate to cathode. The elementary circuit diagram for obtaining V-I characteristics of SCR is shown below.



Anode and cathode are connected to main source voltage through the load.
The gate andcathode are fed from source Es.
A typical SCR V-I characteristic is as shown below:



VBO=Forward breakover voltage
VBR=Reverse breakover voltage
Ig=Gate current
Va=Anode voltage across the thyristor terminal A,K.
Ia=Anode current
It can be inferred from the static V-I characteristic of SCR. SCR have 3 modes of operation:

1. Reverse blocking mode
2. Forward blocking mode (off state)
3. Forward conduction mode (on state)

1. <u>Reverse Blocking Mode</u>

When cathode of the thyristor is made positive with respect to anode with switch open thyristor is reverse biased. Junctions $J1$ and $J2$ are reverse biased where junction $J2$ is forward biased. The device behaves as if two diodes are connected in series with reverse voltage applied across them.

- A small leakage current of the order of few mA only flows. As the thyristor is reverse biased and in blocking mode. It is called as acting in reverse blocking mode of operation.

- Now if the reverse voltage is increased, at a critical breakdown level called reverse breakdown voltage VBR,an avalanche occurs at $J1$ and $J3$ and the reverse current increases rapidly. As a large current associated with VBR and hence morelosses to the SCR.

This results in Thyristor damage as junction temperature may exceed its maximum temperature rise.

2. Forward Blocking Mode

When anode is positive with respect to cathode, with gate circuit open, thyristor is said tobe forward biased. Thus junction $J1$ and $J3$ are forward biased and $J2$ is reverse biased. As the forward voltage is increases junction $J2$ will have an avalanche breakdown at a voltage called forward breakover voltageVBO. When forward voltage is less then VBOthyristor offers high impedance. Thus a thyristor acts as an open switch in forward blocking mode.

3. Forward Conduction Mode

Here thyristor conducts current from anode to cathode with a very small voltage dropacross it. So a thyristor can be brought from forward blocking mode to forward conducting mode:

1. By exceeding the forward breakover voltage.
2. By applying a gate pulse between gate and cathode.

During forward conduction mode of operation thyristor is in on state and behave like a close switch. Voltage drop is of the order of 1 to 2mV. This small voltage drop is due toohmic drop across the four layers of the device.

2b) *Switching characteristics of thyristors*

The time variation of voltage across the thyristor and current through it during turn on and turn off process gives the dynamic or switching characteristic of SCR.

Switching characteristic during turn on

Turn on time

It is the time during which it changes from forward blocking state to ON state. Total turnon time is divided into 3 intervals:

1. Delay time
2. Rise time
3. Spread time

Delay time

If $Ig$and Ia represent the final value of gate current and anode current. Then the delay time can be explained as time during which the gate current attains 0.9 Ig to the instant anode current reaches 0.1 Ig or the anode current rises from forward leakage current to 0.1 Ia.

1. Gate current 0.9 Ig to 0.1 Ia.
2. Anode voltage falls from $Va$to 0.9Va.
3. Anode current rises from forward leakage current to 0.1 Ia.

Rise time (tr)

Time during which

1. Anode current rises from 0.1 Ia to 0.9 Ia
2. Forward blocking voltage falls from 0.9Va to 0.1Va. $Va$is the initial forward blocking voltage.

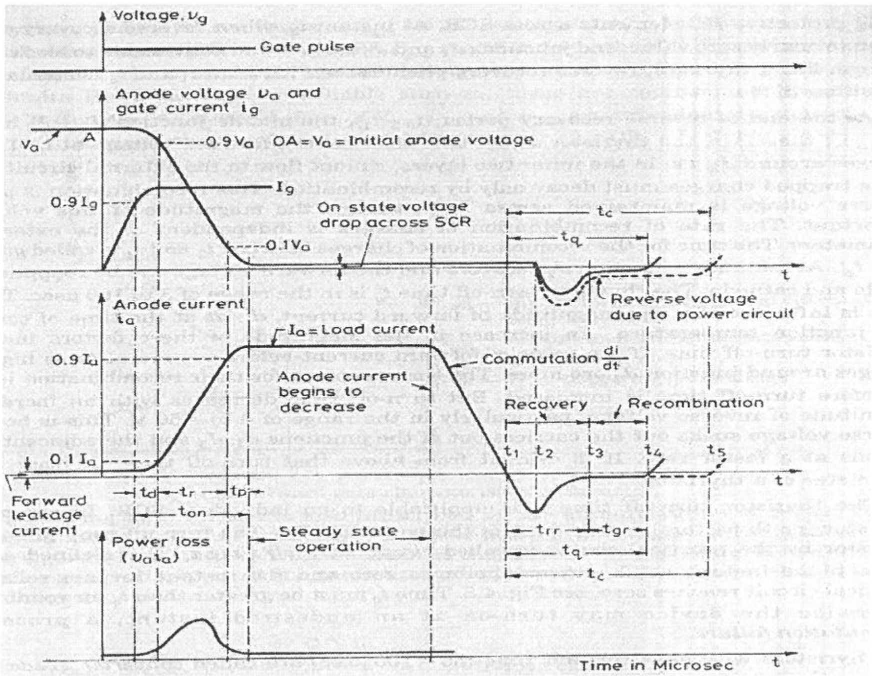
Spread time (tp)

1. Time taken by the anode current to rise from $0.9Ia$ to Ia.
2. Time for the forward voltage to fall from $0.1Vo$ to on state voltage drop of 1 to 1.5V. During turn on, SCR is considered to be a charge controlled device. A certain amount of charge is injected in the gate region to begin conduction. So higher the magnitudeof gate current it requires less time to inject the charges. Thus turn on time is reduced by using large magnitude of gate current.

Switching Characteristics During Turn Off

Thyristor turn off means it changed from ON to OFF state. Once thyristor is ON there is no role of gate. As we know thyristor can be made turn OFF by reducing the anode current below the latching current. Here we assume the latching current to be zeroampere. If a forward voltage is applied across the SCR at the moment it reaches zero then SCR will not be able to block this forward voltage. Because the charges trapped in the 4- layer are still favourable for conduction and it may turn on the device. So to avoid such a case, SCR is reverse biased for some time even if the anode current has reached to zero.

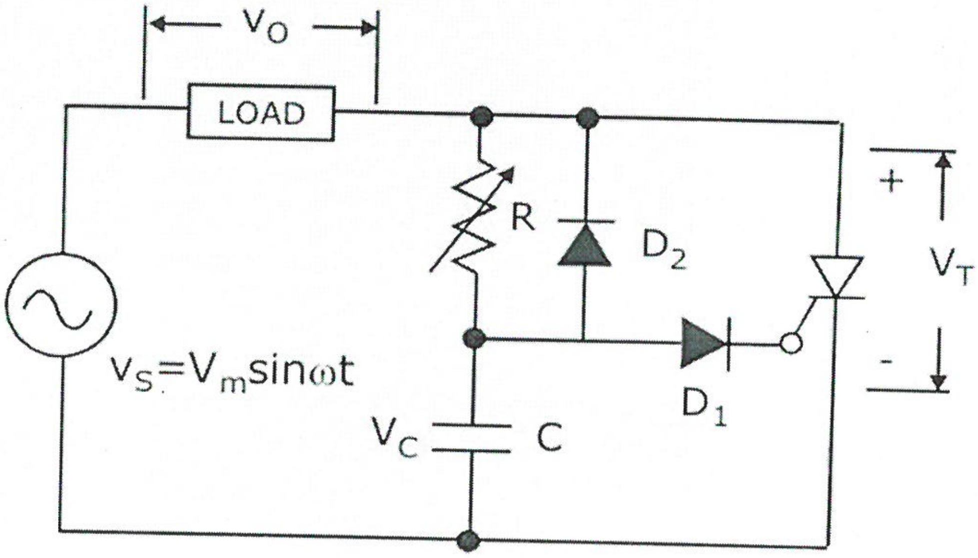
So now the turn off time can be different as the instant anode current becomes zero to theinstant when SCR regains its forward blocking capability. $t_q = t_{rr} + t_{qr}$ Where, tq is the turn off time,trr is the reverse recovery time, tqr is the gate recovery time. At $t1$ anode current is zero. Now anode current builds up in reverse direction with same (dv/dt) slope. This is due to the presence of charge carriers in the four layers. The reverse recovery current removes the excess carriers from $J1$ and $J3$ between the instants $t1$ and$t3$. Atinstant $t3$ the end junction $J1$ and $J3$ is recovered. But $J2$ still has trapped charges which decaydue to recombination only so the reverse voltage has to be maintained for some more time. The time taken for the recombination of charges between $t3$ and $t4$ is called gate recovery time tqr. Junction $J2$ recovered and now a forward voltage can be applied across SCR.

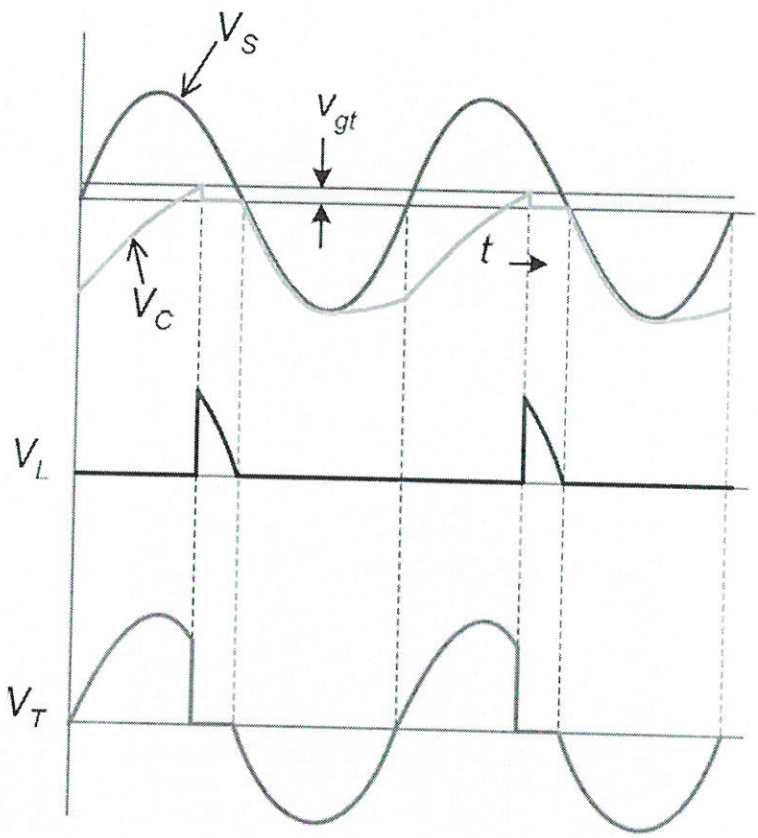


3a)

Resistance-Capacitance Firing Circuit (RC-Firing) :

The limitations of the resistance firing circuit can be overcome by using a resistance-capacitance firing circuit. Using an RC-firing circuit the firing angle can be controlled from 0 to 180 electrical degrees. There are two types of RC-firing circuits,





The above figure illustrates the RC half-wave firing circuit. The capacitor charges to the negative peak of the ac voltage in every negative half-cycle through the diode D_2. During the positive half-cycle, it begins to charge through the resistance R_V. When the voltage across the capacitor reaches the required positive value, the thyristor is fired and the capacitor voltage remains almost constant.

The diode D_1 prevents the breakdown of the gate-cathode junction during the negative half-cycle. For power frequencies, the value of R_V C for zero output voltage is empirically given by,

$$R_V C \geq \frac{1.3T}{2} = \frac{4}{\omega}$$

$$Where, T = \frac{1}{f}$$

$$V_C \text{ is given by,}$$

$$V_C = V_{gt} + V_{D1}$$

The maximum value of variable resistance R_V is given by,

$$V_S \geq R_V I_{gt} + V_C$$

$$V_S = R_V I_{gt} + V_{gt} + V_{D1} \text{ or}$$

$$R_V \leq \frac{V_S - V_{gt} - V_{D1}}{I_{gt}}$$

3b)

IGBT	MOSFET
IGBT stands for Insulated Gate Bipolar Transistor.	MOSFET stands for Metal Oxide Semiconductor Field Effect Transistor
IGBT is a three terminal semiconductor switching device used in the electronic circuits for switching and amplification of signals.	MOSFET is a four terminal semiconductor switching device which is also used as switching and amplification.
IGBT has three terminals, which are: emitter (E), gate (G) and collector (C).	MOSFET has four terminals which are: source (S), gate (G), drain (D) and body (or substrate). Sometimes, the body terminal is merged with the source, making it a three terminal device.
IGBT has PN junctions in its construction.	MOSFET does not have any PN junction in its construction.
IGBT is suitable for medium to high current conduction and controlling.	MOSFET is suitable for low to medium current conduction and controlling.
IGBT has ability to handle very high voltage and high power.	MOSFET is capable of handling only low to medium voltage and power.
IGBT can only be used for relatively low frequencies, up to a few kHz.	MOSFET can be used for very high frequency (of the order of MHz) applications.
When IGBT is conducting current, it produces comparatively low forward voltage drop.	MOSFET produces higher forward voltage drop than IGBT.
For IGBT, the turn-off time is larger than MOSFET.	The turn-off time of a MOSFET is smaller than IGBT.
The switching speed of IGBT is relatively low.	The switching speed of MOSFET is very high.
IGBT has ability to handle any transient voltage and current.	MOSFET cannot handle transient voltage and current. Thus, the operation of a MOSFET gets disturbed when the transient occurs.
For IGBT, the saturation voltage is low.	MOSFET has high saturation voltage.
IGBT is costlier than MOSFET.	The cost of a MOSFET is relatively low.
IGBTs are extensively used in high power AC applications such as in inverter circuits.	MOSFETs are used in low power DC applications like in power supplies.

4a) Given

$V_s = 220V$ $f = 50Hz$

$I_o = 10A$

$\alpha = 30°$.

Formula

Average DC output Voltage

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

Displacement Factor = $\cos\alpha$.

Input current Distortion factor

$$DF = \frac{I_{1,rms}}{I_{rms}}$$

Input power factor

$$PF = \frac{V_o I_o}{V I}$$

output RMS Voltage
with negligible ripple the output is essentially DC

$$V_{orms} = V_o$$

Input Harmonic factor

$$HF = \sqrt{\frac{I_{rms}^2 - I_{1rms}^2}{I_{1rms}^2}} = \sqrt{\frac{1}{DF^2} - 1}$$

Displacement Factor

$DF = \cos 30 = 0.866$.

Output DC voltage

$V_o = 171.5\,V$

Output RMS voltage

$V_{or} = 171.5\,V$

Input power factor

$PF = 0.7797$.

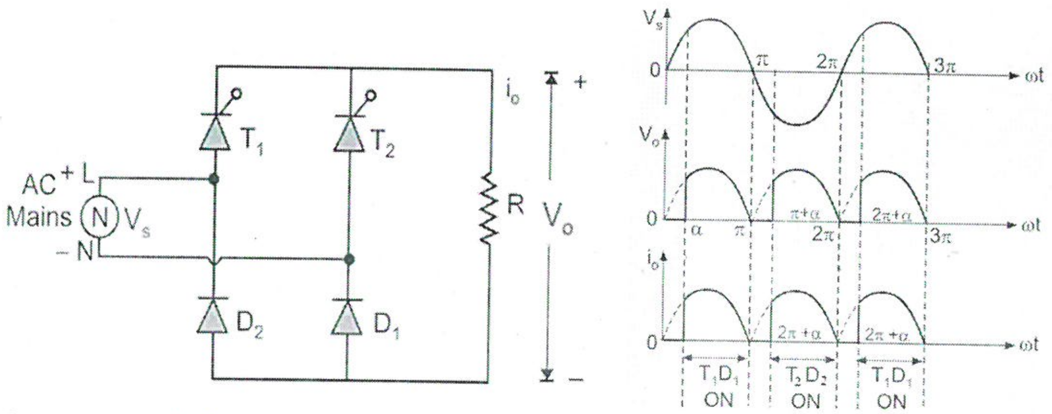
Input Distortion factor

$DF = 0.9$

Input harmonic factor

$HF = 48.34\%$.

5a) **Single Phase Semi-Converter with R Load**



During positive half-cycle of AC input voltage, thyristor T_1 diode D_1 conduct and thyristor T_1 is fired at $\omega t = \alpha$. Therefore the average output voltage is equal to the instantaneous supply voltage and load current flows through T_1, R, D_1 and back supply again. At instant $\omega t = \pi$, the supply goes through zero and after π supply voltage reverses its polarity. Due to reverse supply across conducting devices T_1 and D_1, they turned off at $\omega t = \pi$ and this type of turn-off is called as "natural" or "line commutation". Therefore, the average output voltage is zero and load current is also zero. At instant $\omega t = \pi + \alpha$, the supply voltage becomes completely negative i.e., during negative half cycle of AC input voltage, thyristor T_2 and diode D_2 are forward biased, thyristor T_2 is fired at $\omega t = \pi + \alpha$. Thus the average output is equal to instantaneous supply voltage because due to conduction of T_2 and D_2, the load is directly connected to supply. The load current flows through T_2, R, D_2. Thyristor T_2 and diode D_2 conduct upto 2π, at $\omega t = 2\pi$ commutation takes place due to natural zero appears across supply.

output voltage

$$V_o = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin\omega t \, d(\omega t)$$

$$= \frac{V_m}{\pi}\left[-\cos\omega t\right]_{\alpha}^{\pi}$$

$$\boxed{V_o = \frac{V_m}{\pi}\left[1+\cos\alpha\right]}$$

5 b) $V = 15\,V$

$R = 0.013\,\Omega$, $\alpha = 90^\circ$

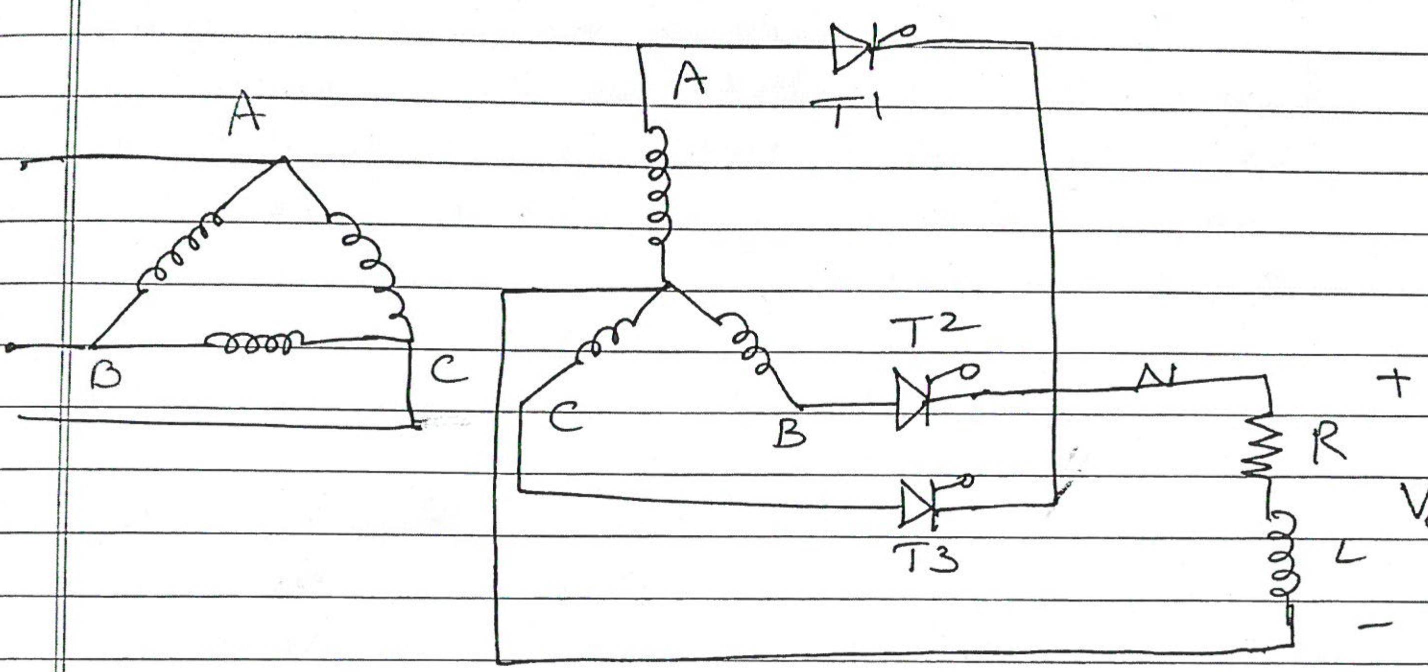
$$V_o = \frac{V_m}{\pi}(1+\cos\alpha)$$

$$V_o = \frac{\sqrt{2} \times 15}{\pi}(1+\cos 90)$$

$$V_o = 6.75\,V$$

$$I_o = \frac{V_o}{R} = \frac{6.75}{0.013} = 519.4\,A.$$

6a) Three phase half wave controlled converter with RL load:



The circuit consist of a delta transformer and 3 thyristors T1, T2, T3 which are connected on the secondary star connected winding and a RL load. When VA is positive T1 becomes forward biased and conducts. During the negative cycle of VA, the current through T_1 is not zero due to inductor present in the load. So T_1 will remain ON during negative cycle of VA. When Vb is positive T2 is triggered and the load current gets transferred from T1 to T2. At this instant T_1 turns off. During the negative cycle of VB, the current through T2 is not zero due to inductor present in the load. So T2 will remain ON during the negative cycle of VB. When T3 is triggered during positive half cycle of Vc, the load current is transferred from T2 to T3. At this instant T2 turns off. Similarly T3 conducts during the negative half cycle of Vc and turns off when T1 is triggered. The average output voltage can be varied by varying the firing angle of the thyristors.

$\alpha = 0^\circ$ $(\omega t = 30 + \alpha)$

SCR	ON	OFF	load Voltage
T1	30°	150°	V_A
T2	150°	270°	V_B
T3	270°	390°	V_C

$\alpha = 30^\circ$

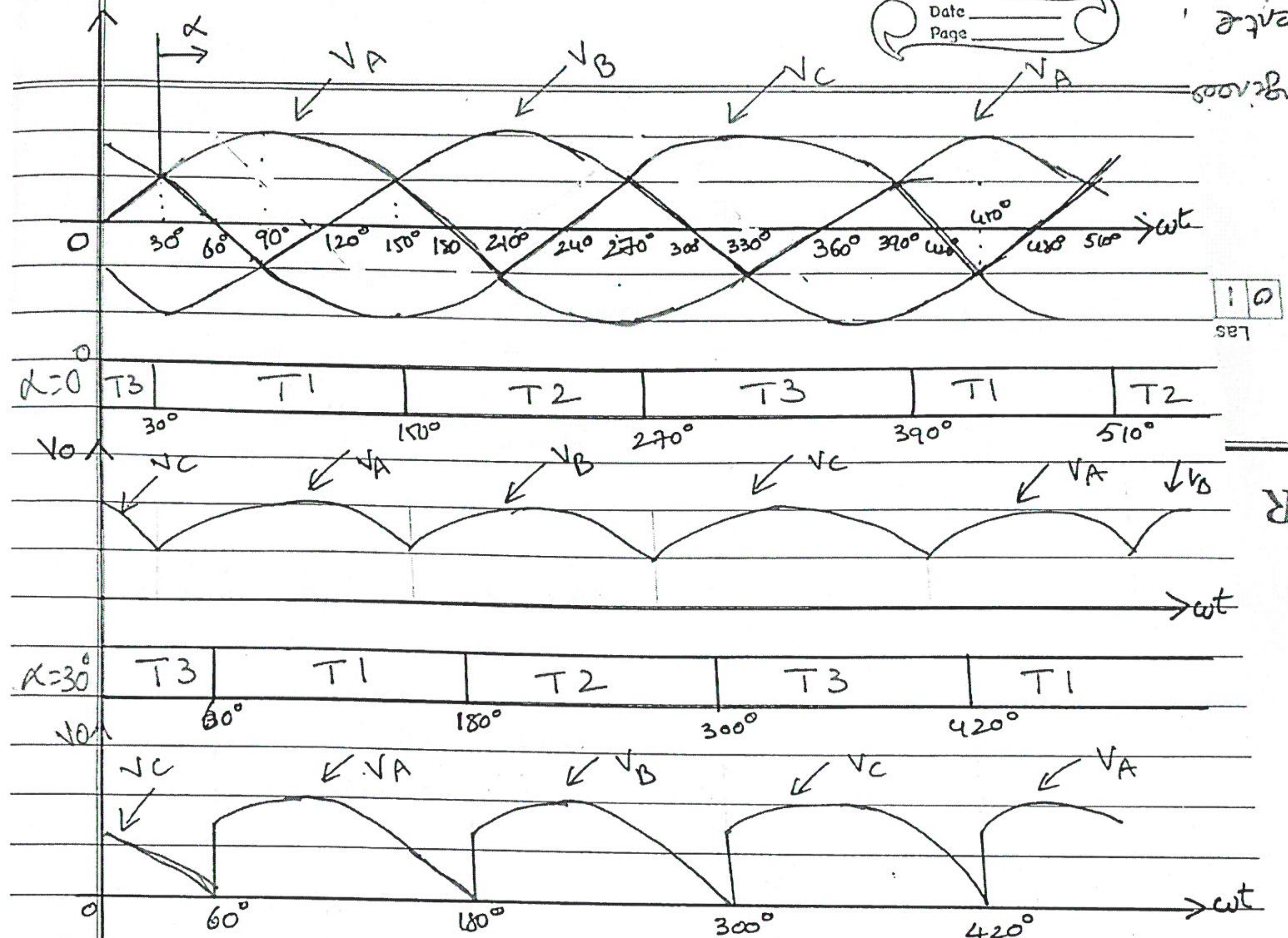
SCR	ON	OFF	load Voltage
T1	60°	180°	VA
T2	180°	300°	VB
T3	300°	420°	Vc

$\alpha = 60^\circ$

SCR	ON	OFF	Load Voltage
T1	90°	210°	VA
T2	210°	330°	VB
T3	330°	450°	Vc

$\alpha = 90^\circ$

SCR	ON	OFF	load Voltage
T1	120°	240°	VA
T2	240°	360°	VB
T3	360°	480°	Vc



6b)

$$V_o = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m \sin\omega t \, d(\omega t)$$

$$V_o = \frac{3V_m}{2\pi}\Big[-\cos\omega t\Big]_{\frac{\pi}{6}+\alpha}^{5\pi/6+\alpha}$$

$$V_o = \frac{3V_m}{2\pi}\left[\cos\left(\frac{\pi}{6}+\alpha\right) - \cos\left(\frac{5\pi}{6}+\alpha\right)\right]$$

$$V_o = \frac{3V_m}{2\pi}\left[\cos\left(\frac{\pi}{6}+\alpha\right) - \cos\left[\pi-\frac{\pi}{6}+\alpha\right]\right]$$

$$V_o = \frac{3V_m}{2\pi}\left[\cos\left(\alpha+\frac{\pi}{6}\right) + \cos\left(\alpha-\frac{\pi}{6}\right)\right]$$

$$V_o = \frac{3V_m}{2\pi} \, 2\cos\alpha \cos\frac{\pi}{6}$$

$$V_o = \frac{3V_m}{\pi} \cos\alpha \frac{\sqrt{3}}{2}$$

$$\boxed{V_o = \frac{3\sqrt{3}}{2\pi} V_m \cos\alpha}$$

7a) Single Phase to Single Phase Cyclo-Converter with RL Load.

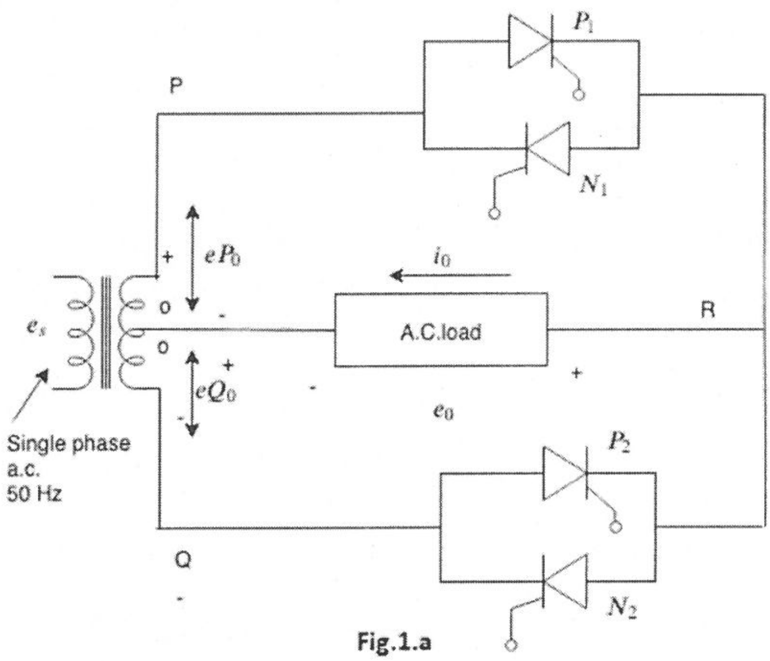
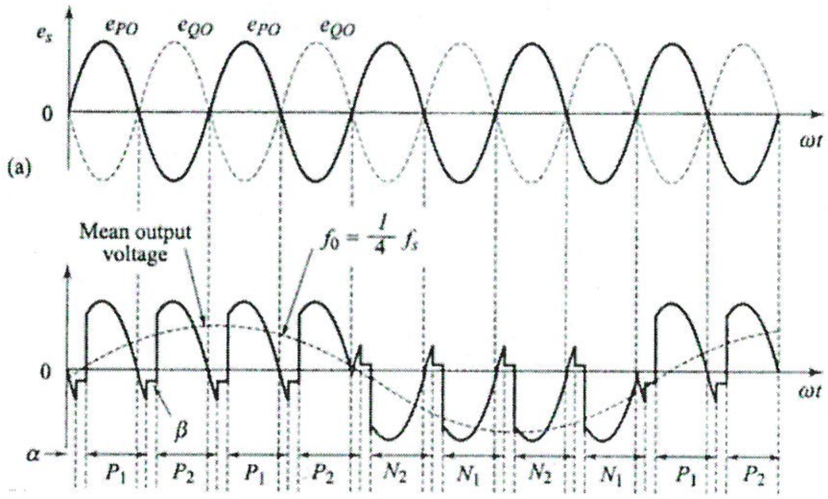


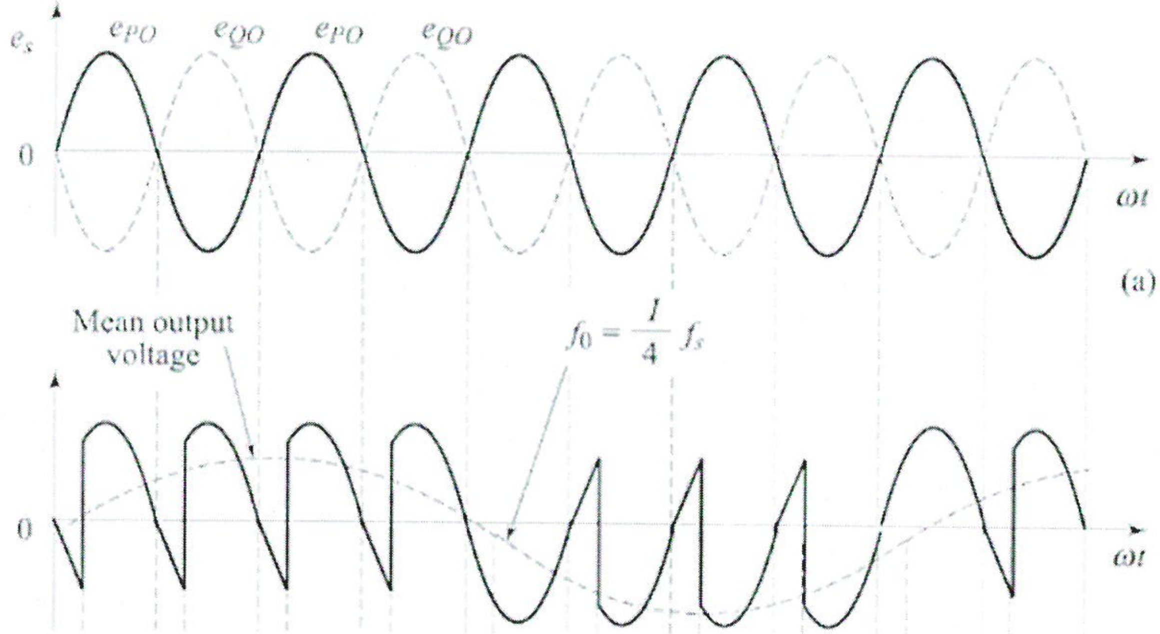
Fig.1.a

a) Discontinuous load current: When point *P* is positive with respect to point *O* in Fig.1.a , forward-biased SCRP_1 is triggered at $\omega t=\alpha$. With this, load current starts building up in the positive direction from point *R* to point *O* Load current i_0 becomes zero at $\omega t=\beta>\pi$ but less than $(\pi+\alpha)$, Thyristor P_1 is thus naturally commutated at $\omega t=\beta$ which is already reverse biased after π . After half a cycle, point *Q* is positive with respect to *O*. Now, forward-biased thyristor P_2 triggered at $\omega t=(\pi+\alpha)$. Load current is again positive from point *R* to *O* and builds up from zero as shown in Fig . At $\omega t=(\pi+\beta)$, current decays to zero and SCRP_2 is naturally commutated. At $(2\pi+\alpha)$,SCRP_1 is again turmed-on.



(b) Continuous load current: When point P is positive with respect to point O in Fig.1.a, SCR P_1 is triggered at $\omega t=\alpha$, positive output voltage appears across load and load curren starts building up, as shown in Fig. At $\omega t=\pi$, supply and load voltages are zero. After $\omega t=\pi$,SCRP_1 is reverse-biased. As load current is continuous, SCR P_1 is not turned-off at $\omega t=\pi$. When SCR P_2 is triggered in sequence at $(\pi+\alpha)$, a reverse voltage appears across SCRP_1; it is therefore turned-off by natural commutation. When SCRP_1 is commutated,load current has built up to a value equal to KJ, as shown in Fig.1.C. With the turning-on of SCRP_2 at $(\pi+\alpha)$, output voltage is again positive as it was with SCRP_1 ON. As a consequence, load current builds up further than KJ as shown in Fig.1.C. At $(2\pi+\alpha)$, when SCRP_1 is again turned-on, SCR P_2 is naturally commutated and load current through SCRP_1 builds up beyond KL as shown.

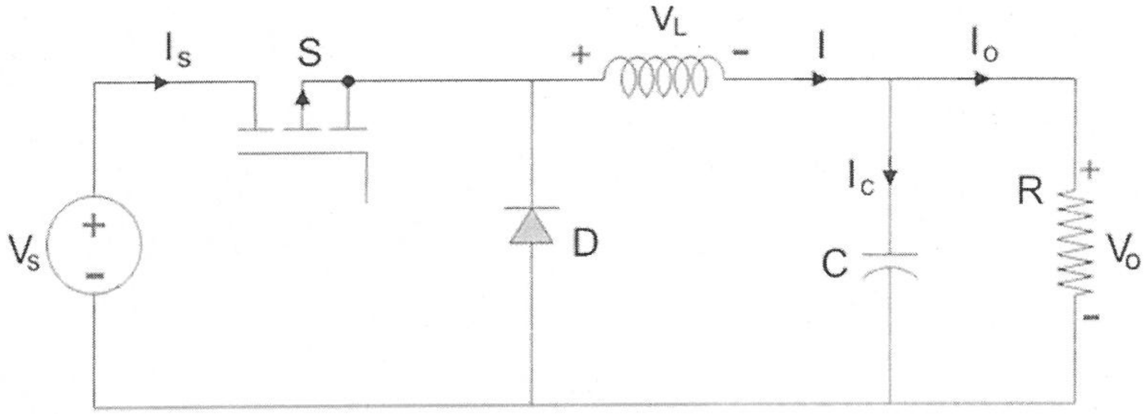
At the end of four positive half-cycles of output voltage, load current is KN .When SCR N_2 is now triggered after SCRP_2, load is subjected to a negative voltage cycle and load current i_0 decreases from positive KN to negative AB as shown in Fig. Now, SCRN_2 is commutated and SCRN_1 is gated at $(5\pi+\alpha)$. Load current i_0 becomes more negative than AB at $(6\pi+\alpha)$, , this is because with SCR N_1 ON, load voltage is negative.



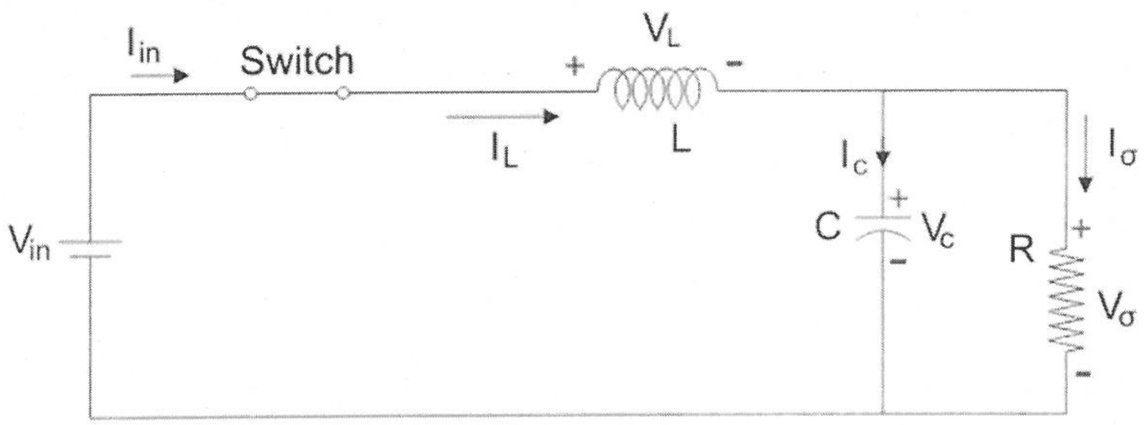
7b) The applications of cycloconverters include:

- Cement mill drives
- Rolling mills
- Ship propulsion drivers
- Water pumps
- Washing machines
- Mine winders
- Industries

8a) BUCK CHOPPER



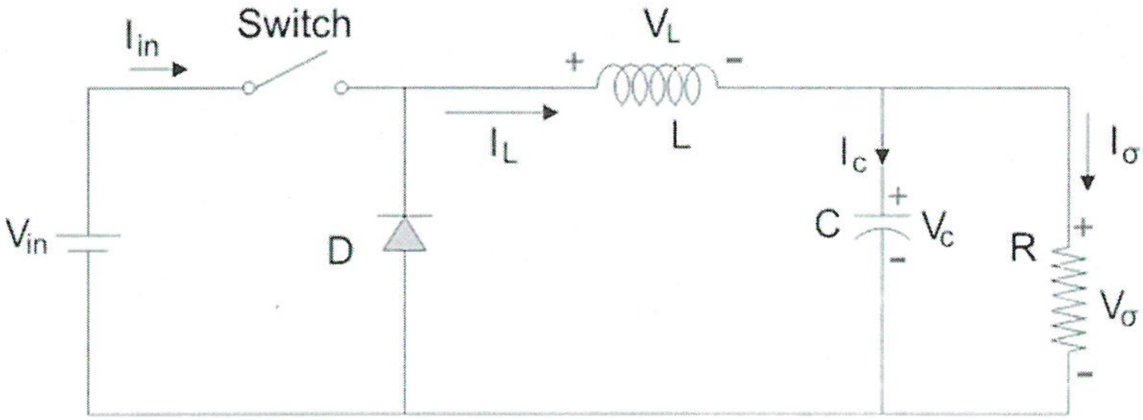
Mode I : Switch is ON, Diode is OFF

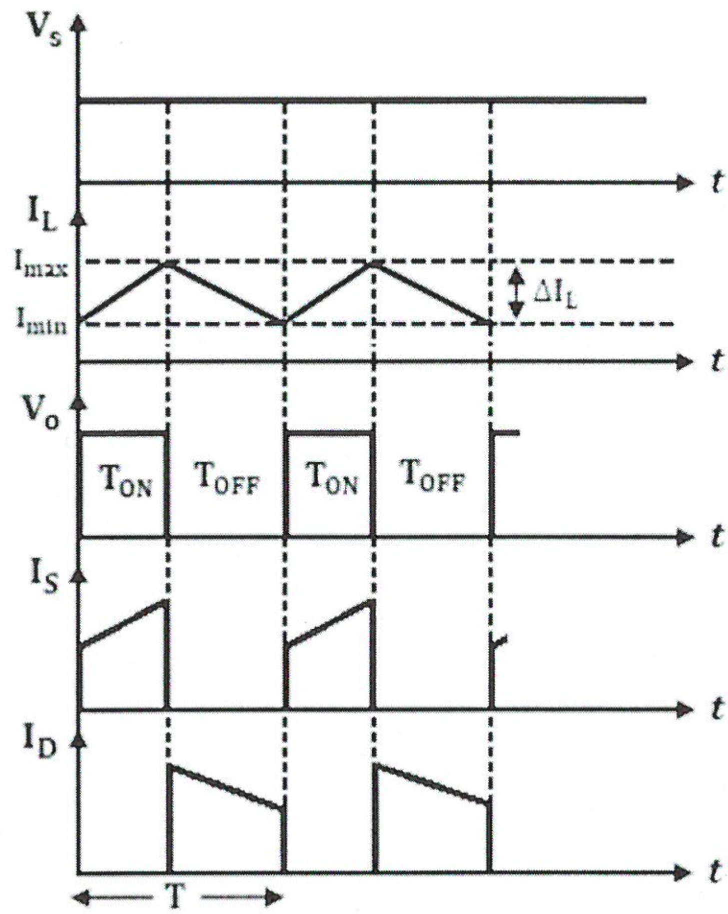


The voltage across the capacitance in steady state is equal to the output voltage. Let us say the switch is on for a time T_{ON} and is off for a time T_{OFF}. We define the time period, T, as $T = T_{ON} + T_{OFF}$

Mode II: Switch is OFF, Diode is ON

Here, the energy stored in the inductor is released and is ultimately dissipated in the load resistance, and this helps to maintain the flow of current through the load. But for analysis we keep the original conventions to analyse the circuit using KVL.





Voltage and Current Waveforms of Buck Converter

8b) $V_s = 12\,V$

$V_o = 5\,V$

$R = 500\,\Omega$

$\Delta V_c = 20\,mV$

$f = 25\,KHz$

$\Delta I = 0.8\,A$

Duty cycle

$$\alpha = \frac{V_o}{V_s} = \frac{5}{12} = 0.4167$$

$$41.67\,\%$$

$$\Delta I = \frac{V_o(V_s - V_o)}{f\,L\,V_s} = \frac{V_s\,\alpha(1-\alpha)}{f.L.}$$

$$L = \frac{V_o(V_s - V_o)}{f\,\Delta I\,V_s} = \frac{V_o\,\alpha\,(1-\alpha)}{f\,\Delta L}$$

$$L = \frac{5(12-5)}{0.8 \times 25 \times 10^3 \times 12} = 145.83\,\mu H.$$

$$C = \frac{V_o(V_s - V_o)}{8 L f^2 V_s \Delta V_c} = \frac{5(12-5)}{8 \times 145.83(25 \times 10^3)^2 \times 18 \times 20 \times 10^{-3}}$$

$$C = 200\,\mu F.$$

9. $V_s = 12V$

$\alpha = 0.25$

$f = 25kHz$

$L = 150\mu H$

$C = 220\mu F$

$I_o = 1.25A.$

average output voltage

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

$$V_o = -12 \frac{0.25}{1-0.25}$$

$$|V_o| = 4V.$$

$$\Delta I = \frac{V_s \alpha}{fL} = \frac{V_s V_o}{f \cdot L (V_o - V_s)}$$

$$\Delta I = \frac{12 \times 0.25}{25 \times 10^3 \times 150 \times 10^{-6}} = 0.8A.$$

$$\Delta V_c = \frac{I_o \alpha}{f \cdot C} = \frac{I_o V_o}{(V_o - V_s) f C}$$

$$\Delta V_c = \frac{1.25 \times 0.25}{25 \times 10^3 \times 220 \times 10^{-6}} = 56.8 mV$$

critical value of Inductor

$$L_{crit} = \frac{V_{in} D}{2 \times I_{L,avg} \times f_s}$$

$$I_{L,avg} = \frac{D}{1-D} = I_o = 0.4167\,A$$

$$L_{crit} = \frac{12 \times 0.25}{2 \times 0.4167 \times 25 \times 10^3} \approx 144\,\mu H.$$

Given $L = 150\,\mu H > L_{crit}$.

Converter operates in CCM.

critical value of capacitor.

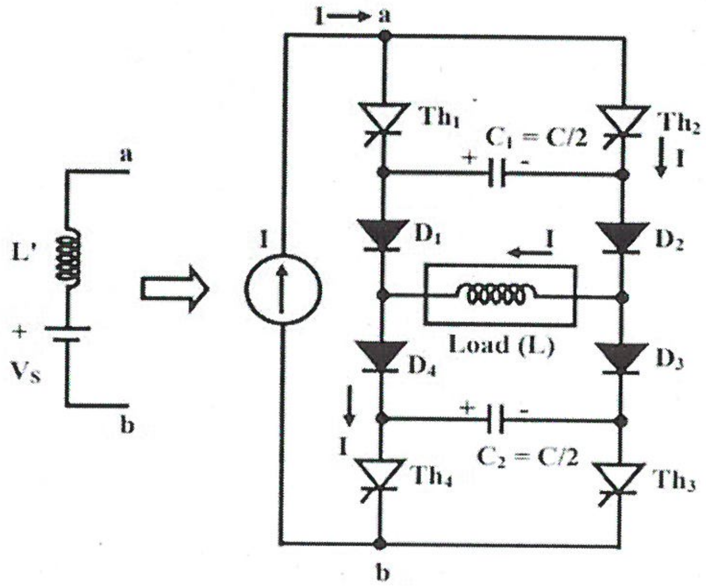
$$C_{min} = \frac{I_o D}{\Delta V_{o(pp)} f_s}$$

1% of $|V_o| = 4V$ is $0.04V$.

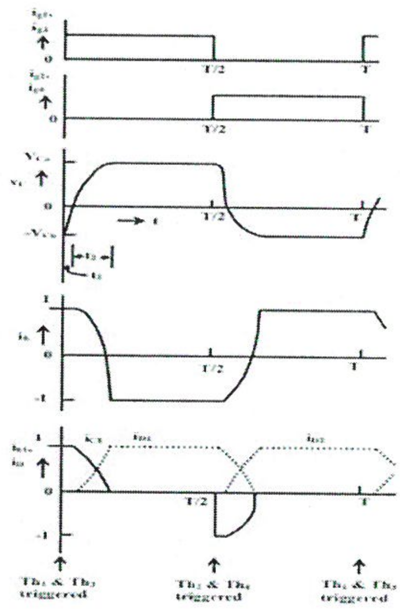
$$C_{min} = \frac{1.25 \times 0.25}{0.04 \times 25 \times 10^3}$$

$$C_{min} = 312.5\,\mu F.$$

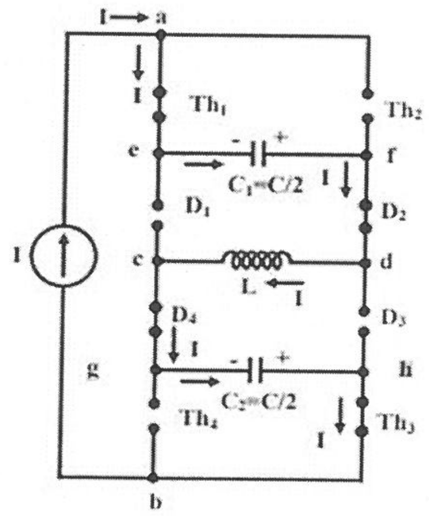
10a) Single-phase Current Source Inverter



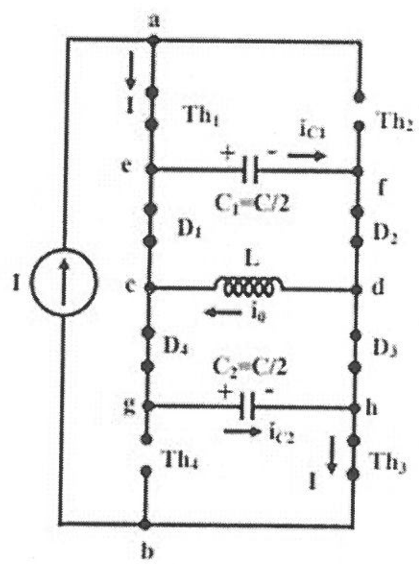
The circuit of a Single-phase Current Source Inverter (CSI) is shown in Fig. The type of operation is termed as Auto-Sequential Commutated Inverter (ASCI). A constant current source is assumed here, which may be realized by using an inductance of suitable value, which must be high, in series with the current limited dc voltage source. The thyristor pairs, Th1 & Th3, and Th2 & Th4, are alternatively turned ON to obtain a nearly square wave current waveform. Two commutating capacitors – C1 in the upper half, and C2 in the lower half, are used. Four diodes, D1–D4 are connected in series with each thyristor to prevent the commutating capacitors from discharging into the load. The output frequency of the inverter is controlled in the usual way, i.e., by varying the half time period, (T/2), at which the thyristors in pair are triggered by pulses being fed to the respective gates by the control circuit, to turn them ON, as can be observed from the waveforms (Fig. 5.36). The inductance (L) is taken as the load in this case, the reason(s) for which need not be stated, being well known. The operation is explained by two modes.



Mode I: The circuit for this mode is shown in Fig. 5.37. The following are the assumptions. Starting from the instant, , the thyristor pair, Th − t = 0 2 & Th4, is conducting (ON), and the current (I) flows through the path, Th2, D2, load (L), D4, Th4, and source, I. The commutating capacitors are initially charged equally with the polarity as given, i.e., . This mans that both capacitors have right hand plate positive and left hand plate negative. If two capacitors are not charged initially, they have to pre-charge.



Mode II: The circuit for this mode is shown in Fig. 5.38. Diodes, D2 & D4, are already conducting, but at = tt 1 , diodes, D1 & D3, get forward biased, and start conducting. Thus, at the end of time t1, all four diodes, D1–D4 conduct. As a result, the commutating capacitors now get connected in parallel with the load (L).



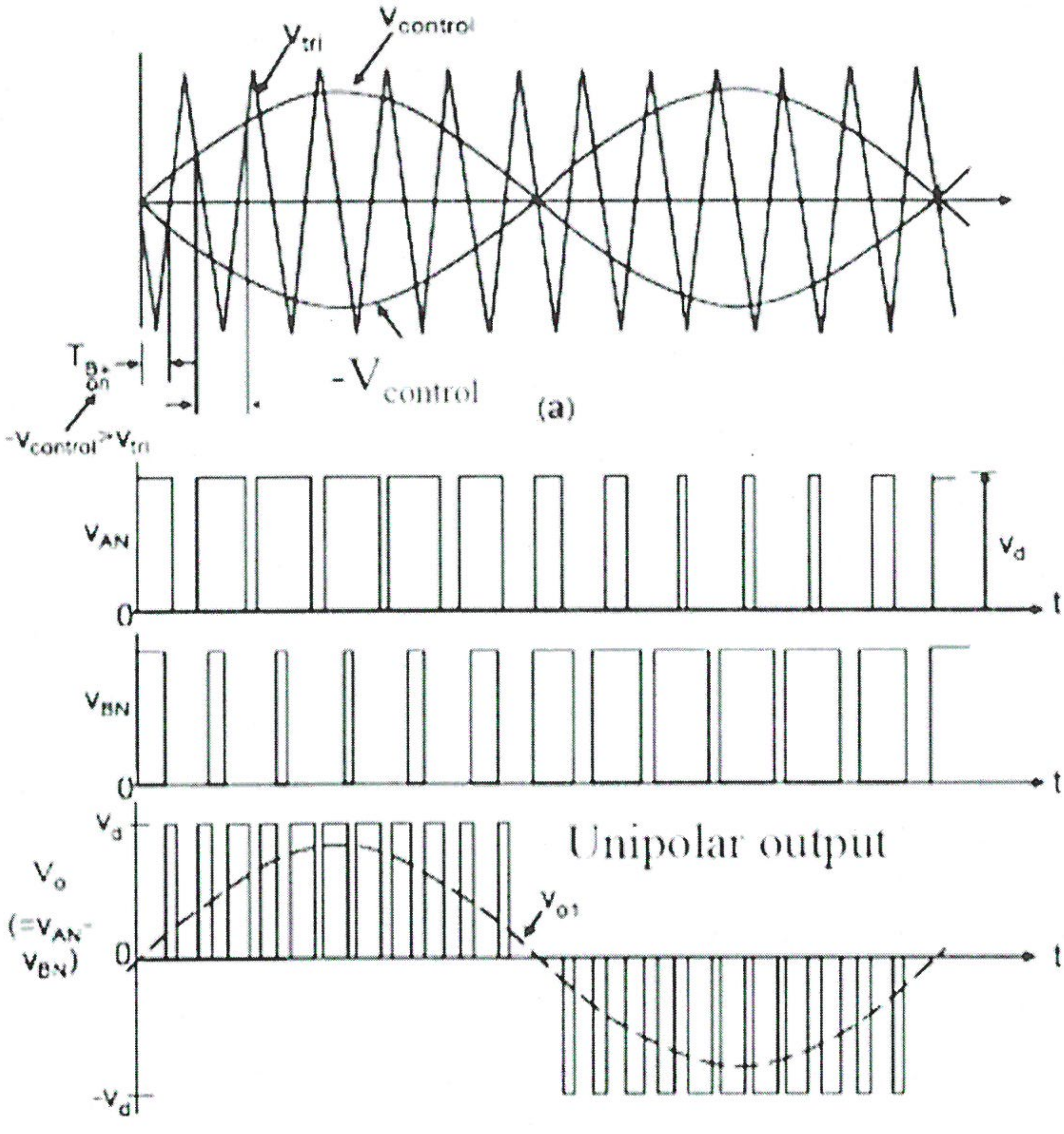
10b)

Unipolar PWM Single Phase Inverter

Pulse-width modulation (PWM) is a method for reducing the overall harmonic distortion of load current. In general, a PWM inverter output with some filtering can more readily meet THD requirements than a square wave switching system. The unfiltered PWM output will have a reasonably large THD, but the harmonics will be at considerably higher frequencies than for a square wave, making filtering simpler.

With PWM, the modulating waveforms can be used to alter the output voltage's amplitude. PWM has two key advantages: it requires fewer filters to reduce harmonics and lets you alter the output voltage's amplitude. The switches control circuits will need to be more intricate, and switching more frequently will result in higher losses.

The reference signal, also known as a modulating or control signal, in this case a sinusoidal, and the carrier signal, a triangular wave that regulates the switching frequency, are needed to control the switches for sinusoidal PWM output.



Frequency modulation index (m_f): The frequency modulation ratio mf is defined as the ratio of the frequencies of the carrier and reference signals.

$$m_f = \frac{f_{tri}}{f_{sine}}$$

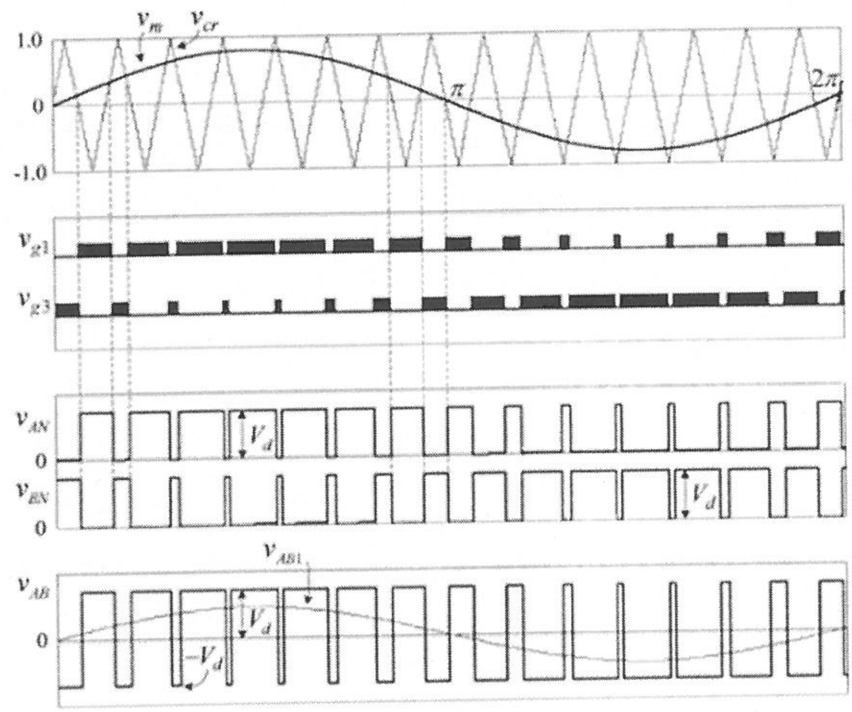
Amplitude modulation index (m_a): The amplitude modulation ratio m_a is defined as the ratio of the amplitudes of the reference and carrier signals.

$$m_a = \frac{V_m sine}{V_m tri}.$$

The sinusoidal reference voltage must be generated within the control circuit of the inverter or taken from an outside reference. It may seem as through the function of the inverter bridge is unnecessary because a sinusoidal voltage must be present before the bridge can operate to produce a sinusoidal output. However, there is very little power required from the reference signal. The power supplied to the load is provided by the dc power source, and this is the intended purpose of the inverter. The reference signal is not restricted to a sinusoidal, and other waveshapes can function as the reference signal.

Bipolar PWM Single Phase Inverter with RL Load

The bipolar PWM inverter produces an AC output waveform by switching the DC input voltage between positive and negative polarities. It generates the desired AC output voltage by varying the width of the pulses while maintaining a fixed frequency. By adjusting the pulse width, the inverter can regulate the amplitude of the output voltage, the operation of a bipolar PWM single-phase inverter involves dividing the input DC voltage into several voltage levels and then applying suitable pulse width modulation techniques to obtain the desired AC output waveform. This is achieved by comparing a reference sinusoidal waveform with a triangular waveform generated by a carrier signal. The inverter generates the necessary pulses to approximate the reference waveform based on the comparison.



11(a)

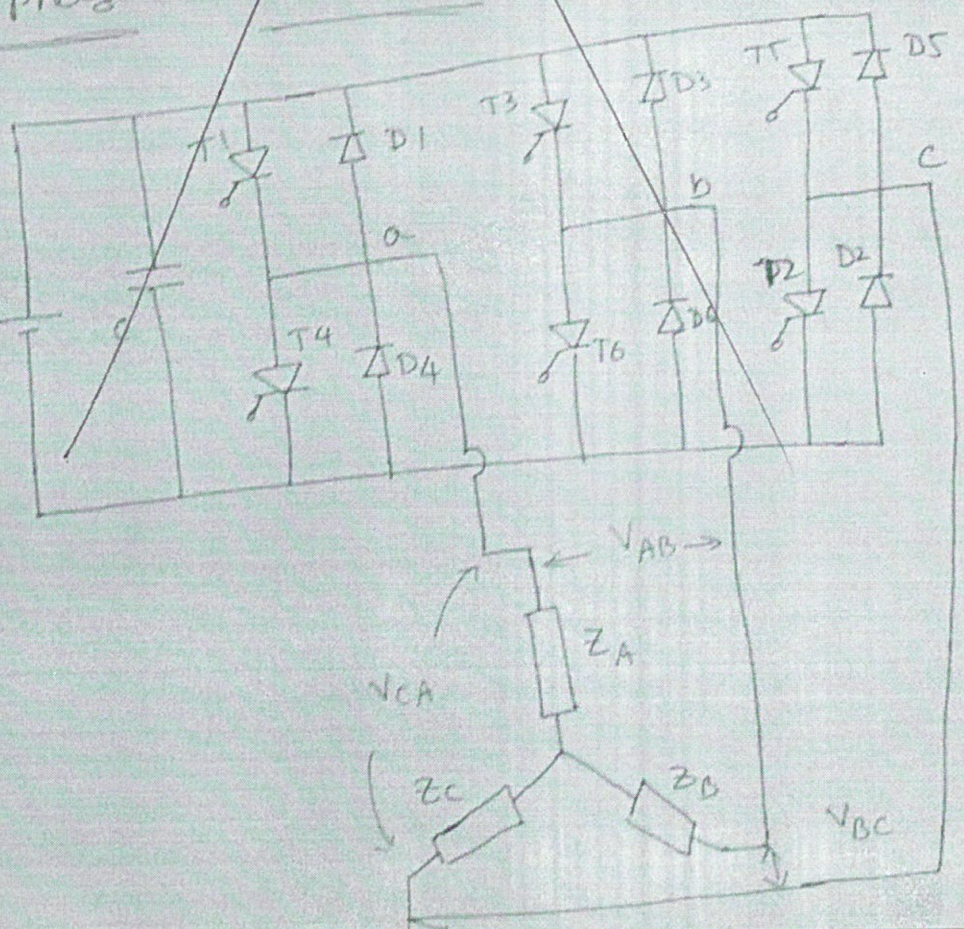
Three-phase bridge Inverters:-

A basic three-phase inverter is a six-step bridge inverter. It uses a minimum of six thyristors. A step is defined as a change in the firing from one thyristor to the next thyristor in proper sequence. For one cycle of 360°, each step would be of 60° interval for a six-step inverter.

There are two possible patterns of gating the thyristors.

1. 180° conduction
2. 120° conduction

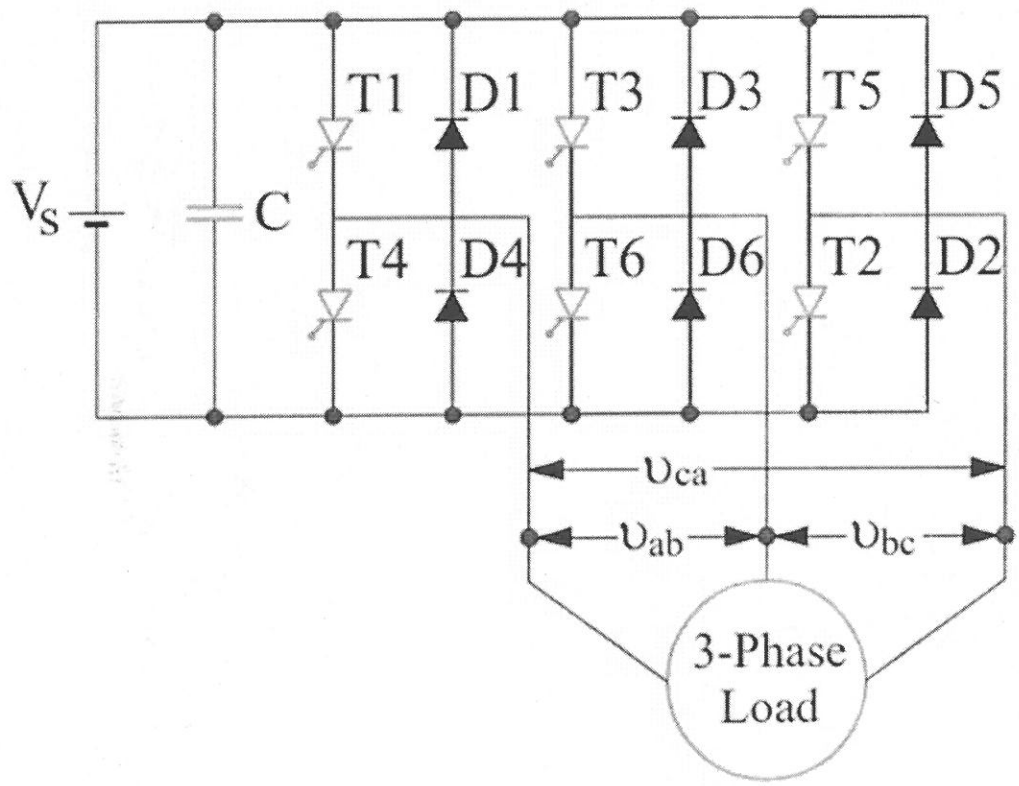
Three-phase 180° Mode VSI:-

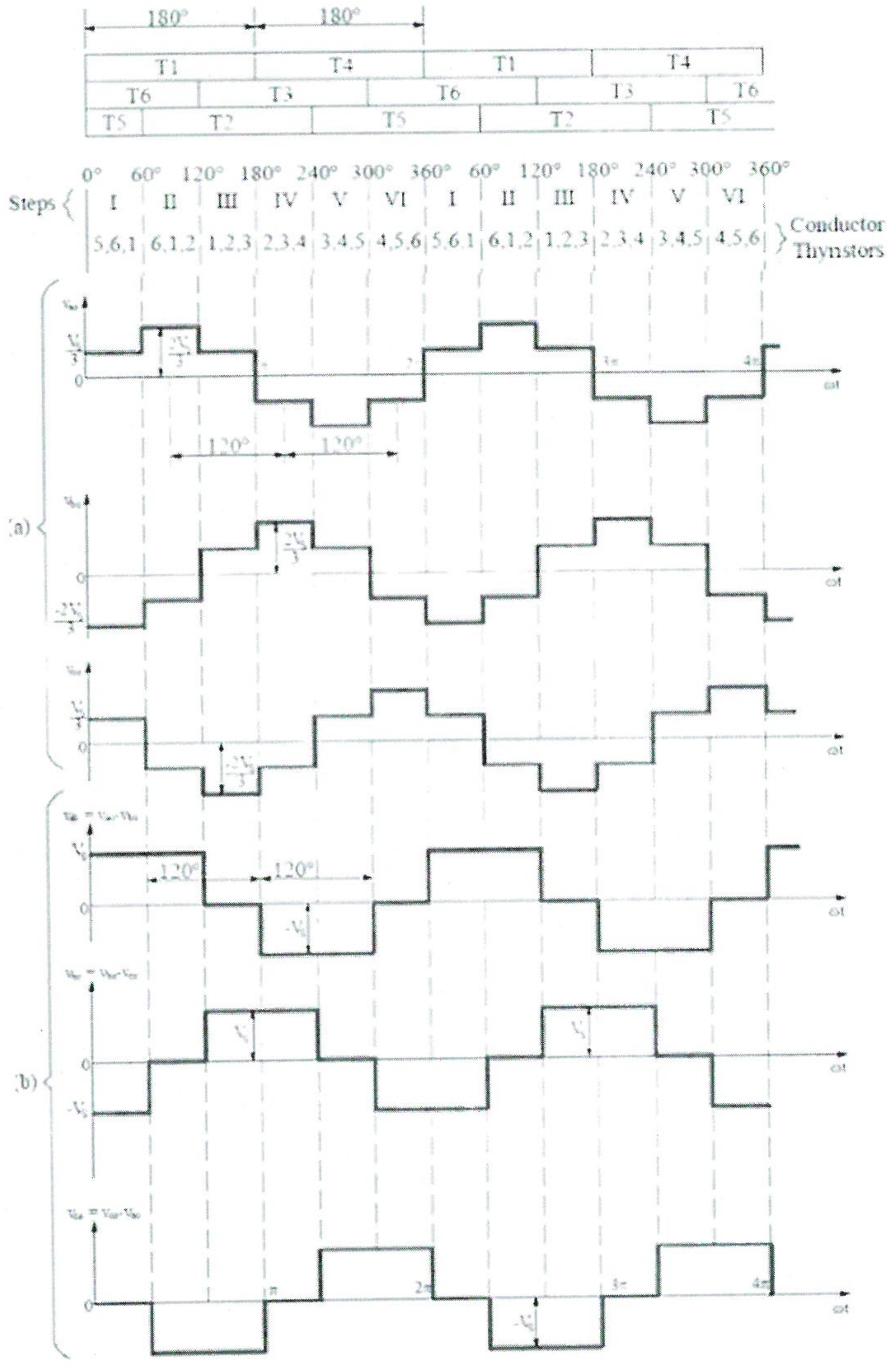


11a)

THREE PHASE INVERTER

In this conduction mode of three phase inverter, each thyristor conducts for 180°. Thyristor pair in each arm i.e. (T1, T4), (T3, T6) and (T5, T2) are turned on with a time interval of 180°. It means that T1 remains on for 180° and T4 conducts for the next 180° of a cycle. Thyristors in the upper group i.e., (T1, T3 & T5) conducts at an interval of 120°. It implies that if T1 is fired at ωt = 0° then T3 will be fired at 120° and T5 at 240°. Same is also true for lower group thyristors i.e., (T4, T6 & T2).




180°
180°
T1
T4
T1
T4
T6
T3
T6
T3
T6
T5
T2
T5
T2
T5
0° 60° 120° 180° 240° 300° 360° 60° 120° 180° 240° 300° 360°
Steps
I II III IV V VI I II III IV V VI
5,6,1 6,1,2 1,2,3 2,3,4 3,4,5 4,5,6 5,6,1 6,1,2 1,2,3 2,3,4 3,4,5 4,5,6
Conductor Thyristors
120°
120°
(a)
(b)
120°
120°
ωt

11b) $V_s = 500V$

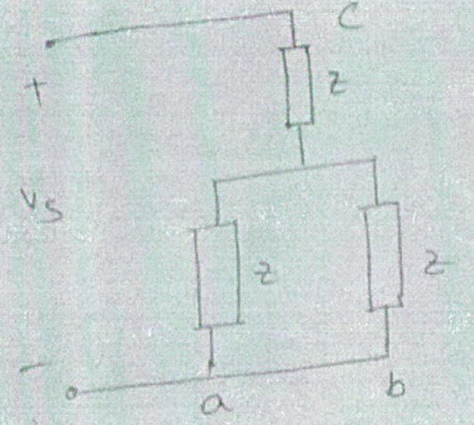
$R = 100\Omega$

Fo single-phase Full bridge Inverter

$V_o = V_s = 500V$

$$I_o = \frac{V_o}{R} = \frac{500}{100} = 5A.$$

step VI (4, 5, 6)



$V_{ao} = -\frac{V_s}{3}$

$V_{bo} = -\frac{V_s}{3}$

$V_{co} = \frac{2V_s}{3}$

$V_{ab} = 0$

$V_{bc} = -V_s$

$V_{ca} = +V_s$