DIPLOMA - BOARD EXAMINATION -APRIL 2024

ANSWER KEY FOR THE QUESTION CODE: 528

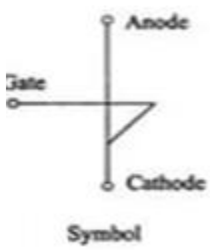
SUBJECT NAME: POWER ELECTRONICS/4030631 **BRANCH: EEE**

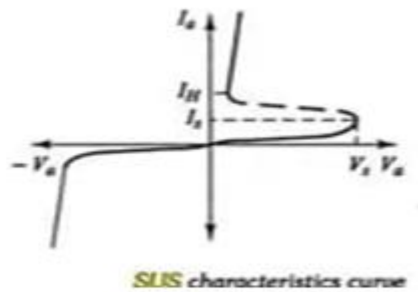
SCHEME: N **MAXIMUM MARK: 100** **SEMESTER: 6th**

PART-A 10×3=30 (Each Question Carries 3 marks)

Q.NO:1.Draw the Symbol of SUS and draw its V-I Characteristics .

(Symbol=2 marks+ V-I Characteristics =1 mark)





Q.NO:2.What is Commutation? (3 marks)

- Commutation is defined as **the process of turning OFF a SCR**.
- Once SCR starts conducting, gate losses it controls over the device, therefore external circuit may be adopted to commutate the SCR

Q.NO:3. .Write short notes on phase controlled rectifier. (3 marks)

Phase controlled rectifier converts a **constant AC voltage in to controlled DC voltage.** To obtain controlled output voltage, phase control thyristors are used instead of diodes. The output voltage of these rectifiers is varied by controlling the delay or firing angle of thyristors.

Q.NO:4.What is the effect of inductive load in the performance of a three – phase bridge rectifier?

(3 marks)

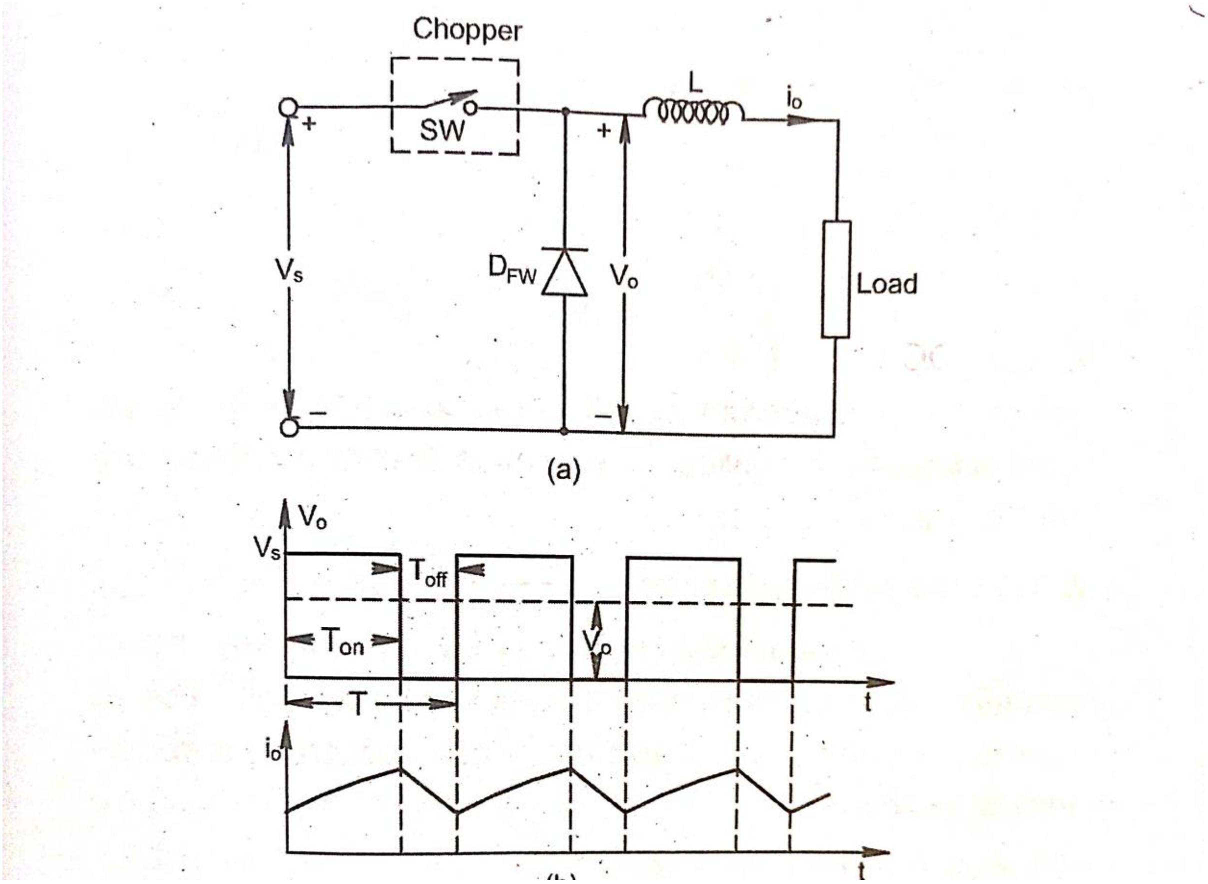
An inductive load can have a significant impact on the output rectifier of a power supply. When an inductive load is connected to the output of a rectifier, it can cause

Voltage spikes and **current surges**, which may lead to increased stress on the rectifier components. These voltage spikes can cause the rectifier to operate at higher voltage levels than anticipated, potentially leading to **decreased efficiency** and **increased heat dissipation.**

To mitigate these effects, additional filtering components such as capacitors and inductors may be required to smooth out the output voltage and current.

Q.NO:5. What is the principle of chopper operation? (3 marks)

DC chopper converts directly from **DC to DC.** A chopper is a **high speed ON/OFF semiconductor switch**. A simplified diagram of DC chopper and its waveforms are shown in the fig. **The fixed DC voltage can be converted to a variable average voltage on a load by placing a high speed switch in between DC source and the load. The high speed static switch is called the chopper.**



Q.No: 6.What are the applications of inverters? (Any 3 Application= 3 Marks)

The applications of inverters are

i) Variable speed AC motor drives.

ii) Speed control of AC motors.

iii) Aircraft power supplies.

iv) Induction heating.

v) Uninterruptible power supplies.

vi) High voltage DC transmission.

Q. No:7.Write down the basic DC motor speed equation. (3 marks)

i) The speed of DC motor Nα $\frac{V-IaRa}{\emptyset} = \frac{V-IaRa}{K1\emptyset}$

Where V= supply voltage

Ia= Armature current

Ra = Armature Resistance

K1 = constant

ii) Torque TαIa = K2ØIa

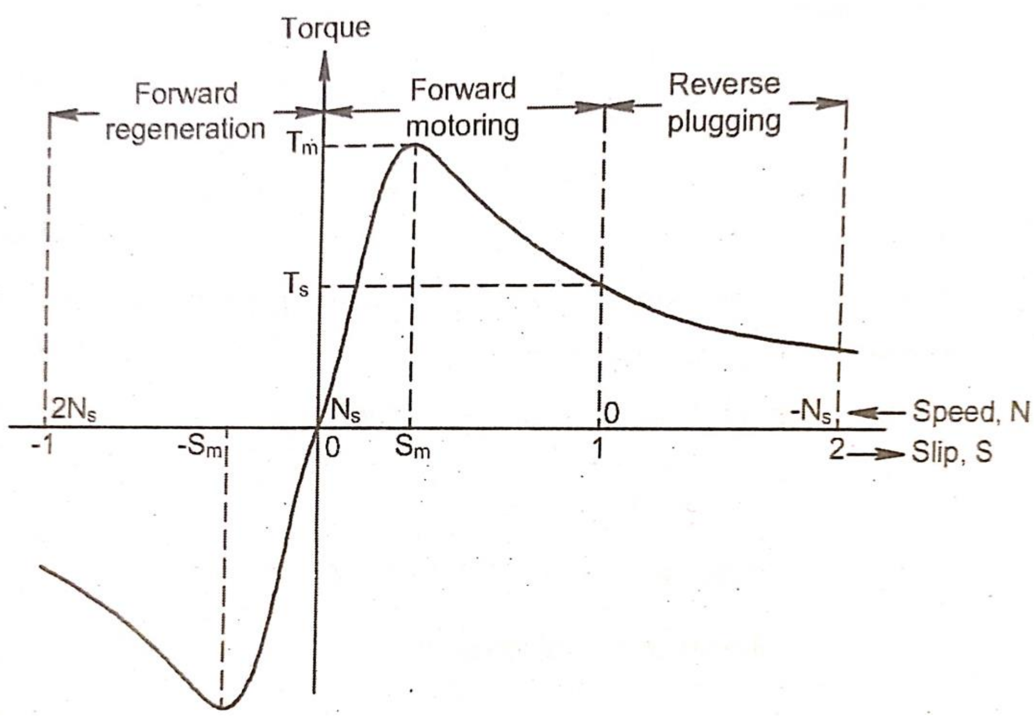
K2 constant

Q.No: 8.What is meant Four quadrant control of DC motors? (3 marks)

Four Quadrant Operation of any drives or DC Motor means that the machine operates in four quadrants There are:

Forward Braking, Forward motoring, Reverse motoring and Reverse braking.

Q.No: 9.What is the torque-speed characteristics of induction motors? (3marks)



The torque-speed characteristics of an induction motor connected to a constant voltage and constant frequency supply. This characteristic is divided into three regions, namely; Motoring (Forward motoring) region, Generating (Forward regeneration) region and Braking (Reverse plugging) region.

Q.No: 10.What is cyclo converter? (3 marks)

A cycloconverter is a **frequency changer** that converts **AC input power at one frequency in to AC output power at a different frequency without using any intermediate DC link**. A cycloconverter is a **one stage frequency changer**. A cycloconverter is also called **cycle converter**.

PART-B 5×14=70 (Each Question Carries 14 marks)

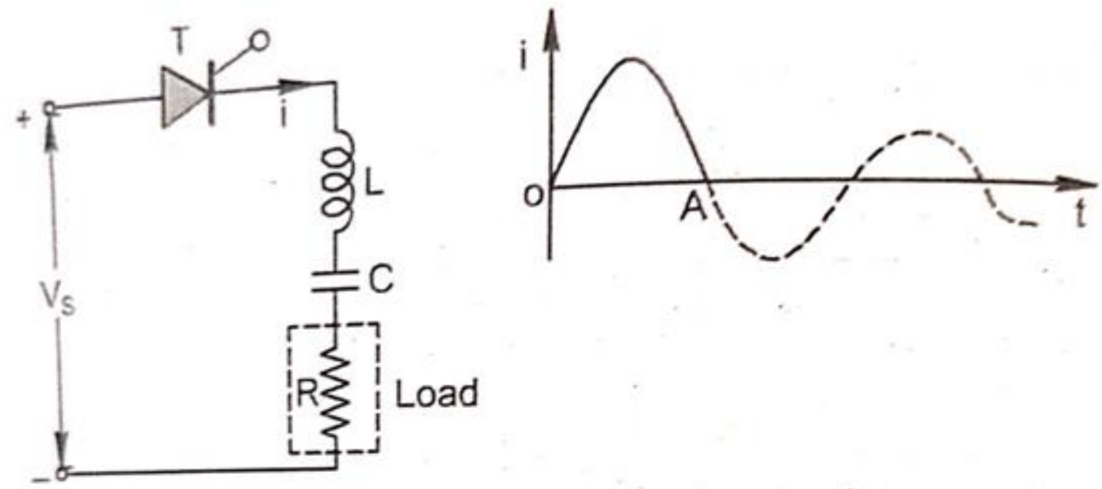
Q.NO:11.(a) Differentiate natural commutation and forced commutation. Explain the methods used for achieving forced commutation

Difference : 4 marks

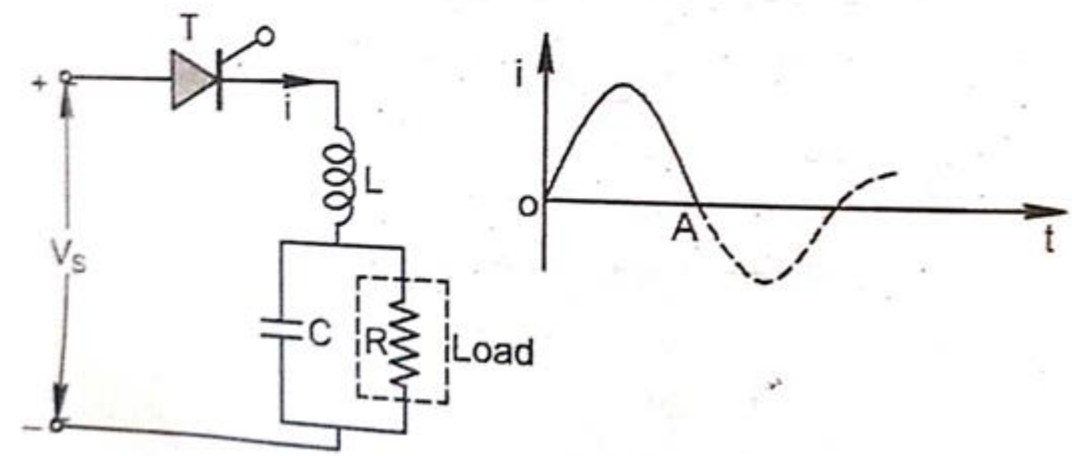
Sr. No.	Natural commutation	Forced commutation
1	Requires AC voltage at input	Requires DC voltage at input
2	External components are not required.	External components are required.
3	Used in controlled rectifiers, AC voltage controller	Used in choppers, inverters etc.
4	SCR turns off due to negative supply voltage.	SCR turns off due to current & voltage both
5	No Power loss takes place during commutation	Power loss takes place during commutation
6	Zero cost	Significant cost

The methods used for achieving forced commutation. (Explanation of Any two commutation Methods: 10 Marks)

CLASS A COMMUTATION



Series capacitor



Shunt capacitor

The circuit diagram of class A commutation is shown in the fig.

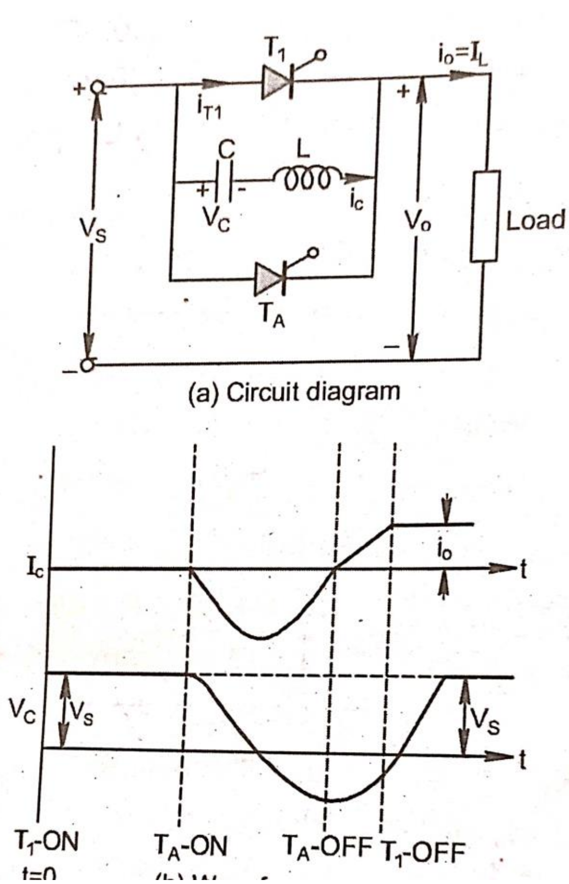
Here R is the load resistance. For low value of R, the L and C are connected in series. For high value of R, load R is connected across C.

When DC voltage is applied, the current 'i' first rises to maximum value and then begins to fall. When current decays to zero and tends to reverse, SCR T is turned OFF on its own at instant A. Beyond point A the current is negative which assures definite commutation of the device.

The time for switching OFF the SCR is determined by the resonant frequency of the commutating circuit.

Hence this method is also called resonant commutation or self commutation. It is more suitable for high frequency operation generally used in series inverters.

CLASS B COMMUTATION



(a) Circuit diagram

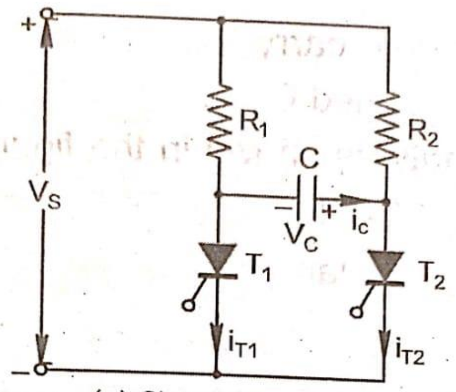
The circuit diagram of class B commutation circuit is shown in the fig. Here the commutation components L and C are connected across the SCR.

The commutation components do not carry load current.

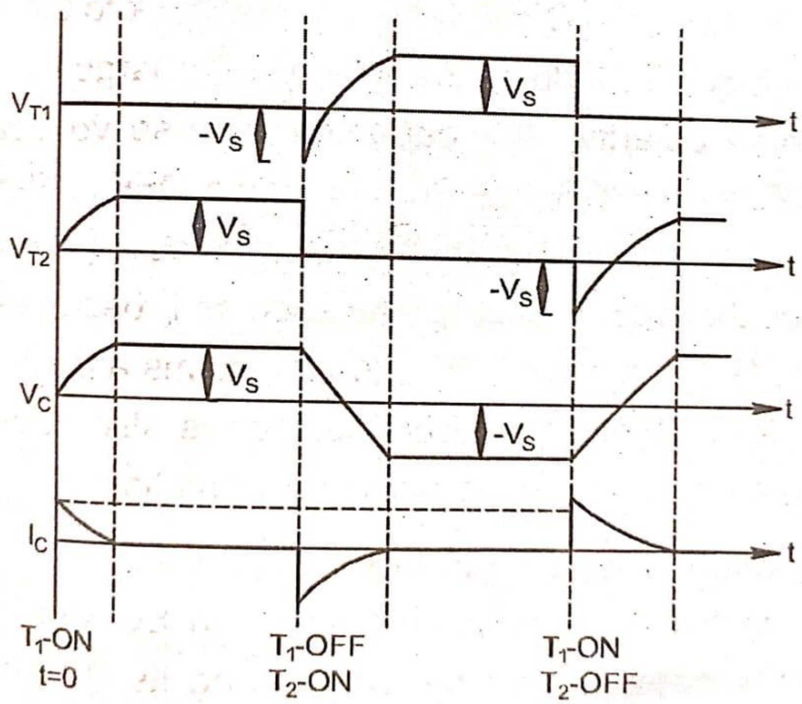
When the supply voltage (V) is switched ON, the capacitor charges to voltage Ve with the polarity as shown in the figure. Main SCR T_1 as well as auxiliary SCR TA are in OFF level. When T, is turned ON at 0, a constant load current I will flow through the load.

When TA is switched ON, a resonant current i begin to flow from C through TA, L and back to C. At the end of discharge, the inductance energy will charge the capacitor in reverse polarity. The capacitor reverse voltage applies reverse bias to SCR TA. So it is turned OFF. After that, the reverse voltage in the capacitor will produce a current i, which opposes the load current IL. As soon as i becomes equal to IL, SCR (T_1) is turned OFF. Its waveforms are shown in the above fig. This type of commutation is also called current commutation or resonant pulse commutation.

CLASS C COMMUTATION



(a) Circuit diagram



In this type of commutation, an SCR carrying load current is commutated by transferring its load current to another incoming SCR.

The circuit diagram and waveforms of Class C commutation are shown in the fig.

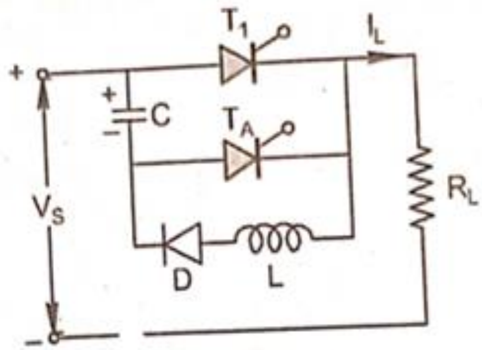
In this figure the firing of SCR T, commutates T_2 and subsequently, firing of SCR T_2 would turn OFF T1.

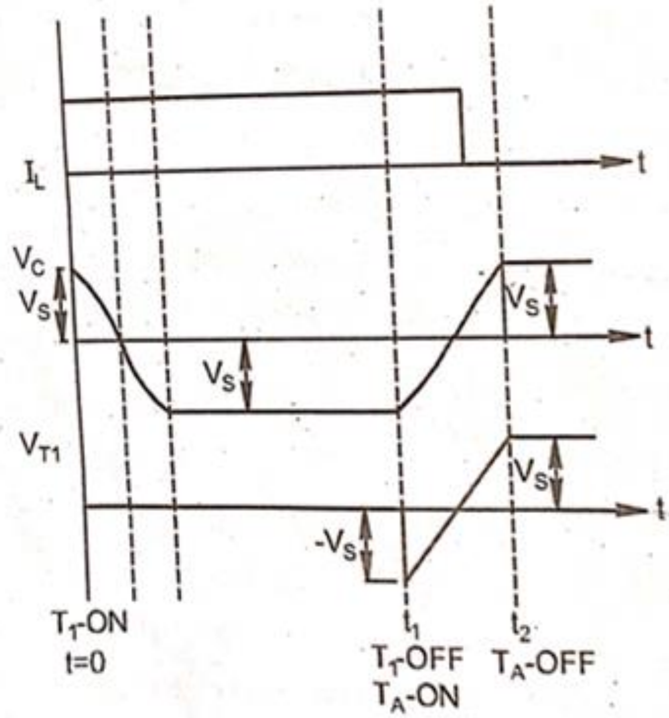
When the SCR T_1 is tuned ON the load current flows through R, and T_1. At the same time the capacitor C is charged to the supply voltage V. through resistor R_2 with the polarity as shown in the figure.

When SCR T2 is turned ON, the capacitor is switched across SCR T_1 and the capacitor voltage gives reverse voltage across SCR T, and it turns OFF. Now the capacitor will be charged in the opposite direction through resistor R_1 and SCR T2. The circuit is now ready to commutate SCR T2 when SCR T_1 is turned ON.

This type of commutation circuit is used in Mc-Murray Bed ford inverter and it is very useful' at frequencies below about 1000Hz.

CLASS D COMMUTATION





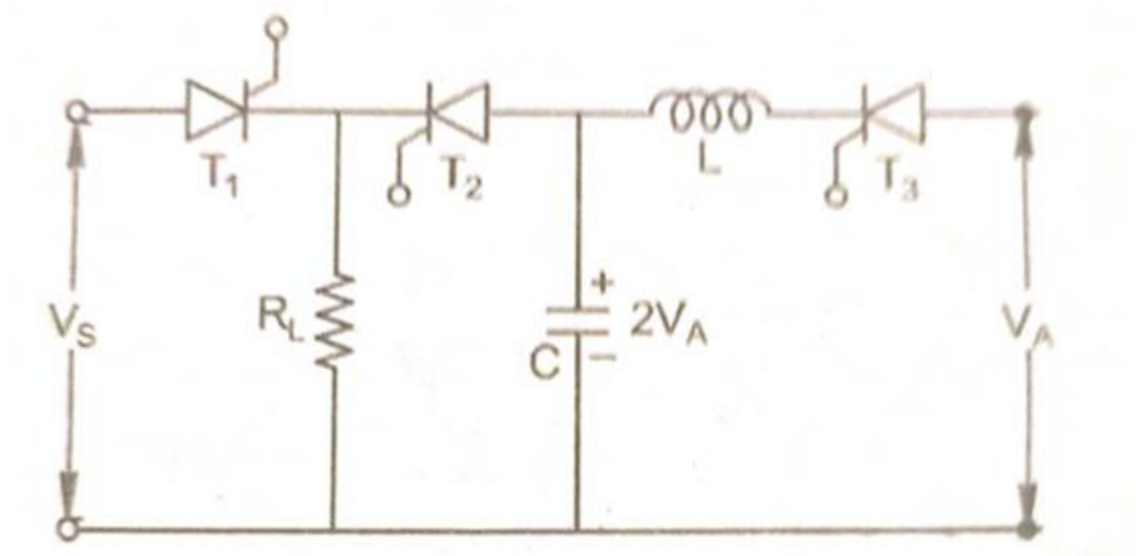
The circuit diagram of class D commutation and its waveforms are shown in the above fig.

In this method an auxiliary SCR (TA) is required for commutating the main SCR (T_1). Initially, the auxiliary SCR (TA) is turned ON so that capacitor C is charged to voltage Vs, with the polarity as shown in the figure. The SCR TA turns OFF when the capacitor is fully charged because the current through TA falls below the holding current value.

When SCR T_1 is turned ON (t = 0), the load current I flows through SCR T_1 and RL. At the same time the capacitor C discharges through SCR T_1, inductor L and diode D. At the end of the discharge the magnetic flux across L is collapsed. So that the capacitor will be charged towards supply voltage (V) with reverse polarity.

When SCR TA is turned ON (time t_1), the capacitor C applies a reverse voltage to SCR T_1 and turns it OFF. Again the capacitor C is charged to voltage V, with the polarity shown in the figure. The auxiliary SCR (TA) is used for turning OFF the main SCR T_1. So this type of commutation is also known as auxiliary commutation or voltage commutation.

CLASS E COMMUTATION



In this type of commutation, a pulse of voltage is obtained from a separate voltage source to turn-OFF the conducting SCR.

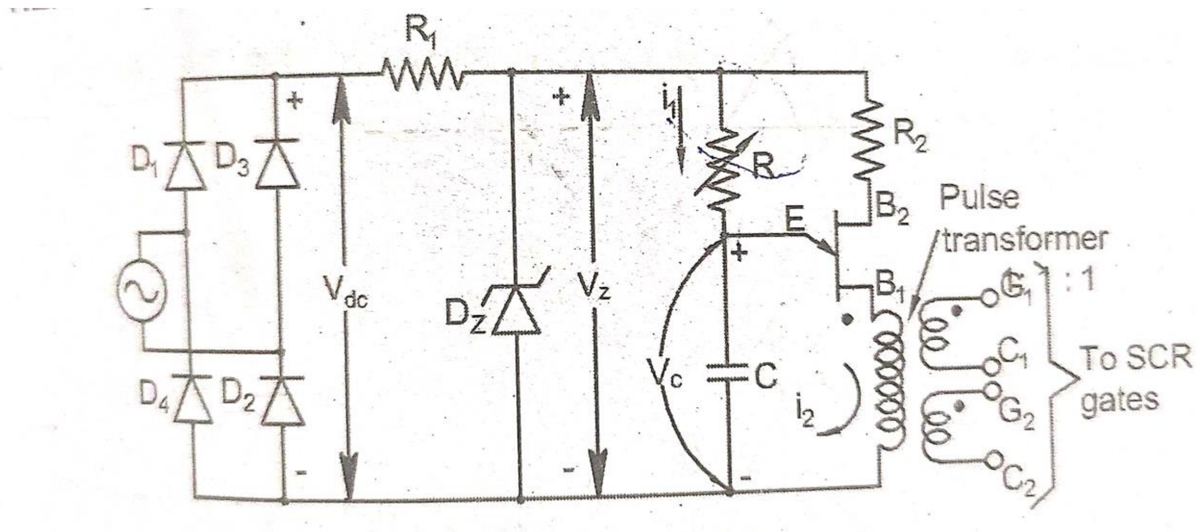
The peak voltage of the pulse must be more than the magnitude of main source voltage.

The circuit diagram for class E commutation is shown in the fig. Here Vs is the main source voltage and Va is the auxiliary supply voltage. When T_1 is conducting, the load is connected to the voltage source Vs. When thyristor Ta is turned ON at t = 0, VA, T3, L and C form an oscillatory circuit. Therefore C is charged to a voltage 2VA, with the upper plate as positive. The capacitor voltage provides reverse bias to T3, so it is commutated.

For turning OFF the main thyristor T1, thyristor T2 is turned ON. When T2 is ON, the capacitor voltage provides reverse bias to T_1. Therefore T_1 is turned OFF. After T_1 is OFF the capacitor discharges through the load. When capacitor is fully discharged, T2 goes to turn OFF automatically.

Q.No: 11.b <u>Draw and explain the circuit diagram for the synchronized UJT trigerring.Also draw the associated voltage waveforms</u>

(Circuit Diagram= 7 marks , Explanation = 7 marks)



Synchronized UJT trigger circuit using an UJT is shown in the above fig. The diode bridge D1-D4 rectifies AC to DC. Resistor R_1 lowers Vdc to a suitable value for the zener diode and UJT. Zener diode Z is used to clip the rectified voltage to a standard level V_2, which remains constant except near the Vac zero. This voltage V_2 is applied to the charging circuit RC. Current i_1 charges capacitor C through R until it reaches the UJT trigger voltage η Vz. The UJT then turn ON and C discharges through the UJT emitter and primary of the pulse transformer, sending a current i2.

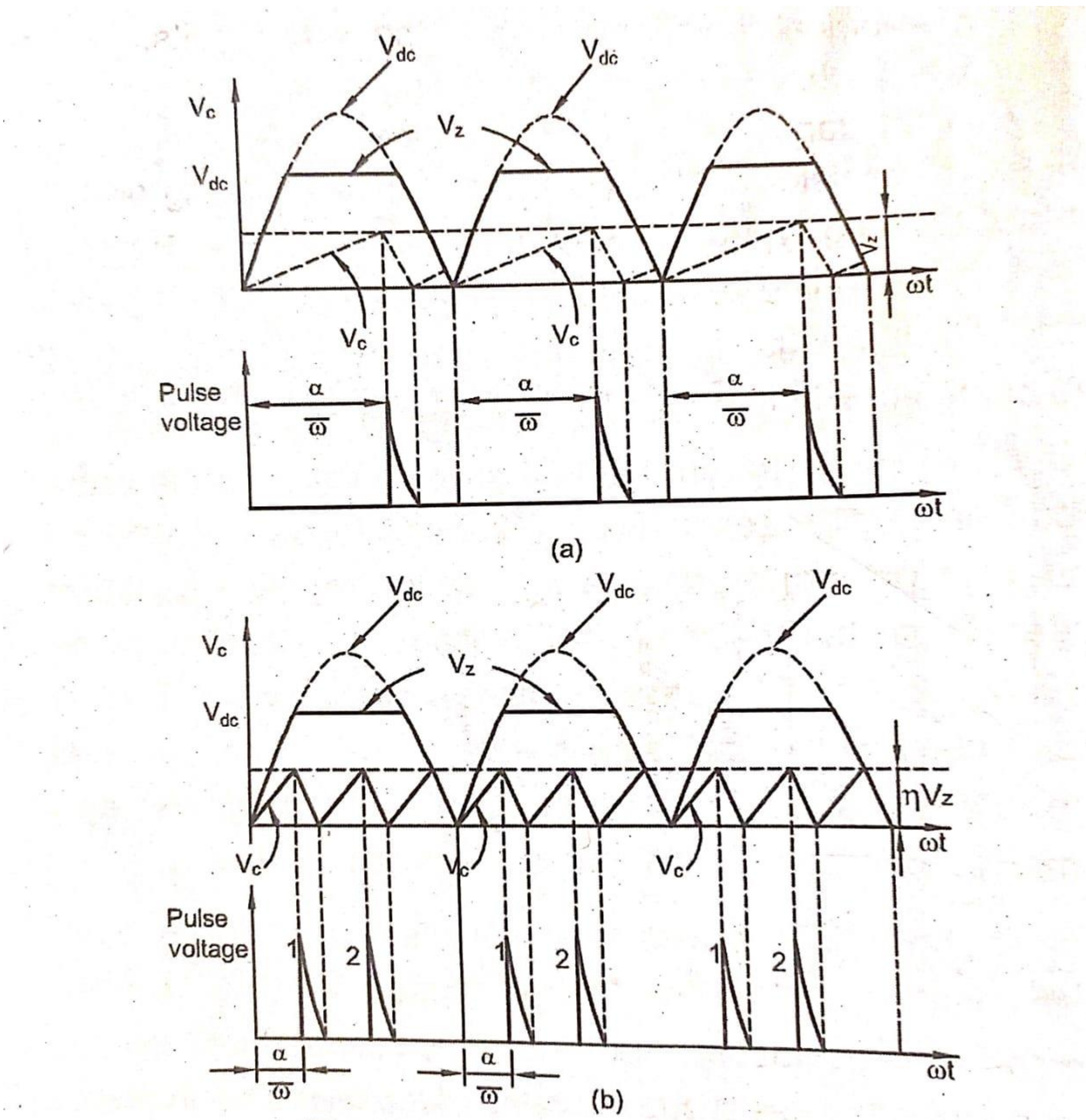
The voltage across capacitor is shown in the fig. As the current iz is in the form of pulses, winding of pulse transformer have pulse voltages at their secondary terminals. Pulses at the two secondary windings feed the same in phase pulse to two SCRs of a full wave circuit. SCR with positive anode voltage would turn ON. Rate of rise of capacitor voltage can be controlled by varying R.

The firing angle can be controlled up to about 150°. This method of controlling is called ramp control, open loop control or manual control.

As the zener diode voltage Vz goes to zero at the end of each half cycle, the synchronization of the trigger circuit with the supply voltage SCRs is achieved.

In case R is reduced, so that Vc reaches UJT trigger voltage twice in each half cycle as shown in the fig. Then there will be two pulses in each half cycle. As the first pulse will turn ON the SCR, second pulse in each cycle is redundant.

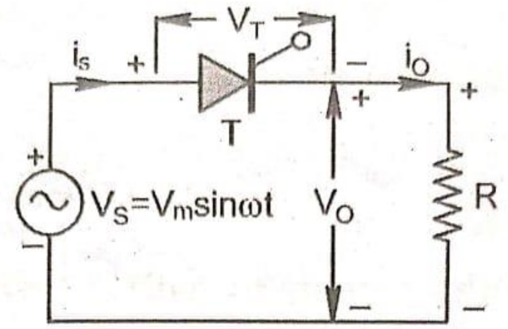
Waveforms:



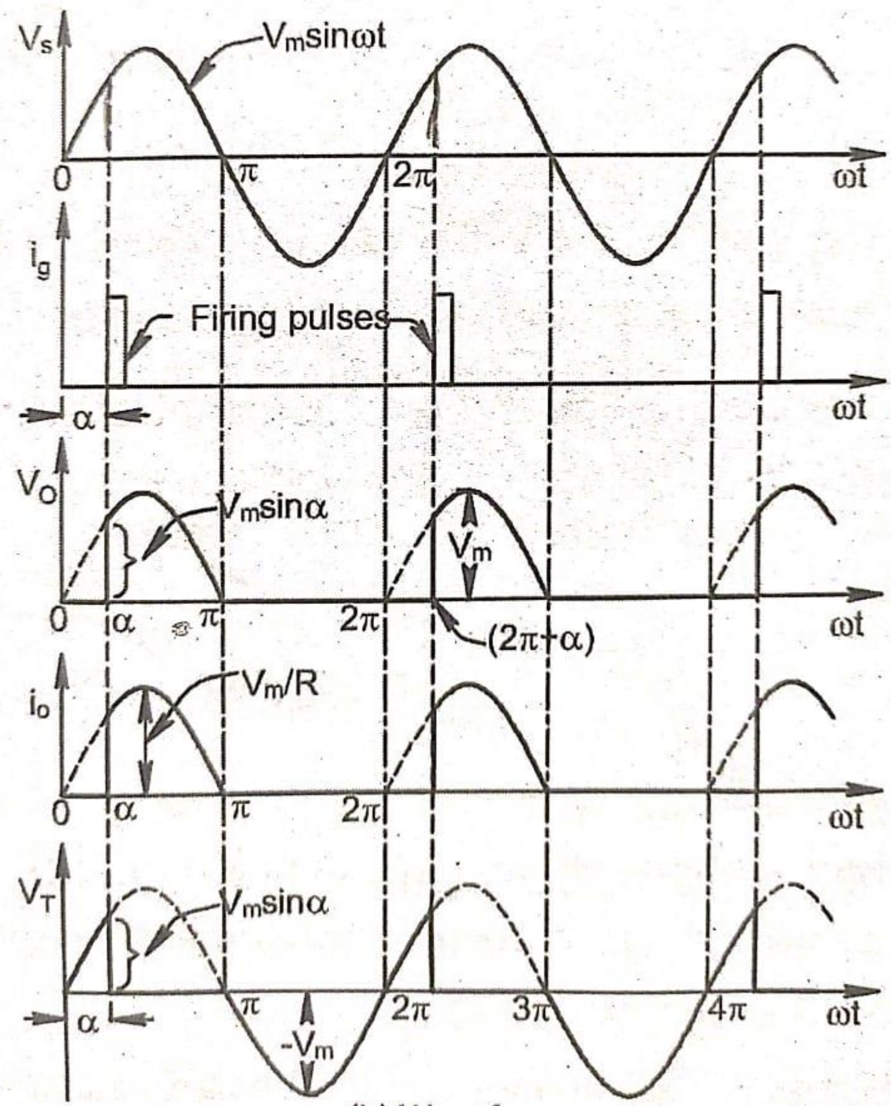
Vdc
Vdc
Vc
Vz
Vdc
Vz
ωt
Vc
Vc
Pulse voltage
α/ω
α/ω
α/ω
ωt
(a)
Vdc
Vdc
Vdc
Vc
Vz
Vdc
ηVz
ωt
Vc
Vc
Vc
Pulse voltage
1
2
1
2
1
2
α/ω
α/ω
ωt
(b)

Q.No: 12.a Explain Half Wave-Controlled Rectifier with resistive Load .

(Circuit Diagram= 7 marks , Explanation = 7marks)



(a) Circuit diagram



(b) Waveforms

A single phase half wave controlled rectifier with resistive load is shown in the fig.

The source voltage Vs = Vmsinωt. An SCR can conduct only when the anode voltage is positive and a gating signal is applied. As such, a thyristor (SCR) blocks the flow of load current i, until it is triggered.

At some delay angle α, a positive gate signal applied between gate and cathode, turns ON the SCR. Immediately full supply voltage is applied to the load as Vo. At the instant of delay angle α, Vo rises from zero to Vmsinα. for resistive load, the current is inphase with Vo

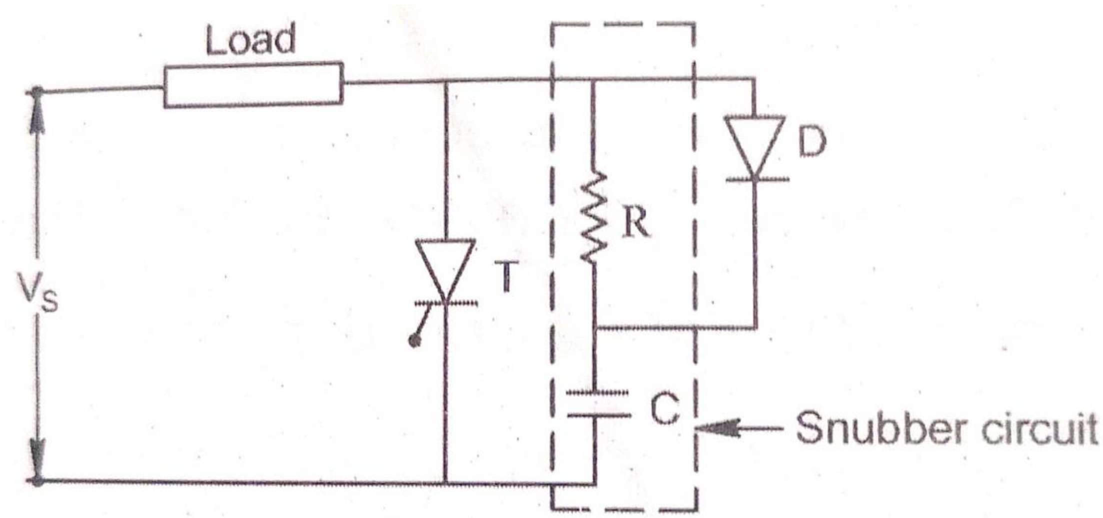
A firing angle may be defined as the angle measured between '0' angle and at which the SCR is triggered.

Once the SCR is turned ON, load current flows until it is turned OFF by reversal of voltage at wt = π, 3π etc. At these angles the load current falls to zero and soon after supply voltage reverse biases the SCR, the device is therefore turned OFF.

A single phase half wave circuit is one which produces only one pulse of load current during one cycle of source voltage. The SCR placed in this circuit conducts from wt = a to π, (2π + a) to 3π and so on. As the firing angle is increased from 0 to π, the average load voltage decreases from the largest value to zero.

Q.No: 12.(b) Explain about dv/dtand di/dt protection short circuit protections

dv/dt protection(Circuit Diagram= 4marks , Explanation = 3marks)



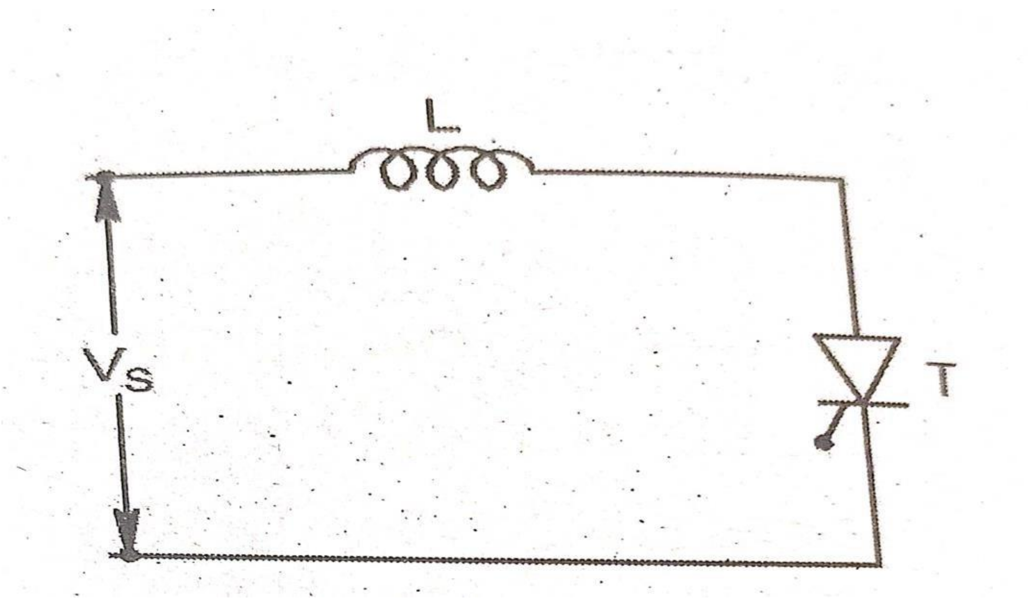
If the rate of rise of forward voltage dv/dt is high, the current flow through the thyristor is large enough to turn- ON If even without the gate pulse. Such a phenomenon of turning ON of a thyristor is called dv/dt turn ON. It has to be avoided because it is a false turn ON of the thyristor without the controlling of gate signal.

For controllable operation of the thyristor, the rate of rise of forward anode to cathode voltage must be kept below the specified rated limit. The limiting value of dv/dt range isinbetween20-500V/µs. False turn-ON of a thyristor is prevented by suppressing the dv/dt values using RC networks called snubber. A basic snubber circuit is shown in the fig. The snubber circuit basically consists of a series connected resistor and capacitor placed in shunt with an SCR. The snubber circuit can be made more effective by connecting a diode across the resistor.

Whenever there is a voltage transient across the SCR, the current flows through the diode and capacitor. Now the capacitor C behaves like a short circuit and brings down the voltage across the SCR to zero. Then the capacitor is linearly charged to a voltage equal to the forward blocking voltage of the thyristor, that is about to be turned ON.

When SCR is turned ON, the capacitor gets short circuited and discharges a heavy current through the SCR. This leads to a very high di/dt that is capable of destroying the SCR. The resistor connected in series with the capacitor is used for limiting the di/dt as well as the peak discharge current.

di/dt protection (Circuit Diagram= 4marks , Explanation = 3 marks)

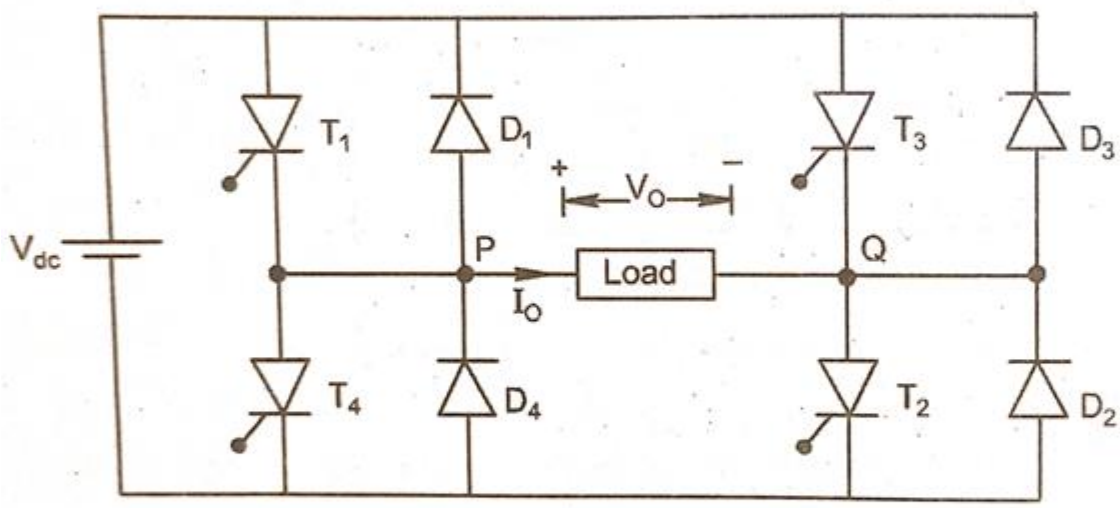


At the instant of turn-ON of the thyristor, conduction of anode current starts in the gate cathode junction. Thereafter the current spread rapidly across the whole area of the junction. But it is necessary that the current spreads uniformly over the surface of the junction.

However if the rate of rise of anode current that is di/dt is very high, the current may not spread uniformly and this will lead to the formation of local hot spots near the gate-cathode junction on This localized heating may destroy the thyristor. Therefore it is essential that the rate of rise of anode current at the time of turn-ON is kept below the specified limiting values. This is achieved by connecting a small inductor in series with the thyristor. Typical di/dt limiting values of SCRs range between 20-500 A/µs.

Q.No: 13.(a) Explain the operation of Single-phase Full Bridge inverter with neat sketch.

(Circuit Diagram= 7marks, Explanation = 7 marks)



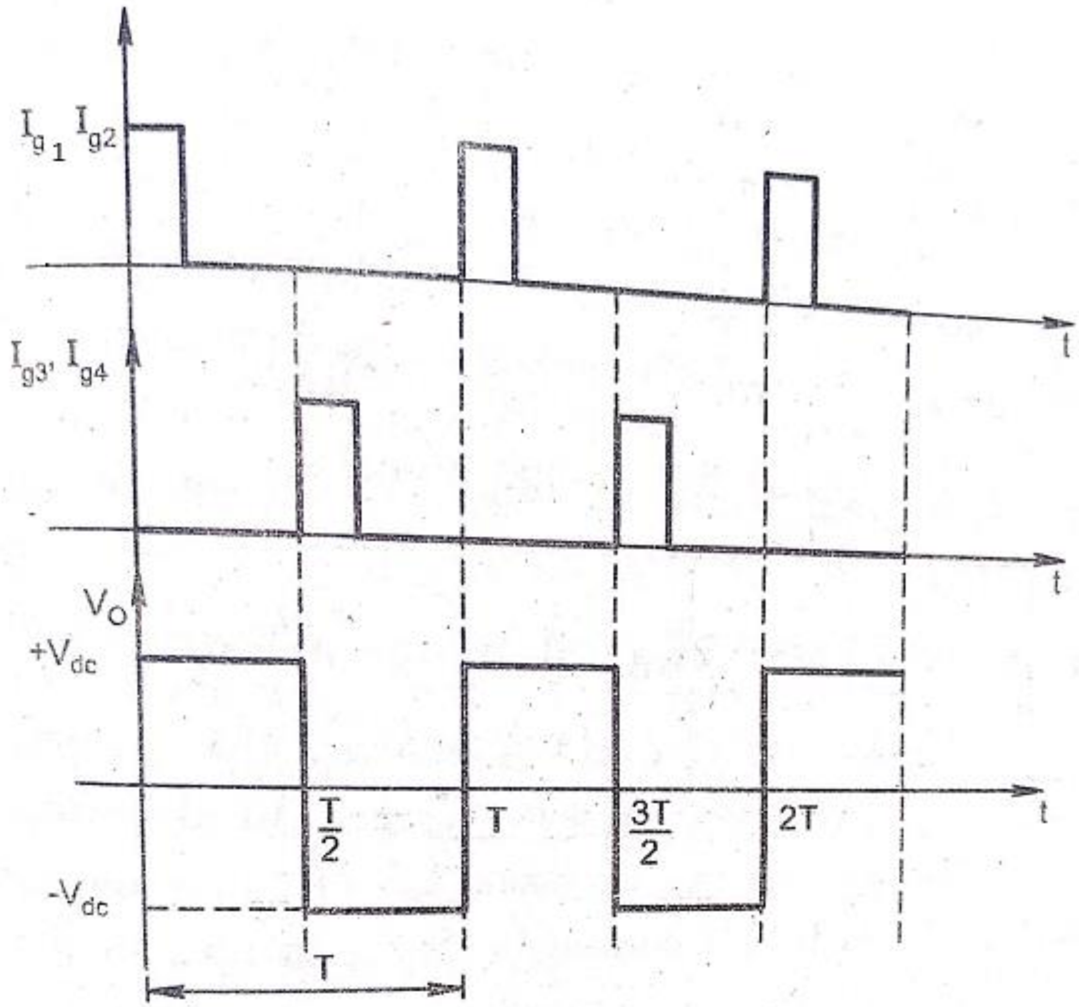
Single phase full bridge inverter

The circuit diagram of full bridge inverter is shown in the fig. It consists of four SCRs (T1, T2, T3 and T4) and four diodes (D1, D2, D3 and D_4) which is double the number of SCRs and diodes employed in a half bridge inverter. The amplitude of the output voltage is also doubled in this inverter as compared to that of half bridge inverter.

When the SCRs T, and T_2 conducts simultaneously at time t = 0, the load current flows from P to Q, and the load voltage is positive (+Vdc). At time t = T/2, the SCRs T1, and T2 are turned OFF and T3 and T4 are turned ON. When T3 and T4 are turned ON, the load current flows from Q to P. and the load voltage is negative (Vdc). At time t = T, the SCRs T3 and T4 are turned OFF and the SCRs T1, and T2 are turned ON again.

The frequency of output voltage can be controlled by varying time period T. During inverter operation, it should be ensured that two SCRs in the same branch (such as T1 and T4 or T2 and T3) do not conduct simultaneously. This would lead to a direct short circuit for the source.

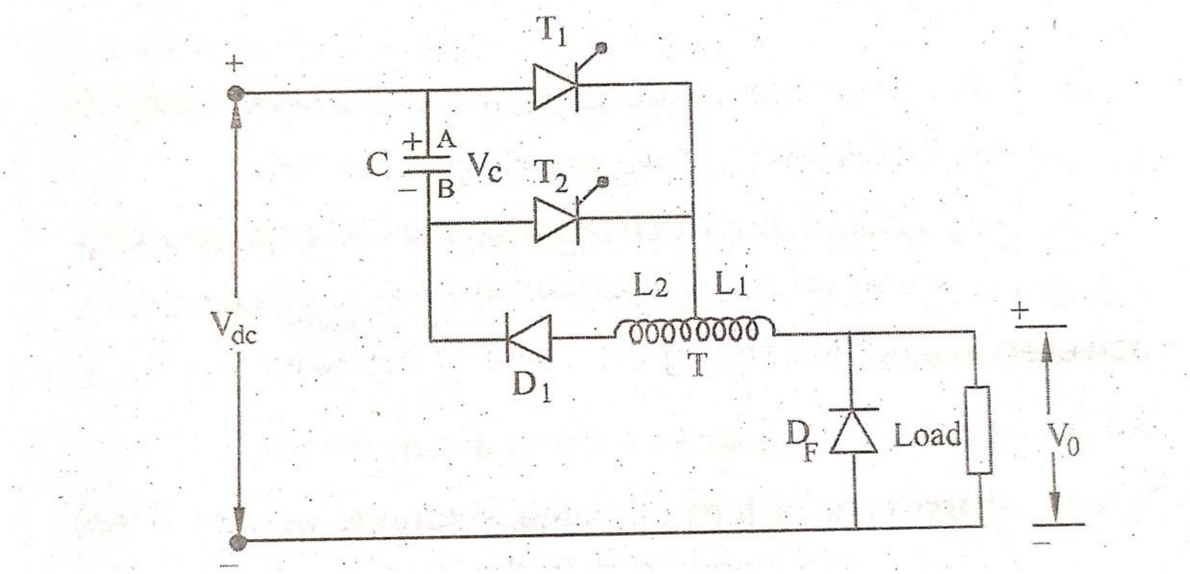
For resistive loads, the feedback diodes are unnecessary because load current (Io) and the load voltage (Vo) would always be in phase with each other. For inductive loads, the load current will not be in phase with load voltage and the diodes connected in antiparallel with SCRs allow the load current to flow when the main SCRs are turned OFF.



Waveforms of full bridge inverter

Q.No: 13 (b) Explain Jones Chopper with suitable circuit and waveforms

(Circuit Diagram= 7 marks, Explanation = 7 marks)



This chopper circuit is an example of class D commutation. In this circuit, SCR T1 is the main thyristor; where as SCR T2, capacitor C, diode D_1 and auto transformer (T) forms the commutating circuit for the main thyristor T1. Because of the auto transformer (T) the capacitor always gets sufficient energy to turn OFF the main SCR T1.

We assume that initially the capacitor C is charged to a supply voltage Vdc with the polarity as shown in the figure. When SCR T1 is turned ON, the charged capacitor C discharges through the path CA. T1. L2. D1, CB and capacitor C, and capacitor C charges to opposite polarity. i.e. the plate B positive and A negative. However diode D_1 prevents further oscillation of the resonating L2C circuit. Hence capacitor C retains its charge until SCR T2 is triggered.

When SCR T2 is turned ON, the capacitor discharges through the path C. T2 and T1. The discharge of capacitor C reverse biases SCR T_1 and turns it OFF. The capacitor again charges up with its original polarity (phase A as positive) and SCR T2 Turns OFF because the current through it falls below its holding current value, when capacitor is recharged. This cycle repeats when SCR T_1 is again turned ON.

The use of auto transformer is that whenever the load current flows through L_1 will induce a voltage in L2 with correct polarity for charging the commutating capacitor (C) to a voltage higher than Vdc. This will enhance the reliability of the circuit.

ADVANTAGES

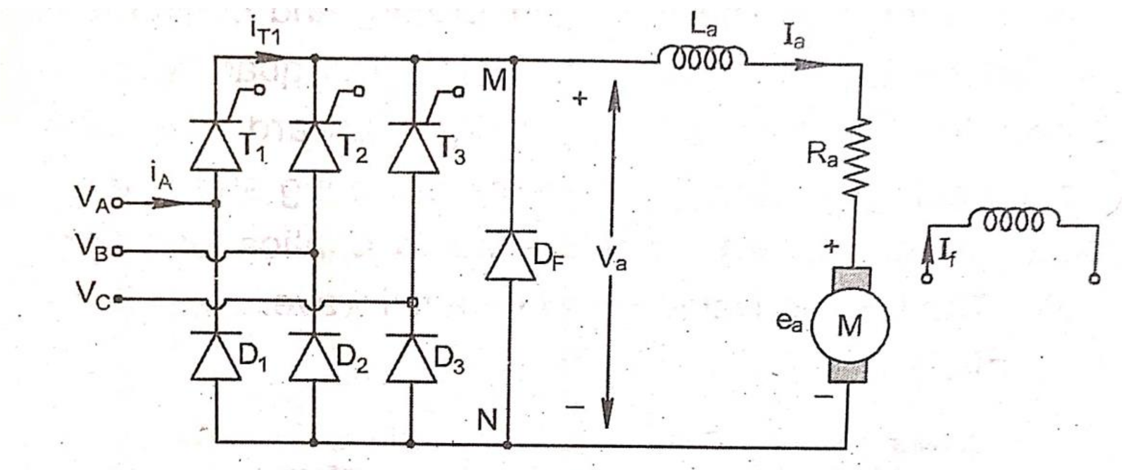
i) This circuit provides good commutation even when the capacitor is not charged to full voltage. This is due to the presence of the auto transformer in the circuit.
ii) Output voltage can be controlled by varying chopper frequency.
iii) This circuit can be used to control DC series and DC shunt motors.
iv) Higher flexibility, because both the ON time and OFF time can be varied individually.

DISADVANTAGE

SCRs with higher PIV rating are required.

Q.No:14(a) Draw and explain the operation of Three phase Semi Converter drive circuit.Also derive the output voltage equation.

(Circuit Diagram= 7 marks, Explanation = 7 marks)



Power circuit

The circuit diagram of three phase semi converter drive is shown in the fig.

It is one quadrant drive without field reversal and is limited to applications up to 115 KW. The field converter should also be a single phase or a three phase semi converter.

The Thyristor T1ω, and diode D3 conduct during the interval $(\pi/6 + \alpha) < \omega t < \omega t3$.

Therefore motor terminal M is connected to phase voltage V and terminal N is connected to phase voltage VA. Thus motor terminal voltage during this period is Va = VA-VC =VAC. At ωt3, Va is zero, and from this time onwards Va tends to be negative. The freewheeling diode DF thus becomes forward biased at ωt3 , and motor current flows through it until the next thyristor T_2 is turned ON at $(a + 2\pi/3)$. In the absence of freewheeling diode, freewheeling action would have taken place through T_1 and D1

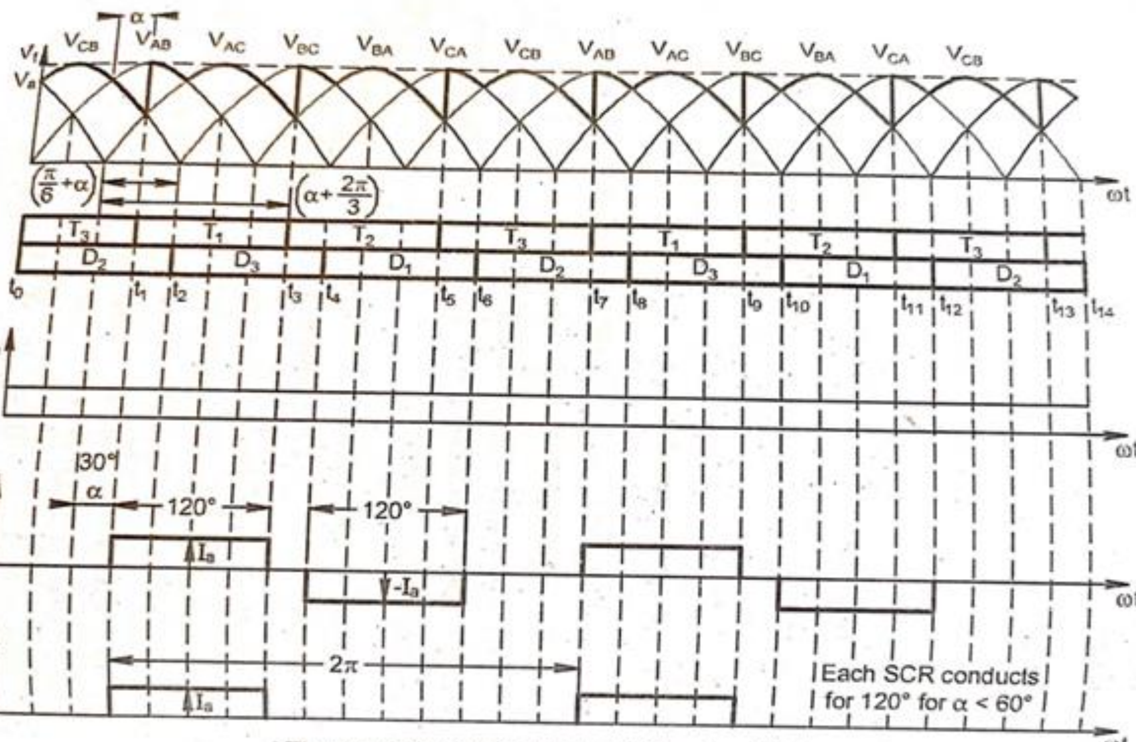
At large firing angles the motor current can be continuous or discontinuous, depending on the current demand and speed.

The armature voltage of this semi converter drive is,

$$V_a = \frac{3\sqrt{3}\,V_m}{2\pi}(1 + \cos\alpha_a) \qquad \text{for } 0 \leq \alpha_a \leq \pi$$

The field voltage is,

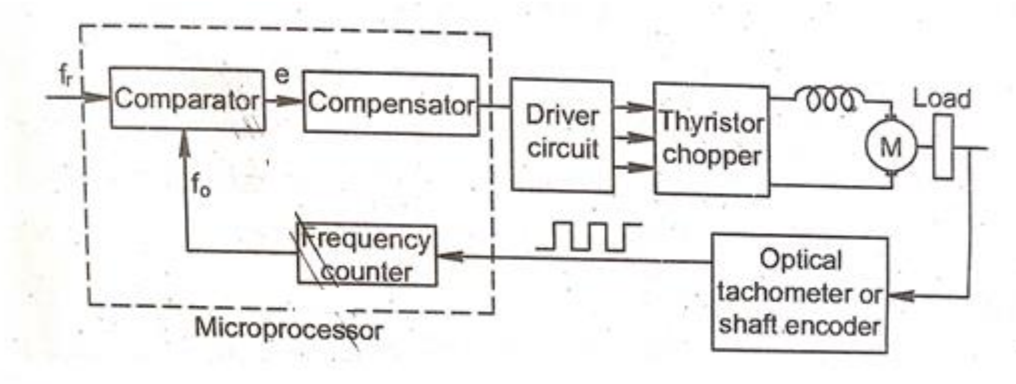
$$V_f = \frac{3\sqrt{3}\,V_m}{2\pi}(1 + \cos\alpha_f) \qquad \text{for } 0 \leq \alpha_f \leq \pi.$$



Three phase semiconverter DC motor drive-waveforms

Q.No:14.(b) (i) Explain the principle of microprocessor based closed loop control of DC drives (10 marks)

(Block Diagram= 5 marks, Explanation = 5 marks)



Microprocessor based closed loop control of DC drive

Practically all newly designed DC and AC drives use microprocessors for some part, or all of the control electronics function. The microprocessor makes possible monitoring and diagnostic functions that were too costly to provide with hardwired circuits.

The speed of DC motor can be controlled by applying variable DC voltage across the armature coil of the motor thereby producing a variable armature current.

To measure the speed of the motor, a circular disc with several slots is attached to the spindle of the motor. An LED and phototransistor assembly is used to generate pulse

train with frequency related to the speed of motor. By using. a suitable pulse shaper it is converted into TTL compatible rectangular wave.

The block diagram of a microprocessor based closed loop control of DC drive is shown in the fig.

The present speed of the motor is converted into pulses by an optical transducer. The microprocessor integrates these pulses over a period of time to compute the actual rpm (speed) of the motor.

After measurement, the feedback signal (actual speed) is compared with reference input (desired speed) and the error is then used to adjust the duty cycle of the voltage pulses applied by the chopper to the motor to achieve the desired speed. The output pulses of the tachometer in a given time give the speed of the shaft. These pulses are processed digitally to obtain required simplification. These are feed to microprocessor using proper interfaces.

The measurement of speed, providing the speed error and control of chopper circuit are done by the microprocessor with suitable software design, as shown below.

Step 1: Measure the motor speed compare it with desired speed to produce error.

Step 2: Compensator changes its output as a function of error.

Step 3: Change the duty cycle of the chopper depends on the information transmitted from the compensator.

Step 4: Go to step 1.

This cycle is repeated for some time to keep the motor speed at desired level. A delay period could be included in between steps 3 and 4.

Step 5: Convert the measured rpm from binary to BCD and output to the display unit.

Step 6: Go to step 1.

Q.No: 14 (b) (ii) List the advantages and applications of microprocessor control of DC drives

(Advantages= 2 marks + Applications= 2 marks)

ADVANTAGES OF DC DRIVES :

- It provides enhance accuracy and precision.
- The Speed can be programmed to suit any application
- The speed can be increased at a controlled rate to a desired speed.

APPLICATIONS OF DC DRIVES

i) Rolling mill motors: Steel and Aluminum industries, continuous cold mills, continuous hot strip mills and reversing hot mills.

ii) Mine hoists: Mine hoists can be over hung from the hoist drum or fitted with supporting bearings.

Industrial duty motors: Used for fan drives, extrudes.

iv) Special applications: Balance machine drives, human centrifuge drives, dynamometers or any application requiring high torque, fast acceleration and low or variable speed.

v) Ship propulsion: DC propulsion motors include ice breakers, submarines, tug boats, mine sweepers, sea going dredges and oceanographic vessels.

vi) Paper mills, Machine tools, Electric traction, and Cranes.

Q.No: 15 (a) With suitable diagram explain the speed control of induction motor

(Any one Method (Diagram= 7 marks, Explanation = 7 marks)

SPEED CONTROL OF INDUCTION MOTOR

There are various methods of controlling the speed of an induction motor. They are as follows,

i) Stator voltage control

ii) Variable voltage, variable frequency control

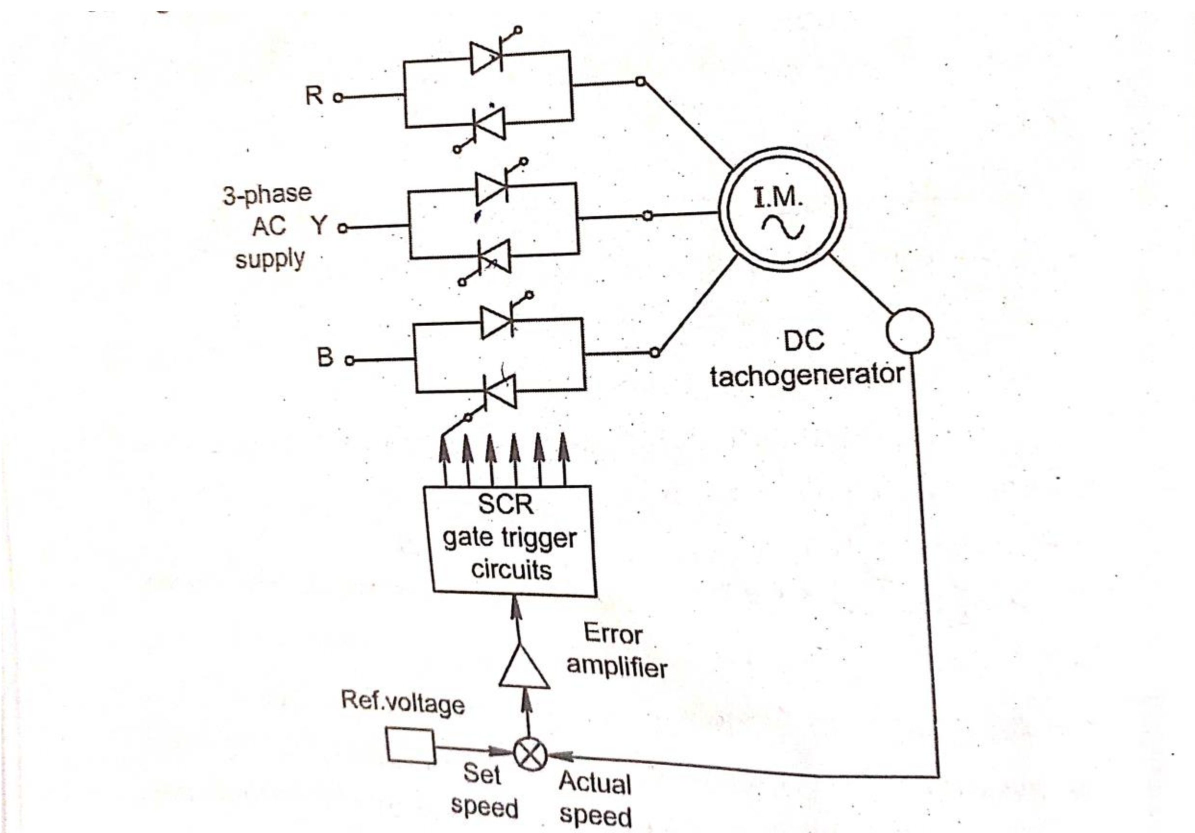
iii) Variable current, variable frequency control

iv) Rotor resistance control

v) Slip energy recovery scheme

vi) Pulse width modulation

Stator voltage control



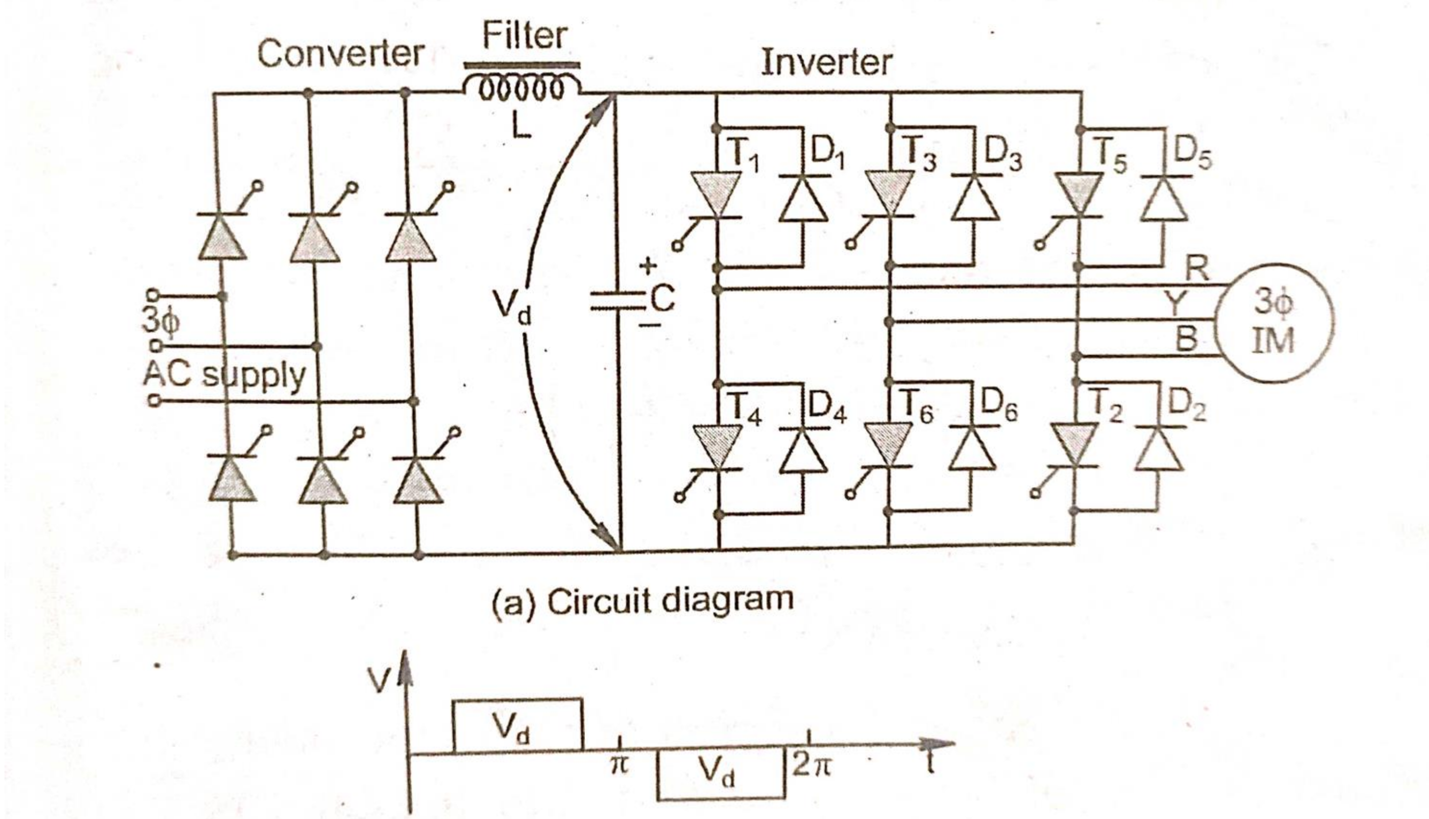
A commonly used symmetrical 3 phase AC voltage control circuit is shown in the fig. It is a simple and reliable method. The stator voltage is controlled with the help of SCRs connected in antiparallel in the three phases of the incoming lines and varying the firing angle. By varying the conduction period of SCRs, the effective voltage delivered to the motor can be varied from zero to full supply voltage. A phase displacement of 120° is maintained between the sets of gating pulses delivered to each controller in order to produce a symmetrical reduction of the three phase voltages.

The SCRs when fired, the forward and return currents pass for the appropriate time intervals. The DC tachogenerator develops a voltage proportional to the motor speed. It is compared with the DC reference voltage representing the desired speed. According to the difference between the two signals it can produce an error signal. This error signal controls the firing angles of SCRs, which in turn changes the terminal voltage output. The motor speed changes accordingly and the error signal is reduced.

If the reference voltage (required speed) is higher than the tachogenerator voltage (present speed), the firing angle advanced, conduction period is increased and stator voltage is increased. As a result more torque is developed and finally the speed is increased. Similarly if the reference voltage is less than the tachogenerator voltage, the firing angle is delayed and the conduction period is reduced. Stator voltage is reduced, developed torque is lowered and finally running speed is lowered.

When the reference voltage is equal to the tachogenerator voltage, the error signal goes to zero. The firing angle is not varied; the output voltage is now equal to the required stator voltage. The motor develops just the required torque. In a closed loop speed control system the desired speed can be accurately maintained.

Variable frequency control



(a) Circuit diagram

(b) Voltage waveform

The synchronous speed of a three phase induction motor having P number of poles is given by $N = 120f\ P$

The equation clearly said that the synchronous speed is directly proportional to the supply frequency. Hence by changing the supply frequency, the synchronous speed and motor speed can be controlled below and above the normal speed.

By keeping the supply voltage as constant and when the frequency is reduced below the rated value, then the air gap flux and stator currents are increased. In induction motors the core is always designed to operate near saturation to make full use of the magnetic materials. Therefore the increasing flux will saturate the motor. This will increase the core loss and stator copper loss, and distort the line currents and voltages.

Similarly if the stator frequency is increased above the rated value then the air gap flux and stator current decreases and the motor will operate at very low flux density resulting in under utilization of its capacity.

The circuit diagram of a variable voltage and frequency control using inverters is shown in the fig. It consists of

three phase bridge converter, filter, do link and bridge inverter configuration. The three phase bridge converter converts the three phase AC supply voltage to variable DC voltage. This is followed by a filter circuit. The output of the filter is then fed to the input of bridge inverter. The inverter produces a variable frequency, variable supply voltage which is then used to control the input of AC motor. The inverter circuit contains six SCRs and six diodes.

Here the SCRs T, and T, are connected to R phase, the SCRs T and T are connected to Y phase and the SCRs, Ts and T_2 are connected to B phase. When the SCR T, conducts R phase load is connected to + V, and when the SCR T conducts R phase load is connected to - Va Depending upon the gate signal applied to the SCRs, two SCRs can conduct at any instant, one from upper group and other from lower group. The firing sequences are as follows To T T1 T2 T2 T3 T3 T4: T4 T5 T6 T and so on. This

Inverter circuit generates a variable voltage variable frequency power supply to control the speed of the AC motor. The capacitor C provides a constant voltage to the inverter and the inverter output voltage waveforms are not affected by nature of load.

The induced emf of each phase winding of the stator is given by.

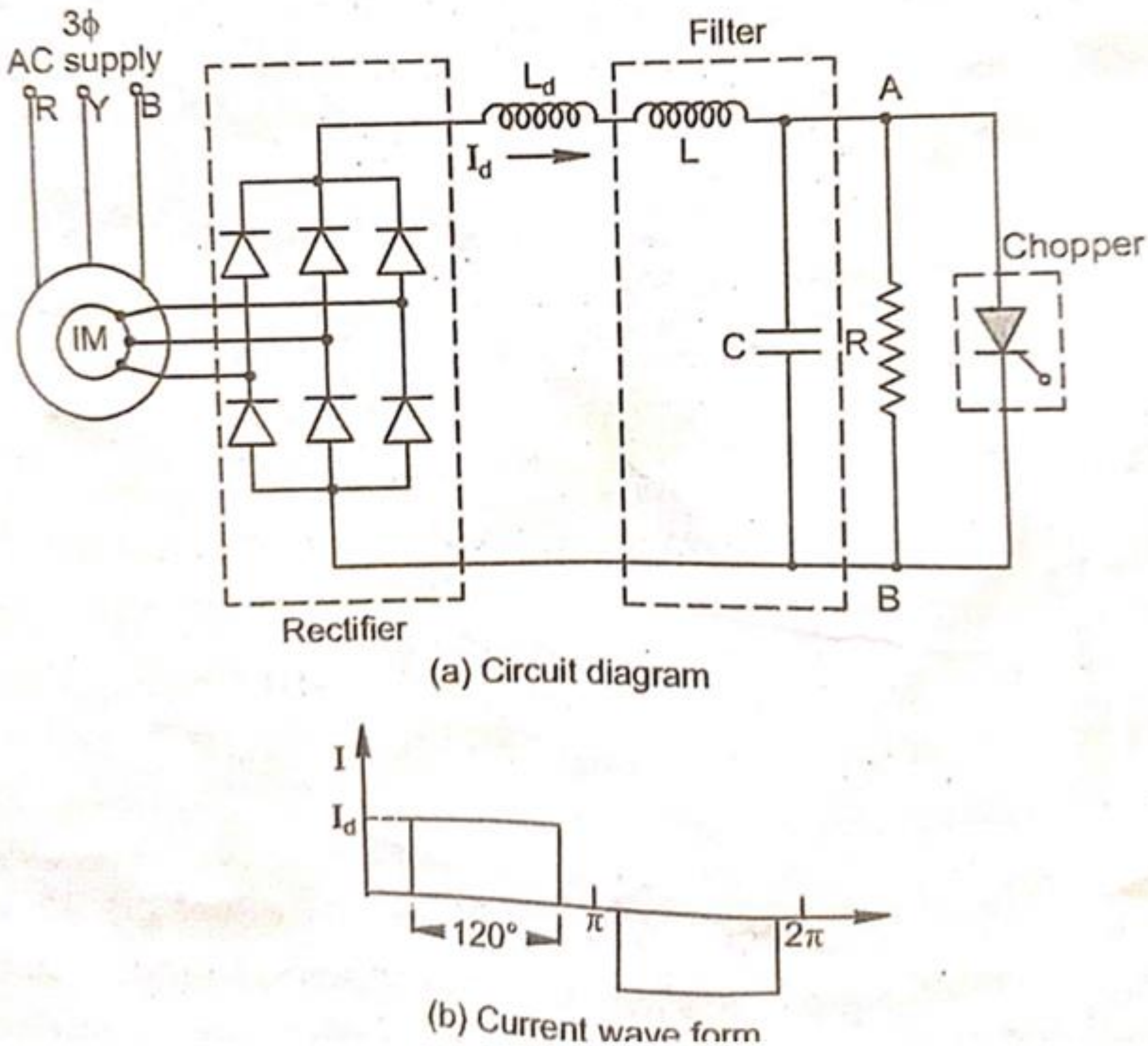
$$V = 4.44\, f\, \phi\, N \text{ volts}$$

where, V = Applied voltage/phase

N = Number of turns/phase in the stator winding.

In order to achieve constant torque operation below rated speed, flux & has to be constant. The flux can be kept constant, if the ratio (V/f) is kept constant. Thus to control the speed of AC induction motor below the rated speed, not only frequency has to be decreased but also voltage has to be decreased in the same proportion, such that V/f ratio is constant.

Rotor resistance control



The speed of a slip ring induction motor can be varied by varying rotor resistance. The rotor resistance can be varied by using a simple chopper circuit as shown in the fig. This method of speed control is inefficient because slip energy is wasted in the rotor circuit resistance. The stator of the motor is directly connected to the line power supply but in the rotor circuit, the slip voltage is rectified to DC by using bridge rectifier. The DC voltage is converted in to current source by connecting a large series inductor (L) and is fed to chopper with an external shunt resistance R.

The chopper periodically connects and disconnects the resistance R. When the chopper is OFF, the resistance R is connected in the circuit and DC current I flow through it. On the other hand if the chopper is ON, the resistance is short circuited and the current I is bypassed through the chopper. The chopper operates with the applied duty cycle.

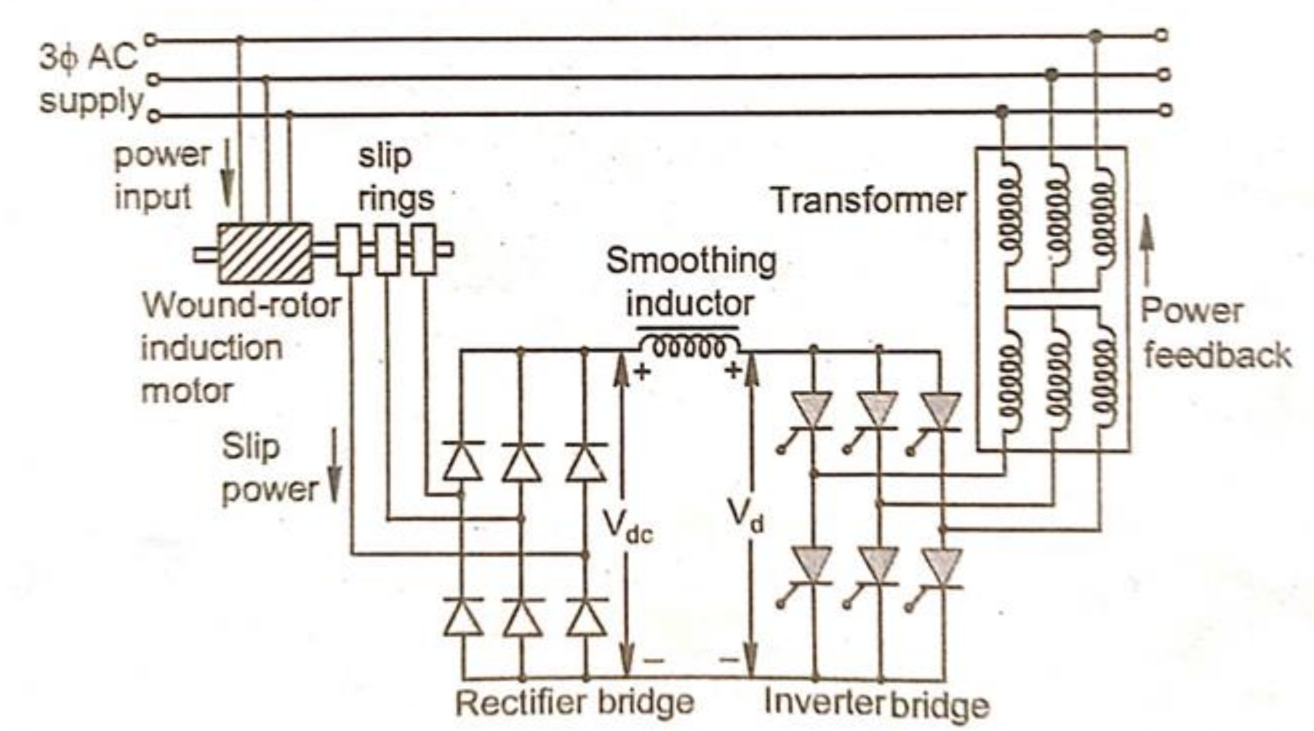
$$\text{Duty cycle, } \delta = \frac{T_{ON}}{T_{ON} + T_{OFF}} = \frac{T_{ON}}{T}$$

The equivalent resistance between terminals A and B can be given by

$$R_{AB} = (1 - \delta) R.$$

From the above equation, it is clear that the rotor resistance can be varied by varying the ON time (TON) and OFF time of the chopper. The high value of harmonics in the rotor current can be minimized by providing an additional LC filter circuit.

Slip energy recovery scheme



Static scherbius drive

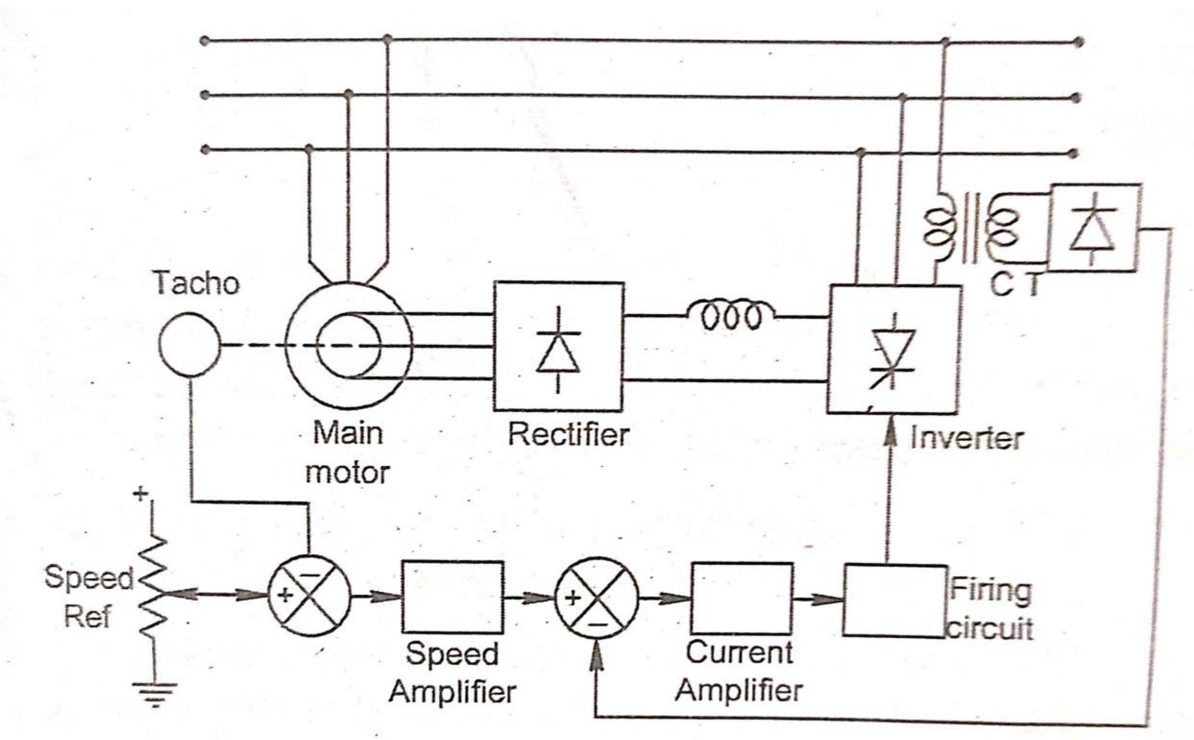
The circuit diagram of static scherbius drive for speed control of a slip ring induction motor is shown in the fig. In this method, slip power in the rotor circuit is converted to line frequency and fed back to the supply lines. This drive system is known as sub synchronous cascade converter
because it can provide the speed control only below the synchronous speed.

In this scheme the slip power is taken from the rotor at slip frequency to vary the motor speed efficiently. The voltage at slip rings is at slip frequency which is not equal to the stator frequency. Therefore slip ring voltage is rectified by using three phase diode bridge, and its output is smoothened by using filter choke. Its output is then fed to the phase controlled SCR inverter bridges. The inverter returns the slip power to the main supply through the transformer. The rectifier and inverter are both naturally commutated by the alternating emfs appearing at the slip ring and supply bus bars respectively.

In this method, the speed control is achieved by varying the firing angle of the inverter bridge. The speed-torque characteristic of this static system resembles the speed-torque characteristics of a separately excited armature controlled DC motor. The main disadvantage of this drive is that the power factor is very poor particularly at reduced rates.

Q.No: 15 (b) With the block diagram the operation of closed of AC Drive.

(Block Diagram= 7 marks, Explanation = 7 marks)



CLOSED LOOP CONTROL OF AC DRIVE:

A closed loop control is normally required in order to satisfy the steady state and transient performance specifications of AC drives. The control can be implemented by any one of the following methods.

i) Scalar control: In this control the magnitudes of control variables are controlled.

ii) Vector control: In this control both the magnitude and phase of the control variables are controlled.

iii) Adaptive control: In this control the parameters of the controller are continuously varied to adapt the variations of output variables.

The block diagram of closed loop control of an AC motor using slip power recovery scheme is shown in the fig.5.11. Since the torque-current characteristics of the cascade system are linear, a double loop control is suitable for variable speed drives.

The actual speed of motor is fed back from a tachogenerator coupled to the main motor and compared with the reference voltage. The error voltage is amplified by the speed amplifier and set the desired current reference.

The current feedback loop adjusts the current of the system by controlling the firing angles of the inverter. This current determines the motor torque.

The current signal is proportional to the AC current of the inverter. This is compared with the current reference setby the speed amplifier. The error voltage is amplified by the current amplifier and fed to firing angle control circuit of the inverter. Thus in this system speed error produces a motor torque which again reduces error.

The maximum current limit can be set to any desired value by setting the current reference through the speed error amplifier. Thus the current can be limited to any desired value under the stalled condition. The acceleration and declaration is fairly smooth. This system is quite simple and stable.

The speed accuracy of 0.1% from no load to full load may be achieved without much difficulty.

<u>Answer Key Prepared By</u>

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