Balasore School of Engineering

Power Electronics & Drives

Branch – Electrical Engineering

Semester – 5th

Sub Code – EET 502

Submitted by

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CHAPTER-01

SHORT QUESTIONS

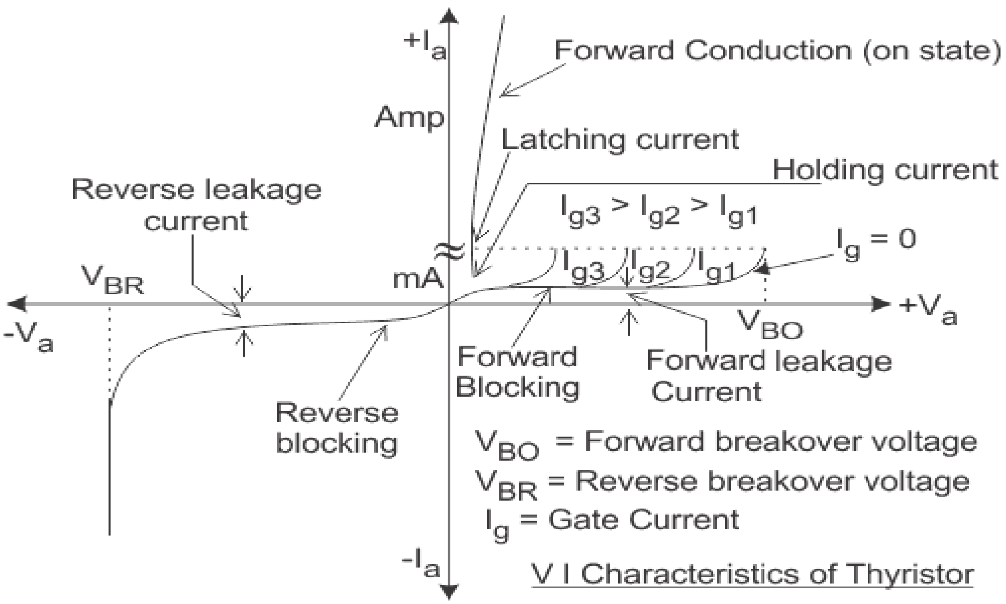
(1)What is rise time?(2015(W))

Ans:It is the time during which90% to 10% of its initial value and current increases 10% to 90% of its final value.

(2) What is the meaning of switching characteristics of scr?

Ans: It is the dynamic charachteristics of scr which shows the variation in voltage and current w.r.t. time during turn on and turn off.

(3)Show the holding current of scr in static characteristics?(2013(s)bp)



Q(4) What is the difference between R firing and RC firing?()2014(w)

Ans: In rc firing the firing angle is in between 0^o and 180^o but in r firing it is between 0^o and 90^o.

Q(5) What is the meaning of switching characteristics of thyristor?(2013)(bp)

Ans: It is the curve between voltage/current w.r.t. time. It is also called dynamic characteristics.

Q(6) What is the difference between power diode and signal diode?(2015(w))

Ans: (i) The voltage, current and power rating of power diodes are more than signal diodes.

(ii) The switching speed of power diodes is less than signal diodes.

Q(7) What do you mean by power BJT?(2014(w))

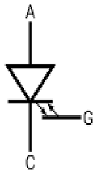
(i) The power BJT has four layers N^+-P-N–N^+.

(ii) The characteristics of the device is determined by the doping level in each of the layers and the thickness of the layers.

(iii)The thickness of the dirft region determines the breakdown voltage of the Power transistor.

Q(8) Draw the symbol of GTO and give its applications.(2014(w))

Ans: Symbol



Application: motor drives, static VAR compensators (SVCs) and AC/DC power supplies with high power ratings.

Q(9) Draw the forward and reverse characteristics of an ideal diode.(2013(bp))

Ans:

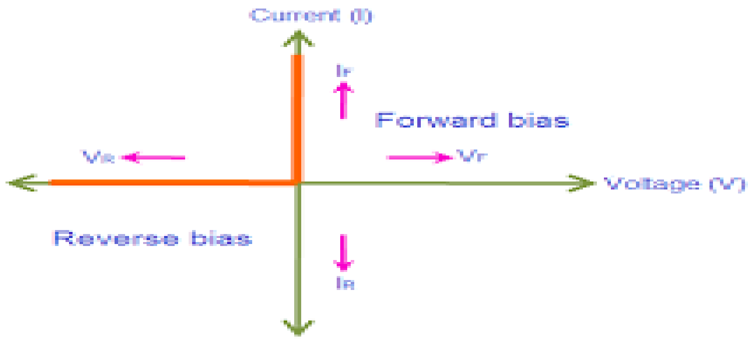
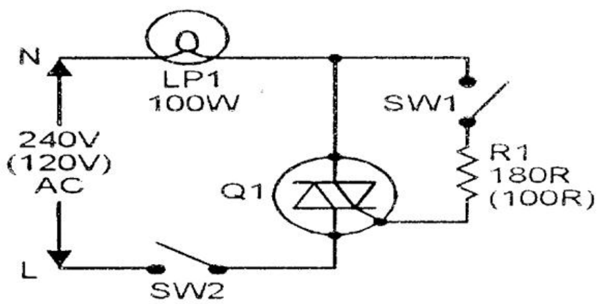


Fig: V-I characteristics of ideal diode

Q(10) Show connection diagram of triac feeding power to resistive load.(2013)(bp)

Ans:



MEDIUM QUESTIONS

Q(1) How thyristor is protected by gate protection? (2015)(w)

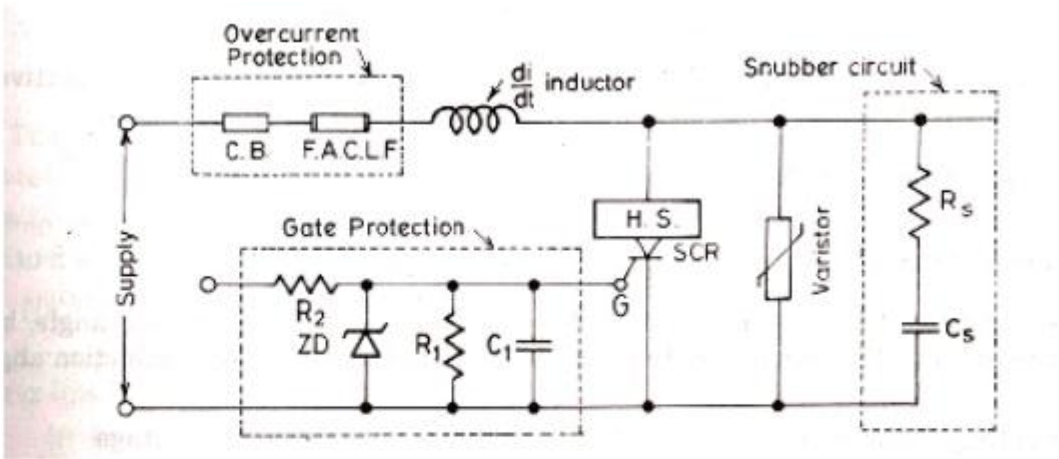
Ans: **GATE PROTECTION**

(1) Protection against overvoltage is achieved by connecting a zener diode across the gate circuit. A resistor R_2 connected in series with the gate circuit provides protection against gate current.

(2) Gate protection against spurious firing is obtained by using shielded cables or twisted gate leads.

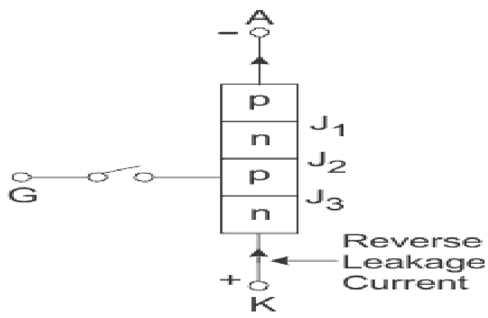
(3) A capacitor and a resistor is also connected across the gate to cathode to bypass noise signals.

Figure



Q(2) Explain the working of scr with necessary diagram?(2013(s)bp)(2015(w))

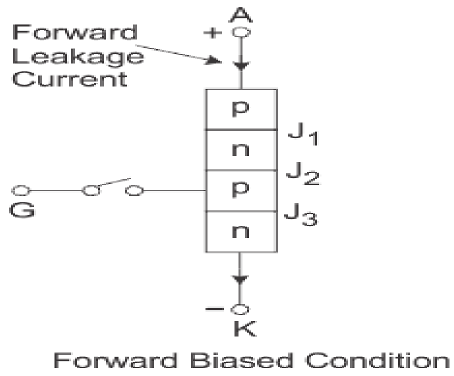
Ans: Reverse Blocking Mode of Thyristor



Reverse Blocking Mode

In this mode cathode is made +ve w.r.t. anode with gate open. Thyristor is reverse biased. A small leakage current of mA or μA flows in the SCR. This is called OFF state of SCR. Beyond a certain voltage V_{BR}, called breakdown voltage, current suddenly increases which can burn the SCR due to excessive heat produced in the SCR.

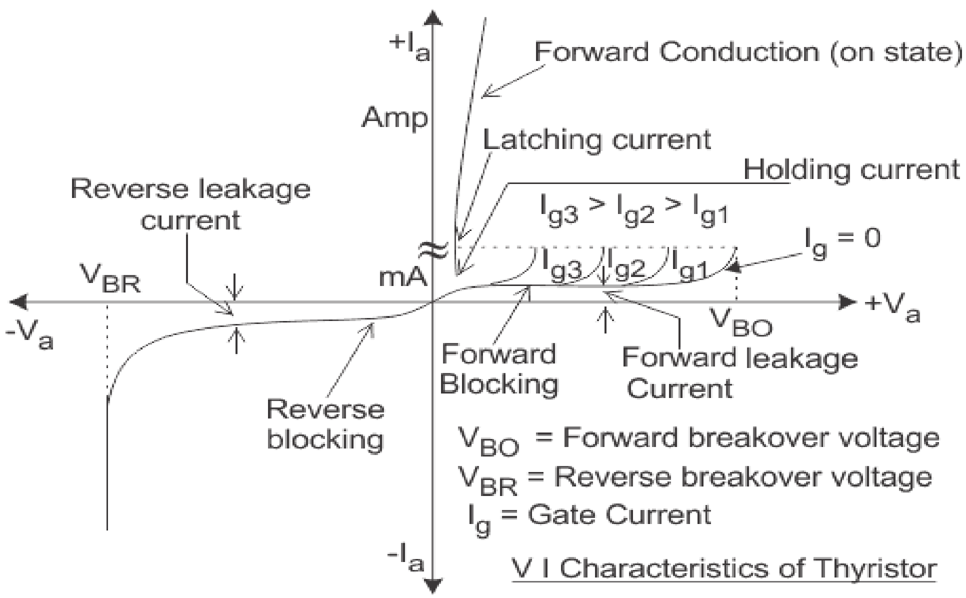
Forward Blocking Mode



When anode is made +ve w.r.t. cathode with gate circuit open, it is called forward biased. In this case, as J_1 and J_2 are forward biased but J_2 is reversed biased, a small leakage current called forward leakage current flows in it. As long as applied voltage is less than forward break over voltage, V_{BO},, SCR is in OFF state. This is called forward blocking mode.

Forward Conduction Mode

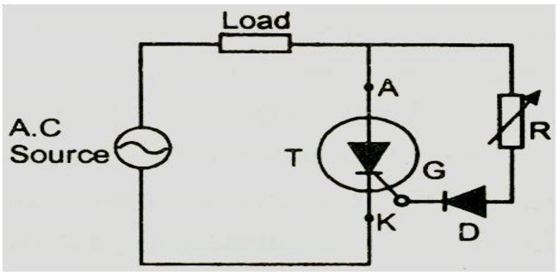
If the applied voltage exceeds V_{BO} then scr starts conducting in forward direction. This is called forward conduction mode. In this mode, SCR is in ON state. Its voltage drop is 1 or 2 volt.



Q(3)Explain gate triggering of thyristor by resistance firing?(2015(W))

Ans : R firing circuits or Resistance triggering circuit:

The following circuit shows the resistance triggering. In this method, the variable resistance R is used to control the gate current.

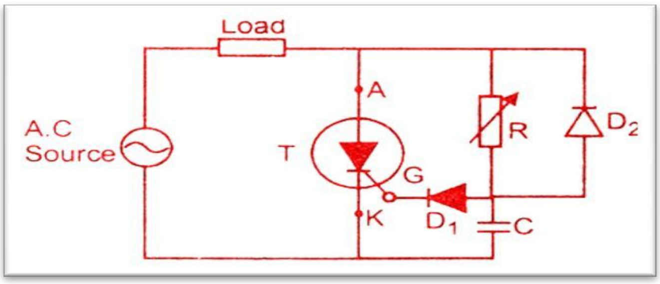


Depending upon the value of R, when the magnitude of the gate current reaches the sufficient value(latching current of the device) the SCR starts to conduct. The diode D is called as blocking diode. It prevents the gate cathode junction from getting damaged in the negative half cycle. By considering that the gate circuit is purely resistive, the gate current is in phase with the applied voltage. By using this method we can achieve maximum firing angle up to 90°.

Q(4) With neat diagram explain the working of R-C firing circuit.(2013(bp))

Ans: **RC-firing circuit**

The following circuit shows the resistance-capacitance triggering.



By using this method we can achieve firing angle more than 90°. In the positive half cycle, the capacitor is charged through the variable resistance R up to the peak value of the applied voltage. The variable resistor R controls the charging time of the capacitor. Depends upon the voltage across the capacitor, when sufficient amount of gate current will flow in the circuit, the SCR starts to conduct. In the negative half cycle, the capacitor C is charged up to the negative peak value through the diode D2. Diode D1 is used to prevent the reverse break down of the gate cathode junction in the negative half cycle.

LONG QUESTIONS

Q(1) Draw the switching characteristics of scr and explain the waveform during turn on and turn off?2013(s(BP))

Ans: Turn ON Time of SCR

A forward biased thyristor can be turned on by applying a positive voltage between gate and cathode terminal. But it takes some transition time to go from forward blocking mode to forward conduction mode. This transition time is called turn on time of SCR and it can be subdivided into three small intervals as delay time (t_d) rise time (t_r), spread time (t_s).

Delay Time of SCR

After application of gate current, the thyristor will start conducting over a very tiny region. Delay time of SCR can be defined as the time taken by the gate current to increase from 90% to 100% of its final value I_g. From another point of view, delay time is the interval in which anode current rises from forward leakage current to 10% of its final value and at the same time anode voltage will fall from 100% to 90% of its initial value V_a.

Rise Time of SCR

Rise time of SCR in the time taken by the anode current to rise from 10% to 90% of its final value. At the same time anode voltage will fall from 90% to 10% of its initial value V_a

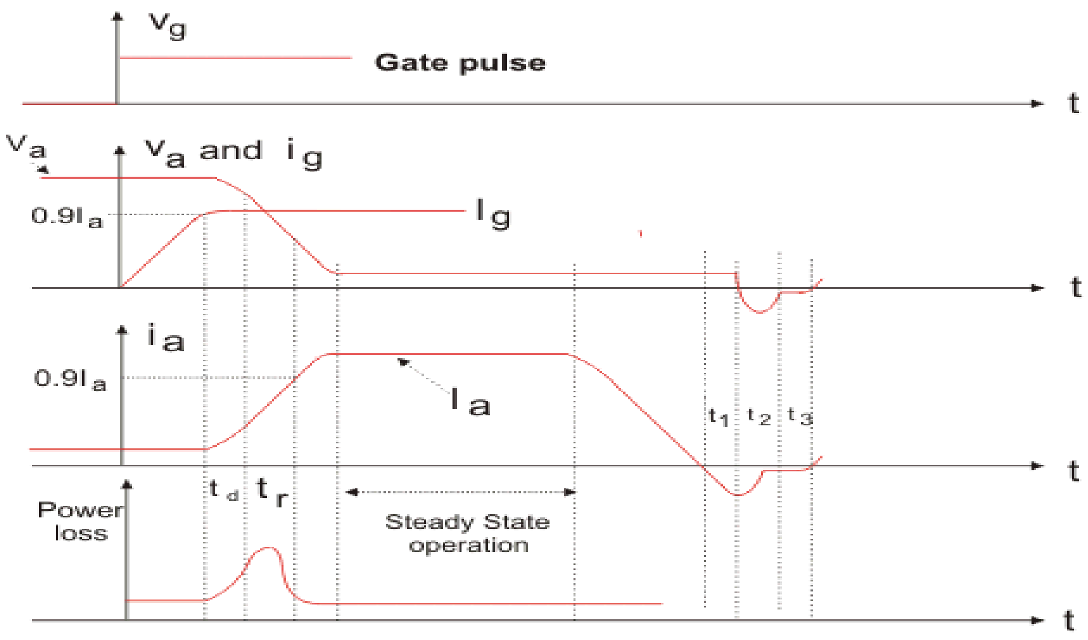
Spread Time of SCR

It is the time taken by the anode current to rise from 90% to 100% of its final value. At the same time the anode voltage decreases from 10% of its initial value to smallest possible value. In this interval of time conduction spreads all over the area of cathode and the SCR will go to fully ON State. Spread time of SCR depends upon the cross-sectional area of cathode.

Turn OFF Time of SCR

That means gate circuit cannot turn off the device. For turning off the SCR anode current must fall below the holding current. After anode current fall to zero we cannot apply forward voltage across the device due to presence of carrier charges into the four layers. So we must sweep out or recombine these charges to proper turn off of SCR**.** So turn off time of SCR can be defined as the interval between anode current falls to zero and device regains its forward blocking mode. On the basis of removing carrier charges from the four layers, turn off time of SCR can be divided into two time regions,

1. Reverse Recovery Time.
2. Gate Recovery Time



Reverse Recovery Time

It is the interval in which change carriers remove from J_1, and J_3 junction. At time t_1, anode current falls to zero and it will continue to increase in reverse direction At the time t_2 carrier charge density is not sufficient to maintain the reverse current hence after t_2 this negative current will start to decrease. The value of current at t_2 is called reverse recovery current. Total recovery time t_3 - t_1 is called reverse recovery time.

Gate Recovery Time

After sweeping out the carrier charges from junction J_1 and J_3 during reverse recovery time**,** there still remain trapped charges in J_2 junction which prevent the SCR from blocking the forward voltage. These trapped charges can be removed by recombination only and the interval in which this recombination is done, called gate recovery time**.**

Q(2) Explain the working of power diode and show the difference between power diode and signal diode?(2013)(bp)(2014(w))

Ans :

A power diode has a P-I-N structure as compared to the signal diode having a P-N structure. Here, I (in P-I-N) stands for intrinsic semiconductor layer to bear the high-level reverse voltage as compared to the signal diode (n- , drift region layer shown in Fig. 2). However, the drawback of this intrinsic layer is that it adds noticeable resistance during forward-biased condition. Thus, power diode requires a proper cooling arrangement for handling large power dissipation. Power diodes are used in numerous applications including rectifier, voltage clamper, voltage multiplier and etc. Power diode symbol is the same as of the signal diode as shown in Fig.1.

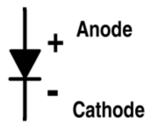


Figure 1. Symbol for Power Diode

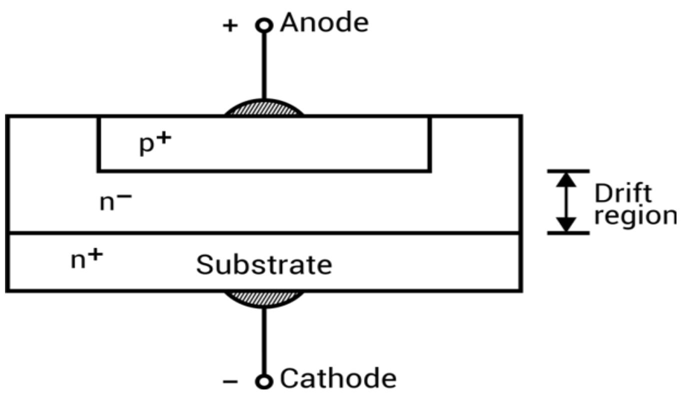


Figure 2. Structure of Power Diode

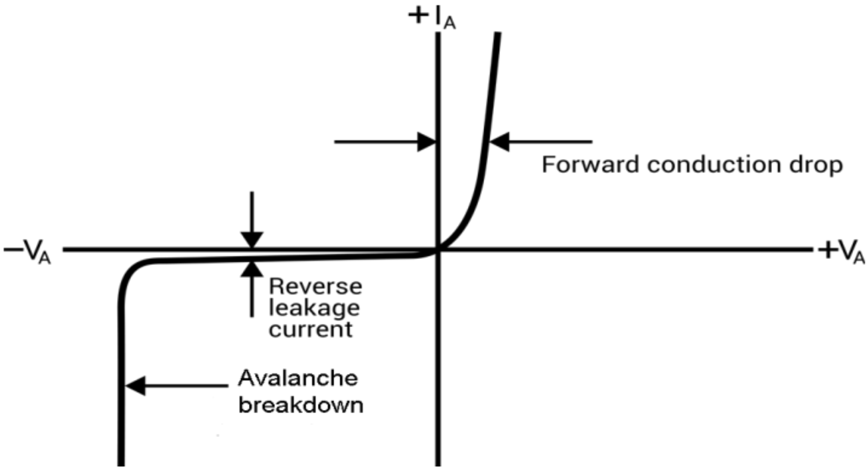
If thickness of lightly doped I layer (n- layer) > depletion layer width at breakdown ⇒ Non-punch through power diode.

(This means depletion layer has not punched through the lightly-doped n-layer.)

If thickness of I layer < depletion layer width at breakdown ⇒ Punch through power diode.

Characteristics of Power Diode

Amp-volt characteristics *(i-v characteristics)*



Cut-in voltage is the value of the minimum voltage for V_A (anode voltage) to make the diode works in forward conducting mode. Cut-in voltage of signal diode is 0.7 V while in power diode it is 1 V. So, its typical forward conduction drop is larger. Under forward-bias condition, signal diode current increases exponentially and then increases linearly. In the case of the power diode, it almost increases linearly with the applied voltage as all the layers of P-I-N remain saturated with minority carriers under forward bias. Thus, a high value of current produces results in voltage drop which mask the exponential part of the curve. In reverse-bias condition, small leakage current flows due to minority carriers until the avalanche breakdown appears as shown in Fig.

CHAPTER-02 (PHASE CONTROLLED RECTIFIER,AC VOLTAGE REGULATOR,CHOPPER)

SHORT QUESTIONS

Q(1) What is latching current?

Ans: It is the minimum anode current above which an scr must attain to continue conduction without gate triggering.

Q(2) What is the difference between uncontrolled rectifier and controlled rectifier?

Ans : Uncontrolled rectifier are semiconductor diodes in which phase can't be controlled. Controlled rectifiers are scrs which can control phase.

Q(3)What is the use of UPS.?(2015(w))

Ans: Applications are major computer installations, process control in chemical plants, safety monitors, hospital intensive care units.

Q(4) What is SMPS and why it is preferred in comparison to linear regulator?(2014(w))

Ans : SMPS stands for Switched Mode Power Supply. In case of SMPS negligible ripples are produced, efficient, light than linear regulator.

Q(5) What happens to frequency in PWM operation of chopper?(2013)(bp)

Ans: In this scheme, on-time T_{on} is varied but chopping frequency is constant.

Q(6) What is duty cycle?

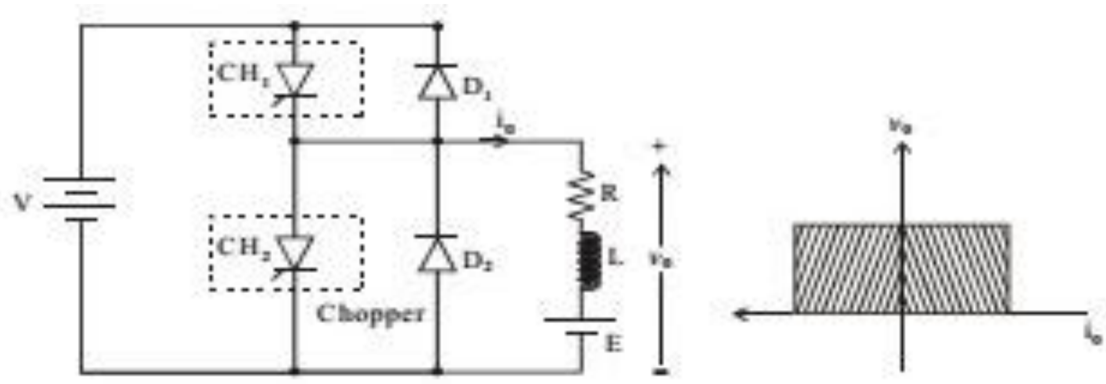
Ans.- Duty cycle is defined as the ratio of turn on period of the chopper to the total time period of the chopper.It is defined as α (alpha). $\alpha = T_{ON}/T$

Medium questions

Q(1) Explain type-c chopper.

Ans: Two Quadrant Class-C Chopper

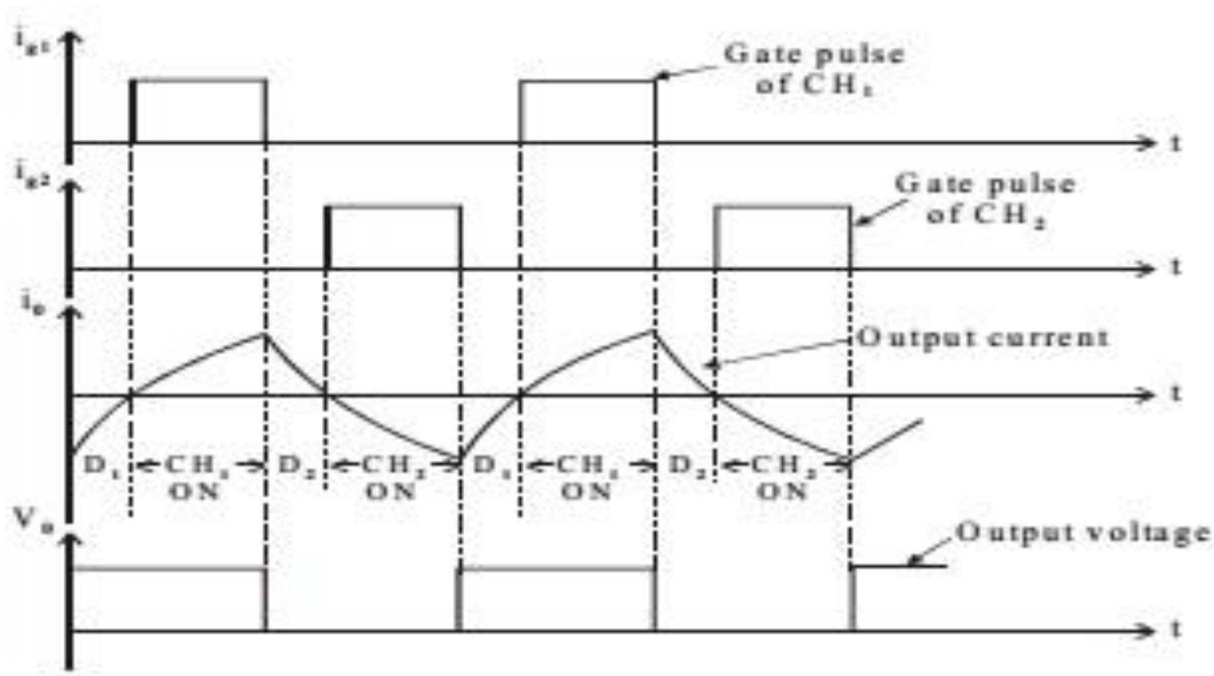
Class C Chopper is a combination of Class A and Class B Choppers. For first quadrant operation, CH1 is ON or D2 conducts.



For second quadrant operation, CH2 is ON or D1 conducts. When CH1 is ON, the load current is positive. The output voltage is equal to ‗V' & the load receives power from the source. When CH1 is turned OFF, energy stored in inductance L forces current to flow through the diode D2 and the output voltage is zero. Current continues to flow in positive direction.

When CH2 is triggered, the voltage E forces current to flow in opposite direction through L and CH2. The output voltage is zero. On turning OFF CH2, the energy stored in the inductance drives current through diode D1 and the supply. Output voltage is V, the input current becomes negative and power flows from load to source. Average output voltage is positive. Average output current can take both positive and negative values. Choppers CH1 & CH2 should not be turned ON simultaneously as it would result in short circuiting the supply.

Class C Chopper can be used both for dc motor control and regenerative braking of dc motor. Class C Chopper can be used as a step-up or step-down chopper.



LONG QUESTIONS

Q(1)Explain single phase full wave ac regulator.((2015((w))

Ans :-(i) The above figure shows the 1-Φ ac voltage controller with resistive load. It consists of two thyristors connected in anti-parallel.

(ii)During +ve half cycle, T1 is forward biased and from α to ∏ it starts conducting. During 0 to α $V_{T1}=e_s$. From α to ∏ when T_1 conducts its voltage drop is 1 volt. From ∏ to (∏+α) it is reverse biased so $V_{T1}=e_s$.

(iii)During –ve half cycle T_2 is forward biased and it starts conducting from (∏+α) to 2∏.From ∏ to (∏+α) it $V_{T2}=e_s$.From (∏+α) to 2∏ its voltage drop is 1 volt.

FIGURE

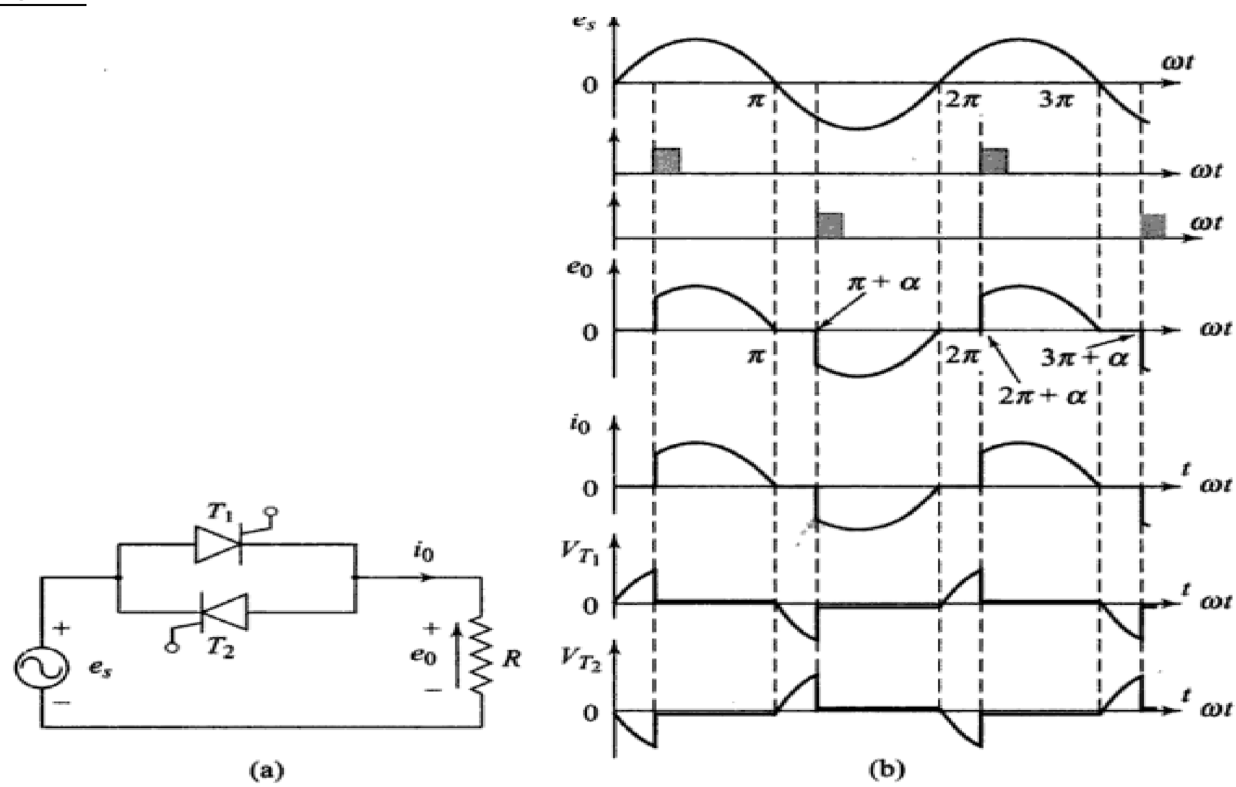


Fig.1 ***(a)** Single-phase a.c. voltage controller with R load **(b)** voltage and current waveforms*

Q(2)Explain the working of half-wave converter with R-L load with and without freewheeling diode. Show the output waveforms under the above use?(2014(w))

Ans: <u>SCR as a Half Wave Rectifier with R load and without freewheeling diode</u>

(i) A supply of $V_s=V_m\sin\omega t$ is given to R-L type load. During +ve half cycle of the supply vltage SCR is forward biased. When gate signal is given to SCR, it starts conducting and load voltage follows supply voltage.

(ii) The energy gets stored in the inductor during the interval $\omega t=\alpha$ to $\omega t=\prod$.At $\omega t=\prod$, source voltage and load voltage becomes zero. The load current doesn't become zero due to presence of inductance in the load circuit. So the SCR doesn't get commutated at some point denoted by β after $\omega t=\prod$.β is known as extinction angle.

Conduction angle(γ)=It is the angle at which SCR is in conduction state. The relation between α,β,γ is given by-$\beta=\alpha+\gamma$.

(iii) During –ve half cycle at $\omega t=\beta$, current flowing through the SCR becomes zero. Hence it is naturally commutated. The output voltage and current becomes zero. The SCR is reverse biased from $\omega t=\beta$ to 2Π.Hence circuit turn off time, $t_{c}=(2\Pi-\beta)/\omega$.

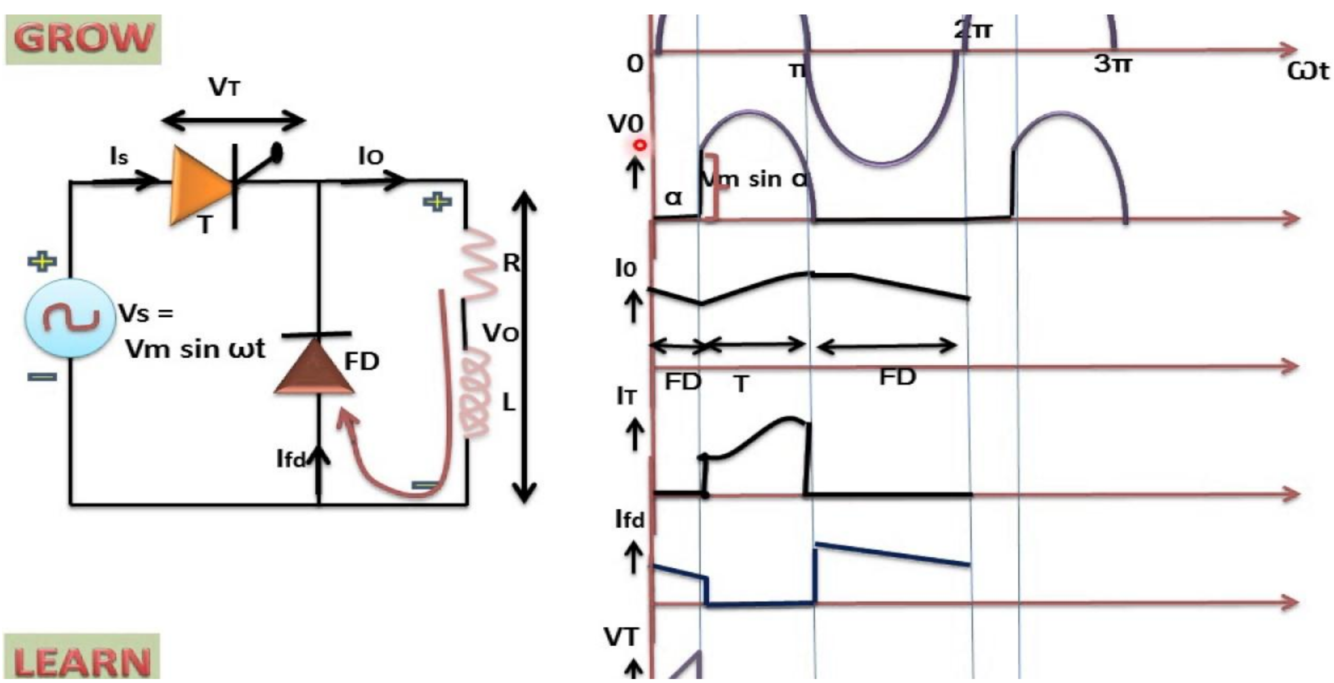
SCR as a Half Wave Rectifier with R load and with freewheeling diode

The diode used in single phase half wave rectifier is known as flywheeling ,bypass or commutating diode.

Advantages of freewheeling diode

(i) The load current waveform is improved.
(ii) The load performance is better.
(iii) The input power factor is improved.

Figure

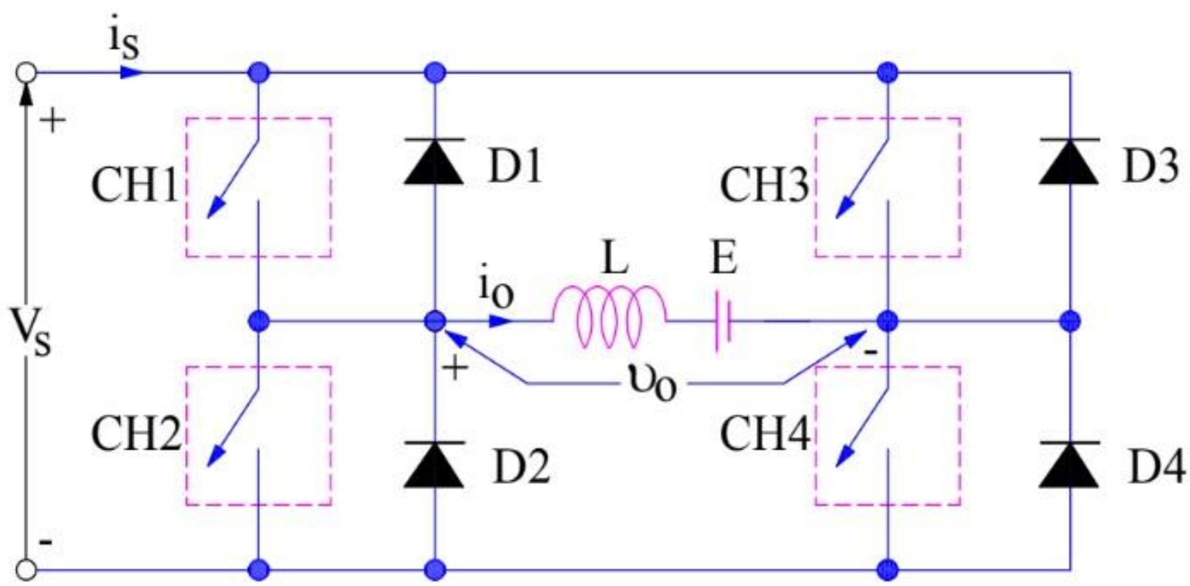


Q(3) Explain Type – E chopper or four quadrant chopper ?

Ans A four quadrant chopper is a chopper which can operated in all the four quadrants. The power can flow either from source to load or load to source in this chopper. In first quadrant, a Class-E chopper acts as a Step-down chopper whereas in second quadrant it behaves as a Step-up chopper. This type of chopper is also known as Class-E or Type-E chopper. This article describes the working principle and operation of Class-E chopper with the help of circuit diagram.

Working Principle / Operation of Class-E Chopper:

The circuit of a four quadrant chopper or class-E chopper basically consists of four semiconductor switches CH1 to CH4 and four diodes D1 to D4. The four diodes are connected in anti-parallel. The circuit diagram of this type of chopper is shown below.



In the above circuit diagram, the choppers are numbered CH1 to CH4. For first quadrant operation CH1 is made ON, for second quadrant operation CH2 is made ON and so on. To better understand the working of four quadrant chopper, we will discuss its operation separately for each quadrant.

First Quadrant Operation:

For first quadrant operation, CH4 is kept ON, CH3 is kept OFF and CH1 is operated. When both CH1 & CH4 are ON simultaneously, the load gets directly connected to the source and hence the output voltage becomes equal to the source voltage. This essentially means that $v_o = v_s$. It may be noted that the load current flows from source to load as shown by the direction of i_o.

When CH1 is switched OFF, the load current free wheels through CH4 and D2. During this period, the load voltage and current remains positive. Thus, both the output voltage v_s and load current i_o are positive and hence, the operation of chopper is in first quadrant. It may be noted that, Class-E chopper operates as a step-down chopper in this case.

Second Quadrant Operation:

To obtain second quadrant operation, CH2 is operated while keeping the CH1, CH3 & CH4 OFF. When CH2 is ON, the DC source in the load drives current through CH2, D4, E and L. Inductor L stores energy during the On period of CH2.

When CH2 is turned OFF, current is fed back to the source through D1, D4. It should be noted at this point that *(E+Ldi/dt)* is more than the source voltage Vs. As load voltage Vo is positive and Io is negative, it is second quadrant operation of chopper. Since, the current is fed back to the source, this simply means that load is transferring power to the source. Kindly read Step-up chopper for detailed analysis and better understanding.

For second quadrant operation, load must contain emf E as shown in the circuit diagram. In second quadrant, configuration operates as a step-up chopper.

Third Quadrant Operation:

To obtain third quadrant operation, both the load voltage and load current should be negative. The current and voltage are assumed positive if their direction matches with what shown in the circuit diagram. If the direction is opposite to what shown in the circuit diagram, it is considered negative. One important thing to notice is that the polarity of emf E in load must be reversed to have third quadrant operation.

For third quadrant operation, CH1 is kept off, CH2 is kept ON and CH3 is operated. When CH3 is ON, load gets connected to source and hence load voltage is equal to source voltage. But carefully observe that the polarity of load voltage vo is opposite to what shown in the circuit diagram. Hence, v_o is assumed negative. Let us now see what is the status of load current i_o. It may be seen that i_o is flowing in the direction opposite to shown in the circuit diagram and hence negative.

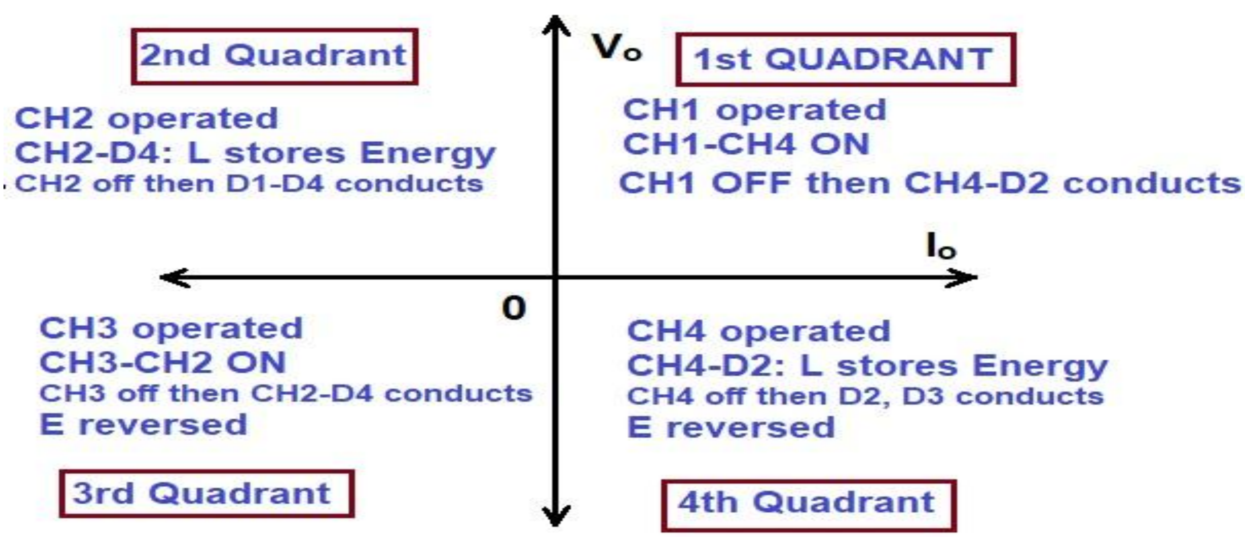
Now, when CH3 is turned OFF, the negative load current free wheels through the CH2 and D4. In this manner, v_o and i_o both are negative. Hence, the chopper operates in third quadrant.

Fourth Quadrant Operation:

To obtain fourth quadrant operation, CH4 is operated while keeping CH1, CH2 and CH3 OFF. The polarity of load emf E needs to be reversed in this case too like third quadrant operation.

When CH4 is turned ON, positive current flows through CH4, D2, L and E. Inductance L stores energy during the time CH4 is ON. When CH4 is made OFF, current is fed back to the source through diodes D2, D3. Here load voltage is negative but the load current is always positive. This leads to chopper operation in fourth quadrant. Here, power is fed back to the source from load and chopper acts as a step-up chopper.

The operation of a four quadrant chopper or Class-E chopper is summarized in the figure below.



CHAPTER-03 (INVERTER AND CYCLO-CONVERTER)

LONG QUESTIONS

Q(1) Explain the working of voltage source series inverter with neat diagram.(2014(w))(2013*(bp))

Ans:

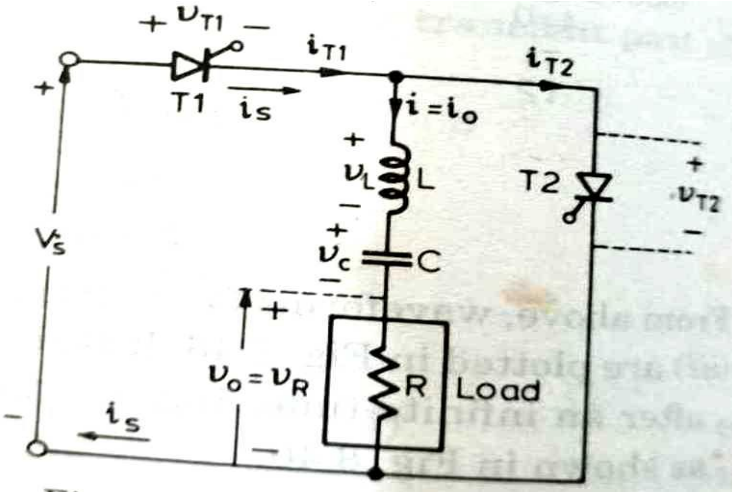


Fig. 8.47. Basic series inverter.

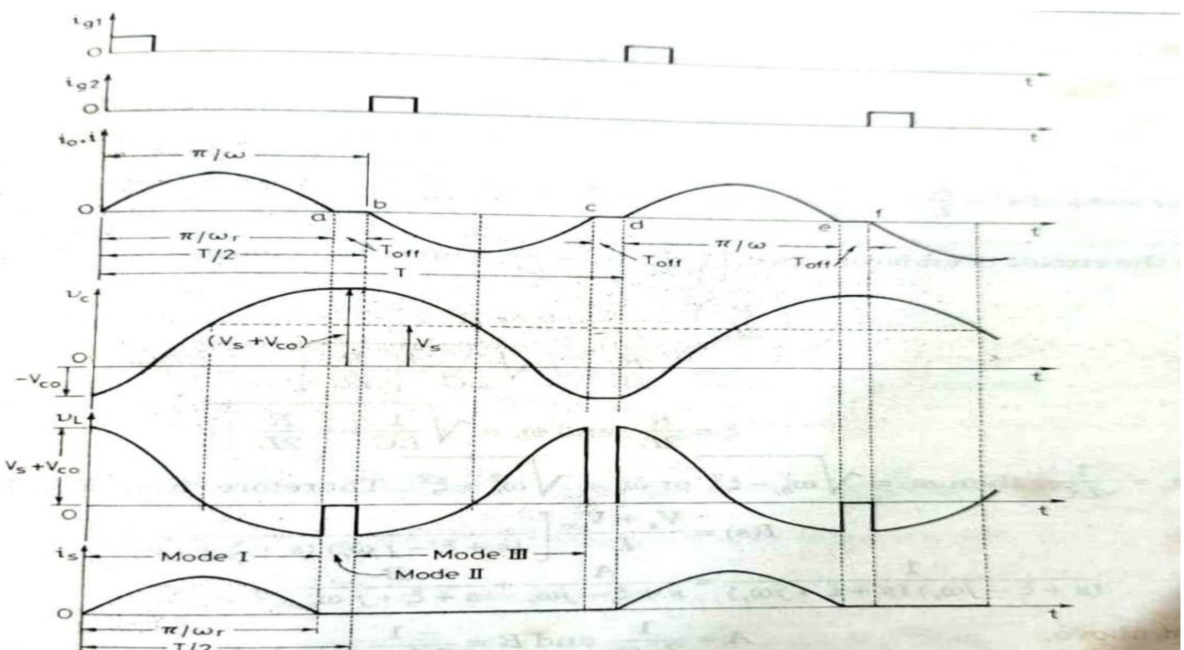


Fig. 8.48. Current and voltage waveforms for basic series inverter of Fig. 8.47.

Series Inverter

Voltage source series inverter consists of load resistance R in series with commutaing components L and C. The RLC circuit is an underdamped circuit.

Mode-1

A dc supply is connected to the inverter circuit. When the scr T_1 is turned onby giving gate signal to it,T_1 starts conducting. It results in current flow through R-L-C series circuit. Now the capacitor C gets charged up to a voltage E_c with the polarity as shown in the figure. The load current flows through the path V_s^+-T_1-C-L-R-V_s^-.

When the load current reaches its peak value, the voltage across the capacitor "C" is the supply voltage V_s. After this current starts deceasing whereas the capacitor voltage rises to value (V_S=E_C+V_S).When the load current reaches zero, SCR T_1 is turned off.

Mode-2

During this mode, the load current remains constant for sufficient period of time before scr T_2 is triggered. Both scr T_1 and T_2 are in off state. The capacitor voltage remains constant.

Mode-3

The +ve polarity of capacitor "c" appears at the anode of scrT_2 and hence T_2 is forward biased. When scr T_2 is triggered it starts conducting and the capacitor discharges through

Scr T_2 .The load current direction is opposite to that of assigned load current direction. The load current flows through path C^+-T_2-R-L-C^-.This current builds off to –ve maximum and reaches to zero value. Scr T_2 is turned off. This process is repeated.

Q(2) What is a cycloconverter ?Explain the circuit and waveform of step-up cycloconverter.(2013(bp))

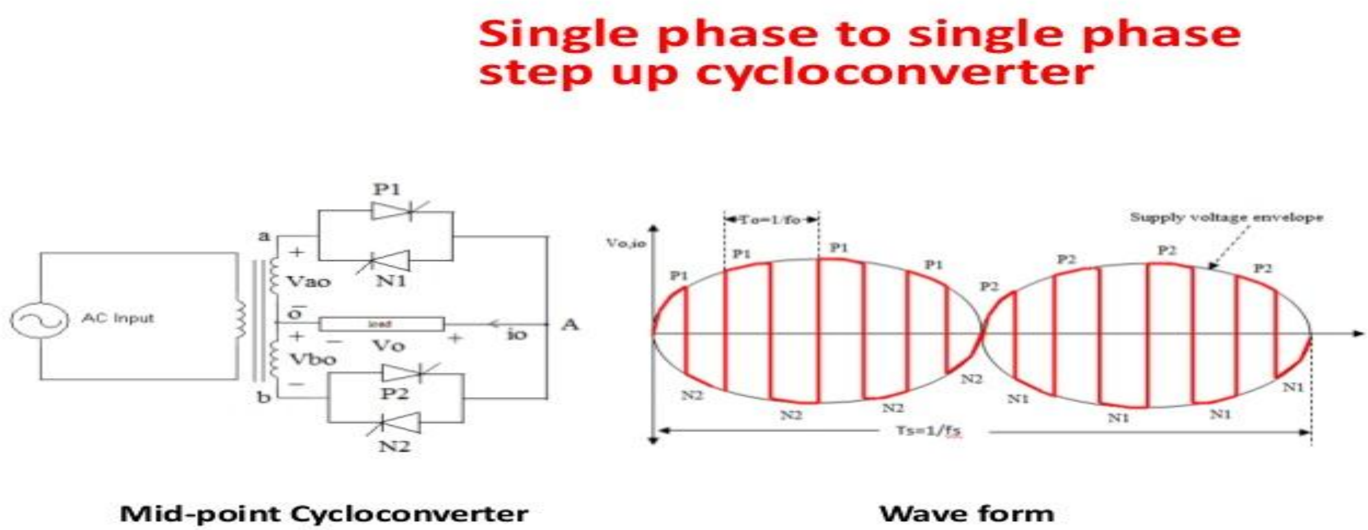
Ans: Circuit Description

(i)Here the scrs are arranged in bridge type and is known as bridge type cycloconverter.

(ii)It has eight scrs(P_1,P_2,P_3,P_4) constitute +ve group whereas (N_1,N_2,N_3,N_4) constitute –ve group.

(iii)Load is connected between two bridges which are connected anti-parallel.

FIGURE



Operation

Mode-1 ($0 < \omega t < \prod$)

(i)During the +ve half cycle of supply voltage, P1, P2, N3, N4 are forward biased. Initially P_1&P_2 are triggered. The load voltage follows the +ve envelope of supply voltage. The circuit completes its path through a-P_1-X-load-Y-P_2-b.

(ii)At instant ωt_1,P_1& P_2 are turned off due to forced commutation.N_3 & N_4 are turned on. The output voltage follows the –ve envelope of supply voltage. The circuit completes its path through N-N_3-Y-load-X-N4-M.At ωt_2 N_3, N_4 are forced commutated and P_1, P_2 are turned on. This process continues till $\omega t=\prod$ radian.

Mode-2 ($\prod < \omega t < 2\prod$)

(i)During –ve half cycle of supply voltage, thyristors P_3,P_4,N_1,N_2 are forward biased.P_3,P_4 are turned on by giving the gate signal where the load voltage follows the +ve envelope of the supply voltage .The circuit competes its path through b-P_3-X-load-Y-P_4-a.

(ii)At instant ω̦t_4, P_3, $P_4$are forced commutated. The gate signal is given to N_1,N_2.The output voltage traces the –ve envelope of supply voltage. The current flow is:-M-N_1-Y-load-X-N_2-N.In this way, +ve and -ve envelopes are traced during ∏ to 2∏.

CHAPTER-04 (APPLICATIONS OF POWER ELECTRONICS CIRCUITS)

MEDIUM QUESTIONS

Q(1) Explain the operation of speed control of induction motor by stator voltage/frequency control method.(2014(w))(2013)(BP).

Stator Voltage and Frequency Control Method

We know that $T_{em} = \frac{3P}{4} . (\frac{V_1}{W_1})^2$ (1 / l_1 + l_2)

The above equation shows that if $(\frac{V_1}{W_1})$, or air gap flux Φ1 is kept constant, the maximum torque remains unaltered. So the staring torque increases even if air gap flux is kept constant. At low values of frequencies the magnitude of maximum torque reduces so supply voltage is increased to maintain the level of maximum torque. This method of speed control is called volts / hertz control.

From the equation it is seen that speed of the drive can be controlled by varying both voltage & frequency below their rated values. The control both voltage & frequency can be carried out through the use of 3 Φ inverter or cycloconverter. Inverters are used in low & medium power drives where as cycloconvertes are suitable for high power drive.

LONG QUESTIONS

Q(1)Explain 1-Φ full CONVERTER dc drive with circuit diagram.(2015(w))

1-Φ full CONVERTER dc drive

Two full converters , one feeding the armature circuit & other feeding the field circuit of separately excited DC motor as shown in the figure,

It is a two quadrant drive. Its use is limited to 15 KW. For regenerative braking of the motor the power most flow from motor to AC source and this is feasible only if motor counter emf is reversed because then e_a I_a would be negative this is possible by reversing the direction of motor field current making an delay angle of full converter to than 90˚. In order that current in field winding can be reversed, the field winding must be energized through single phase full converter.

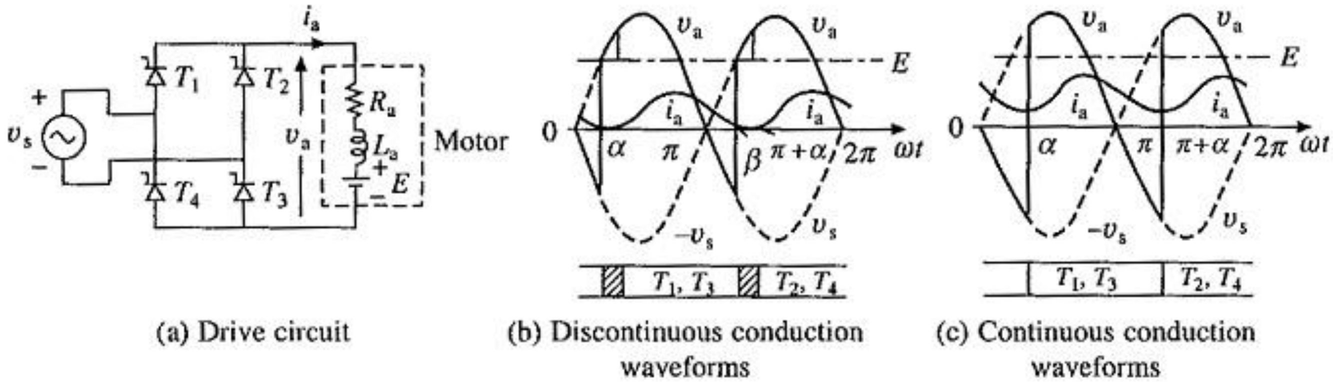


Fig. 5.26 Single-phase fully-controlled rectifier-fed dc separately excited motor

Q(2) Explain the armature voltage control method for dc motor with neat circuit diagram.(2014(w)).

Ans:-<u>Armature Voltage Control Method:-</u>

In this method speed below rated speed can be obtained .We know that the speed in dc motor directly depends on supply voltage .In this method field current and armature current are kept constant .So armature voltage control method is also called constant torque drive Method.

<u>Armature Voltage Control</u>

This method of speed control needs a variable source of voltage separated from the source supplying the field current. This method avoids disadvantages of poor speed regulation and low efficiency of armature-resistance control methods. The basic adjustable armature voltage control method of speed d control is accomplished by means of an adjustable voltage

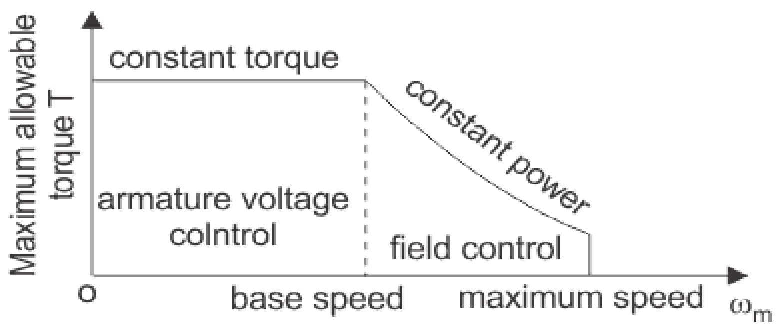
Generator is called Ward Leonard system. This method involves using a motor – generator (M-G) set. This method is best suited for steel rolling mills, paper machines, elevators, mine hoists, etc. Advantages

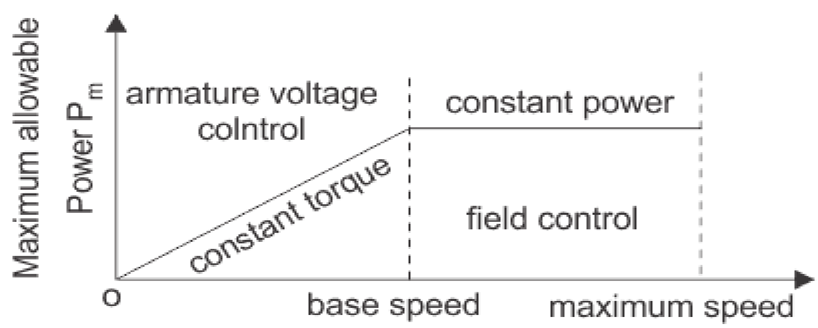
1. Very fine speed control over whole range in both directions
2. Uniform acceleration is obtained

3. Good speed regulation

Disadvantages

1. Costly arrangement is needed , floor space required is more
2. Low efficiency at light loads

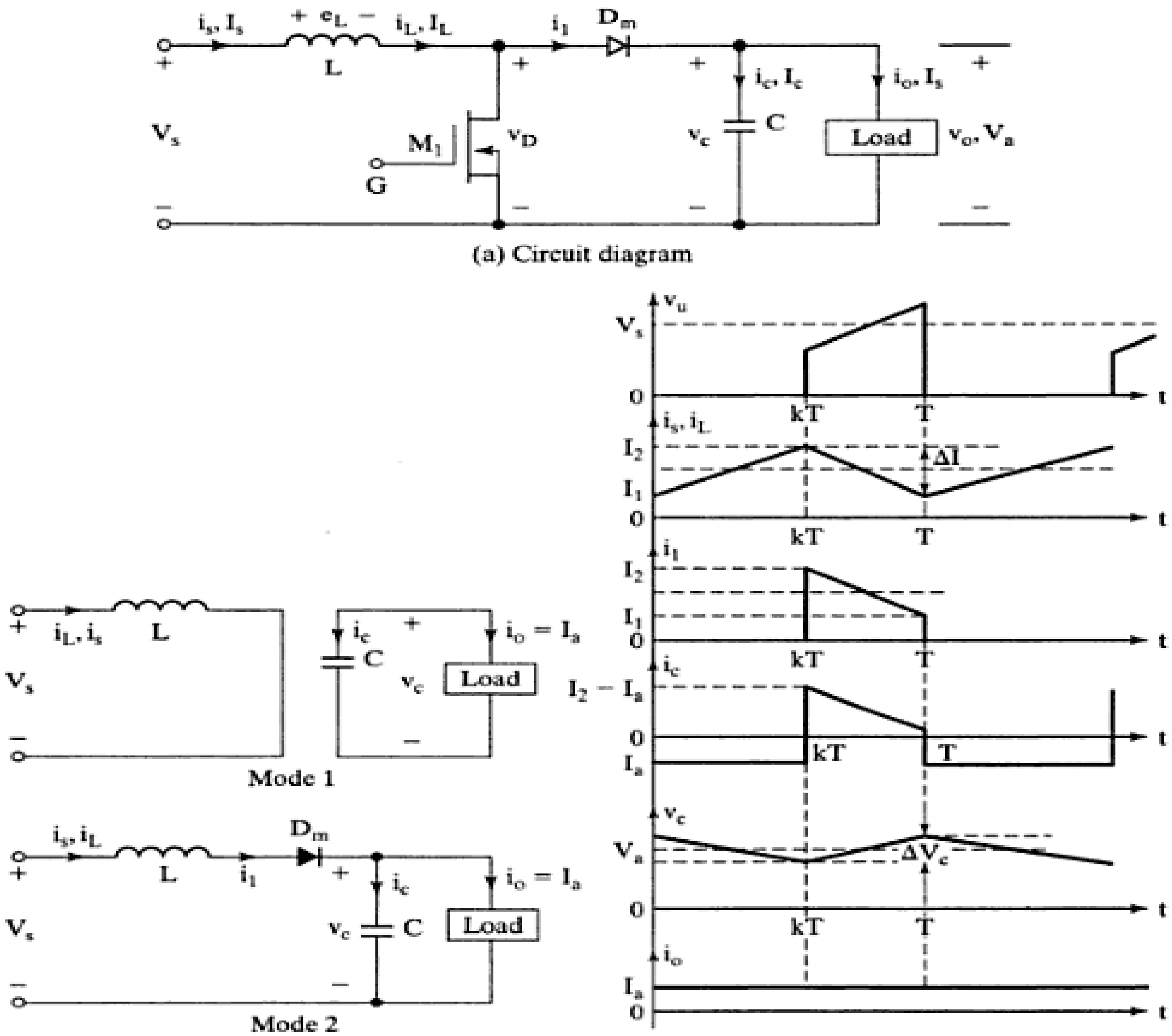




Q(2) Explain the working of boost converter.(2013)(bp)

Ans: (i) In this type of converter, the output voltage is greater than input voltage. When the power MOSFET is ON, the inductor stores energy during T_{on}. Hence diode D_f is reverse biased and isolates the output stage.

(ii) When power mosfet is off, the output stage receives energy from the inductor as well as from the input. The current was flowing from the transistor would flow through L , D_f, C, load.



(a) Circuit diagram

(b) Equivalent circuits

(c) Waveforms

LONG QUESTIONS

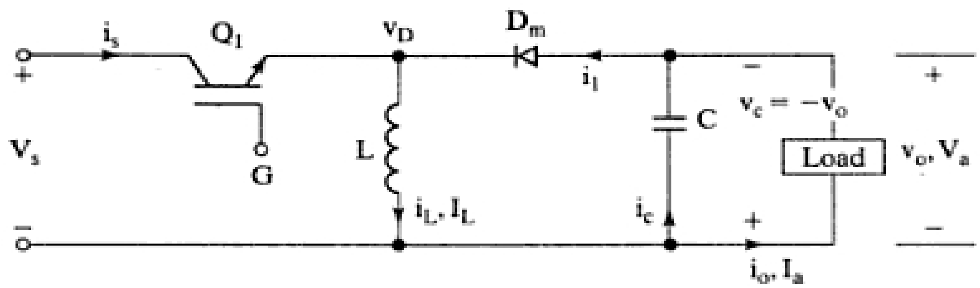
Q(1)Explain buck-boost converter with its waveforms.

Ans: i) A buck-boost converter is a cascade connection of step-down converter and step-up converter.

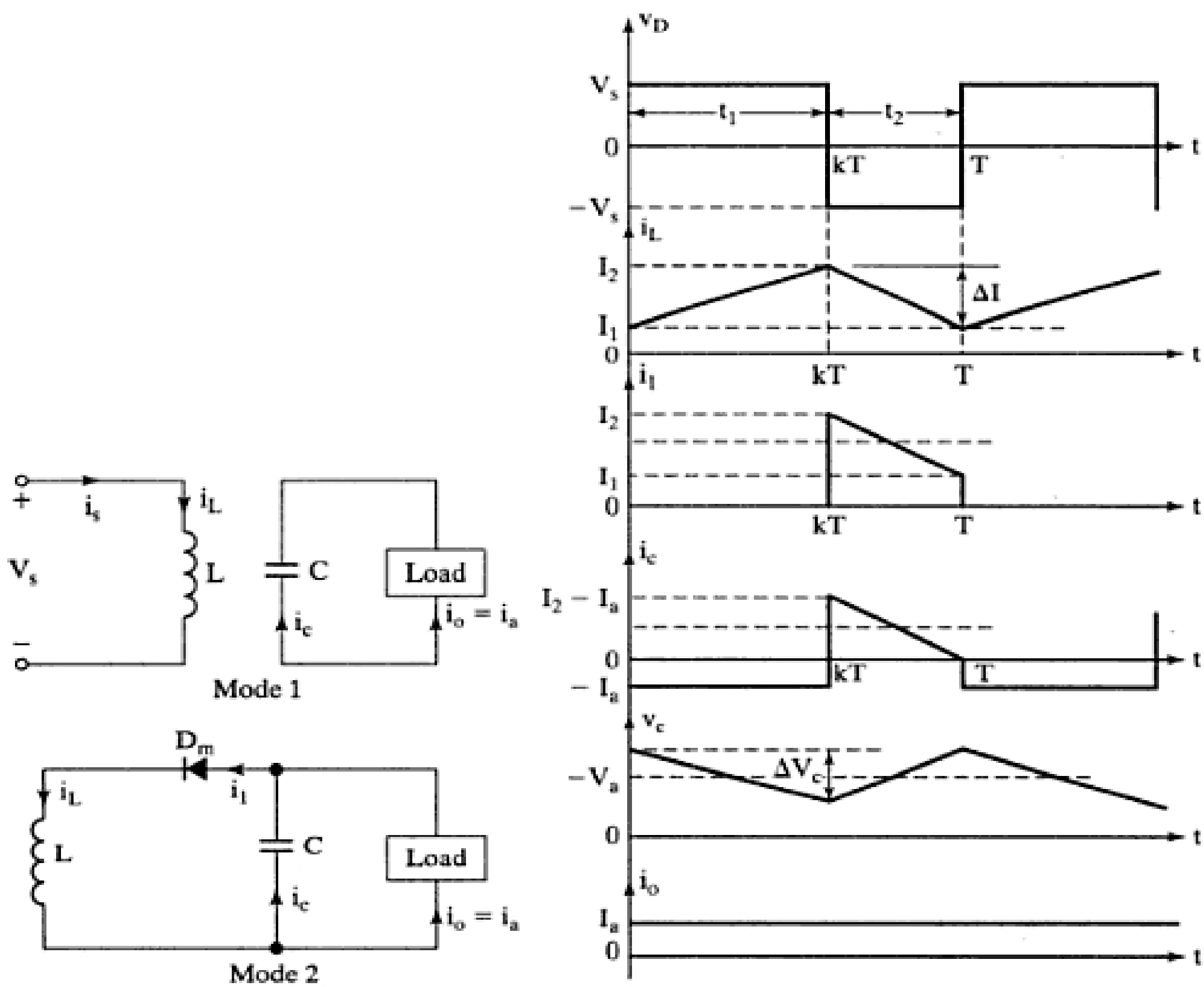
(ii) When the power mosfet is switched on, the supply current flows through the path E_{dc+}-T_1-L-E_{dc-}.Hence the inductor L stores the energy during T_{on} period.

iii) When the power mosfet is switched off the inductor current tends to decrease. The polarity of the inductor gets reversed. As a result diode get forward biased. Thus inductance energy discharge through the load through L^{+}-load-D-L^{-}.

(iv) This converter has high efficiency. The inductor L limits the di /dt of the fault current when the device is under fault condition.



(a) Circuit diagram



(b) Equivalent circuits

(c) Waveforms