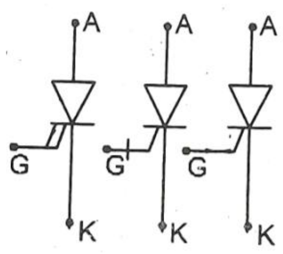
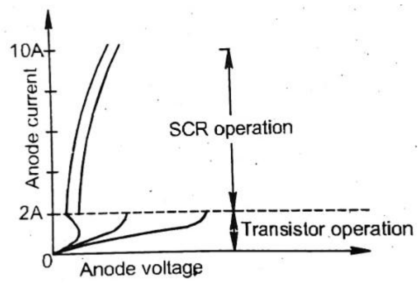
1882-POWER ELECTRONICS

Part-A.

1.Draw the symbol of GTO and its V-I -characteristics (3 Marks)

Symbol **V-I -characteristics**





2.Distinguish between holding current and Latching Current of SCR. (3 Marks)

Holding current (I)

The holding current may be defined as the minimum value of anode current below which the SCR stops conducting and returns to its OFF state.

Latching current (I)

The latching current of a device may be defined as the minimum ON state current required to keep the SCR in the ON state after the triggering pulse has been removed.

3. Write the applications of phase-controlled rectifier.(Any 3) (3 Marks)

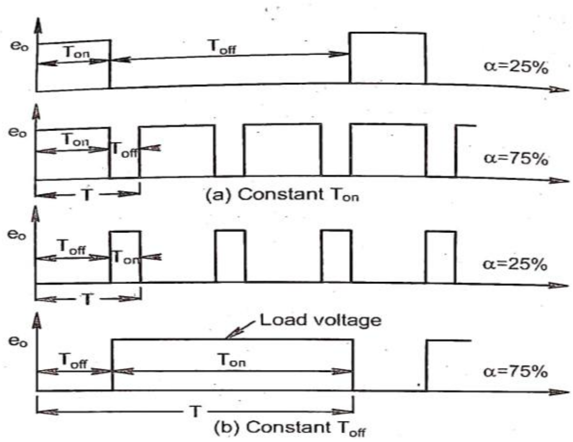
i) Steel rolling mills, paper mills, printing presses and textile mills employing DC motor drives.
ii) Tracking systems working on DC.
iii)Electro chemical and electro metallurgical processes.
iv) Magnet power supplies.
v) Portable hand tool drives.
vi) High voltage DC transmission.

4.Define surge current rating. (3 Marks)

Surge current rating is the maximum amount of surge current that a device can withstand before it restricts the flow of electricity. It's measured in kilo ampere (kA).

5.What is meant by FM control in a DC chopper? (3 Marks)

In this method, the chopping frequency F is varied by keeping the ON time (Ton) or OFF time (Toff) as constant. This type of control is called frequency modulation control.



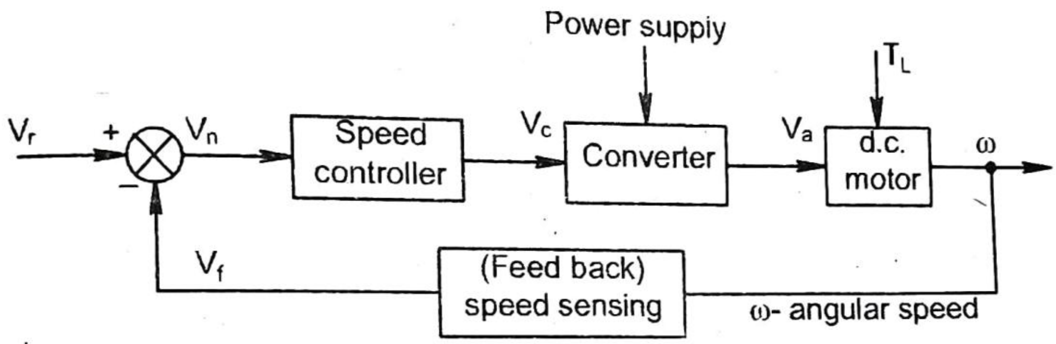
6.Mention the merits of 120° mode of operation of an inverter .(Any 3) (3 Marks)

- **Less susceptible to short circuit**: The 120° mode is less likely to experience a short circuit.
- **Easy control**: The 120° mode is easier to control than other modes.
- **Low switching loss**: The 120° mode has low switching loss.
- **Simple output phase to neutral voltage pattern**: The output phase to neutral voltage pattern is easy to understand.

7.List the advantages of three-phase semi converter DC motor drives.(Any 3) (3 Marks)

1. Better performance
2. Higher capacity
3. Better regulation and response
4. Can operate in continuous or discontinuous modes
5. Can be used for high power applications
6. Can be used for traction and heavy lifting equipment

8.Draw the block diagram of closed loop control of DC drives. (3 Marks)

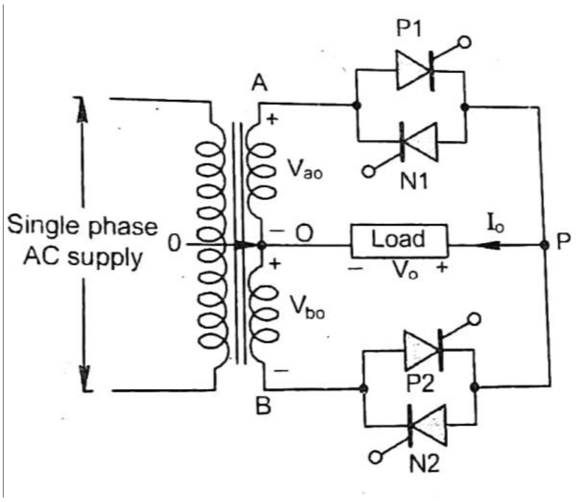


9.What is static VAR compensation? (3 Marks)

- A Static VAR Compensators [SVC] consists of TCRS connected in parallel with two or more TSCS.
- The reactive elements of the compensators are connected to the transmission line through the transformer for removing the full voltage elements.
- A control system depends on the predetermined strategy, to decide the accurate gating instants of the reactors.

- The main aim of this strategy maintains the transmission line voltage in fixed level.
- Due to this reason, a control system takes a input voltage through the Potential Transformer The other input parameters in additional are connected with the control system.
- By adjusting the conduction angle, the compensator voltage of the control system is high or low constant value.

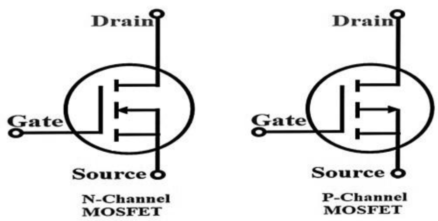
10. Draw the circuit diagram of single phase cyclo converter. (3 Marks)



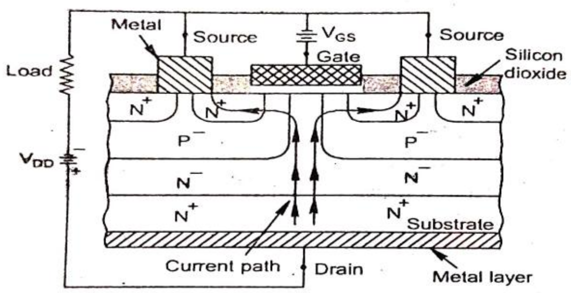
PART-B

11. (a) Draw the symbol, circuit, characteristics of a MOSFET and explain its operation.

SYMBOL(2 MARKS)



Circuit, operation of a MOSFET (7 MARKS)

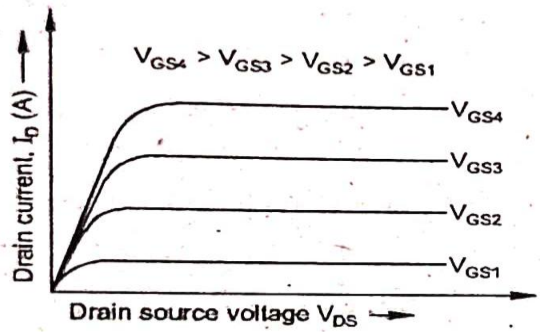


A power MOSFET is a specific type of metal oxide semiconductor field effect transistor (MOSFET). It is a voltage controlled device because the output current (drain current) can be controlled by gate-source voltage (V_{GS}). The power MOSFET has three terminals, called drain D, source S and gate G. Compared to the other semiconductor devices (IGBT, thyristor etc) its main advantages are high commutation speed and good efficiency at low voltages. The power MOSFET Ís the most widely used low voltage(i.e., less than 200V) switch. It can be found in most power supplies, DC to DC converters and low voltage motor controllers.

The bottom layer is N^+ substrate. The N^- layer is called the drain drift region. The drift region determines the breakdown voltage of the device. A metal layer is deposited on the N^+ substrate to form the drain terminal.

The P^- regions are diffused in the epitaxial grown N^- layer. Further N^+ regions are diffused in P^- regions. Then Sio_2, is added which is then etched so as to fit metallic source and gate terminals.

Characteristics of a MOSFET: (5 MARKS)



When the gate source voltage V_{Gs} İS zero, and the drain source voltage V_{DD} is present, then N^-–P^-junctions are reverse biased. So no current flows from drain to source. Now the device is considered as an open switch.

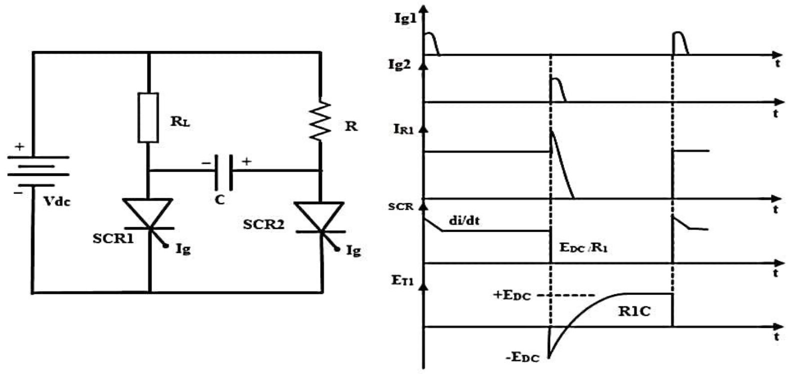
When gate terminal is made positive with respect to source, an electric field is created and electrons form N channel in the P^- region. Now the current flows from drain to Source, and the current direction is indicated by arrow. The gate voltage V_{Gs} is increased, drain current I, also increases. That is output current can be controlled by gate voltage. So power MOSFET is also called as voltage controlled device. The controlling parameter is gate-source voltage V_{Gs} .

For low values of VDs the graph between VDs- ID is almost linear. This indicates a' constant value of on-resistance (R_{DS}). If VDS is increased drain current is nearly Constant.

11. (b) Explain class C and class D commutation circuits.

Class C Commutation (7 MARKS)

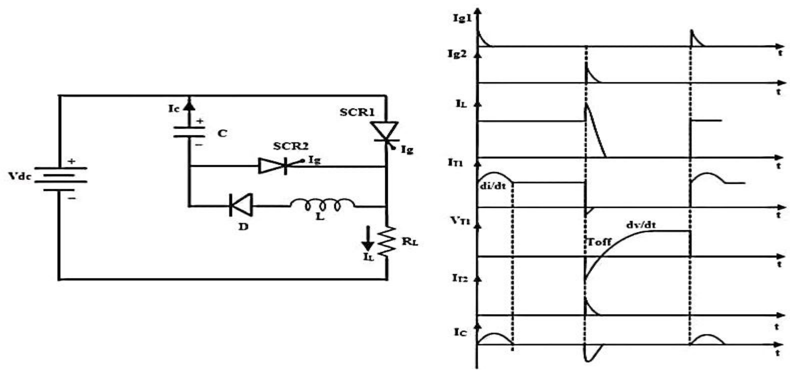
In this commutation method, the main SCR which is to be commutated is connected in series with the load. An additional or complementary SCR is connected in series with the resistor ‘R’. This method is also called as complementary commutation. In this, SCR turns OFF with a reverse voltage of a charged capacitor. The figure shows the complementary commutation with appropriate waveforms. Initially, both SCRs are in OFF state so the capacitor voltage is also zero. When the SCR1 or main SCR is triggered, current starts flowing in two directions, one path is E+ – R1 – SCR1 – E- and another path is the charging current E+ – R2- C+ – C- SCR1 – E- . Therefore, the capacitor starts charging up to the value of E.



When the SCR2 is triggered, it is turned ON and simultaneously a negative voltage is applied across the SCR1. So this reverse voltage across the SCR1 immediately causes to turn OFF the SCR1. Now the capacitor starts charging with a reverse polarity through the path of E+ – R1- C+ – C- SCR2 – E-. If the SCR 1 is triggered, discharging current of the capacitor turns OFF the SCR2. This commutation is mainly used in single phase inverters with a centre tapped transformers. The Mc Murray Bedford inverter is the best example of this commutation circuit. This is a very reliable method of commutation and it is also useful in circuits even at frequencies below 1000Hz.

Class D Commutation :(7 MARKS)

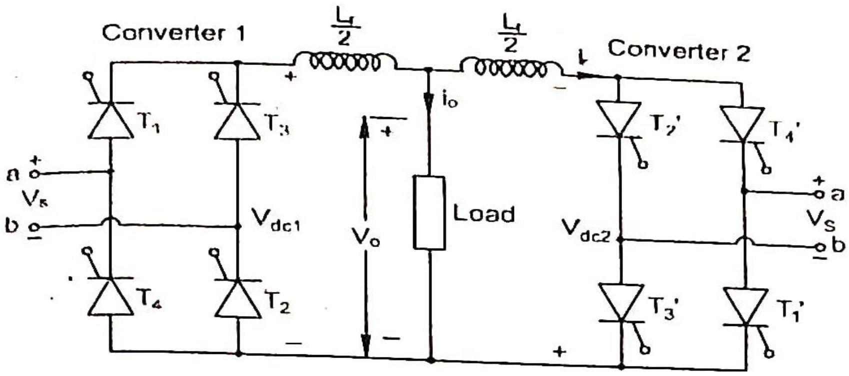
This is also called as auxiliary commutation because it uses an auxiliary SCR to switch the charged capacitor. In this, the main SCR is commutated by the auxiliary SCR. The main SCR with load resistance forms the power circuit while the diode D, inductor L and SCR2 forms the commutation circuit.



When the supply voltage E is applied, both SCRs are in OFF state and hence the capacitor voltage is zero. In order to charge the capacitor, SCR2 must be triggered first. So the capacitor charges through the path E+ – C+ – C- – SCR2- R- E-. When the capacitor is fully charged the SCR2 becomes turned OFF because no current will flow through the SCR2 when capacitor is charged fully. If the SCR1 is triggered, the current will flows in two directions; one is the load current path E+ – SCR1- R- E- and another one is commutation current path C+ – SCR1- L- D- C. As soon as the capacitor completely discharges, the inductor 'L' is fully charged. This inductor charges the capacitor in reverse direction. When inductor completely discharges the capacitor is charged fully. Now the capacitor is unable to discharge because of the reversed diode. When the SCR2 is triggered capacitor starts discharging through C+ – SCR2- SCR1- C-. When this discharging current is more than the load current the SCR1 becomes turned OFF. Again, the capacitor starts charging through the SCR2 to a supply voltage E and then the SCR2 is turned OFF. Therefore, both SCRs are turned OFF and the above cyclic process is repeated. This commutation method is mainly used in inverters and also used in the Jones chopper circuit

12. (a) Explain about the working of single phase dual converter with RL load with neat circuit diagram.

(Diagram 5 marks, Waveform 2 marks, Explanation 7 marks)



A single phase full converter with inductive load allows only a two-quadrant operation. If two of these converters are connected back to back, the output voltage and output current can be reversed. Such a circuit that provides four quadrant operations is called dual converter. The delay angles of converters 1 and 2 are α1 and a2 respectively. Their corresponding output voltages are Vdc1 and Vdc2.The delay angles are controlled such that one converter operates as a rectifier and the other converter operates as an inverter, but both converters produce the same average output voltage.

The average output voltage of both converters is,

$$V_{dc1}=\frac{2v_m}{\pi}\cos\alpha_1$$

$$V_{dc2}=\frac{2v_m}{\pi}\cos\alpha_2$$

Because one converter is rectifying and the other one is inverting,

$$V_{dc1}= -V_{dc2}$$

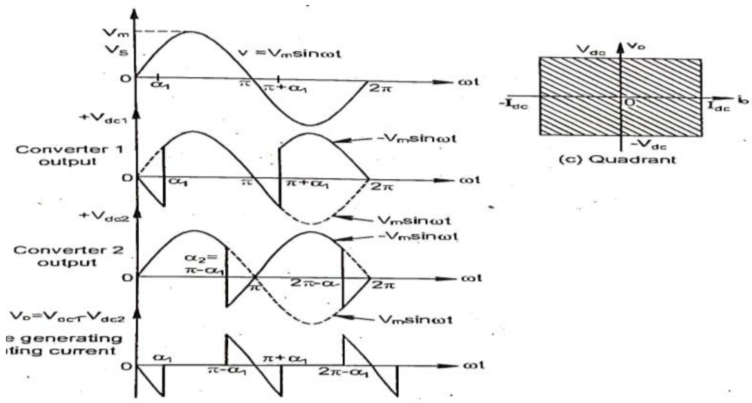
$$\cos\alpha_1= - \cos\alpha_2$$

$$=\cos(\pi - \alpha 2)$$

$$\alpha 1=\pi - \alpha 2 \text{ (or) } \alpha 2=\pi - \alpha 1$$

The instantaneous output voltages of the two converters are out of phase, so the voltage difference can produce a circulating current between the two converters. This circulating current cannot flow through the load and is normally limited by a circulating current reactor L, as shown in the circuit diagram.

The dual converter can be operated with or without a circulating current. In case of operation without circulating current, only one converter operates at a time, and carries the load current, and the other converter is completely blocked by inhibiting gate pulse.



The operation with circulating current has the following advantages.

i) The circulating current maintains continuous conduction of both converters over the whole control range, independent of the load.

ii)Because one converter always operates as a rectifier and the other converter operates as an inverter, the power flow in either direction at any time is possible.

iii) Because both converters are in continuous conduction, the time response for changing from one quadrant operation to another is faster.

The gating sequence is as follows.

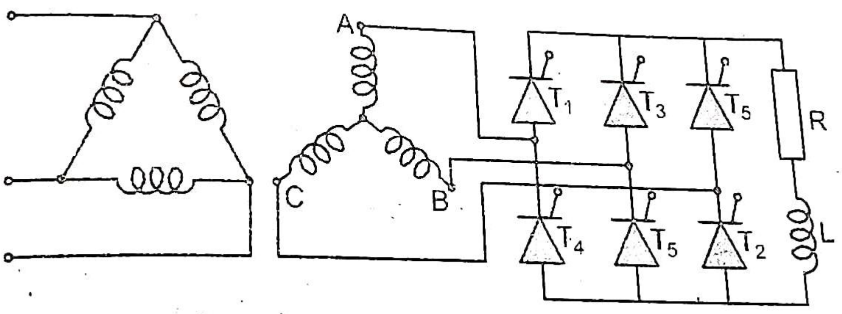
a) Gate the positive converter with a delay angle of α1 = α

b) Gate the negative converter with a delay angle of α2 = π- α through gate - isolating circuits.

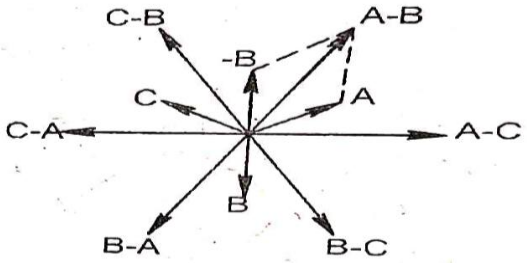
12. (b) Discuss about the operation of three phase fully controlled bridge converter with RL load with necessary diagrams.

(Circuit Diagram 5 marks, Waveform 2 marks, Explanation 7 marks)

A three phase fully controlled bridge with RL load and its waveforms are shown.



In this circuit, the load current will be continuous and ripple free. This circuit consists of two groups of SCRS i.e., positive group and negative group. The SCRS T1, T3 and T5 forms a positive group, and the SCRS T4, T6 and T2 forms a negative group. For proper operation, only two SCRS conduct at a time, one from positive group and other from negative group. Therefore each SCR conducts for 120° but each SCR pair conducts for one interval of 60°.



For describing the operation of the circuit, we make the following assumptions.

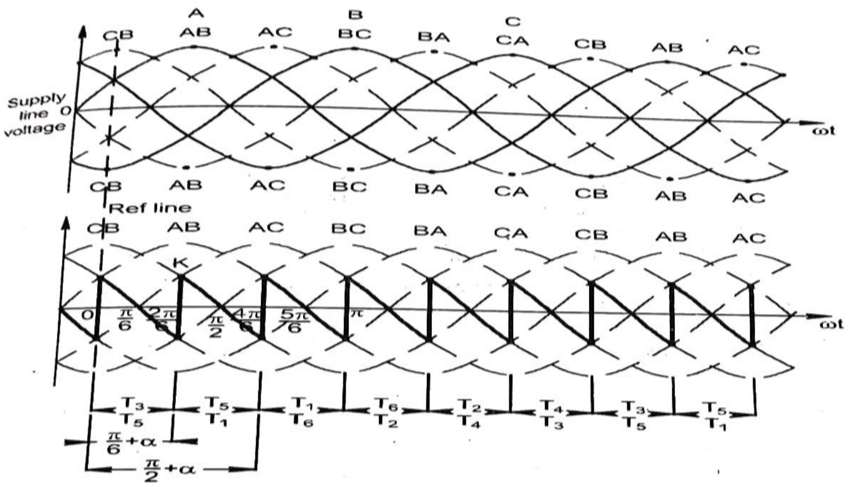
i) The converter is in working state with SCRS T5 and T6 which are in conduction state.

ii) The load inductance is assumed to be very large so as to produce a constant load current.

iii) Effect of source inductance is neglected.

At instant K, the SCR T, is triggered with firing angle($\frac{\pi}{6}+a$).When T1 is conducting, the voltage between lines A and C reverse biases SCR T5 as voltage of phase A is more than the voltage of phase C. Therefore SCR T5 becomes OFF. Now the line voltage V_{AB} appears across output terminals through the SCRS T1 and T6 and current i_o flow through the load

The SCR pair (T6 - T1) conduct from (π/6+ a) to (π/2+α). At (π/2 + α) the SCR T2 is turned ON and the line voltage VBC reverse biases SCR T6 and is turned OFF. Hence T1- T2 starts conducting and line voltage V_{AC} is applied across the load.



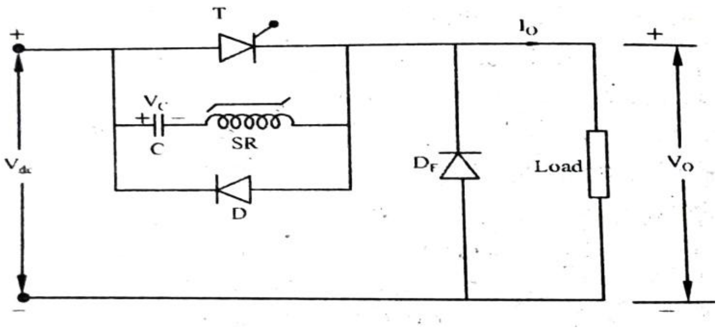
At($\frac{5\pi}{6}+a$). the SCR T3 is turned ON. Hence T1 turns OFF and T2- T3 start conducting. Therefore line voltage V_{BC} is applied across the load. In this way the SCRS T1-T2-T3-T4-T5-T6 - T1 are triggered at proper firing angle. The following table shows the six modes of firing sequences of SCRS.

Modes of operation	**Conducting SCRs**	**SCR's to be fired**	**Out going SCR**
Mode 0	5,6	1	5
Mode 1	6,1	2	6
Mode 2	1,2	3	1
Mode 3	2,3	4	2
Mode 4	3,4	5	3
Mode 5	4,5	6	4

13. (a) Explain the working of Morgan chopper circuit with a neat sketch.

(Circuit Diagram 5marks,Explanation 9 marks)

The circuit diagram of Morgan chopper is shown. This chopper circuit is based on class B commutation method. In this circuit, the SCR T is the main thyristor, whereas capacitor C, saturable reactor SR and diode D forms the commutating circuit. When the saturable reactor is saturated, it has very low inductance.



We assume that the capacitor C is initially charged to a voltage Vdc with the polarity as shown in the figure. When SCR T is turned ON, the input voltage is applied to the load. As soon as T is turned ON, the capacitor C tends to discharge its voltage through saturable reactor and SCR T. Since the unsaturable inductance of saturable reactor is very high and the capacitor will take the relatively longer time interval to discharge its voltage. After this, the capacitor C getting charges in reverse direction and the core is driven from negative saturation towards positive saturation.

After a fixed interval of time, the core flux reaches positive saturation after which the capacitor discharges very quickly through SCR T in the reverse direction. The discharge current first passes through SCR T, turning it OFF and then through diode D. When the SCR is turned OFF, the load current flows through the free wheeling diode DF.

Due to the use of saturable reactor in place of linear inductor, the ON time is considerably increased and this is achieved without increasing the value of capacitor C.

Advantages

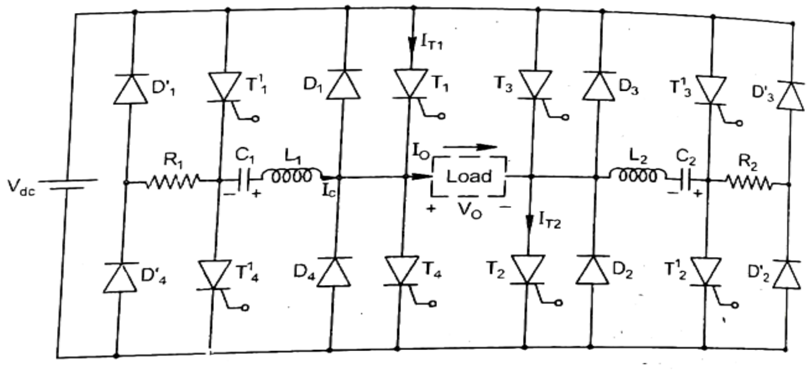
i) At the time of turn OFF the saturable reactor offers very low inductance due to the core saturation. This ensures very fast turn OFF of SCR.

ii) Since the circuit works with a single SCR there is a saving of cost.

13. (b) Explain the working of modified Mc Murray full bridge inverter with a neat diagram.

(Circuit Diagram 5marks, Explanation 9 marks)

Basically a McMurray inverter is an impulse commutated inverter, which relies on an LC circuit and an auxiliary SCR for commutation in the load circuit. The impulse is derived from the resonating LC circuit and is applied to turn-OFF a SCR carrying the load current.



The modified McMurray full bridge inverter is shown. The circuit consists of main SCRS T1, T2, T3 and T, free wheeling diodes D1, D2, D3, and D4, auxiliary SCRS T1', T2', T3' and T4', auxiliary diodes D1', D2', D3' and D4', commutating components L (L1 and L2) and C (C1and C2) and resistors (R1 and R2). When SCR pairs T1, and T2 conducts load is connected across the DC supply causing a positive voltage across the load. Similarly when the SCR pair T3 and T4 conducts, a negative voltage is produced across the load. Thus alternatively making the pair of SCRs to conduct, an alternating voltage is produced across the load.

The resistors R1 and R2 and auxiliary diodes D'1 - D'4 are used to permit the removal of the capacitor overcharge at the end of the commutation process. After the commutation of thyristor T1, the excess energy stored in C1 is partly dissipated in the resistance R1 and partly returned to supply (DC source) by a current flowing through the path R1 - D'1 - the DC source D4-L1. Similarly, excess energy stored in C2 is partly returned to the DC source by a current flowing through L2 - D3 - DC source - D'2 - R2. The voltage across R1 and D'1, commutates T'1 and voltage drop across R2 and D'2 commutates T'2.

Mode 1

This mode begins when the SCR pair T1, T2 is triggered. When thyristors T1, T2 become turned ON, the supply current flows through the path Vdc (+), T1, load, T2 and Vdc (-) and hence positive load voltage Vo is obtained. The commutating capacitors C1, C2 are already charged to a voltage Vc with the polarities as shown in the figure, because of the commutation of the previously conducting SCRS T3, T4.

Mode 2

This mode begins when SCRS T'1, T'2 are triggered to turn OFF the main SCRS T1, T2 which were conducting. When SCRS T'1, T'2 have been turned ON, capacitors C1, C2 start discharging.

The capacitor C1 forms the discharging loop through C1 (+), L1, T1, T'1 and C1 (-). The capacitor C2 form the discharging loop through C2 (+), T'2, T2, L2 and C2 (-). Therefore current Ic rises taking part of load current from T1, T2. The voltage drop across T1, T2 reverse biases D1, D2. Therefore current flow only through T1, T2 and not through D1, D2. As load current Io is constant, an increase in Ic causes a corresponding decrease in IT1, IT2. A particular instant the capacitor current Ic ($I_T = I_o - I_c$) rises to Io, and therefore the currents IT_1 and IT_2 becomes zero. As a result main SCR T1 and T2 turned OFF.

Mode 3

After that the current Ic exceeds Io, the excessive current circulates through feedback diodes D1, D2. The resonating oscillation continuous through the paths C1 (+), L1, D1, T'1, C1 (-) and C2 (+), T'2, D2, L2, C2 (-) respectively. The voltage drop across D1 and D2 reverse biases T1, T2 to bring it to forward blocking capability. The commutating current Ic rises to a peak value when the capacitor voltage (Vc) is zero and then decreases as the capacitor is charged in the reverse direction. At this time, Ic falls back to the load current Io, and diodes D1, D2 stop conducting.

Mode 4

This mode starts when diodes D1 and D2 stop conducting. The load continuous to draw a constant current through T'1, C1, L1, load, L2, C2 and T'2. So, the capacitor recharges through the load. This mode ends when the capacitor voltage becomes equal to the DC supply (Vdc) and due to overcharge due to the energy stored in inductor L.

Mode 5

This mode starts when the capacitor voltage tends to be greater than Vdc and diodes D3 and D4 becomes forward biased. The energy stored in inductor L is transferred to the capacitor, causing it to be overcharged with respect to supply voltage Vdc Now the auxiliary SCRS T'1 and T'2 are commutated. This mode ends when the capacitor current falls again to zero and the capacitor voltage is reversed to that of original polarity and now the circuit is ready for the next cycle of operation. During the next half cycle, SCR pair T3 and T4 are triggered and a negative half cycle of voltage is produced across the load.

14. (a) Explain the methods of speed control of DC motor with necessary waveforms.

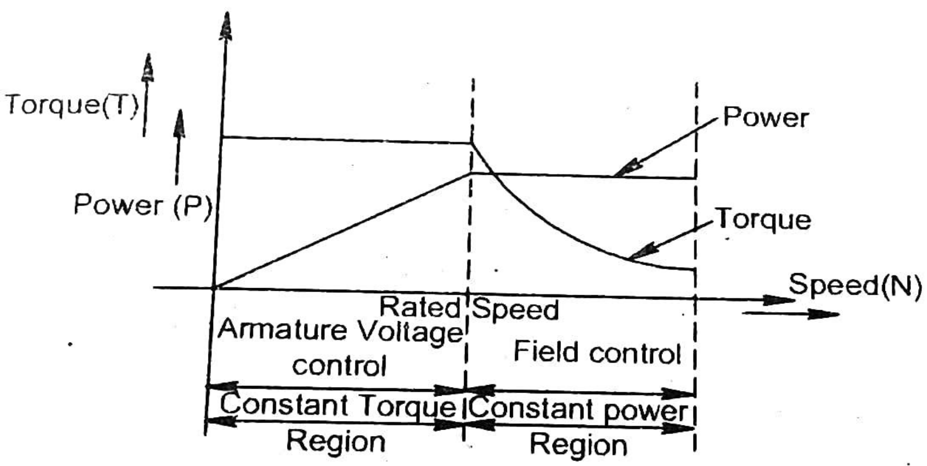
(Diagram 5marks, Explanation 9 marks)

The speed control of DC motors is possible in two ways. They are

i) **Armature voltage control method** - In this method the voltage across the armature is varied.

ii) **Field control method** - In this method the current through the field is varied.

In DC motors the speed less than the rated speed can be achieved by varying the armature voltage with constant armature current and field current. Therefore the speed from zero to rated value can be at constant torque because of constant armature current (Ia). Hence this region is called 'constant torque region'. In this region the torque is constant, but the power developed in the armature is varied and it is maximum when the motor reaches its rated value.

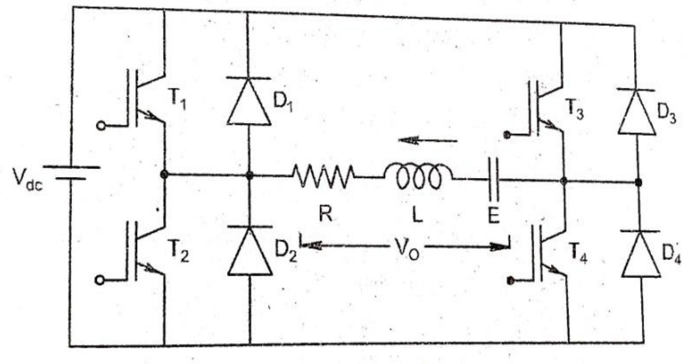


On the other hand, the speed greater than the rated speed can be achieved by varying the field current($I_f \alpha \phi$) with constant armature voltage. During this region the voltage and current drawn by the motor are constant and hence this region is called "constant power region", and the power drawn from the mains will be constant. In this region when the speed increases correspondingly the torque can be decreased. The representation of armature voltage control, and field control with constant torque and constant hp regions are shown in the above fig.

14. (b) Explain the operation of DC to DC converter using IGBTs.

(Diagram 5marks, Waveform 2 marks Explanation 7 marks)

The circuit diagram of a four quadrant DC-DC converter drive using IGBT is shown. It consists of four IGBTS (T1 to T4) and four diodes (D1 to D4). Operation of this converter is described below.



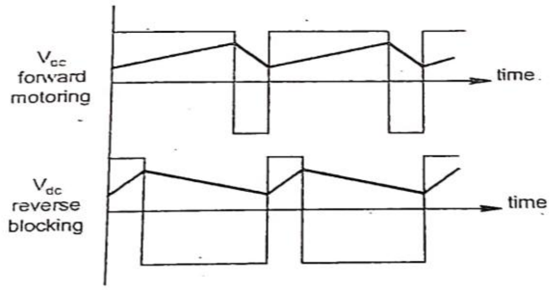
First quadrant: In the first quadrant operation, T4 is kept ON, T3 is kept OFF and T1 is operated. With T1 and T4, load voltage is equal to supply voltage, ie., $V_o = V_{dc}$ and load current I_o begins to flow. Now the current flow through T1, load and T4. output voltage V_o and load current I_o are positive giving first quadrant operation. When T1 is turned OFF, positive current free wheels through T4 and D2. In this way both the output voltage (V_o) and load current (I_o) can be controlled. First quadrant operation give forward motoring mode.

Second quadrant: Here T2 is operated and T1, T3 and T4 are kept OFF. With T2 ON, reverse current flows through L, T2, D4 and E. During this ON time of T2 the inductor L stores energy. When T2 is turned OFF, current is feedback to source through diodes D1 and D4. Now the voltage of E + L di/dt is greater than the source voltage V_{dc}. So the load voltage V_o is positive and load current I_o is negative. The power is flows from load to source. This second quadrant operation gives forward braking mode.

Third quadrant: Here T1 is kept OFF, T2 is kept ON and T3 is operated. Polarity of load emf E must be reversed for this quadrant operation. With T3 ON, load gets connected to source Vdc' so that both output voltage Vo and load current Io are negative. It gives third quadrant operation. Now the current flow through T3, load and T2. It is also known as reverse motoring mode. When T3 kept OFF, negative current free wheels through T2 and D4.

Fourth quadrant: Here T4 is operated and other devices are kept OFF. Load emf E must have its polarity reversed. In the fourth quadrant with T4 ON, positive current flows through T4, D2, L and E. During the ON time of T4 inductor L stores energy. When T4 is turned OFF, current is feedback to source through D3 and D2. Here load voltage is negative but load current is positive. Now power flows from load to source. This operation gives reverse braking mode.

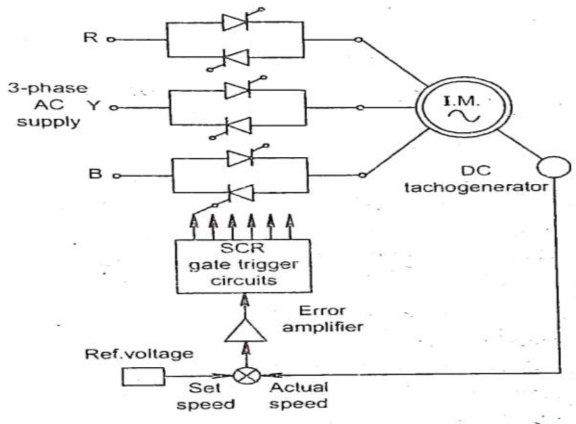
The voltage and current waveforms are shown



15. (a) Explain how speed is controlled in an induction motor by stator voltage control method.

(Diagram 5marks, Explanation 9 marks)

A commonly used symmetrical 3 phase AC voltage control circuit is shown. It is a simple and reliable method. The stator voltage is controlled with the help of SCRS connected in anti parallel 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 120^0 is maintained between the sets of gatting 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 passes 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 is 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 tachogenerator voltage, the firing angle is delayed and conduction period is reduced. Stator voltage is reduced, developed torque is lowered and finally runningspeed 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.

15.(b) Explain the operation of micro computer based PWM control of induction motor with a block diagram.

(Diagram 5marks, Explanation 9 marks)

Microcomputers are having a major impact on industrial applications including the areas of testing, control, instrumentation, data acquisition, numerical machine control and even robotics.

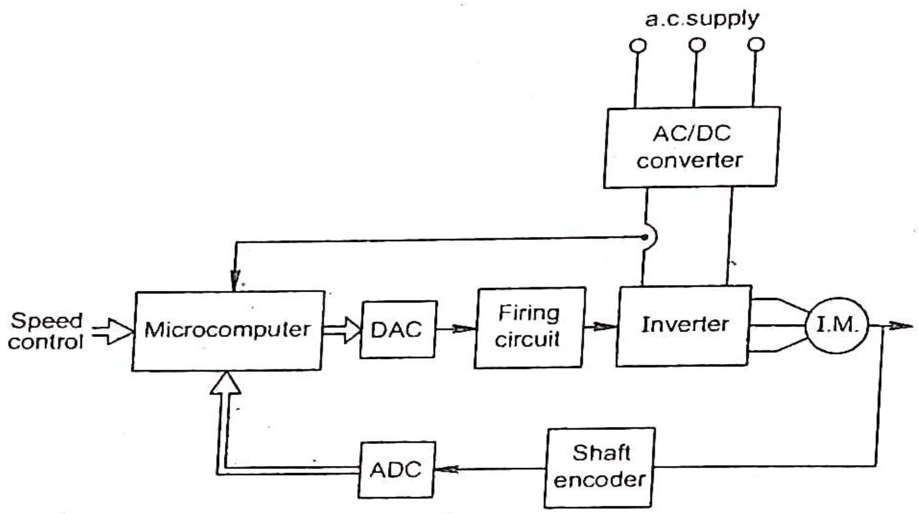
In any motor, if we want to keep the ratio of voltage to frequency (V/f) constant, constant torque is required throughout the speed range. This task is achieved by using pulse width modulation (PWM) technique.

Modern PWM AC driver systems have more performance and reliability with reduction of control and power conversion cost. In an ordinary hardware modulator, the PWM waveforms are generated by comparing the sine reference wave with the triangular carrier wave by the natural sampling process. In this system low order harmonics are generated and dropping of pulses near the middle of the wave causes a current surge problem.

In a microcomputer based modulator, the wave can be fabricated precisely in the transition region controlling the harmonics and nonlinearity problem can be easily eliminated.

The block diagram of microcomputer based pulse width modulation control of induction motor drive is shown. The microcomputer performs all the functions of closed loop control using software. A suitable software and digital logic are used to develop the necessary PWM waveform. The uniform sampling techniques are used to develop the necessary PWM waveforms.

A microcomputer system may be evolved to provide the real time simulation besides implementing the control programs. The real time aspects of the computer ADC, DAC, parallel interfaces and the capability of the system to provide control and other functions are taken to advantage. The system can be designed with a flexibility to provide monitoring functions, to change the parameters such as sampling rates of ADC.



The operation of this controller is given below.

i)The shaft encoder generates the voltage signal proportional to the rotational speed of induction motor.

ii) ADC converts analog signal to its equivalent digital signal.

iii) The microcomputer compares the actual speed of motor with required speed, and produces PWM signal proportional to its difference between them.

iv) DAC converts the PWM signal to its equivalent analog signal.

v) The signal obtained from DAC changes the firing angle of thyristors used in inverters.

vi) The speed of motor is then changed from its actual speed to required speed and finally attains its required speed.

The microcomputer control must be capable of performing control tasks as it interacts with the system. This includes selection and sampling of signals and mathematical computation necessary for A/D and D/A conversion.

If the execution speed of the microcomputer is slow, the control may not be accurate because some input measurements may be missed or false timing of signals may be generated. The multi-task may be executed in parallel almost simultaneously by developing algorithms, which may be performed independently by a multiprocessor system.

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