Model Answers

Winter – 2019 Examinations

Subject & Code: Power Electronics (17638)

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.

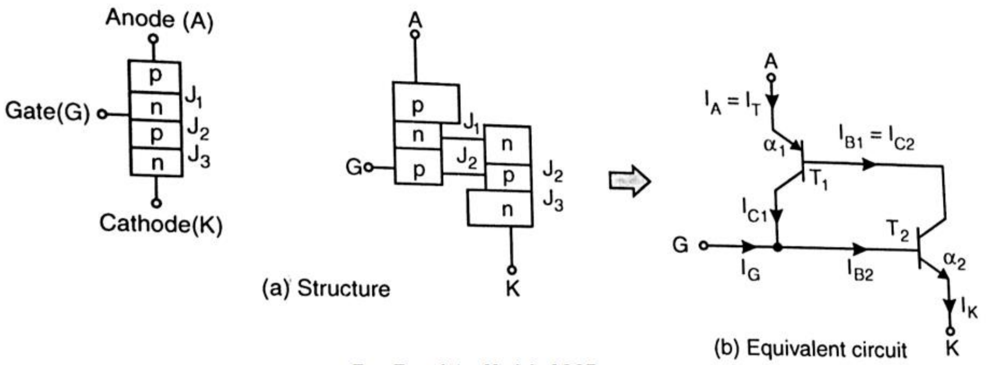
Model Answers
Winter – 2019 Examinations
Subject & Code: Power Electronics (17638)

1 a) Attempt any THREE of the following: **12**

1 a) i) Explain operating principle of SCR using two transistor analogy.

Ans:

Operating Principle of SCR using Two-Transistor Analogy:



Two Transistor Model of SCR

A simple p-n-p-n structure of thyristor can be visualized as consisting of two complimentary transistors: one pnp transistor T_1 and other npn transistor T_2 as shown in the fig. The collector current of transistor is related to emitter current and leakage current as:

2 Marks for Correct diagrams + 2 Marks for Explanation = 4 Marks

$$I_C = \alpha I_E + I_{CBO}$$

where, α = common-base current gain

I_{CBO}= leakage current from collector to base with emitter open

For transistors T_1 and T_2, we can write,

$I_{C1} = \alpha_1 I_A + I_{CBO1}$ and $I_{C2} = \alpha_2 I_K + I_{CBO2}$

From KCL applied to T_1, we can write

$I_A = I_{C1} + I_{C2}$

$= \alpha_1 I_A + I_{CBO1} + \alpha_2 I_K + I_{CBO2}$

From KCL applied to entire equivalent circuit,

$I_K = I_A + I_G$ and substituting in above equation,

$I_A = \alpha_1 I_A + I_{CBO1} + \alpha_2 (I_A + I_G) + I_{CBO2}$

$= I_A(\alpha_1 + \alpha_2) + \alpha_2 I_G + I_{CBO1} + I_{CBO2}$

$I_A(1 - [\alpha_1 + \alpha_2]) = \alpha_2 I_G + I_{CBO1} + I_{CBO2}$

$$I_A = \frac{\alpha_2 I_G + I_{CBO1} + I_{CBO2}}{1 - [\alpha_1 + \alpha_2]}$$

From this equation it is clear that the anode current depends on the gate current, leakage currents and current gains. If $(\alpha_1 + \alpha_2)$ tends to be unity, the denominator $1 - [\alpha_1 + \alpha_2]$ approaches zero, resulting in a large value of anode current and SCR will turn on. The current gains vary with their respective emitter currents. When gate I_G current is applied, the anode current I_A is increased. The increased I_A, being emitter current of T_1, increases the current gain α_1. The gate current and anode current together form cathode current, which is emitter current of T_2. Thus increase in cathode current results in increase in current gain α_2. Increased current gains further increase the anode current and the anode current further increases the current gains. The cumulative action leads to the loop gain to approach unity and the anode current drastically rises which can be controlled by external circuit only. In this way, the gate triggering can be explained using two-transistor model of SCR.

1 a) ii) Differentiate between 1ϕ & 3ϕ controlled converter on basis of no. of SCRs, Current capacity, application and cost.

Ans:

Sr. No.	Single phase converter	Three phase converter
No. of SCRs	No. of SCRs used are 1, 2 or 4 for half-wave, full-wave Centre-tapped (mid-point) and full-wave bridge converters respectively.	No. of SCRs used are 3, 6 for half-wave and full-wave, converters respectively.
Current capacity	Comparatively lower	Comparatively higher
Application	Low power applications: Portable hand tool drives, electrochemical and electrometallurgical process	High power applications: HVDC transmission, steel rolling mill, paper mill etc.
Cost	Cost is less compared to 3 phase converter	Costlier than 1-phase converter

1 Mark for each correct difference =4 Marks

1 a) iii) State the need of inverter. Give its classification.

Ans:

Inverter & its Classification:

An inverter refers to a power electronic device that converts power in DC form to AC form at the required frequency and voltage output. Alternating Current (AC) supply is used for almost all the residential, commercial and industrial applications. But the AC power cannot be stored for future use. So AC is converted into DC and then DC is stored in batteries and ultra-capacitors. And now whenever AC is needed, DC can be again converted into AC to run the AC based appliances. Also the variation can be done in the magnitude of voltage, number of phases, frequency or phase difference.

2 Marks for need

They are classified as

i) According to nature of input source
- Voltage source inverter (VSI)
- Current source inverters (CSI)

2) According to the wave shape of the output voltage.
- Sine wave inverter
- Square wave inverter
- Quasi square wave inverter
- Pulse width modulated inverter

3) According to the commutation of SCRs
- line commutated inverter
- forced commutated inverter

2 Marks for classification on any two basis

4) According to the connection of thyristor and commutation components

- Series inverter
- Parallel inverters
- Bridge inverters which are further classified as half bridge and full bridge.

5) According to the semiconductor device used

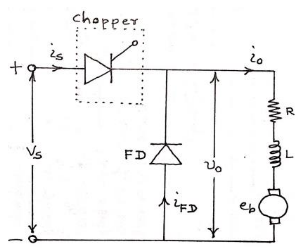
- Thyristorised inverter
- Transistorized inverter
- MOSFET based inverter
- IGBT based inverter

1 a) iv) Give the operation of speed control of DC series motor with step down chopper with a neat diagram. Also draw its waveform.

Ans:

<u>Speed control of DC series motor with step down chopper:</u>

Figure shows the basic arrangement for speed control of DC series motor using step down chopper. Armature current is assumed continuous and ripple free. The waveforms for the source voltage V_s, Motor terminal voltage v_0, motor current i_0, dc source current i_s and freewheeling diode current i_{FD} are also shown.



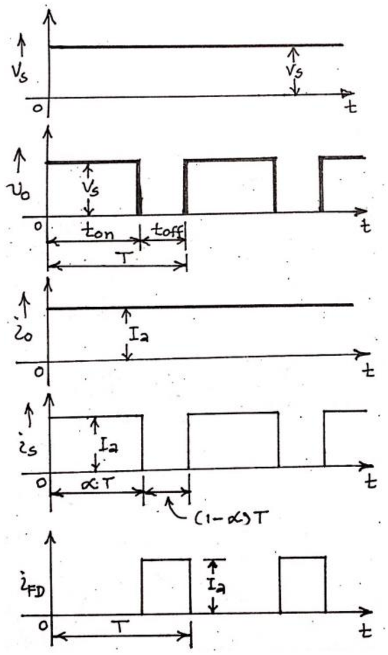
1 Mark for circuit diagram

Average motor voltage is given by,

$$V_0 = \frac{t_{on}}{T} V_s = \alpha V_s = f t_{on} V_s$$

where α = duty cycle = $\frac{t_{on}}{T}$

and f = Chopping frequency = $\frac{1}{T}$



1 Mark for waveform

Power delivered to motor is given by,

Power delivered to motor = Average motor voltage × Average motor current

$= V_t I_a = \alpha\, V_s I_a$

2 Marks for explanation

Motor voltage equation can be expressed as,

$V_0 = \alpha\, V_s = E_b + I_a(R_a + R_{se})$

The back emf is proportional to speed,

$E_b \propto \omega_m \therefore E_b = K_m \omega_m$

Thus voltage equation becomes,

$V_0 = \alpha\, V_s = K_m \omega_m + I_a(R_a + R_{se})$

The speed can be obtained as,

$$\omega_m = \frac{\alpha\, V_s - I_a(R_a + R_{se})}{K_m}$$

It is seen that by varying the duty cycle α of the chopper, armature terminal voltage can be controlled and thus speed of the dc series motor can be regulated.

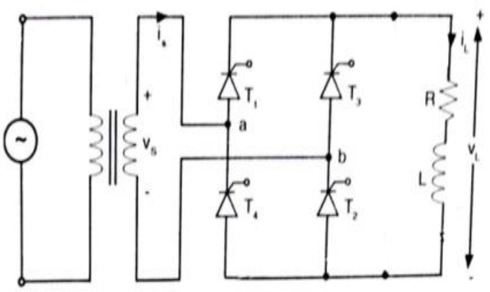
1 b) Attempt any <u>ONE</u> of the following: **6**

1 b) i) Draw a neat circuit diagram of 1ϕ fully controlled bridge converter with RL load and give its operation with waveforms.

Ans:

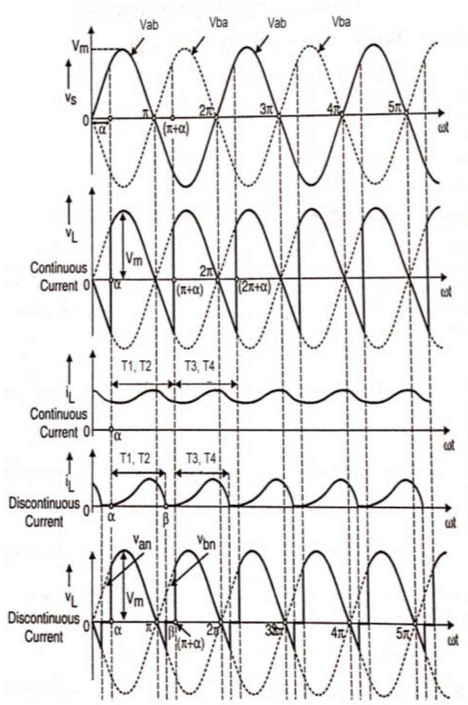
Single phase fully control bridge converter with RL load:

1. During positive half cycle of input voltage, T_1 and T_2 are forward biased and during negative half cycle, T_3 and T_4 are forward biased. Therefore, T_1-T_2 pair and T_3-T_4 pair are fired alternately in positive and negative half cycles of input voltage respectively, as shown in the waveform figure (b).
2. In each half cycle, the respective SCRs are fired at firing or delay angle α, as shown. Once SCR pair conducts (at delay angle in each half cycle), the input source voltage appears across load, the current flows and if the load is inductive in nature, the conducting SCRs remain into conduction till the fall of current to zero or firing of next pair of SCRs as shown in the waveform diagram.
3. Due to load inductance, the current lags behind the output voltage and falls to zero after the end of that half cycle. Therefore, during the time interval between voltage zero instant and current zero instant, the reversed supply voltage appears across load for discontinuous conduction.
4. At current zero, the SCRs are turned off and load gets isolated from source, causing load voltage zero till the firing of next pair of SCRs.
5. If load inductance is large, the load current never falls to zero. The current attempts to fall, but before it could fall to zero, the next pair of SCR get fired and we get continuous conduction.



(a) Circuit arrangement

1 Mark for circuit diagram



(b) Waveforms

3 Marks for waveforms

2 Marks for explanation

In this situation, the reversed voltage appears across load after the end of each half cycle till the firing of next pair of SCRs as shown in the waveform

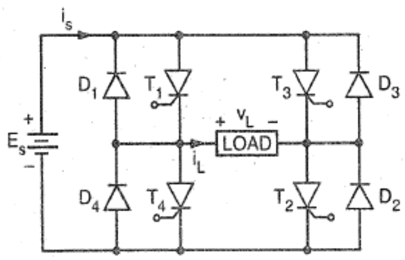
1 b) ii) Draw the circuit diagram of full bridge inverter. Draw waveform of load voltage and load current for RL load. Explain its operation.

Ans:

Single phase SCR full bridge inverter:

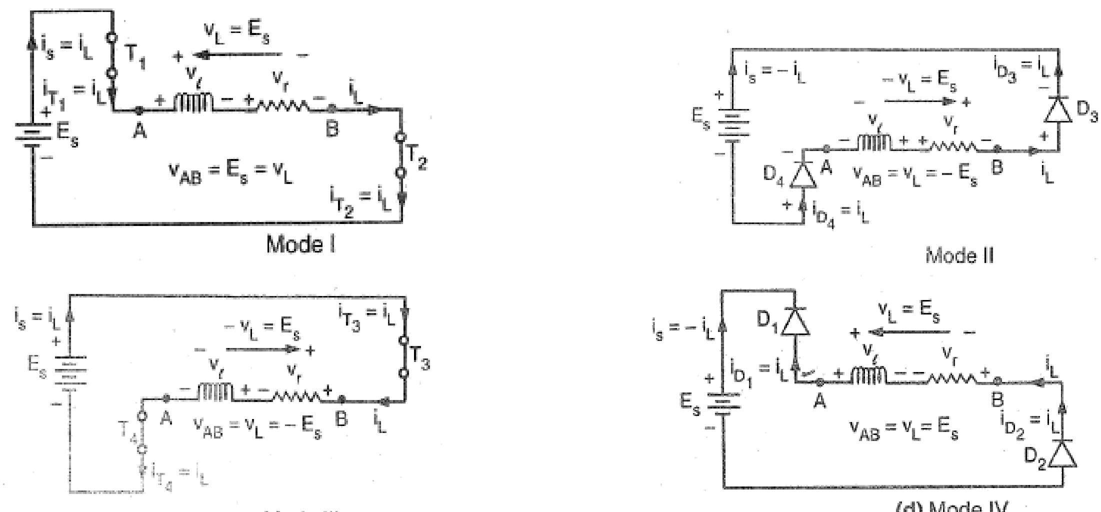
The circuit arrangement for single-phase SCR full bridge inverter is shown in fig.(a). The load is RL load. All the SCRs are forward biased by the input DC source. When

T_1 T_2 are turned on, load voltage becomes positive and when T_3 T_4 are turned on the load voltage becomes negative. For inductive load the circuit operation is divided in four modes:



(a) Circuit arrangement

2 Marks for circuit diagram



Mode I

Mode II

Mode III

(d) Mode IV

2 Marks for explanation

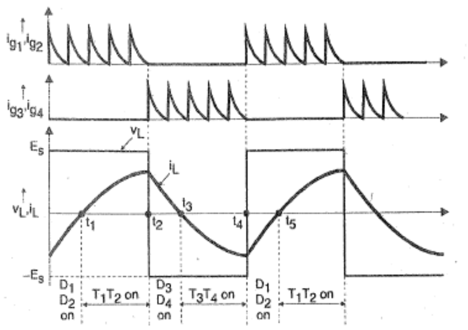
Mode I (t_1 to t_2): By gate pulses, the SCRs T_1 T_2 are turned on at t_1. The supply voltage E_s appears across load, the load current starts rising gradually due to inductive nature of load. The power flows from input DC source to load. During this mode the energy received by load is partly stored by its inductance.

Mode II (t_2 to t_3): At t_2 the gate pulses of T_1 T_2 are prohibited and they are turned off by commutating components. Due to load inductance, the load current cannot be reduced to zero suddenly. The load current is maintained in the same direction by load inductance voltage. The load current flows through diode D_3, DC source E_s, diode D_4 and load. Due to conduction of diodes D_3 and D_4, the load voltage appears to be negative. The load power therefore becomes negative i.e load returns or supplies back power to DC source. With energy feedback, load inductance loses its energy. So the load current slowly decreases and finally falls to zero. So far diodes are conducting, reverse bias is maintained across T_3 T_4 and they cannot be turned on.

2 Marks for waveforms of load voltage & current

Mode III (t_3 to t_4): At t_3 the SCRs T_3 T_4 are turned on by gate pulses. The DC source voltage E_s appears as reversed voltage across load. The load current is also reversed and starts to establish. Since load inductance has already lost its energy, it starts absorbing energy from DC source. Thus during this mode, the load receives energy from DC source, just similar to mode I, but with reversed voltage and current. At t_4 gate pulses of T_3 T_4 are prohibited and they are turned off by forced commutation circuit.

Mode IV (t_4 to t_5) or (0 to t_1): The turning off of T_3 T_4 would block the current, but due to load inductance, the load current is maintained in the same reversed direction by forcing it through diodes D_1 and D_2 and DC source E_s. Through diodes D_1 and D_2, the load voltage appears to be positive, making load power negative i.e load returns or feedback the power to load.



The waveforms of load voltage, load current, SCR currents, diode currents are shown in the figure.

2 **Attempt any FOUR of the following:** **16**

2 a) State different SCR triggering methods. Explain dv/dt triggering method.

Ans:

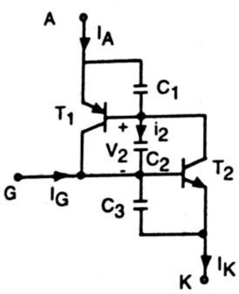
SCR Triggering Methods:

(i) Forward voltage triggering
(ii) Thermal triggering (Temperature triggering)
(iii) Radiation triggering (Light triggering)
(iv) dv/dt triggering
(v) Gate triggering
- D.C. Gate triggering
- A.C. Gate triggering
- Pulse Gate triggering

1 Mark for triggering methods

dv/dt Triggering Method of SCR:

Any p-n junction has capacitance. Under transient conditions, these capacitances influence the characteristics of SCR. Fig. shows two-transistor transient model of SCR wherein the junction capacitances have been shown external to the transistors. If SCR is in forward blocking state and rapidly rising voltage is applied between anode and cathode, the high current will flow through the device to charge the capacitors. The current through capacitor C_2 (junction J_2) can be expressed as:



Two-traisistor transient model of thyristor

1 Mark for diagram

$$i_2 = \frac{d(q_2)}{dt} = \frac{d}{dt}(C_2V_2) = V_2\frac{dC_2}{dt} + C_2\frac{dV_2}{dt}$$

where, C_2 = capacitance of junction J_2
V_2 = voltage across junction J_2
q_2 = charge in the junction J_2

2 Marks for explanation

If the rate of rise of the voltage $\frac{dV_2}{dt}$ is large, then current i_2 would be large. As these capacitor currents are basically leakage currents, the transistor leakage currents

i_{CBO1} and i_{CBO2} would be increased. The high values of leakage currents may cause $(\alpha_1 + \alpha_2)$ tending to unity and result in unwanted turn-on of the SCR by regenerative action. The rapidly rising anode voltage produces charging current through the junction capacitance, leading to gate terminal. This current then acts as gate current and SCR is triggered.

2 b) Give the concept of firing angle and conduction angle with a neat waveform.

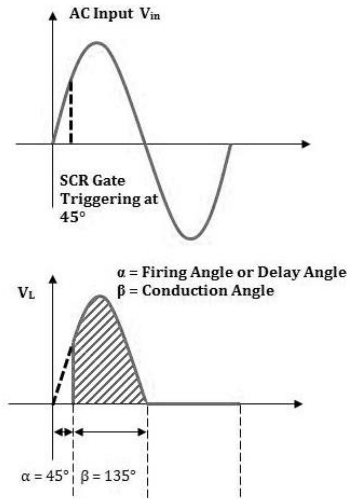
Ans:

Firing Angle (α):

Firing angle is defined as the angle between the instant the SCR would conduct if it would be a diode and the instant it is triggered or fired.

Firing angle or delay angle can be defined as the angle measured from the angle that gives maximum average output voltage to the angle when the SCR is actually triggered or fired by gate pulse.

1 Mark for firing angle



Conduction Angle (β):

Conduction angle is defined as the angle between the in stant the SCR is triggered or turned on and the instant at which the SCR is turned off.

1 Mark for conduction angle

2 Marks for waveform

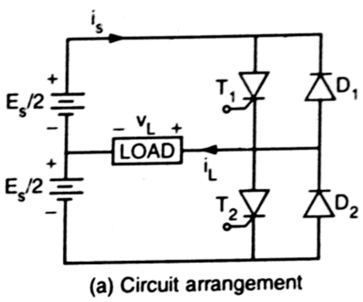
Assuming that the SCR is turned off naturally at the end of positive half cycle, the relation between the firing or delay angle (α) and conduction angle (β) can be expressed as:

$$\alpha + \beta = \pi \text{ radian or } 180$$

2 c) Draw and explain working of single-phase half controlled bridge inverter.

Ans:

Single-phase half-bridge inverter:



(a) Circuit arrangement

The circuit diagram of single-phase half-bridge inverter is shown in fig.(a). The circuit configuration requires three-wire DC supply, two SCRs and two diodes. The firing and commutation of SCRs is carried out by separate circuits, which are not shown here. The firing pulses and voltage-current waveforms are shown in fig.(b). The SCRs are turned off by commutation circuits when the gate pulses are removed. The SCRs are turned on alternately, thereby providing alternating voltage to the load.

1 Mark for circuit diagram

2 Marks for explanation

(a) <u>Purely Resistive Load:</u>

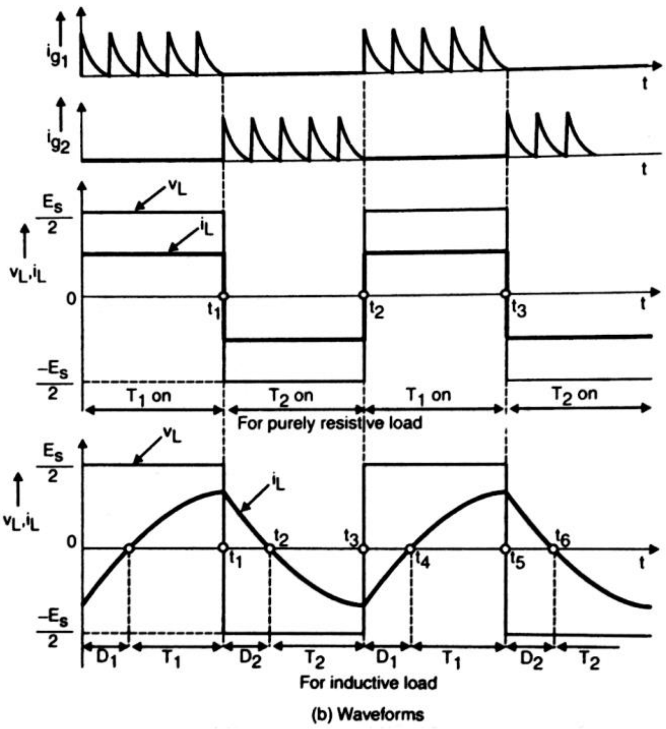
Referring to waveforms in fig.(b), at t=0, the SCR T_1 is fired by gate pulse train. Once T_1 conducts, the upper source voltage ($E_s/2$) appears across the load. Thus constant voltage $+E_s/2$ appears across load when T_1 is on and T_2 is off. The load current is positive. At instant $t = t_1$, the gate pulses of T_1 are removed and gate pulses are provided to T_2. Thus at $t = t_1$, T_1 is turned off and upper source voltage appears across T_1 whereas, T_2 is turned on and lower source voltage appears across load. Therefore load voltage is reversed and reversed current flows. During the period when T_2 is on, constant voltage $-E_s/2$ appears across load. Thus alternate switching of T_1 and T_2 causes alternating voltage across load and the load current follows the load voltage variations. The load voltage and load current both have rectangular waveforms as shown in fig.(b).

(b) Inductive Load:

When the load is inductive, the load current cannot be changed or interrupted instantly. When T_1 is on and T_2 is off, the current exponentially rises in the path through upper source, T_1 and load. The load voltage is positive.

At instant $t = t_1$, T_1 is turned off, however load current is not interrupted due to inductive nature of load. The load inductive voltage plays here important role to circulate the load current. The load current continues to flow through path consisting load, lower source and diode D_2. The lower source voltage appears across load. Thus load voltage becomes negative but current is still positive. Now the load current is opposed by lower source, hence it falls. Since Diode D_2 is conducting, a small reverse bias is maintained across T_2which prevents it from turning on in presence of gate pulses.

At instant $t = t_2$, the load current falls to zero, voltage across T_2 rises to $E_s/2$ and gate pulse train turns T_2 on. Now the lower source delivers opposite current through load. Thus load current is reversed and starts developing in exponential manner. Both load voltage and load current are negative.



(b) Waveforms

At instant $t = t_3$, T_2 is turned off, however load current continues through load, upper source and diode D_1. The upper source voltage appears across load. Thus load voltage becomes positive but current is still negative. This current is opposed by upper source, hence it falls. Due to conducting diode D_1, small reverse bias is maintained across T_1, which prevents it from turning on.

At instant $t = t_4$, the load current falls to zero, voltage across T_1 rises to $E_s/2$ and gate pulse train turns T_1 on. Now the upper source delivers positive current through load. Thus load current starts developing in exponential manner and cycle repeats.

1 Mark for waveform

2 d) Explain with waveforms Constant frequency system and Variable frequency system for chopper control.

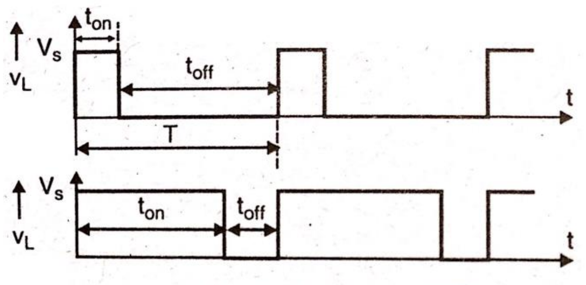
Ans:

Duty cycle of chopper : It is defined as the ratio of the on time T_{on} of chopper to the period T (= $T_{on} + T_{off}$) of the on-off cycle of chopper.

$$Duty\ Cycle\ k = \frac{T_{on}}{T} = \frac{T_{on}}{T_{on} + T_{off}}$$

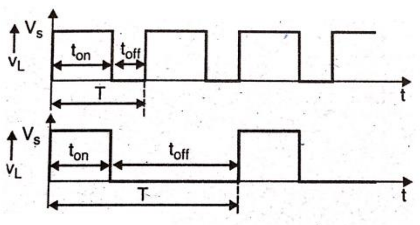
Time Ratio Control:
In this technique, the duty cycle 'k' is controlled to control the output voltage. It is carried out by two ways:

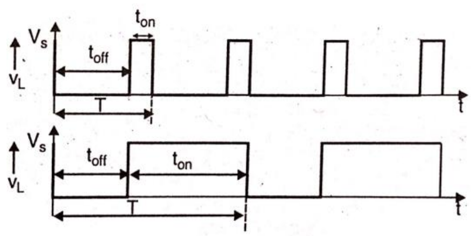
(i) **Constant Frequency System:** In this scheme, T_{on} is varied keeping frequency constant i.e. time period T=1/f constant. Variation of T_{ON} means varying pulse width. Hence it is also known as pulse-width modulation scheme. 2 Marks for constant frequency system



(a) Constant frequency TRC

(ii) **Variable Frequency System:** In this scheme, the chopping period T is varied and either On-time T_{ON} is kept constant or Off-time T_{OFF} is kept constant.
This method of controlling duty cycle is also called as frequency-modulation scheme. 2 Marks for variable frequency system


(i) t_{on} Constant


(ii) t_{off} Constant

2 e) Explain operation of speed control of three phase induction motor with variable frequency square wave VSI method.

Ans:

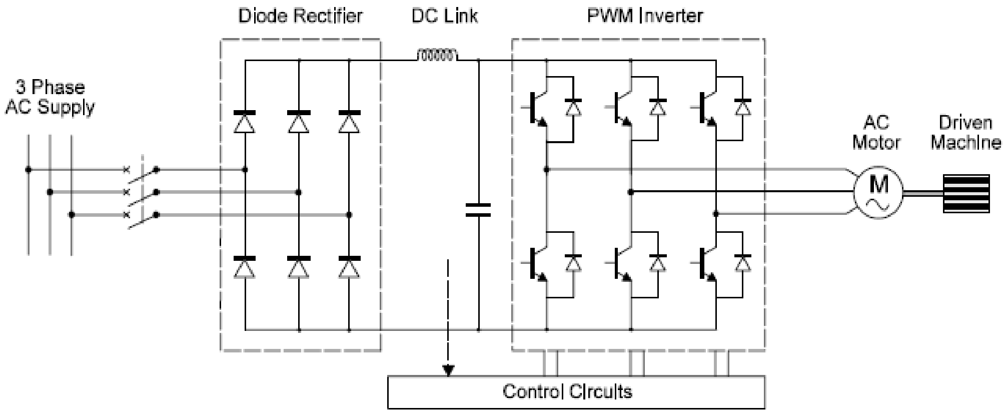
Speed control of 3ϕ Induction Motor with Variable-frequency Square-wave VSI method:

The speed of an induction motor can be controlled by varying the supply voltage and frequency. The torque is proportional to the square of air-gap flux. But air-gap flux is directly proportional to supply voltage with frequency kept constant. Thus by controlling the supply voltage at fixed frequency, the torque and ultimately speed can be controlled. 2 Marks for explanation

When the supply frequency is changed, the synchronous speed N_s (=120f/P) is changed and accordingly the motor speed get changed.

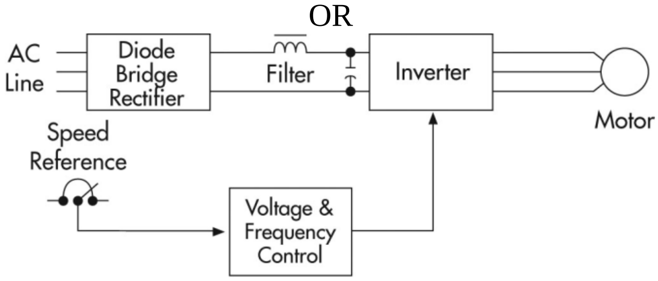
If the supply frequency f is changed to f* such that f* = β.f, the synchronous speed at new frequency f*becomes,

$N_s^* = \frac{120f^*}{P} = \frac{120\beta f}{P} = \beta N_s$ and the slip becomes $s^* = \frac{\beta N_s - N}{\beta N_s} = 1 - \frac{N}{\beta N_s}$



2 Marks for any one diagram

OR



The maximum torque developed at any supply frequency is inversely proportional to the square of frequency. Therefore, maximum torque gets reduced in inverse proportion when frequency is increased.

When the frequency is changed, the values of the reactances in the equivalent circuit are changed and therefore circuit currents are also changed. If the frequency is increased above its rated value, the reactances are also increased, the currents fall, the flux and maximum torque get decreased but synchronous speed is increased and motor speed is also increased. If the frequency is reduced, the reactances are also reduced and motor current increases. To maintain the motor current within the limit, it is highly essential to change supply voltage with frequency so that airgap flux is maintained.

With a Square wave inverter indicated in figure, the supply frequency to the motor can be easily adjusted for variable speed. However, if rated airgap flux is to be maintained at its rated value at all speeds, the supply voltage to the motor should be varied in proportion to the frequency. In the figure, the dc voltage obtained from diode rectifier remains constant, however, properly firing the switching devices of inverter, the voltage and frequency can be controlled within the inverter. The firing pulses to switching devices are supplied according to the requirement of speed.

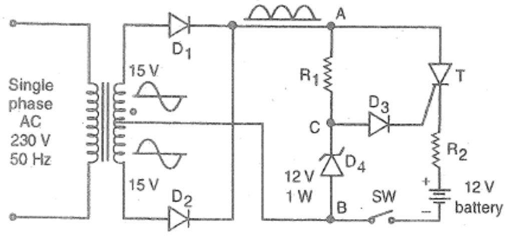
2 f) Describe with the sketch working of battery charger using SCR.

Ans:

Battery Charger circuit using SCR:

The figure shows the battery charger circuit using SCR. A 12V discharged battery is connected in the circuit and switch SW is closed. The single-phase 230V supply is stepped down to (15-0-15) V by a centre-tapped transformer. The diodes D_1 and D_2 forms full wave rectifier and pulsating DC supply appears across terminals A and B. When SCR is off, its cathode is held at the potential of discharged battery. During each positive half-cycle, when the potential of point C rises to sufficient level so as to forward bias diode D_3 and gate-cathode junction of SCR, the gate pulse is provided and SCR is turned on. When SCR is turned on, the charging current flows through battery. Thus during each positive half-cycle of pulsating DC supply, voltage across A-B, SCR is fired and charging current is passed till the end of that half-cycle. Due to Zener diode D_4, the maximum voltage at point C is held at 12V. Due to the charging process, the battery voltage rises and finally attains full value of 12V. When the battery is fully charged, the cathode of SCR is held at 12V. So the diode D_3 and gate-cathode junction of SCR cannot be forward biased, since the potential of point C can reach up to 12V. Therefore, no gate current is supplied and SCR is not fired. In this way, after full charging, further charging is automatically stopped.

2 Marks for circuit diagram



Automatic battery charger using SCR

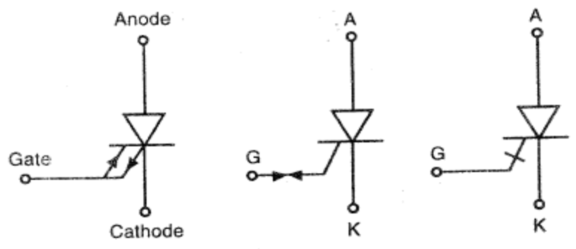
2 Marks for explanation

3 **Attempt any FOUR of the following:** **16**

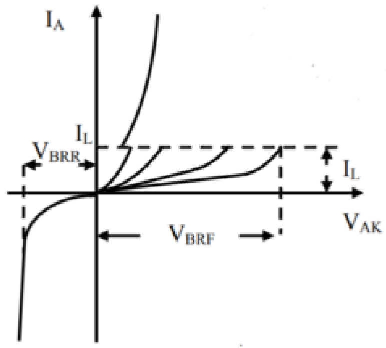
3 a) Draw symbol and V-I characteristics of following device:
i)GTO ii) IGBT iii)LASCR iv)TRIAC

Ans:

i) GTO:

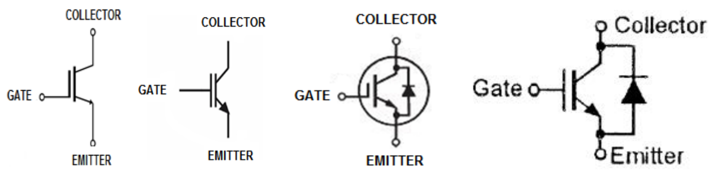


GTO Symbols



½ Mark for symbol
½ Mark for characteristic
= 1 Mark for each device

ii) IGBT:



Model Answers
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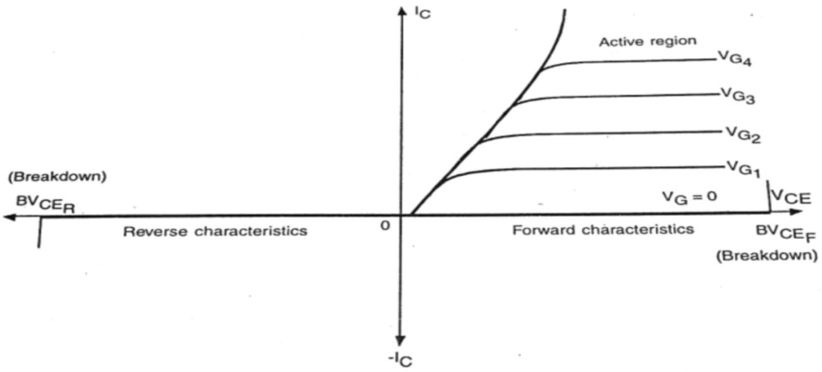
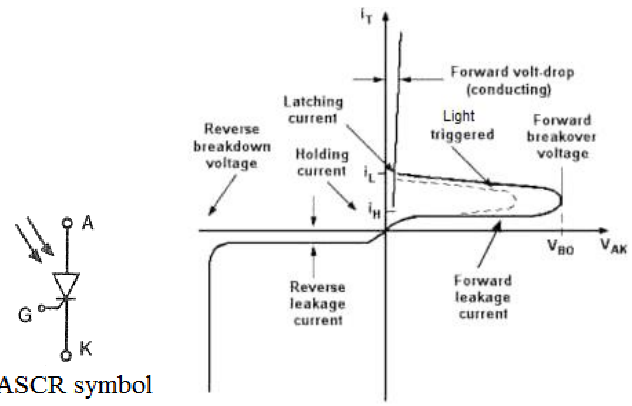


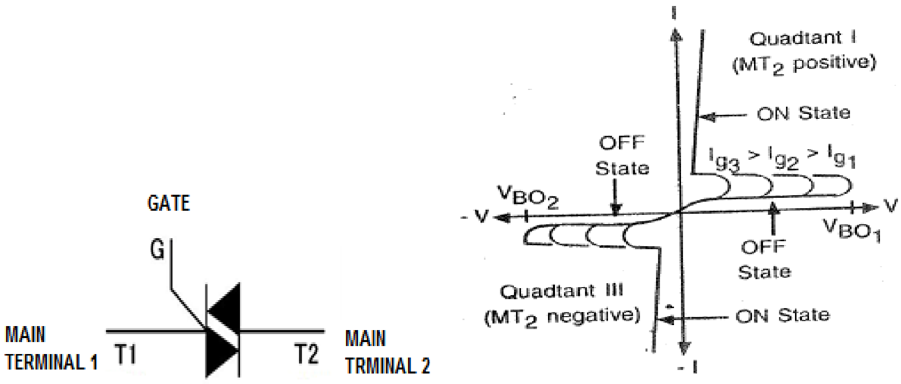
V-I characteristics of IGBT

iii) LASCR:



LASCR symbol

iv) TRIAC:



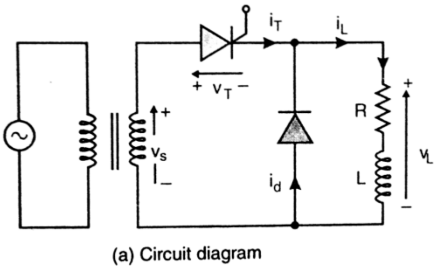
V-I Characteristics

3 b) Draw circuit diagram of single phase fully controlled half wave converter with RL load and freewheeling diode.

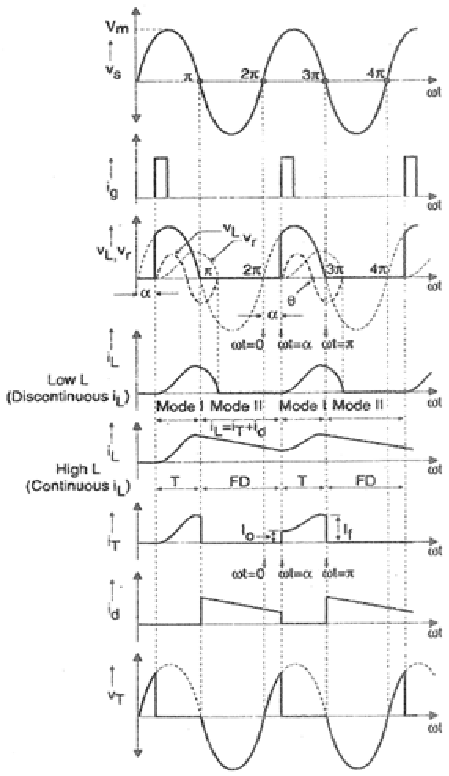
Ans:

Single-phase half-wave controlled rectifier:

The circuit diagram of 1ϕ half wave controlled rectifier with RL load and free-wheeling diode is shown in fig.(a). During positive half-cycle of v_s the SCR get forward biased. After the starting instant ωt = 0, at delay angle (α) gate pulse is



(a) Circuit diagram



(b) Waveforms

provided to SCR and it is triggered. Once it conducts, the voltage v_s appears across load. As the load is inductive, the current starts from zero, then rises, attains peak and then falls. During positive half cycle, the reverse bias is maintained across free-wheeling diode through conducting SCR. At the end of positive half cycle, v_s becomes zero, but load inductance maintains current in the same direction through v_s and SCR. After $\omega t = \pi$, the supply voltage is reversed, which causes forward bias across free-wheeling diode and it is turned on. Once the diode conducts, the reversed supply voltage appears across the SCR. The load inductance forces current through the diode. Thus the load current which was flowing through SCR, now shifted to free-wheeling diode D. The SCR is subjected simultaneously to reverse voltage and zero current. Therefore, the SCR is turned off at $\omega t = \pi$. When the free-wheeling diode conducts, the load voltage becomes zero. Thus the effect of free-wheeling diode is that the load voltage never becomes negative in presence of free-wheeling diode and hence the average value of the load voltage is improved. The load current continues to flow after $\omega t = \pi$ for some time depending upon the value of the load inductance. If the load inductance is less, the current becomes zero, prior to the next firing of SCR in the next positive half cycle. Thus we get discontinuous load current. However, if the load inductance is large, the current continues after $\omega t = \pi$ and does not become zero until the SCR is fired again in the next positive half cycle. Thus we get continuous load current without any zero value. The waveforms are shown in fig.(b).

1 Mark for circuit diagram

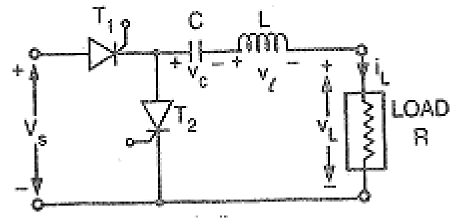
1 Mark for waveform

2 Marks for explanation

3 c) Describe the operation of single phase series inverter. How the basic circuit performance can be improved?

Ans:

Series Inverter:

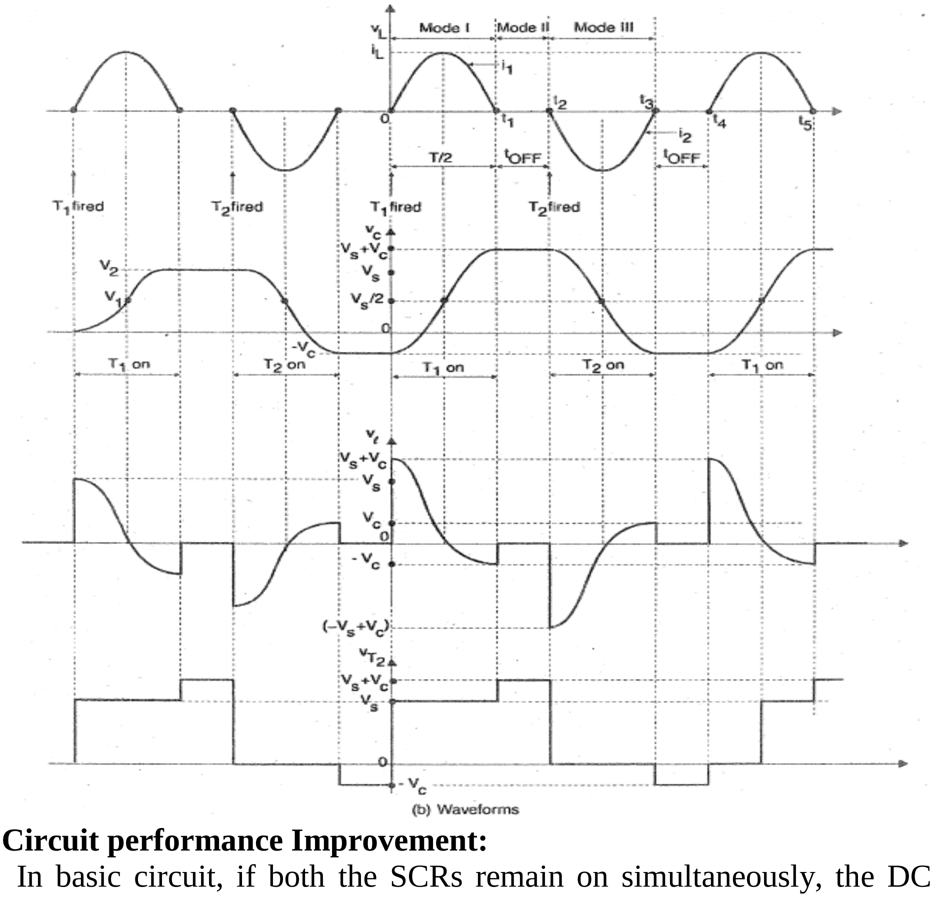


Assume initially that both the SCRs are off and there is no charge on the capacitor, so $v_c = 0$. Both the SCRs are forward biased by the input dc voltage V_s. If gate pulse is applied to T_1, it conducts and input voltage V_s appears across series combination C-L-R. The component

1 Mark for circuit diagram

values of C, L and load R are such that the R-L-C series combination is an underdamped circuit. For such underdamped circuit, when DC supply is given (which is the case when T_1 is fired), a current in the form of a pulse is observed as shown in the waveform. During this current pulse, the capacitor charges through inductor L and load resistor R. Due to inductor L, the capacitor charges with shown polarity to voltage higher than the supply voltage and the current drops to zero, turning T_1 off. Due to the capacitor voltage T_2 is forward biased. If gate pulse is applied to T_2, it is turned on and it provides path for the discharge current of capacitor. The capacitor discharges through T_2, Load R and inductor L. Since discharging circuit is same under damped R-L-C combination, the current is in the form of pulse as before but now in the reverse direction. Thus alternate firing of T_1 and T_2 causes alternate positive and negative half cycles of current respectively as shown in the waveform.

2 Marks for operation



(b) Waveforms

Basic Circuit performance Improvement:

1) In basic circuit, if both the SCRs remain on simultaneously, the DC source gets short-circuited. This is overcome by using coupled inductor with connection arrangement such that when any one SCR is fired, the other conducting SCR is turned off.
2) In basic circuit, there is limitation on the output frequency. When coupled inductor is used, the frequency can be further increased beyond ringing frequency.
3) With coupled inductor configuration, the harmonic content is reduced as compared to basic circuit.

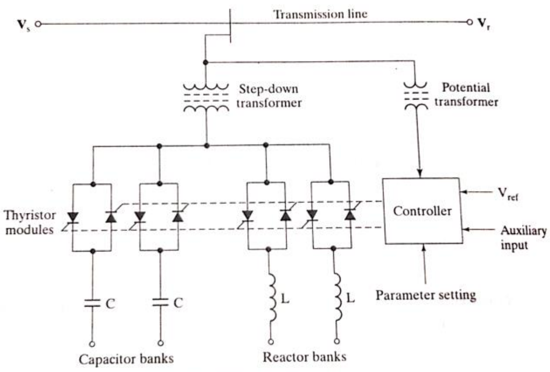
1 Mark for performance improvement

3 d) Explain with circuit diagram the application of SCR for static VAR compensation in power system.

Ans:

Static VAR compensator:

- Static VAR compensation is a process of compensating the reactive power in the power system using static switches (semiconductor switches). In this process, the reactors and capacitors are switched to absorb or supply the reactive power respectively.
- Static VAR compensators (SVC) consists of combinations of thyristor controlled reactor (TCR), thyristor switched capacitor (TSC) and fixed capacitor (FC).
- The electrical transmission and distribution networks are dominantly reactive in nature. During no or light load condition, the line capacitances play major role to produce the reactive power. If this reactive power is not absorbed by load then voltage rises and may cross the limit. In this situation, TCR is used to insert reactors in power system to absorb the reactive power.
- During peak load condition, most of the loads are inductive and they demand the reactive power. In this situation, TSC is used to insert capacitors in power system to generate the reactive power.
- In fact, SVC comprises combinations like (TCR+TSC), (TCR+FC) as per the need.
- In TCR, phase control is used to vary the effective inductance of the inductor.
- In TSC, the integral-cycle control is employed to vary the effective capacitance of the capacitor.



General arrangement of static VAR compensator

2 Marks for diagram

2 Marks for explanation

3 e) List the advantages of AC drives over DC drives (Any four points).

Ans:

1) AC drive is more reliable compare to DC drive.
2) In AC drive, variable frequency can be controlled by using both frequency duty cycles and voltage values while DC drive can only control the voltage.
3) Due to the fact of frequency control, the AC variable frequency is more sufficient in energy consumption compare to DC drivers.
4) AC drives have the lowest starting current of any starter type.
5) AC drives reduce thermal and mechanical stresses on motors and belts.
6) AC drive installation is as simple as connecting the power supply to the AC drive.
7) AC drives provide high power factor, eliminating the need for external power factor correction capacitors.
8) AC drives provide lower KVA, helping alleviate voltage sags and power outages.

1 Mark for each of any four advantages = 4 Marks

4 a) **Attempt any THREE of the following:** **12**

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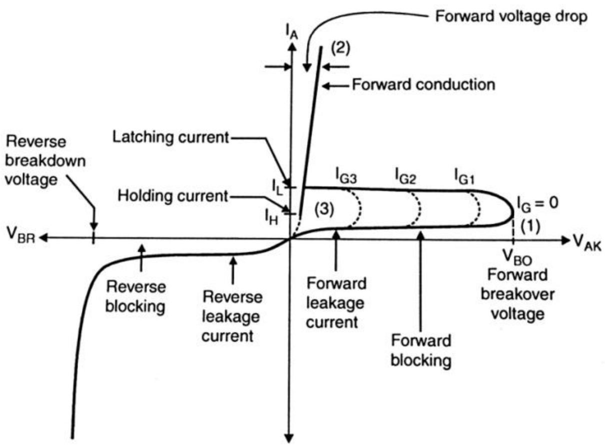
4 a) i) Draw a neat labelling VI characteristics of SCR and explain the region.

Ans:

V-I characteristics of SCR:



V-I Characteristics of SCR

2 Marks for labeled diagram

Operating regions:

1) **Forward Blocking region**: In this region, the SCR is forward biased but not triggered. It carries only forward leakage current. The SCR in this region is treated as OFF switch.

2) **Forward conduction region**: In this region, the SCR conducts the forward current and latched into conduction after triggering. The SCR in this region is treated as ON switch.

3) **Reverse blocking region**: In this region, the SCR is reverse biased, hence carries only reverse leakage current. The SCR in this region is treated as OFF switch.

4) **Reverse conduction region:** In this region, the SCR conducts the reverse current after the breakdown of reverse biased junctions. The SCR get damaged if operated in this region.

½ Mark for each region = 2 Marks

4 a) ii) Explain the effect of source impedance on the performance of 1φ fully controlled converter.

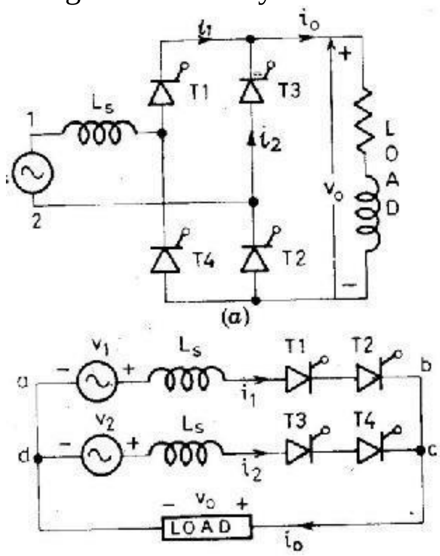
Ans:

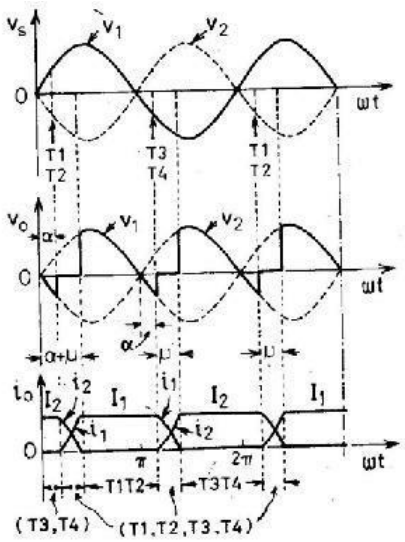
Effect of Source Impedance On Converter:

1. The effect of source inductance is delay in commutation of thyristors, as it takes a finite time for the current to decay to zero in the outgoing thyristor, while the current will rise at the same rate in the incoming thyristor.
2. Thus, in practice, the commutation process may occupy a quite significant period of time, during which both the "incoming" and "outgoing" thyristors are simultaneously in conduction.
3. This period, during which both the outgoing and incoming thyristors are conducting, is known as the over-lap period and the angle for which both devices share conduction is known as the overlap angle or commutation angle, as shown in the waveforms below.
4. The output average voltage is dropped due to loss of output voltage during commutation angle.
5. If the source impedance is purely resistive, it causes voltage drop and output

2 Marks for explanation

voltage is reduced by that amount.



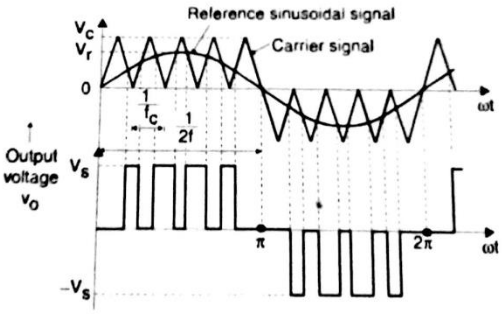


2 Marks for circuit & waveforms

4 a) iii) Explain working of sinusoidal pulse width modulation.

Ans:

Sinusoidal Pulse Width Modulation: (Sin PWM)



Sinusoidal-pulse-width modulation (Sin M)

2 Marks for diagram

2 Marks for explanation

In this modulation technique, several pulses per half cycle are used to fabricate output AC waveform. The pulse width is a sinusoidal function of the angular position of the pulse in the half cycle. The gating signals for turning on the thyristors are generated by comparing a high frequency carrier signal v_c with a sinusoidal reference signal v_r of desired frequency. The trigger pulse is generated at the intersection point of v_c and v_r. The thyristor is maintained on during the interval when $v_r > v_c$. When v_r becomes equal to v_c the on thyristor is commutated by forced commutation. In fact, the comparison of v_c and v_r is carried out in comparator and when $v_r > v_c$, the comparator output is high, otherwise it is low. The comparator output is processed in such manner that the output voltage has pulse width in agreement with the comparator output pulse width.

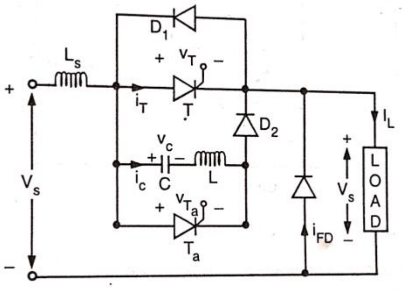
4 a) iv) Sketch circuit diagram of current commutated chopper. Explain its operation with waveforms.

Ans:

Current commutated chopper:

The circuit arrangement of current-commutated chopper is shown in the figure. The main thyristor is T and the commutation circuit includes auxiliary thyristor T_a, commutating capacitor C, inductor L, diodes D_1 and D_2. The freewheeling diode is connected across load. The commutation is carried out by passage of reverse resonant current pulse through main thyristor T to reduce its forward current to zero.

When supply voltage V_s is given to circuit, the capacitor gets charged through source inductance L_s, L, D_2 and load, with polarity as shown. The final steady state voltage across capacitor is $v_c = V_C$ which is higher than V_s, because the capacitor is overcharged by inductance L and also by source inductance L_s.

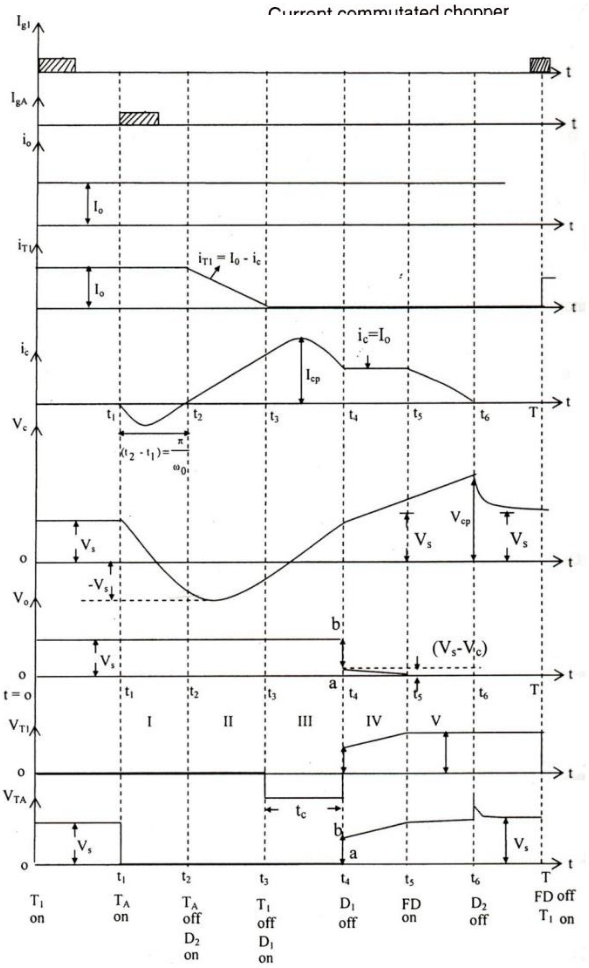


Current commutated chopper

1 Mark for circuit diagram

The circuit operation can be divided into six modes:

Mode I ($0<t<t_1$): At t = 0 the main thyristor T is fired. Once it turns on, the load gets connected across the source and supply voltage appears across load. The constant load current I_L flows through main thyristor T and load during this mode.



2 Marks for waveforms

1 Mark for explanation

Mode II ($t_1<t<t_2$): This mode begins with firing of auxiliary thyristor T_a at $t = t_1$. Since it is forward biased by capacitor voltage it is turned on and LC circuit gets closed through T_a. The oscillatory current flows through L, T_a and C, discharging C and recharging with opposite polarity.

Mode III ($t_2<t<t_3$): At $t = t_2$ the capacitor current falls to zero and auxiliary thyristor is self-commutated. Then mode III begins, the charged capacitor forces current through L, D_2, T for its discharging. This current being oscillatory and sinusoidal in nature, the net current through main thyristor T falls to zero at particular instant $t = t_3$ and it is commutated.

Mode IV ($t_3<t<t_4$): Once main thyristor is commutated at t_3 the capacitor current i_c is maintained through D_1 and the capacitor voltage polarity gets reversed due to inductance L. At $t = t_4$, the capacitor current i_c becomes equal to load current I_L, the diode current becomes zero and diode D_1 is turned off.

Mode V ($t_4<t<t_5$): In this mode, the capacitor further charges linearly due to constant load current with the polarity shown in the figure. At $t = t_5$, the capacitor voltage becomes equal to V_s, therefore load voltage must be zero to satisfy the KVL. So at $t = t_5$, the freewheeling diode conducts and load voltage falls to zero.

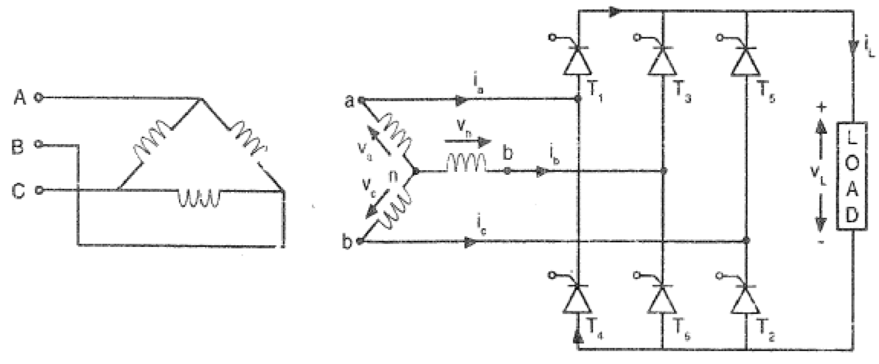
Mode VI ($t_5<t<t_6$): During this mode, the load voltage remains zero due to conducting FD, the capacitor gets overcharged. At the end, the capacitor current falls to zero and FD continue to conduct till the energy in load inductance is dissipated.
After this mode, if main thyristor is fired, mode I starts and the cycle is repeated.
The waveforms are as shown in the figure.

4 b) Attempt any ONE of the following: **6**

4 b) i) Give the operation of 3phase fully controlled bridge converter with R load with a neat diagram. Also draw it's waveforms.

Ans:

Three Phase full controlled bridge converter with R Load:



(a) Circuit arrangement

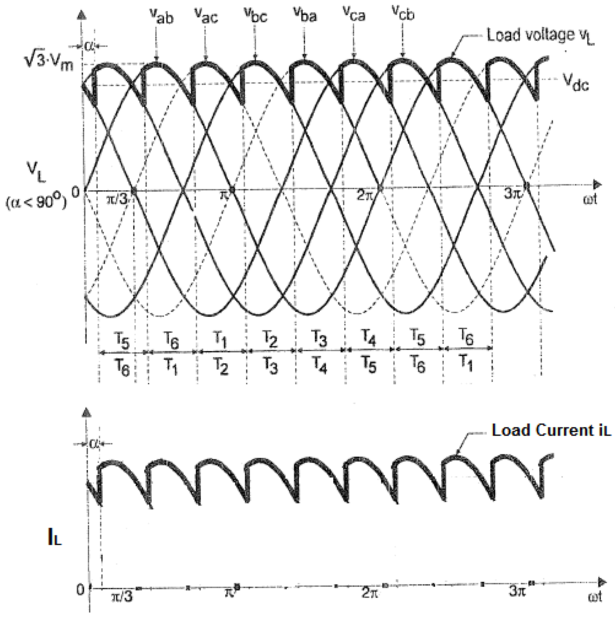
2 Marks for circuit diagram

The circuit diagram of 3ϕ fully controlled bridge converter is shown in fig.(a). Six thyristors are connected in bridge to obtain full wave rectification. One of the upper thyristors T_1, T_3, T_5 carry current from secondary winding to load and one of the lower thyristors T_2, T_4, T_6 carry current back from load to secondary winding. The pair of the thyristors which is connected to those lines having a positive instantaneous line-to-line voltage is fired. If v_{ab} is positive, then the thyristor connected to phase a i.e T_1 and thyristor connected to phase b i.e T_6 are fired. The thyristors are fired at an interval of $\pi/3$ rad or 60°. Each thyristor conducts for $2\pi/3$ rad or 120°. The fig.(b) shows the waveforms of line voltage, output load voltage and load current.

2 Marks for explanation

At $\omega t = 0$, the line voltage v_{cb} is higher than any other line voltage, hence thyristor T_5 connected to phase c and thyristor T_6 connected to phase b are fired at delay angle α. After firing T_5 and T_6, the load voltage becomes equal to v_{cb}. The upper load terminal gets connected to phase c and voltage v_{ac} appears across T_1 and voltage v_{bc} across T_3. As both v_{ac} and v_{bc} are negative, both T_1 and T_3 are reverse biased. Similarly the lower load terminal gets connected to phase b through T_6 and voltage v_{ba} appears across T_4 and voltage v_{bc} across T_2. As both v_{ba} and v_{bc} are negative, both T_4 and T_2 are reverse biased. Thus firing of a pair of thyristors causes all other thyristors to be reverse biased. This condition is continued till $\omega t = \pi/3$. After this the line voltage v_{ab} becomes higher than v_{cb}. At $\omega t = \pi/3$, the line voltage v_{ac} crosses zero value and becomes positive, due to which T_1 get forward biased. So a gate pulse is applied to T_1 at $\omega t = (\pi/3)+\alpha$. Once T_1 is turned on, the upper load terminal gets connected to phase a, causing line voltage v_{ca} across conducting T_5. As

v_{ca} is negative, T_5 get reverse biased and turned off. The load current get shifted from T_5 to T_1. However, the thyristor T_6 remains on and continue to carry load current with T_1. The load voltage then becomes equal to v_{ab}. In this way the thyristors are fired in sequence and successively line voltages appear across load as shown in fig.(b).
Since the load is purely resistive, the load current follows same variations as that of load voltage. The waveform of load current is similar to the load voltage waveform as shown in the fig.(b).



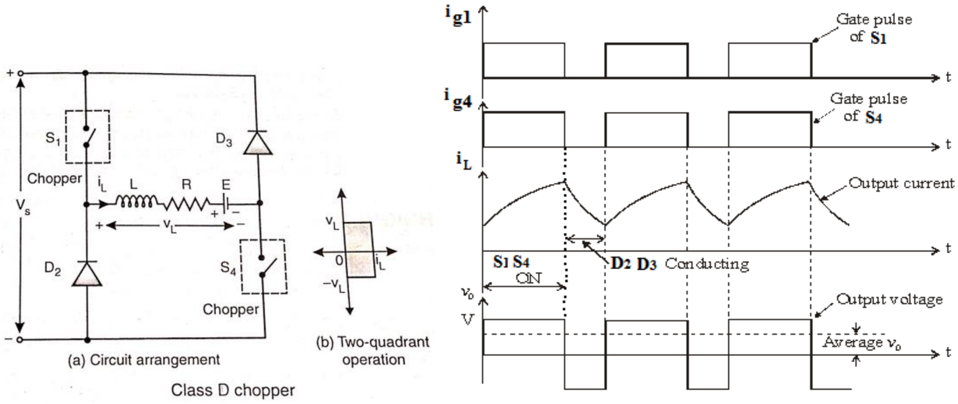
(b) Waveforms

2 Marks for waveforms

4 b) ii) Draw a neat circuit diagram of class D chopper and give it's operation with waveforms.

Ans:

Class D Chopper:



Class D chopper

1 Mark for circuit diagram

1 Mark form waveform

2 Marks for explanation

In this chopper, the load current is always maintained positive as shown in the Fig. (a), but the load voltage can be either positive or negative.
When chopper switches S_1 and S_4 are on, the input dc source voltage appears across load and it drives the positive load current i_L as shown in Fig. (a). During this time, both v_L and i_L are positive, power is supplied by input dc source V_S to load and the chopper is said to be operated as rectifier in the first quadrant.
When chopper switches S_1 and S_4 are turned off, the load current i_L is maintained in the same direction by reversed load inductor voltage v_ℓ, through D_3, V_S and D_2. The load inductance gives out stored energy. Due to the reversed load inductor voltage, the load voltage v_L becomes negative. During this time, i_L is positive, v_L is negative, power is supplied by load inductance to input dc source V_S and the chopper is said to be operated as an inverter in the third quadrant. The conducting devices and nature of

load (output) voltage and current is shown in the waveform.

5 Attempt any FOUR of the following: 16

5 a) Give any four specifications of SCR.

Ans.

Specifications of SCR

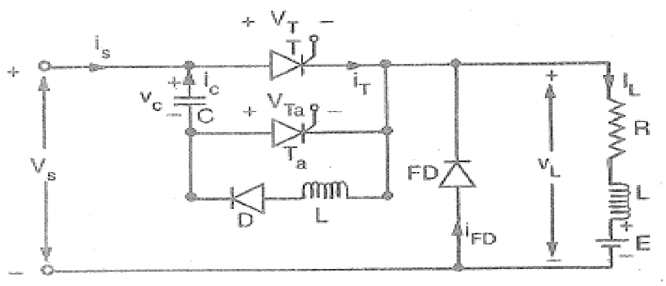
1. **Voltage Rating:**
   - i) Peak working forward-blocking voltage V_{DWM}
   - ii) Peak repetitive forward-blocking voltage V_{DRM}
   - iii) Peak surge or non-repetitive forward blocking voltage V_{DSM}
   - iv) Peak working reverse voltage V_{RWM}
   - v) Pear repetitive reverse voltage V_{RRM}
   - vi) Peak surge or non-repetitive reverse voltage V_{RSM}
   - vii) On-state voltage drop V_T
   - viii) Finger voltage
   - ix) Forward dv/dt rating (Critical rate of rise voltage)
2. **Current Rating:**
   - i) Average on-state current I_{TAV}
   - ii) RMS current I_{Trms}
   - iii) Surge current rating I_{TSM}
   - iv) I^2t rating
   - v) di/dt rating
3. **Power Rating:**
   - i) Maximum gate power P_{gm}
   - ii) Average gate power P_{gav}
   - iii) Average Power dissipation (Forward on-state conduction loss)
   - iv) Loss due to leakage current during forward and reverse blocking
   - v) Switching losses during turn-on and turn-off
4. **Temperature Rating:**
   Maximum junction temperature

½ Mark for each of any 8 Specification = 4 Marks

5 b) Explain auxiliary commutation with a neat diagram.

Ans:

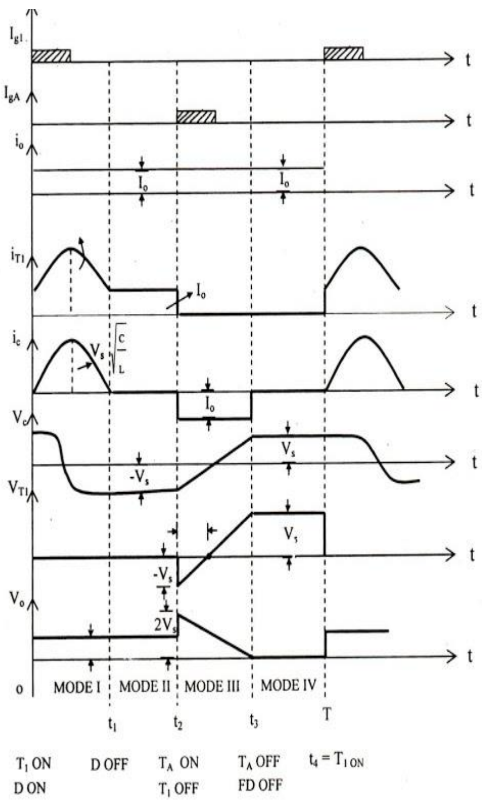
Auxillary commuted chopper:



Voltage-commutated chopper

2 Markd for circuit diagram

The fig. shows the circuit arrangement of voltage commutated chopper employing auxiliary commutation. At start, the Ta is triggered and turned on to carry the load current. Due to the resonant circuit R-L-C, the current initially rises, attains peak and then falls to zero. This turns off the auxiliary SCR Ta. This current charges the capacitor C with upper plate positive. The capacitor thus forward biases the main SCR T. When main SCR T is triggered, it is turned on and charged capacitor C is placed across Ta so as to apply reverse bias across it. The load current now flows through T. The capacitor continues to discharge through T, L and D. Since this LC is resonant combination, the capacitor discharges completely first and then charges with opposite polarity till the current falls to zero. The capacitor current cannot reverse because of diode D. Now the oppositely charged capacitor forward biases the auxiliary SCR Ta. Thus when Ta is triggered, T is turned off and the same cycle is repeated. In this configuration, the firing of auxiliary SCR commutates the main SCR, hence name is auxiliary commutation.



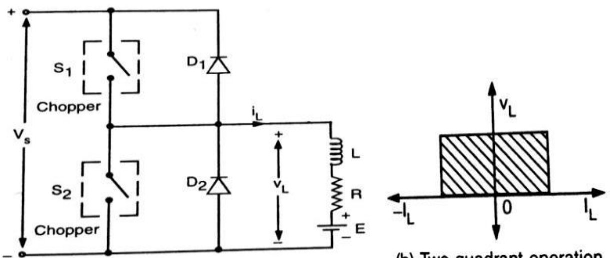
2 Marks for explanation

(Waveforms are optional)

5 Give the operation of Class C chopper with a neat diagram also draw the waveform.

Ans:

Class C chopper



(a) Circuit arrangement (b) Two-quadrant operation

1 Mark for circuit diagram

The circuit configuration is shown in fig.(a). It is essentially a two-quadrant chopper in the sense that the load current can be either positive or negative but the load voltage is always positive, as shown in fig.(b). It is a combination of class A and class B chopper. Keeping switch S_2 inoperative, the circuit behaves as class A chopper and keeping S_1 inoperative, the circuit behaves as class B chopper.

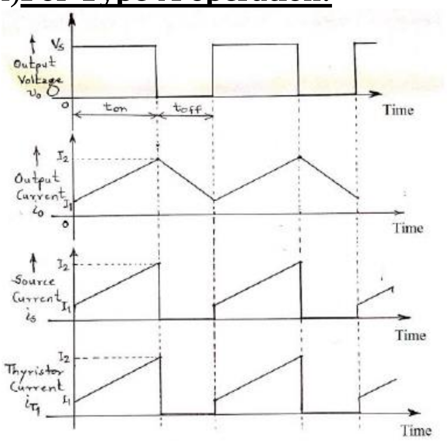
2 Marks for explanation

(i) Class A operation (Switch S_2 maintained off):

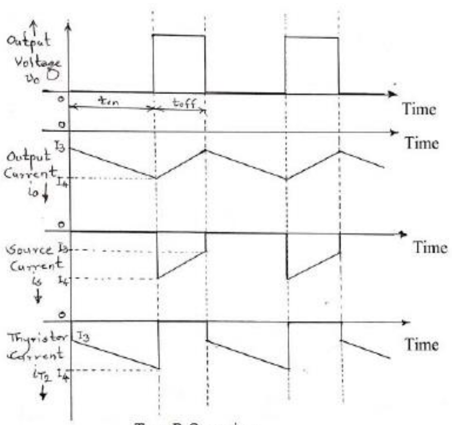
In this operation the switch S_1 is turned on and turned off alternately. When the switch S_1 is turned on, the DC source voltage get applied across the load and supplies load current. When the switch S_1 is turned off, the load inductance forces current through free-wheeling diode D_2 which makes the load voltage zero. Thus the load voltage is either positive or zero and the load current is positive as shown in the fig. (a). Thus the chopper is operated in first quadrant.

(ii) Class B operation (Switch S_1 maintained off):
In this operation, the load current is opposite to that shown in the fig.(a). When the switch S_2 is turned on, the load voltage becomes zero, the emf E drives load current i_L through load parameters R-L and S_2. When switch S_2 is turned off (opened), the load inductive voltage reverses its polarity and aids the emf E to force current through D_1 and V_s. The load voltage thus becomes equal to V_s. Thus the load voltage is either zero or positive and the load current is negative. Thus the chopper is operated in second quadrant. The class C chopper can operate either as a rectifier or as an inverter. This chopper is used for controlling the motoring and regenerative braking of DC motors.

i)**For Type-A operation:** ii)**For Type B operation** ½ Mark for each waveform = 1 Mark



Type A Operation



Type B Operation

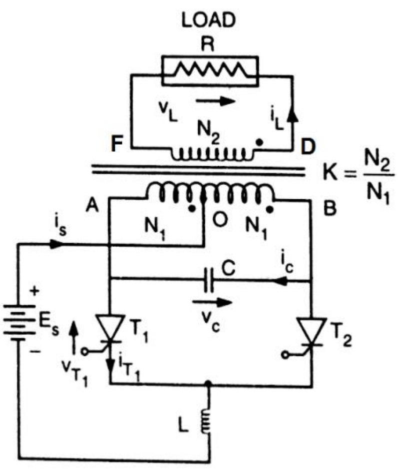
5 d) Draw circuit diagram of basic parallel inverter and describe its operation.
Ans.

Parallel Inverter

Basic Parallel Inverter:

1 Mark for circuit diagram

The circuit diagram of basic parallel inverter is shown in fig.(a). The load is connected on the secondary side of centre-tapped transformer. The commutating capacitor C is connected across full primary winding, hence appears effectively in parallel with load. This is the reason why the inverter is termed as parallel inverter.



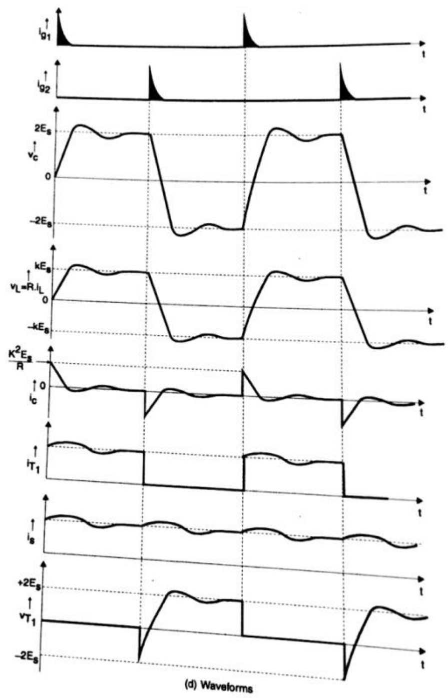
(a) Circuit arrangement

When T_1 is turned on, the DC source voltage E_s appears across half primary winding OA, neglecting small voltage drop in inductor L. Due to auto-transformer action, same voltage E_s is induced in other half primary winding OB. Thus total voltage across full primary becomes $2E_s$ with terminal B positive with respect to A. Since capacitor C is in parallel with full primary, it gets charged to $2E_s$ with right plate positive. The voltage is induced in secondary with terminal D positive with respect to terminal F. The charged capacitor C is placed across non-conducting SCR T_2 via conducting SCR T_1. Thus T_2 get forward biased

2 Marks for explanation

is ready to conduct.

When gate pulse is applied to T_2, it is turned on and charged capacitor C is placed across T_1 via T_2. It causes reverse bias across T_1 and it is turned off. The capacitor then discharges through T_2, L and DC source and recharges with opposite polarity to $-2E_s$. Thus primary voltage gets reversed, which also cause reversal of secondary (load) voltage. It is seen that the charged capacitor always provides forward bias to non-conducting SCR. If that SCR is gate triggered, it is turned on and already conducting SCR is turned off due to reverse bias provided by the capacitor placed across it through just triggered SCR.



(d) Waveforms

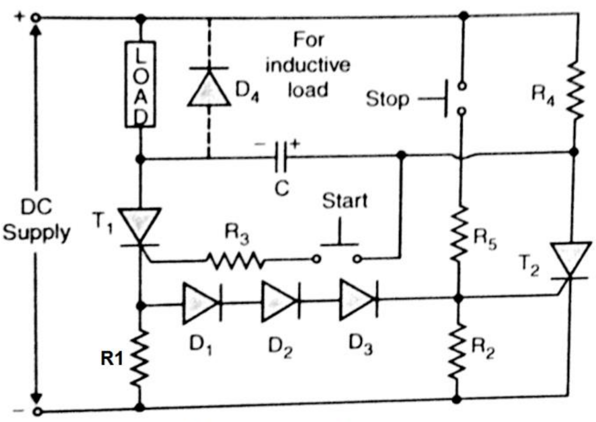
1 Mark for waveform

Ideally the voltages across primary and secondary have rectangular waveforms but due to capacitor charging and non-linearity's in magnetic circuit, the primary and secondary voltage waveforms appear close to trapezoidal. The waveforms of load voltage, SCR voltage, source current, SCR current and capacitor current are shown in Fig.(d).

5 e) Draw the circuit diagram of DC static circuit breaker & give it's operation

Ans:

DC Static Circuit Breaker:



DC static Circuit Breaker

The figure shows circuit configuration of DC static circuit breaker using SCR. When the 'Start' button is momentarily pressed, the SCR T_1 receives gate current through R_3 and starts to conduct. The turning on of T_1 causes major part of DC supply voltage to appear across the load and power is delivered to load. The capacitor C charges to load voltage with polarity as shown in the figure, through R_4.

2 Mark for circuit diagram

If we attempt to break the DC load current i.e switch off the load, using mechanical contact type switch, since current is DC, heavy arcing may damage the switch. Instead, if we use this circuit configuration, the load current can be interrupted by turning off the SCR T_1. When 'Stop' button is pressed momentarily, SCR T_2 receives gate current through R_5 and it is turned on. The turning on of T_2 causes the charged capacitor C to place across conducting SCR T_1. The capacitor provides reverse bias across T_1 and discharges quickly through T_2, resistance and T_1. The discharge current is reverse current for T_1 and it is turned off. The load current is then continued through C and T_2. The capacitor C first discharges

2 Marks for explanation

and then charges with reverse polarity to supply DC voltage. At this instant, the load current falls to zero, and further since current falls below holding current level, T_2 is turned off naturally. Thus manual firing of T_2 by pressing 'Stop' button interrupts load current through T_1.

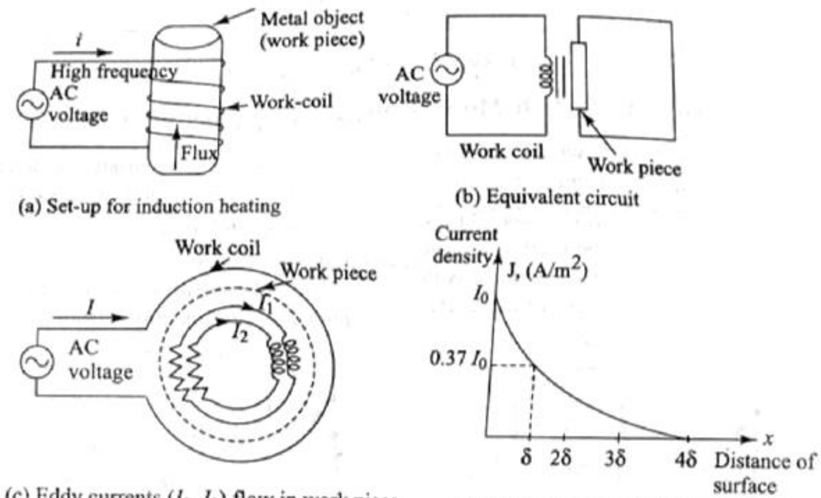
The load current can be automatically interrupted under overload condition. With T_1 on and carrying load current, if overload occurs, the voltage drop across R_1 exceeds the forward voltage drop of string of diodes D_1, D_2, D_3 and gate-cathode junction of T_2. Therefore, gate current is provided to T_2 and it is turned on. Turning on of T_2 immediately causes turning off of T_1 as mentioned above. The load current is interrupted and thus over-load protection is provided. Since no moving contact type mechanism is used for interruption of load current, this circuit configuration is called DC static circuit breaker. By proper selection of R_1 and number of diodes in string and replacing 'Stop' button by NO relay contact in fault sensing circuit, the circuit can be made to trip and interrupt the overload and fault current.

5 f) Give the principle of induction heating control with a neat representation.

Ans:

Principle of Induction Heating:

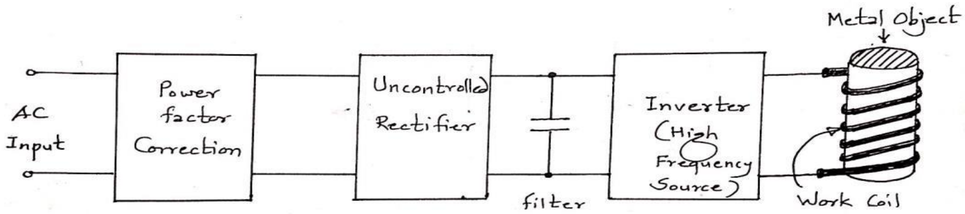
When a conducting object is subjected to a changing magnetic field, according to Faraday's laws of electromagnetic induction, emf is induced in the object. The object, being conductor, offers many short-circuited paths. So the circulating currents flow through these paths. The currents are in the form of eddies (circular in nature), hence called "eddy currents". The eddy currents flowing through resistive paths in metal object cause power loss (i^2R loss) and heat is produced. Since the heat is produced by eddy currents, which are induced by electromagnetic induction, this heating is called "Induction heating". The material to be heated is known as the work piece and the coil around it is known as work coil, as shown in the figure. The coil acts as primary and work piece acts as short circuited secondary. When primary is excited by high frequency ac supply, eddy currents are set up in the work piece and electrical power loss heats up the object. 2 Marks for principle



(a) Set-up for induction heating (b) Equivalent circuit

(c) Eddy currents (I_1, I_2) flow in work piece (d) Current density variation

2 Marks for diagrams



6 **Attempt any FOUR of the following:** **16**

6 a) List the factors required for selection of heat sink used for SCR.

Ans:

Factors required for selection of heat sink used for SCR:

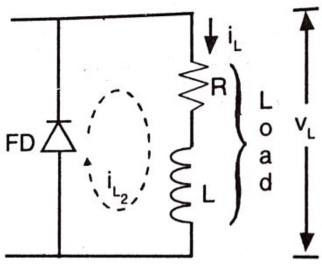
1)Thermal Resistance
2)Material
3)Arrangement shape size & location of fins
4)Fin efficiency
5)Thermal interface material
6)Heat sink attachment methods

1 Mark for each of any four factors = 4 Marks

6 b) Explain use of free wheeling diode in controlled converter

Ans:

The freewheeling diode (FD) is connected across output or load with its cathode to positive terminal and anode to negative terminal. When the load is highly inductive, the load inductance voltage gets reversed during the fall of load current. The output or load voltage then attempts to reverse but as soon as the reversed voltage becomes more than threshold voltage, the freewheeling diode conducts and provides path for inductive load current. Since diode conducts, it maintains the load voltage nearly equal to zero and prevents from becoming negative. It improves the average load voltage and helps to dissipate the power stored in load inductance.



1 Mark for diagram

3 Marks for explanation

6 c) List draw backs of harmonics at the o/p of inverter. Explain filter method of harmonic reduction.

Ans:

Drawbacks of harmonics in the output of Inverters:

Harmonics are voltage and current components at frequencies which are integral multiple of fundamental frequency. The harmonics are injected into the load supplied from the inverter and have following undesired effects:

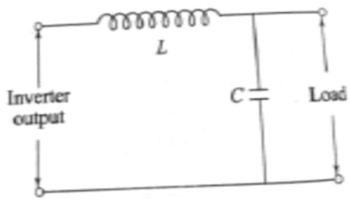
1) Overheating of neutral conductor because of high neutral current with harmonics
2) Overheating of motors and transformers due to additional losses caused by harmonics.
3) Torque pulsation of induction motor because of multiple torque production due to harmonics.
4) Drop in efficiency of motors and transformer as losses are increased due to the harmonics.

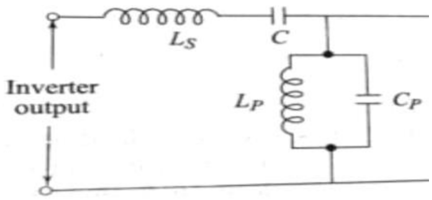
1 Mark for each of any three drawbacks = 3 Marks

5) Mal operation of relay and switchgear due to high frequency harmonics.
6) Possibility of overvoltage because of resonance at harmonic frequency.
7) Interference with the communication networks.

Filter method of harmonic reduction:

Harmonic filters come in many "shapes and sizes." In general, harmonic filters are "shunt" filters because they are connected in parallel with the power system and provide low impedance paths to ground for currents at one or more harmonic frequencies. 1 Mark for filter

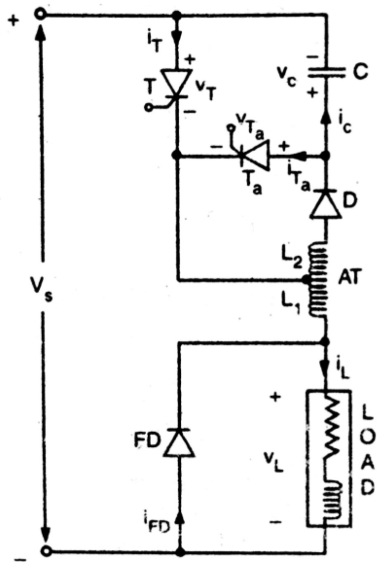




6 d) Describe the operation of jone's chopper with circuit diagram?

Ans:

Jones Chopper



Jones chopper

Explanation:

The circuit diagram of Jones Chopper is shown in the fig. It employs class D commutation technique in which a charged capacitor is switched by an auxiliary SCR to commutate the main SCR. The circuit operation can be divided into various modes as follows: 2 Marks for circuit diagram

Mode 1: In this mode, the main SCR T is triggered at start and then it conducts the load current. Since L1 and L2 are coupled inductors, the applied voltage across L1 results in emf induced in L2. This emf charges the capacitor C with shown polarity through diode D and conducting T. When capacitor is fully charged, the charging current falls to zero and cannot reverse due to diode. 2 Marks for explanation

Mode 2: In this mode, the auxiliary SCR Ta is triggered. Once Ta is turned on, the charged capacitor C is placed across main SCR T so as to apply reverse bias across it. Due to this reverse bias and alternate path provided by C and Ta to the load current, the main SCR is turned off. The load current now flowing through C and Ta causes capacitor to discharge fully.

Mode 3: The inductance L1 and load inductance try to maintain the load current through C and Ta. The load current charges the capacitor with reverse polarity i.e upper plate positive. With rising capacitor voltage, the load current attempts to fall. To maintain the falling load current, the inductive voltages in L1 and load changes their polarity. The reversal of load voltage VL forward biases the free-wheeling diode and it conducts. The capacitor gets overcharged due to the energy supplied by Vs and L1. The load current falls below holding current level of Ta , hence Ta is turned off.

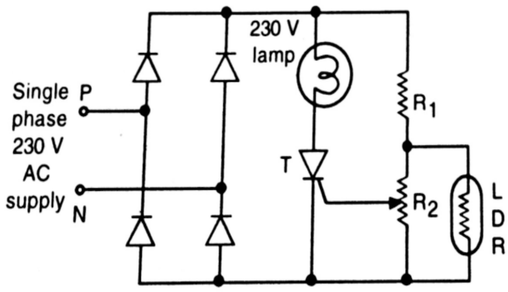
Mode 4: The overcharged capacitor C, with upper plate positive, then starts discharging through Vs, FD, L1, L2 and D. The discharging current is in the form of a pulse. At the end of this mode, the capacitor voltage falls to a level less that Vs and therefore current falls to zero and attempts to reverse but diode stops conducting

Mode 5: The capacitor voltage with upper plate positive is maintained till the next firing of T. The load current is continued through free-wheeling diode till the next conduction of main SCR T. Jones chopper offers flexible control and effective use of trapped energy in coupled inductors. There is no starting problem and any SCR can be triggered at start.

6 e) Give the operation of automatic street lighting circuit using SCR with neat diagram.

Ans:

Automatic street lighting circuit using SCR:



Automatic street lighting system

2 Mark for circuit diagram

2 Marks for explanation

The circuit configuration of automatic street lighting system using SCR is shown in the fig. This circuit provides automatic glowing of street lamps in the evening. A light dependent resistor (LDR) is used as sensor for sensing the intensity of day light. When sufficient light falls on LDR, its resistance becomes very low as compared to R2. The R2 is then bypassed by LDR, and major part of current flowing through R1, flows through LDR. Since negligibly small current flows through R2, sufficient gate current is not received by SCR T and it is maintained off. Thus no current can flow through lamp and it remains off. In the evening hours, the intensity of day light is reduced. Hence resistance of LDR increases. Therefore current through R2 also increases. At certain darkness, the resistance of LDR becomes so high that the sufficient current flows through R2 to provide sufficient gate current to SCR and it is fired. Therefore, current flow through lamp and it glows. Since bridge rectifier provides pulsating DC, the SCR is triggered in every positive pulse and turn-off at the end of pulse at natural current zero value, assuming lamp is purely resistive. However, if the lamp is inductive, the lagging current prevents SCR from turning off at the end of positive pulse. Thus once SCR is turned on, it loses control and separate arrangement is necessary to turn-off the SCR.

(any other relevant explanation & circuit diagram should also considered)