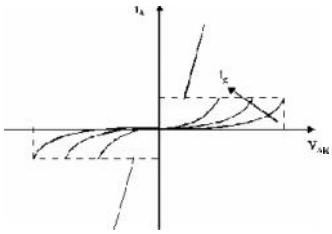
SUMMER – 13 EXAMINATION

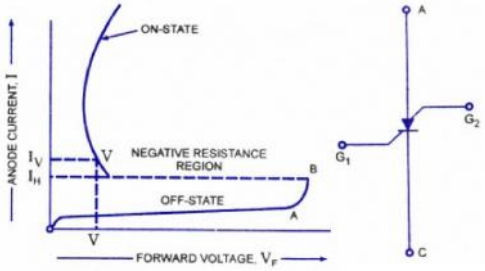
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

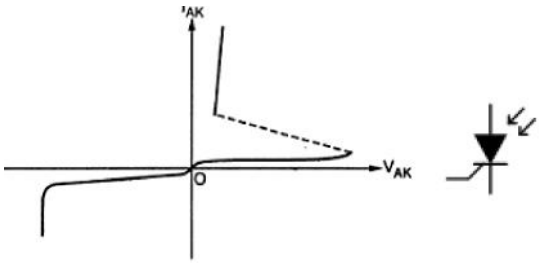
Que 1.a) i) Draw symbol and v-I characteristics for a)TRIAC, b)SCS ,c)LASCS & d)DIAC — 1 each



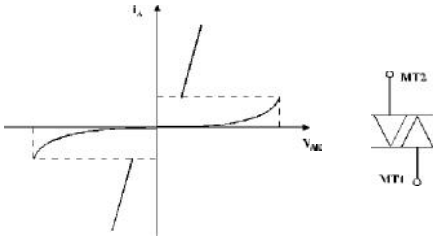
DIAC



SCS



LASCR



DIAC

ii) State and explain the four specification of SCR. — 1 each

1) **Holding Current (I_H) :-** This is the minimum anode current required to maintain the thyristor in the on-state. To turn off a thyristor, the forward anode current must be reduced below its holding current for a sufficient time for mobile charge carriers to vacate the junction.

2) **Latching current (I_L):-** This is the minimum anode current required to maintain the thyristor in the on-state immediately after a thyristor has been turned on and the gate signal has been removed. If a gate current, greater than the threshold gate current is applied until the anode current is greater than the latching current I_L then the thyristor will be turned on or triggered.

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3) Maximum on-state voltage (V_T) It is the maximum value of the voltage appearing across the device during the conduction. For an SCR with current load, the voltage across load is also included. Normally value of this voltage is of 1.5 V.

4) Critical rate of rise rating (dv/dt): Critical rate of rise of voltage, dv/dt, is the maximum rate at which the voltage in the forward direction can rise without triggering the device. It is expressed in volts /microseconds.

Note: Any four specifications may be given credit, not limited to above.

iii) Compare 1Ø fully controlled half wave converter and 1Ø fully controlled full wave converter with six points.

1 for major two diff.

½ for minor four diff.

	Fully controlled HW converter	Fully controlled F.W. converter
1	No of SCRs used in only one	No of SCRs 2,4
2	Only half wave is rectified	Full wave is rectified
3	More ripple in output	Less ripple as compared to half wave
4	Average voltage less as compared to full wave	More output voltage
5	Peak reverse voltage is equal to supply voltage peak, Vm	It may be Vm or 2Vm depending upon bridge or mid-point
6	Can't be used for braking operation	Can be used for braking operation
7	One quadrant operation (First)	Two quadrant operation((First and Fourth)
8	Used for battery charges	Used for DC drive applications

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iv) State need for reduction in harmonics, how waveform control is done by single pulse width modulation? 2+2

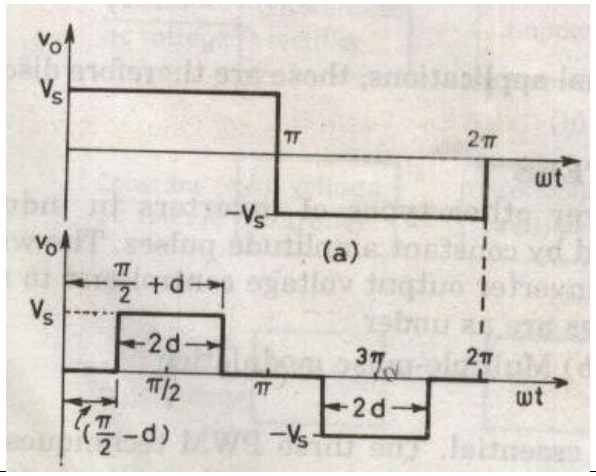
Harmonics are unwanted odd integer multiple fundamental frequency components present in the system. Presence of harmonics causes following drawbacks,

1) Increase in neutral current.
2) Relay circuit mal-operation
3) Increased heating of conductors because of increased current.
4) Interference with the communication network.
5) Increase in the losses of the motor and torque pulsations
6) Overheating of transformers

In order to avoid problems caused by harmonics, the inverter switching is controlled to minimize the harmonics present in the inverter output voltage.

Single pulse modulation:

In single pulse modulation, the inverter output consists of a pulse of width 2d centred around π/2. By controlling width of pulse, harmonics are controlled. For 2d=120 degrees, third harmonic is eliminated.



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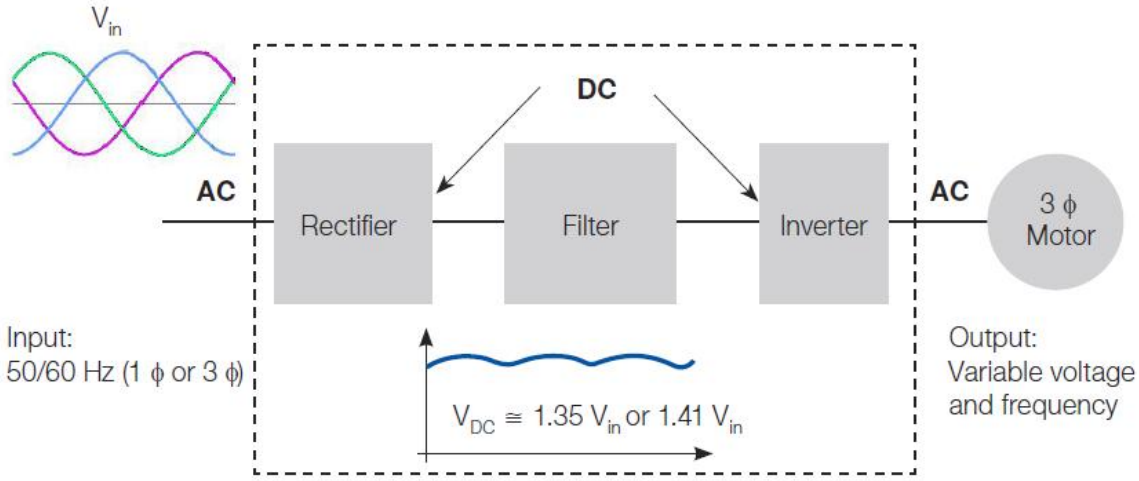
b) i) Describe speed control of 3-Ø Induction motor with variable frequency square wave inverter (VSI) method.	3+3



The basic relation between speed, frequency is given by

N = 120f/P where f is the supply frequency, P are the no. of poles and N is the speed.

The equation indicates that, by controlling freq. f, induction motor speed can be controlled.

Control of frequency also requires control of voltage to keep the air gap flux constant. This method is also called as V/f control method as the ratio V/f has to be maintained constant.

The Power circuit consists of AC-DC uncontrolled rectifier, DC smoothing filter and Voltage source inverter with six power semiconductor switches. The VSI output voltage and frequency is simultaneously controlled to regulate speed of the induction motor.

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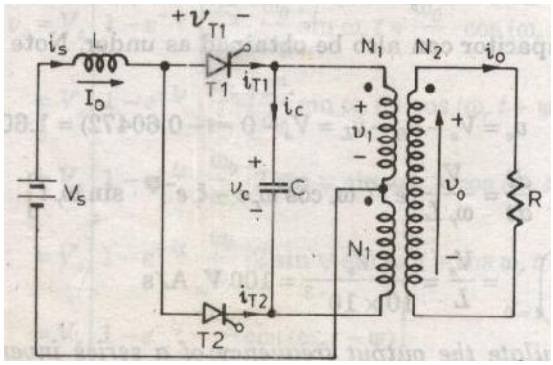
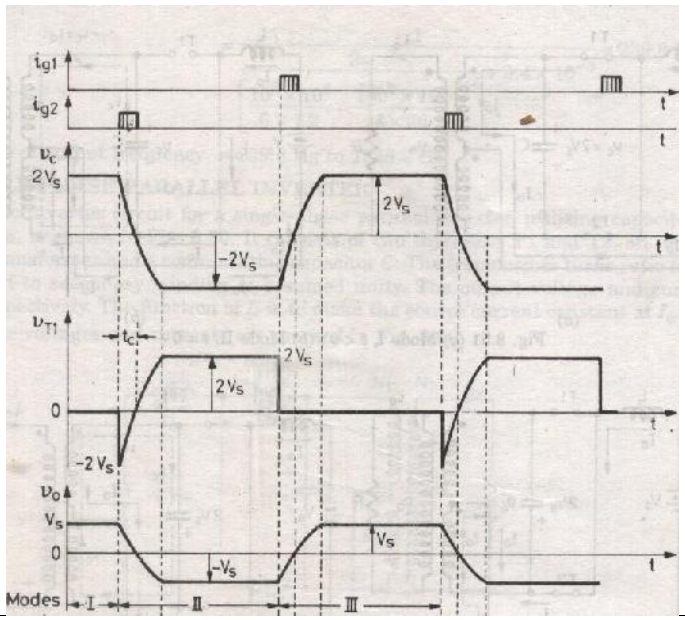
ii)) Describe the operation of basic parallel inverter circuit. Draw its I/P and o/p waveform. It consists of two thyristors T1 and T2 and commutating capacitor C and input current smoothing inductor L and an output transformer. Mode1: T1 is conducting and current flows in the upper half of the primary wdg. This current establishes flux that links both halves of the primary winding. As a result , an emf Vs is induced in upper as well as lower half of primary winding.. Total voltage across primary winding is 2Vs. Capacitor C is charged to 2Vs with upper plate positive. Mode2: When T2 is turned ON, capacitor voltage reverse biases T1 and turns it off. The load voltage changes to –Vs. The capacitor is discharged and charged to -2Vs. Mode3: When T1 is turned ON, capacitor voltage reverse biases T2 and turns it OFF. The load voltage changes from –Vs to +Vs. As the turn ratio is 2, the load voltage is half the capacitor voltage. The load voltage waveform is same as capacitor voltage.   	2+2+2

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Q2. a) What are different turn-ON methods of SCR? Explain voltage triggering. 2+2

Different turn-on methods:

Turn-on by exceeding the breakover Voltage

Turn-on by leakage current(thermal triggering)

Turn-on by dV/dt

Turn-on by gate triggering

Voltage triggering:

In this mode, an additional forward voltage is applied between anode and cathode.

When the anode terminal is positive with respect to cathode(VAK) , Junction J1 and J3 is forward biased and junction J2 is reverse biased.

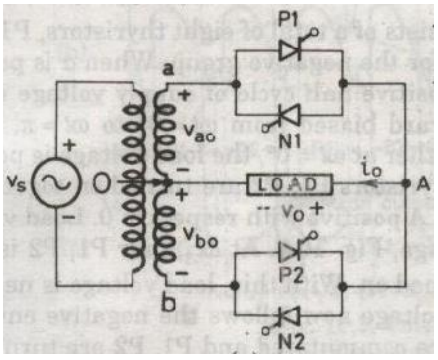
No current flows due to depletion region in J2 is reverse biased (except leakage current).

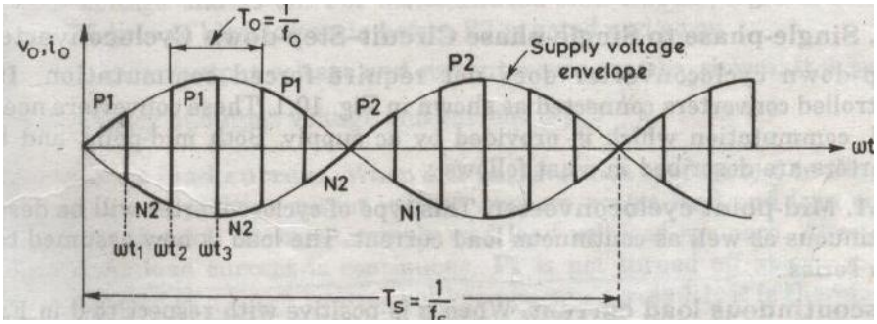
As VAK is further increased, at a voltage VBO (Forward Break Over Voltage) the junction J2 undergoes avalanche breakdown and so a current flows and the device tends to turn ON(even when gate is open)

b) State the principle of cyclo-inverter. Draw and describe the single phase cyclo-inverter. 2+2

A cyclo inverter is a frequency converter that converts the ac power of small frequency to an ac power higher frequency without using intermediate dc link.

A single phase cyclo inverter is shown in diagram. It consists of single phase transformer with mid-point on the secondary wdg. And four thyristors. P1,P2 belong to positive group and N1N2 belong to negative group. Load is connected between N and terminal A. During positive half cycle of the supply voltage, a is positive wrt b. P1 and N2 are forward biased from 0 to 180 deg. P1 and N2 are alternately operated to produce positive and negative half cycles of load voltage. During negative half cycle of the supply voltage P2 and N1 are forward biased from 180 to 360 deg. Here P2 and N1 are alternately operated to produce positive and negative half cycles of load voltage. As it can be seen that the output freq. is 6 times the supply frequency.





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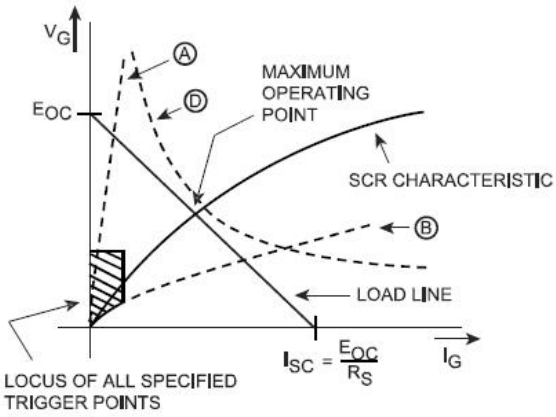
c) Draw and explain DC gate signal characteristic of SCR for gate control. 2+2

Gate characteristics is graph of Vg and Ig. i.e. forward gate voltage and gate current dc values. As the gate cathode junction is a PN junction, the characteristics are same as that of a diode. For a particular type of SCRs, Vg-Ig characteristics is spread between two curves A and B. Curve D represents the Pgav curve. The operating point is the intersection of gate circuit source line and the thyristor characteristics. The intersection should be as close to Pgav curve and lie within A and B for reliable turn ON of thyristor.,



d) Describe the operation of basic series inverter circuit. State its limitation. 2+2

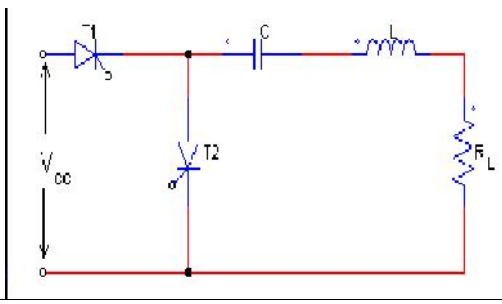
Mode - 1

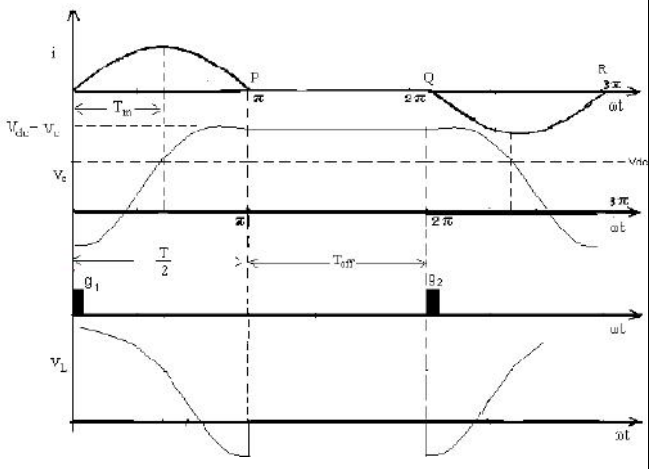
- Due to under-damped circuit, load current is of alternate in nature.
- T1 triggered – C charges to Vc
- After some time vc returns to zero
- Current decreases but capacitor voltage retains its voltage. (Vdc+Vc)
- At "P", SCR T1 turned OFF since current though it is zero

Mode - 2

- Load current remains at zero – T1 and T2 are OFF
- During this period (PQ) Vc remains constant.

Limitation of the circuit: If T2 is turned ON before T1 OFF, it will cause short circuit across supply.





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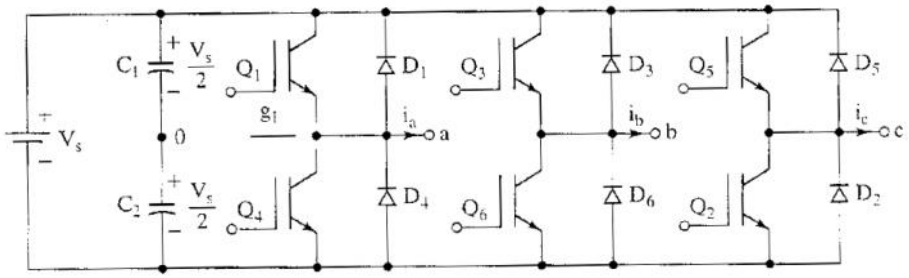
e. Draw a circuit diagram for three phase bridge inverter circuit and list two conduction modes.



Modes of conduction: 1) 180 deg mode 2) 120 deg mode

f) Describe the speed control of DC series motor using step up and step down chopper. 1+2+1

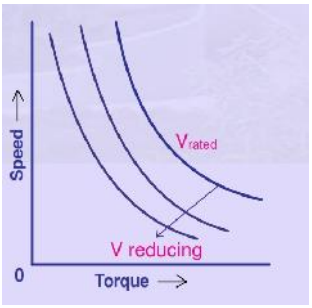
The basic equations of dc series motor are:

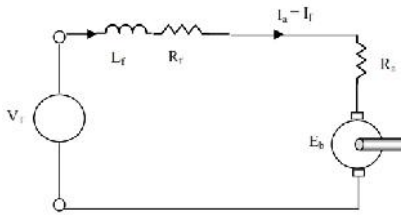
$$T = K¤I_a \quad and \quad ¤ = K_1 I_a$$

$$T = K_2 I_a^{\,2} \qquad V_T = (R_f + R_a) I_a + E_b$$

$$E_b = K¤\mu = K' I_a \mu \Rightarrow I_a = \frac{V_T}{R_a + R_f + K'\mu}$$

$$T = \frac{K_2 V_T^{\,2}}{(R_a + R_f + K'\mu)^2} \Rightarrow T \propto \frac{V_T^{\,2}}{\mu^2}$$





The above equation indicates that for constant armature voltage the speed and torque are inversely related. The torque speed characteristics is shown in following figure,

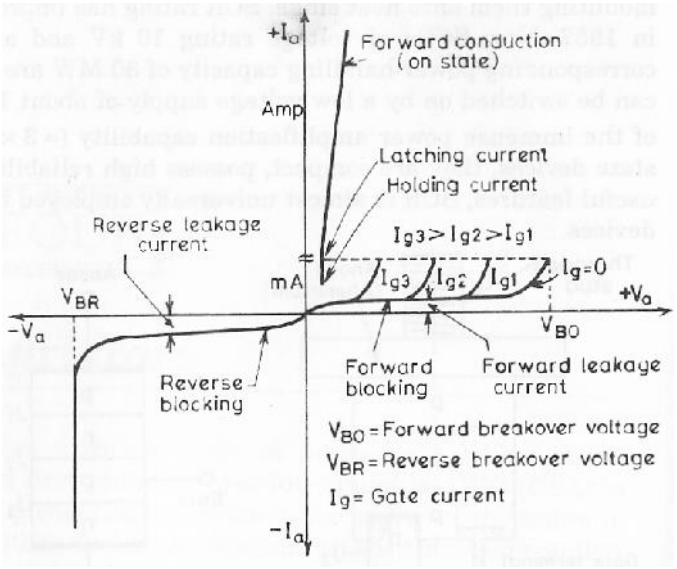
By control of armature voltage the speed can be controlled.

Type-C chopper integrates step –up and step –down choppers as it is a parallel combination of type-A and type-B chopper.

Step-down chopper offers motoring mode, by controlling CH1, D1 offers freewheeling action. Average armature voltage and current are positive. Control of duty ratio controls the average armature voltage and speed of motor

Step up mode offers regenerative braking mode by controlling CH2. When CH2 is ON, the motor acts as generator and energy is stored in armature inductance La. When CH2 is OFF, D2 becomes forward biased and the current direction is reversed and energy is fed back to supply which results in regenerative braking.

Que 3)a) Draw and explain V-I characteristics of SCR. 2+2



A thyristor has three basic modes of operation ; namely, reverse blocking mode, forward blocking (off-state) mode and forward conduction (on-state) mode.

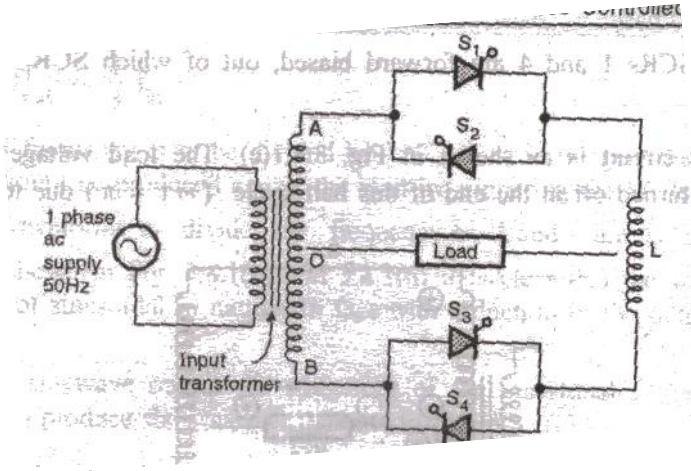
Reverse Blocking Mode: When cathode is made positive with respect to anode with switch S open , thyristor is reverse biased. Junctions J1 J3 are seen to be reverse biased whereas junction J2 is forward biased. The device behaves as if two diodes are connected in series with reverse voltage applied across them. A small leakage current of the order of a few milliamperes (or a few microamperes depending upon the SCR rating) flows. This is reverse blocking mode, called the off-state, of the thyristor. If the reverse voltage is increased, then at a critical breakdown level, called reverse breakdown voltage VBR, an avalanche occurs at J1 and J3 and the reverse current increases rapidly. A large current associated with VBR gives rise to more losses in the SCR. This may lead to thyristor damage as the junction temperature may exceed its permissible temperature rise. It should, therefore, be ensured that maximum working reverse voltage across a thyristor does not exceed VBR. The SCR in the reverse blocking mode may therefore be treated as an open switch.

Forward Blocking Mode : When anode is positive with respect to the cathode, with gate circuit open, thyristor is said to be forward biased. It is seen from this figure that junctions J1, J3 are forward biased but junction J2 is reverse biased. In this mode, a small current, called forward leakage current. In case the forward voltage is increased, then the reverse biased junction J2 will have an avalanche breakdown at a voltage called forward breakover voltage VB0. When forward voltage is less than VBO, SCR offers a high impedance. Therefore, a thyristor can be treated as an open switch even in the forward blocking mode.

Forward Conduction Mode : In this mode, thyristor conducts currents from anode to cathode with a very small voltage drop across it. A thyristor is brought from forward blocking mode to forward conduction mode by turning it on by exceeding the forward breakover voltage or by applying a gate pulse between gate and cathode. In this mode, thyristor is in on-state and behaves like a closed switch. Voltage drop across thyristor in the on state is of the order of 1 to 2 V depending on the rating of SCR. voltage drop increases slightly with an increase in anode current. In conduction mode, anode current is limited by load impedance alone as voltage drop across SCR is quite small. This

small voltage drop vT across the device is due to ohmic drop in the four layers.

b) Describe midpoint cycloconverter to change the output frequency to one third of supply frequency with R-L load. 2+2

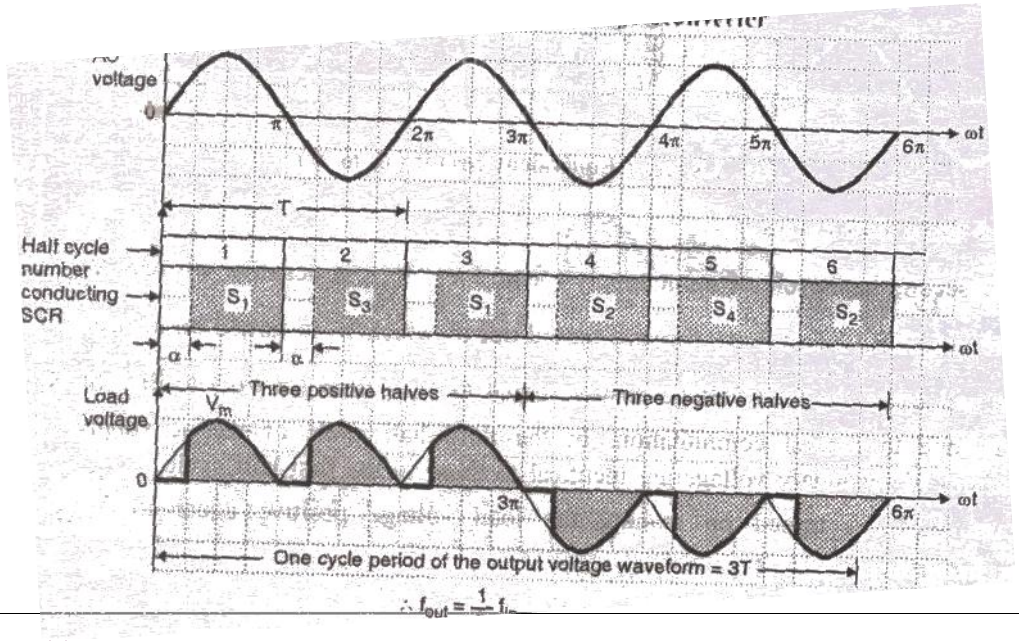


During Positive half cycle of supply voltage, S1 is operated to produce positive half cycle at load.

During negative half cycle of supply voltage, S3 is operated to produce positive half cycle at load.

Thus by controlling S1-S3-S1, three positive half cycles are produced at load.

By controlling, S2-S4-S2, three negative half cycles are produced at load. The control sequence is repeated thereafter. The resulting output waveform is 1/3rd of supply frequency.



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c) Compare series and parallel inverter with six points. — 1 each for 2 major diff; ½ for 4 minor diff

Series Inverter	Parallel Inverter
Commutating components in series with load	In parallel with load
Class A commutation	Class D commutation
Requires resonant circuit	Not necessary
Output transformer not required	Essential
Output waveform depends on load	Square wave
Feedback diodes are not used	Used
Output waveform shape -sinusoidal	Square

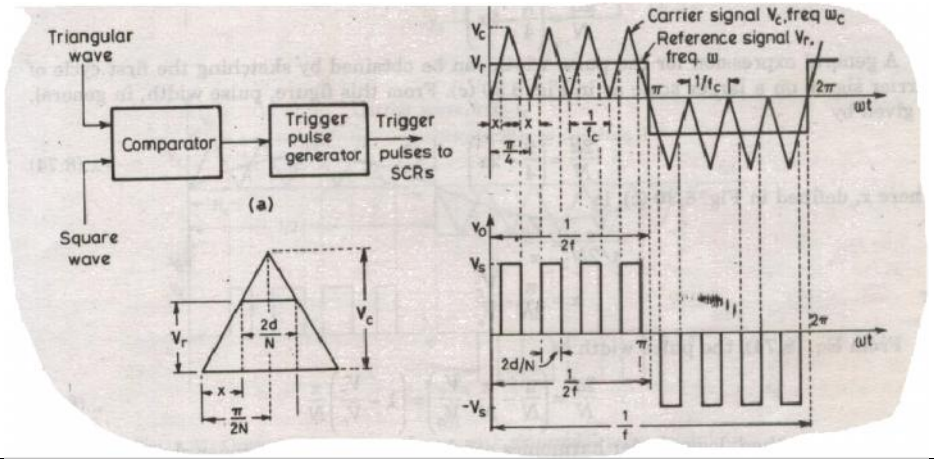
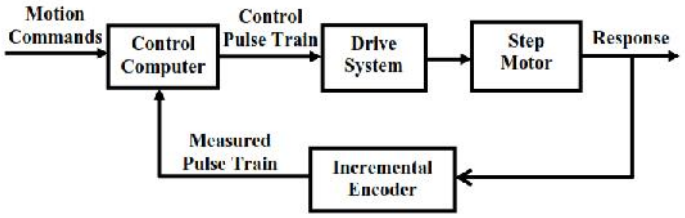
d) Classify choppers based on O/P voltage and quadrants of operation. Give applications of chopper.(at least four) — 2+2

Types of Choppers and their quadrants

Chopper Type	Quadrant
Type –A	First
Type B	Second
Type C	First and Second
Type D	First and Fourth
Type E	All four

Applications of Chopper:

1) Battery operated vehicles
2) Fork Lifts
3) Battery chargers
4) DC motor Drives
5) Subway car motor drives

e) Describe MPWM (Multiple pulse width modulation) with neat diagram for voltage control in 1Ø.inverters This method is an extension of single pulse modulation in which several equidistant pulses per half cycle are used. By using this technique, harmonics amplitudes are reduced as compared to single pulse modulation. MPWM is implemented by using a comparator with two inputs: a triangular carrier and a square wave reference. The frequency of triangular carrier is much higher than that of fundamental square wave reference.  	2+2
Q4a) i) Describe closed loop control of stepper motor with schematic diagram. In closed loop control, it does not allow any pulse to be missed and a pulse is send to the driving circuit after making sure that the motor has rotated in the proper direction by the earlier pulse sent. In order to implement this, we need a feedback mechanism that will detect the rotation in every step and send the information back to the controller. The incremental encoder is used for measuring actual rotor angular position.  	

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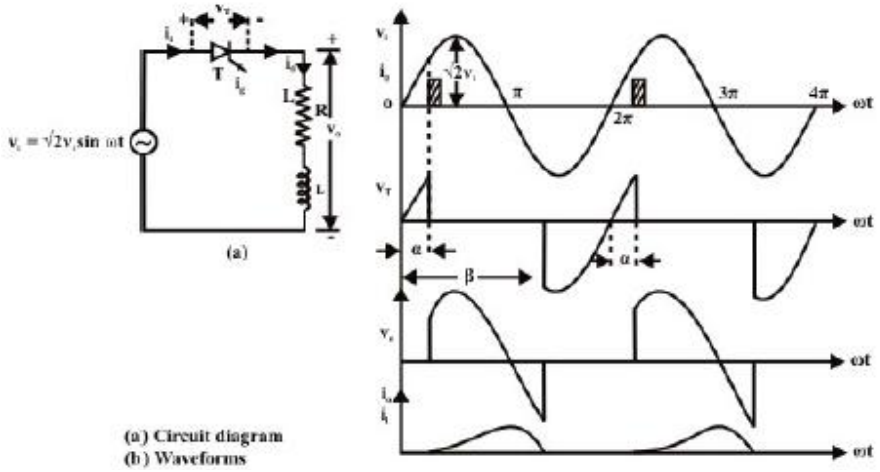
ii) With the help of a neat circuit diagram and waveforms. explain 1Ø fully controlled half wave controlled rectifier with R-L load and fly wheeling diode.



With R+L load, the load current does not become zero at ωt =π, instead it continues to flow through the thyristor and the negative supply voltage appears across the load forcing the load current to decrease. Finally, at ωt = ß (ß> π) the load current becomes zero and the thyristor undergoes reverse recovery. From this point onwards the thyristor starts blocking the supply voltage and the load voltage remains zero until the thyristor is turned ON again in the next cycle. It is to be noted that the value of ß depends on the load parameters. Therefore, unlike the resistive load the average and RMS output voltage depends on the load parameters.

iii) State any 4 advantages of bridge inverter.

1) The load voltage waveform is not dependant on load
2) Only two SCRs are required.
3) It uses simple class C commutation with a single capacitor
4) It a simple and economical circuit.
5) Be connecting a passive harmonic filter, quality of the output waveform can be improved.

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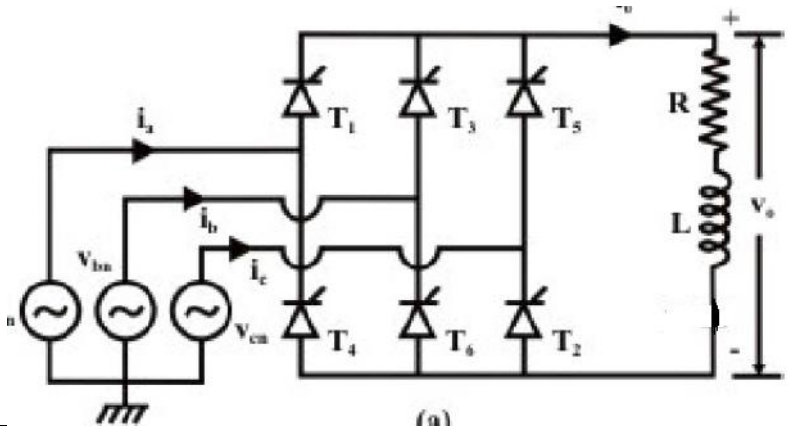
iv) Draw a neat circuit diagram for three phase fully controlled bridge converter with R-L load.

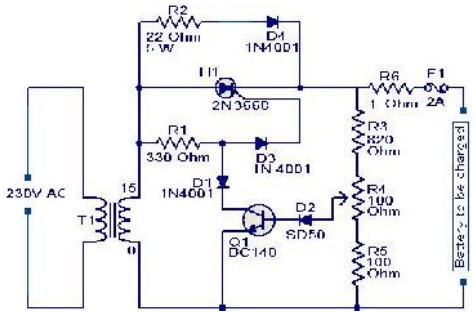


Que 4) b) i) Draw and explain battery charging circuit with waveforms.

A simple battery charger based on SCR is shown. Here the SCR rectifies the AC mains voltage to charge the battery. When the battery connected to the charger gets discharged the battery voltage gets dropped. This inhibits the forward biasing voltage from reaching the base of the transistor Q1 through R4 and D2.This switches off the transistor. When the transistor is turned OFF, the gate of SCR (H1) gets the triggering voltage via R1 & D3.This makes the SCR to conduct and it starts to rectify the AC input voltage. The rectified voltage is given to the battery through the resistor R6(5W).This starts charging of the battery.

When the battery is completely charged the base of Q1 gets the forward bias signal through the voltage divider circuit made of R3,R4,R5 and D2.This turns the transistor ON. When the Q1 is turned ON the trigger voltage at the gate of SCR is cut off and the SCR is turned OFF. In this condition a very small amount of charge reaches the battery via R2 and D4 for trickle charging. Since the charging voltage is only half wave rectified, this type of charger is suitable only for slow charging. For fast charging full wave rectified charging voltage is needed

(any other relevant circuit and explanation may be given credit)



SUMMER – 13 EXAMINATION

ii) What is commutation of choppers? State its methods to commutate and describe any one method.

The process of turning off a conducting thyristor in chopper is commutation. As it operates on DC source, force commutation method has to be adopted.

Various techniques for commutation in chopper:

1) Forced Commutation

   i) Voltage commutation

   ii) Current commutation

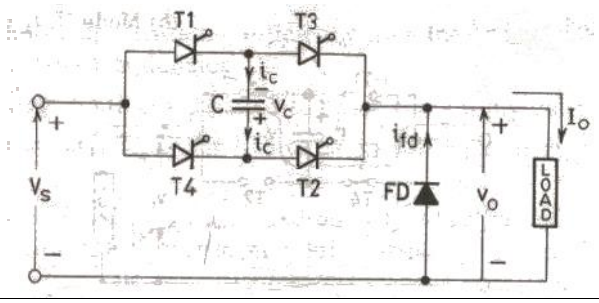
2) Load commutation

Load commutation: This chopper consists of T1,T2,T3,T4 SCRs and capacitor C. When T1, T2 are ON, C gets charged with top plate + and bottom plate negative to supply voltage. When it is fully charged FWD takes over.

When T3,T4 are trigerred, the charged capacitor reverse biases T1, T2 and turns them off.

Capacitor will now get charged to supply voltage with bottom + and top negative. When fully charged, FWD will take over.

When T1 T2 are ON , charged capacitor will reverse bias T3 T4 and turn them OFF.



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Q5 a.) With a neat circuit diagram describe speed control of DC motor using single phase fully controlled converter with resistive load. Draw waveform for α=90. (Please see 6th important instruction to examiners at beginning) 2+2+4

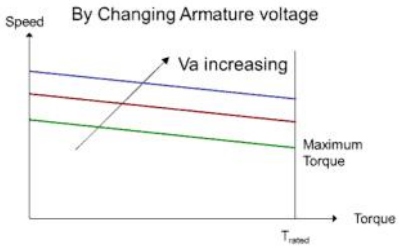
For DC motor,

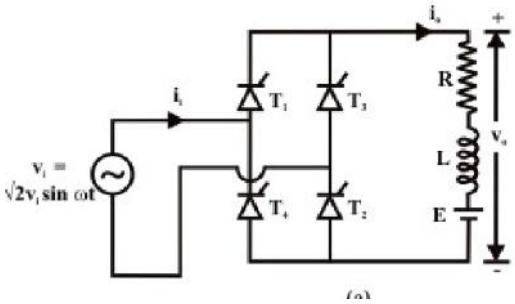
Eb = Ke × ¤ × wm

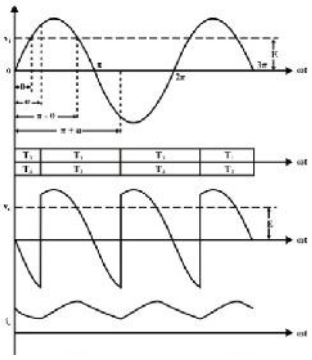
Vdc = Eb + Ia × Ra

Te = Ke × ¤ × Ia

Where Eb is back emf., Ia is armature current, ¤ is flux





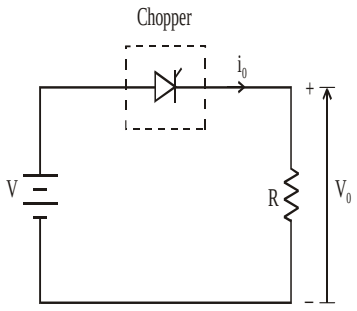


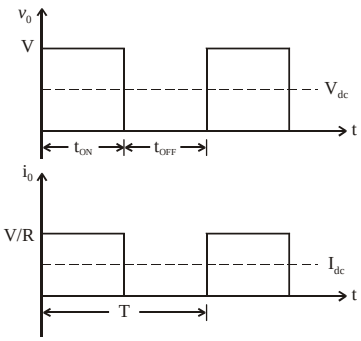
The speed torque characteristics shows upward shift by increasing armature voltage. The full wave controlled converter circuit is shown in fig. The load is RLE load which is equivalent of dc motor load. The waveforms indicate that by controlling firing angle, the average dc voltage to motor can be controlled. The fully controlled bridge converter offers motoring as well as braking operative modes.

b) State working principle of chopper. Describe the constant frequency system of control technique of chopper. 2+2+2+2

Chopper is a dc-dc converter. The input is uncontrolled dc and the output is a controlled dc. A thyristor chopper with resistive load is shown in fig.

- The thyristor in the circuit acts as a switch.
- When thyristor is ON, supply voltage appears across the load
- When thyristor is OFF, the voltage across the load will be zero.





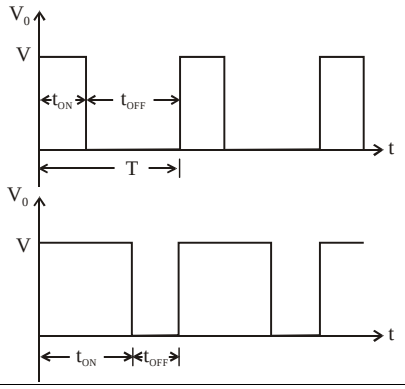
Average Output Voltage

$$V_{dc} = V\left(\frac{t_{ON}}{t_{ON}+t_{OFF}}\right)$$

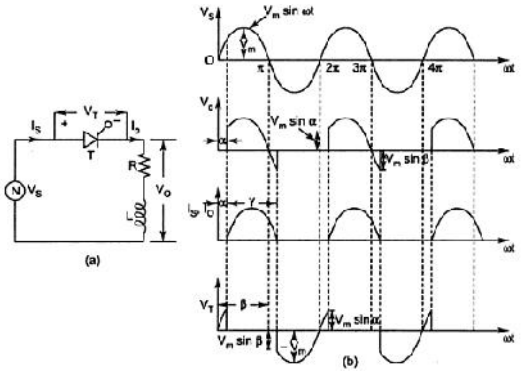
$$V_{dc} = V\left(\frac{t_{ON}}{T}\right) = V.d$$

$$but\ \left(\frac{t_{ON}}{t}\right) = d = \text{duty cycle}$$

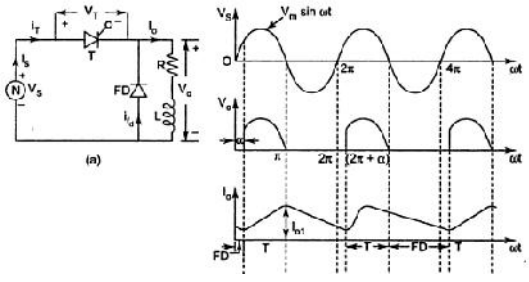
Constant frequency operation
t_{ON} is varied keeping chopping frequency 'f' & chopping period 'T' constant.
Output voltage is varied by varying the ON time t_{ON}



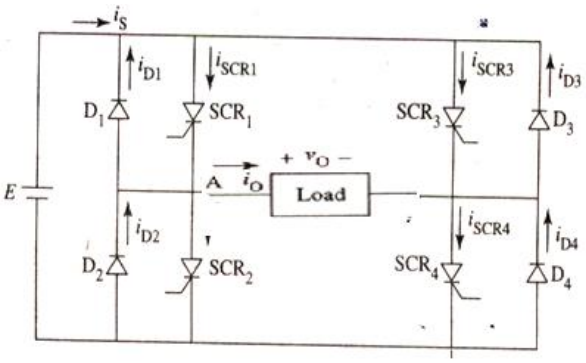
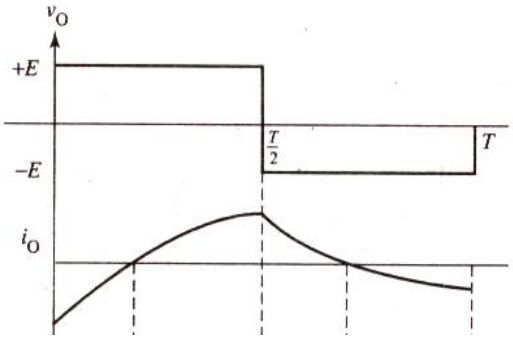
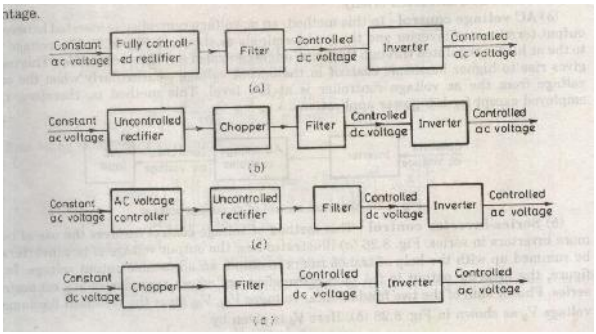
C) Give significance of freewheeling diode and describe how converter changes its operating mode with the presecence of freewheeling diode with R-L load. Draw its necessary waveforms. 4+4

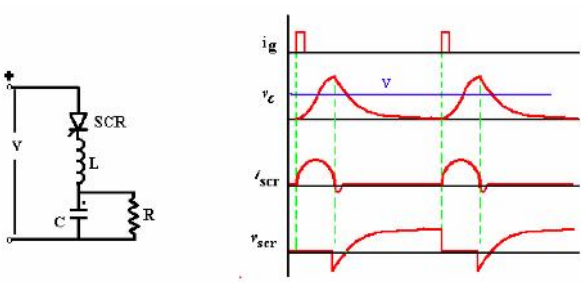
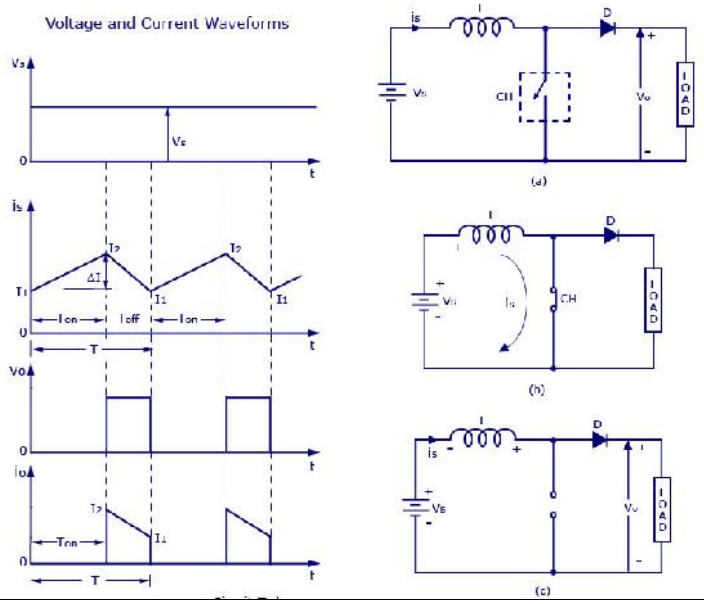


The above figure shows operation of half converter with RL load. As it can be seen that thyrsitor continues to conduct after wt=π as the current has not become zero. This is because there is stored energy in the inductance. This causes drop in the average output voltage as it has a negative going period after wt= π . If the inductance is large, trigger circuit loses it control on the thyristor. This situation is overcome by forcibly turning off the thyristor at wt= π. This can be achieved by connecting a diode across load which is called as a freewheeling diode. Which is shown in the fig. below.

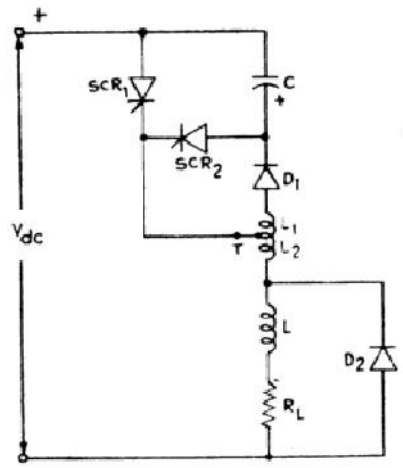
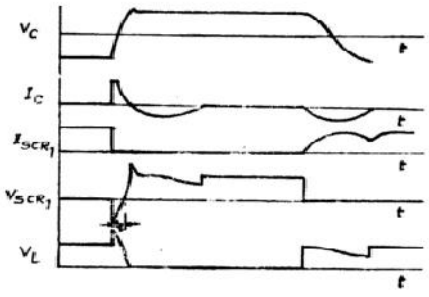


When supply voltage tends to reverse, it will forward bias the freewheeling diode and the load voltage will be zero at wt= π.

Q6. a) Describe operation for single phase full bridge inverter with circuit diagram. In full bridge inverter, four switches are connected to form H-bridge. When T1 T4 are ON , the output voltage is +vdc and when T3 T2 are ON, the output voltage is –Vdc. DC side is constant voltage, low impedance (voltage source, or bulk cap) AC side voltage is square wave or quasi-square wave. AC side current is determined by the load.Anti-parallel diodes are necessary to provide energy feedback pa   	2+2
b) Enlist and sketch block diagram of any four methods of input DC voltage control for variation in output of inverter 1) Fully controlled converter 2) Chopper based 3) AC voltage controller and uncontrolled rectifier 4) DC-DC controller using chopper  	1each

c) What is meant by commutation of thyristor. Describe forced commutation method. Commutation of thyristor is a process of turning off already conducting thyristor Class A commutation:  When the SCR is triggered, anode current flows and charges up C with the dot as positive. The L-C-R form a second order under-damped circuit. The current through the SCR builds up and completes a half cycle. The inductor current will then attempt to flow through the SCR in the reverse direction and the SCR will be turned off.	2+2
d) Describe step up chopper with neat circuit diagram. Draw its I/P and O/P waveform. Mode1: In step-up chopper a large inductor, L is in series with the source voltage V_s. This forms a closed path as shown in the figure (b). During the time period T_{on} the chopper is on. The inductor stores energy. When the chopper is turned off the current is forced to flow through the diode and load for a time T_{off} and as the inductor current cannot die suddenly. When the current decreases the polarity of the emf induced in L is reversed. Fig (c). As a result the total voltage available across the load is given by the equation $V_0 = V_s + L\,(di/dt)$. The voltage V_0 exceeds the source voltage and hence the circuit acts as a step-up chopper and the energy which is stored in L is released to the load. 	2+2

SUMMER – 13 EXAMINATION

e) Draw and describe the jones chopper. When SCR1 is turned on, the capacitor C discharges resonantly through SCR1, L1, and D1 This discharge current does not flow through L2 and back to the battery because of the transformer action of T. The load current is picked up by SCR1, and the flywheel diode D1 is reverse-biased and its current reduced to zero. As the capacitor voltage swings negative, the reverse bias on diode D2 decreases. This continues up to a time and capacitor voltage assumes a polarity as shown in waveforms. When SCR2 is turned ON, the negative voltage on capacitor C is applied across SCR1 which is turned OFF after its recovery current becomes zero. The load current which is nominally constant starts to flow in SCR2 and capacitor C. The capacitor C is charged positively at first up to a voltage equal to the supply voltage Vdc. The flywheel diode becomes forward biased and begins to pick up the load current and capacitor current starts to reduce.   	2+2
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