22326

22326

11819

3 Hours / 70 Marks

Seat No. | | | | | | | | |

Instructions : *(1) All questions are compulsory.*
(2) Illustrate your answers with neat sketches wherever necessary.
(3) Figures to the right indicate full marks.
(4) Assume suitable data, if necessary.

Marks

1. Attempt any five of the following : 10
   a) State the applications of MOSFET (any two).
   b) Draw the V-I characteristics of power transistor.
   c) Draw the symbol of GTO and TRIAC.
   d) Define triggering. List the type of triggering.
   e) Define commutation. Give the types of commutation.
   f) Define transfer time and back up time of UPS.
   g) State the applications of power electronics.

2. Attempt any three of the following : 12
   a) Describe with neat sketch the construction and working principle of MOSFET.
   b) Draw construction of SCR using two transistor model. Explain its operation.
   c) Explain the operation of RC triggering circuit with neat diagram.
   d) Draw a neat diagram of 1φ half wave controlled converter with RL load. Give its operation.

3. Attempt any three of the following : 12
   a) Draw a neat labelling V-I characteristics of SCR and explain the region.
   b) Explain the operation of PUT relaxation oscillator with diagram.
   c) Explain with sketch the operation of single phase fully controlled midpoint configuration with R load.
   d) Give the operation of battery charger using SCR with a neat diagram.

P.T.O.

Marks

4. Attempt any three of the following : 12

a) Explain the operation of snubber protection circuit with diagram.

b) Explain the operation of opto coupler based triggering circuit with diagram.

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

d) Draw the circuit diagram of DC static circuit breaker and give its operation.

e) Describe emergency lighting system with neat diagram.

5. Attempt any two of the following : 12

a) Draw a symbol and neat labelling V-I characteristics of GTO and explain its operation.

6. b) Explain auxiliary commutation with a neat diagram. Also draw its waveform.

c) Explain in detail over-voltage protection.

Attempt any two of the following : 12

a) Give the operation of single phase full wave bridge controlled converter with RL load with a neat diagram. Also draw its waveform.

b) Give the effect of source impedance on converter operation.

c) Explain the operation of UPS with a neat block diagram.

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MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC-27001-2013 Certified)

Model Answers
Winter – 2018 Examinations
Subject & Code: Fundamentals of Power Electronics (22326)

Important Instructions to examiners:

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

Model Answers
Winter – 2018 Examinations
Subject & Code: Fundamentals of Power Electronics (22326)

1 Attempt any FIVE of the following: 10

1 a) State the applications of MOSFET (any two).

Ans:

Applications of MOSFET:

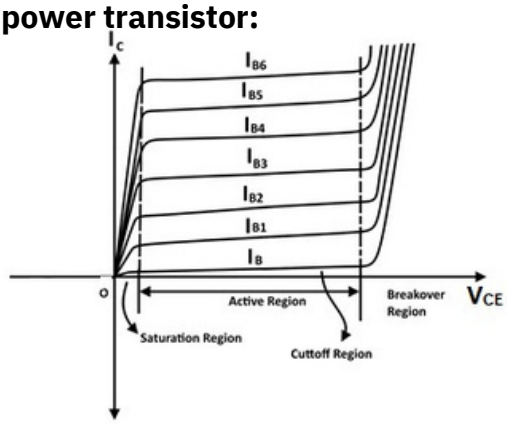
i) Switching-mode-power-supplies (SMPS) and linear power supplies.
ii) Brushless DC motor drives
iii) Solid state DC relay
iv) Automobile applications
v) Stepper motor controller
vi) Lighting controls
vii) Solenoid drivers
viii) Robotics
ix) Induction heating

1 mark for each of any two valid applications = 2 marks

1 b) Draw the V-I characteristics of power transistor.

Ans:

V-I characteristics of power transistor:



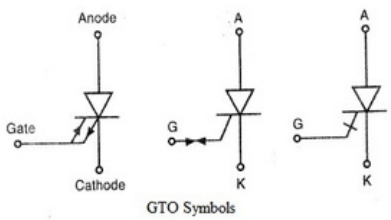
2 marks for labelled diagram

1 mark for partially labelled diagram
No marks for unlabeled diagram

1 c) Draw the symbol of GTO and TRIAC.

Ans:

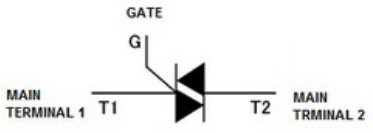
1) GTO:



GTO Symbols

1 mark for any one symbol

2) TRIAC:



1 mark

Model Answers
Winter – 2018 Examinations
Subject & Code: Fundamentals of Power Electronics (22326)

1 d) Define triggering. List the type of triggering.

Ans:

Triggering:

Triggering means turning-ON of a device from its OFF-state. — 1 mark for correct definition

Types of Triggering:

1) Forward voltage triggering
2) Thermal triggering (Temperature triggering)
3) Radiation triggering (Light triggering)
4) dv/dt triggering
5) Gate triggering
   (i) D.C. Gate triggering
   (ii) A.C. Gate triggering
   (iii) Pulse Gate triggering

— 1 mark for types

1 e) Define commutation. Give the types of commutation.

Ans:

Commutation:

The process of turning-off a conducting thyristor is called "commutation". — 1 mark for definition

Types of Commutation:

i) Line commutation (Natural commutation)
ii) Load commutation
iii) Forced commutation
iv) External pulse commutation

— 1 mark for types

OR

i) Class A: load commutation (Self-commutated by resonating the load)
ii) Class B: Resonant pulse commutation
iii) Class C: Complementary commutation
iv) Class D: Auxiliary commutation
v) Class E: External pulse commutation
vi) Class F: AC line commutation

1 f) Define transfer time and back up time of UPS.

Ans:

Transfer time of UPS:

The transfer time, sometimes also called switchover time, is the amount of time the UPS will take to switch from utility to battery supply during a mains failure, or from battery to mains when normal utility power is restored. — 1 mark

Back up time of UPS:

The backup time is the amount of time for which the UPS will supply the power to load during mains failure. — 1 mark

Model Answers
Winter – 2018 Examinations
Subject & Code: Fundamentals of Power Electronics (22326)

1 g) State the applications of power electronics.

Ans:

Applications of power electronics:

- Solid-state controllers for home appliances
- Light dimmers in home and theatres
- Switch-mode-power-supply (SMPS) and Uninterruptible-power-supply (UPS)
- Power supply for air-craft, space shuttle and satellites
- AC and DC drives in rolling mills, paper mills, textile mills, cement mills etc.
- Solid-state-controllers for mine winders, cranes, elevators, lifts, excavators etc.
- Solid-state-controllers for traction vehicles.
- Power control in chemical processes, metallurgical processes.
- HVDC transmission
- Active power filters and reactive power compensators in power system
- Static circuit breakers
- High voltage supplies for electrostatic precipitators, X-ray machines.

½ mark for each of any four applications i.e. 2 marks

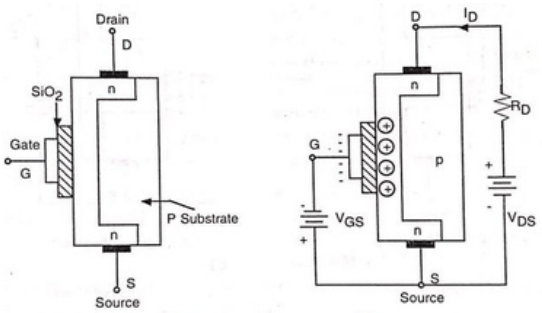
2 Attempt any THREE of the following: 12

2 a) Describe with neat sketch the construction and working principle of MOSFET.

Ans:

Construction and working principle of MOSFET:

A) Depletion type MOSFET:



A) Depletion type power MOSFET

1 mark for diagram

Construction:

The N-channel depletion type MOSFET is formed on P-type silicon substrate with two heavily doped n silicon for low resistance connections of terminals Drain (D) and Source (S). The third terminal Gate (G) is isolated from the N-channel by a thin oxide layer. The substrate is normally connected to the source.

1 mark for construction

Operation:

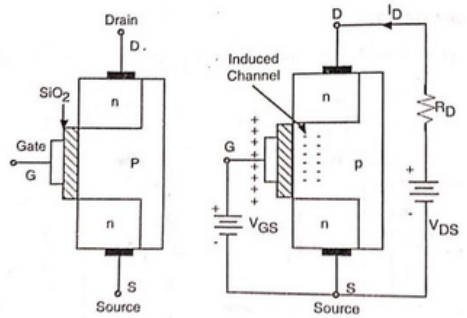
The gate-to-source voltage VGS can be either positive or negative. When VGS is negative, gate becomes negative with respect to source and some of the electrons in the N-channel are repelled leaving behind positive ions. The depletion region is created below the oxide layer, effective channel width is reduced, resulting a high resistance from the drain to source, RDS. At certain negative voltage VGS the channel will be completely depleted, offering very high value of RDS and no current will flow from drain to source i.e. IDS = 0. The value of VGS when this happens is

2 marks for operation

RDS will be the normal resistance of the N-channel. When VGS is positive, the gate is positive and hence attracts electrons into the N-channel. Thus channel becomes wider, more carriers are available for current, RDS get reduced and the current IDS increases.

OR

B) Enhancement type MOSFET:



B) N-channel enhancement type MOSFET

1 mark for diagram

Construction:

The N-channel enhancement type MOSFET is formed on P-type silicon substrate with two heavily doped n+ silicon for low resistance connections of terminals Drain (D) and Source (S). It has no physical N-channel. The third terminal Gate (G) is isolated from the substrate by a thin oxide layer. The substrate is normally connected to the source.

1 mark for construction

Operation:

When VGS is positive, gate is positive and hence on opposite side of oxide layer, the electrons are attracted from the P-substrate and accumulated on the surface beneath the oxide layer. If VGS is greater than or equal to a value known as threshold voltage, VT, sufficient electrons are accumulated to form a virtual N-channel and the current flows from the drain to source. Further increase in VGS will result in more accumulation of electrons and hence more current. Thus the MOSFET is a gate voltage controlled device.

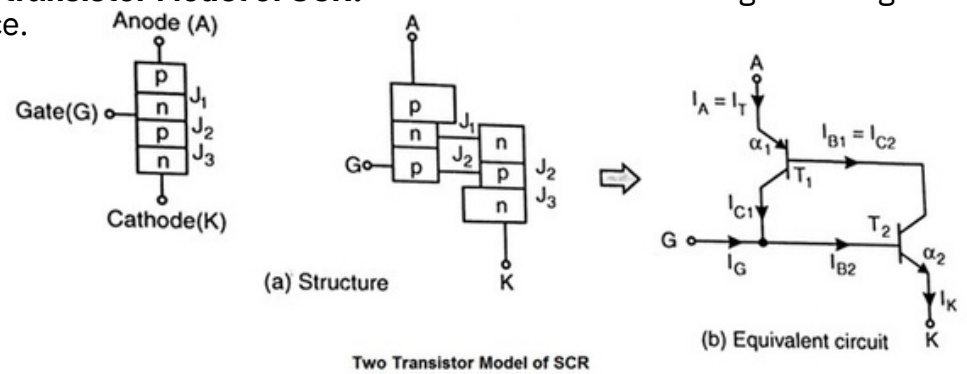
2 marks for operation

(Examiner is requested to award marks for P-channel MOSFET as well)

2 b) Draw construction of SCR using two transistor model. Explain its operation.

Ans:

Two transistor Model of SCR:



Two Transistor Model of SCR

1 mark for (a)
1 mark for (b)
= 2 marks for diagram

A simple p-n-p-n structure of thyristor can be visualized as consisting of two complimentary transistors: one pnp transistor T1 and other npn transistor T2 as shown in the figures. The collector current of transistor is related to emitter current and

leakage current as:

where, = common-base current gain
= leakage current from collector to base with emitter open
For transistors T1 and T2, we can write,
and
From KCL applied to T1, we can write

From KCL applied to entire equivalent circuit,
and substituting in above equation,

2 marks for mathematical treatment

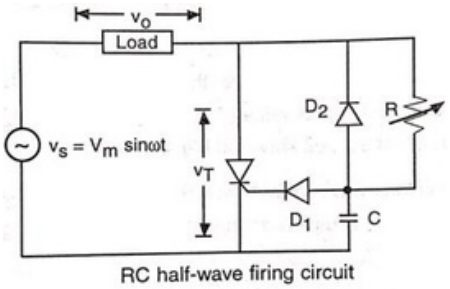
[ ]

[ ]

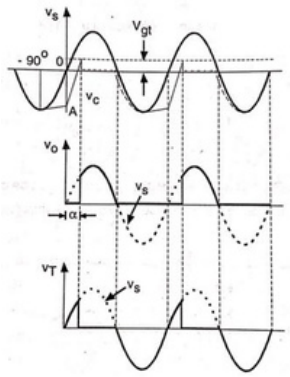
From this equation it is clear that the anode current depends on the gate current, leakage currents and current gains.
If tends to be unity, the denominator [ ] approaches zero, resulting in a large value of anode current and SCR will turn on. The current gains vary with their respective emitter currents.
When gate current is applied, the anode current is increased. The increased , being emitter current of T1, increases the current gain . The gate current and anode current together form cathode current, which is emitter current of T2. Thus increase in cathode current results in increase in current gain
Increased current gain further increase the anode current and the anode current further increases the current gains. The cumulative action leads to the loop gain to approach unity and the anode current drastically rises which can be controlled by external circuit only. Thus the SCR is turned-ON.

2 c) Explain the operation of RC triggering circuit with neat diagram.

Ans:
RC triggering circuit:



RC half-wave firing circuit



1 mark for circuit diagram

2 marks for explanation

The RC half-wave triggering circuit is as shown in the figure. During negative half-cycle of supply voltage vs, the capacitor C charges through diode D2 and load, with lower plate positive. The charging time constant depends upon C and load impedance. If this charging time constant is low, the capacitor gets quickly charged to supply voltage and may attain peak value Vm at -90° as shown in the waveform diagram. At

1 mark for waveform

this instant, as both capacitor voltage and supply voltage are equal and opposite, capacitor current is zero. During period after $\omega t = -90°$ to $\omega t = 0°$, the supply voltage vs drops from Vm as capacitor discharges. The discharging current passes through supply source, load and R. At $\omega t = 0°$, the capacitor voltage reduces to a value less than Vm, represented by OA in the waveform diagram. After $\omega t = 0°$, the supply voltage become positive, it now helps the discharging current and therefore, the capacitor gets discharged at faster rate. Its negative voltage (lower plate positive) get reduced to zero at a particular instant. The discharging current further continues in the same direction to charge capacitor with upper plate positive. When the capacitor voltage reaches to gate trigger voltage, the SCR is fired. After firing, voltage across SCR drops to low

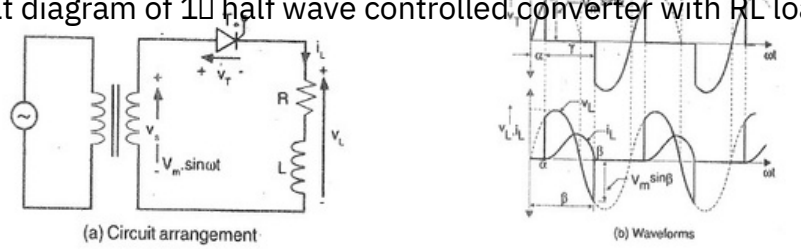
2 d) value and hence capacitor voltage also get reduced to low value as shown. The discharging of negatively charged (lower plate positive) capacitor and further charging with upper plate positive is through load and R. Therefore, R determines the discharging and positive charging time-constants. If R is increased, the time-constant get increased and firing is delayed. The SCR can never be triggered at 0° & 180° because the supply voltage is zero and less than finger voltage.

Single phase fully controlled half wave converter:

1 mark for circuit diagram

Draw a neat diagram of 1ϕ half wave controlled converter with RL load. Give its operation.

Ans:



2 marks for explanation

The circuit diagram of single-phase half-wave controlled rectifier with RL load and without freewheeling diode is shown in Fig. (a). The SCR T is forward biased only during positive half cycle whereas reverse biased during negative half cycle. Therefore, it is triggered in positive half cycles only. When the gate pulse is applied in positive half cycle with delay angle of α as shown in waveform diagram (b), the SCR conducts and starts to carry the load current. Since the load is inductive (RL), the current lags behind the voltage. The load inductance maintains the load current and keeps SCR on even if the supply voltage is reversed. Thus every positive half cycle of load voltage is followed by some negative voltage till the current drops to zero. The negative voltage appearing across load reduces the average load voltage. Thus the use of freewheeling diode helps to increase the average load voltage. For

1 mark for waveforms

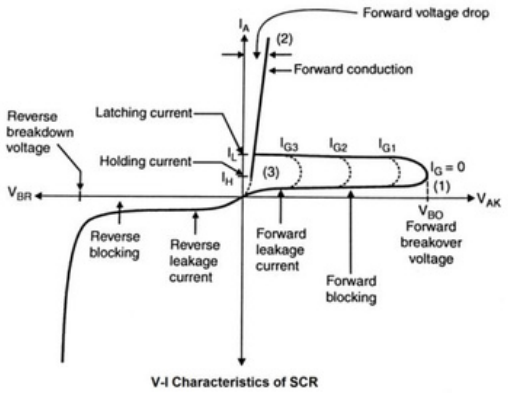
some sensitive loads, the negative voltage is undesirable. In such cases freewheeling diode is used to prevent the negative voltage across the load.

3 Attempt any THREE of the following: 12

3 a) Draw a neat labelling V-I characteristics of SCR and explain the region.

Ans:

V-I characteristics of SCR:



2 marks for labeled diagram

1 mark for partially labeled diagram

Operating regions:

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

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

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

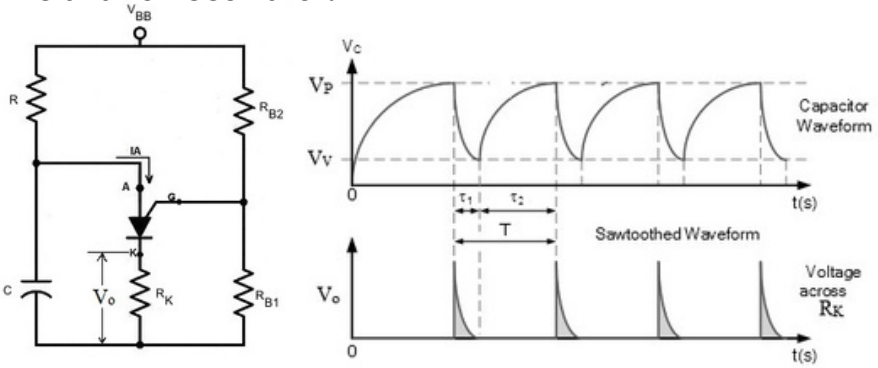
4) **Reverse conduction region:** In this region, the SCR conducts the reverse current after the breakdown of reverse biased junctions. The SCR get damaged if operated in this region.

2 marks for four regions and proportionally reduced if all are not covered.

3 b) Explain the operation of PUT relaxation oscillator with diagram.

Ans:

PUT as a Relaxation Oscillator:



1 mark for circuit diagram

1 mark for waveforms

1. The circuit diagram of PUT as relaxation oscillator is as shown in the above figure.

2. The gate terminal is held at potential ———

   where, is called intrinsic stand-off ratio & given by, ———

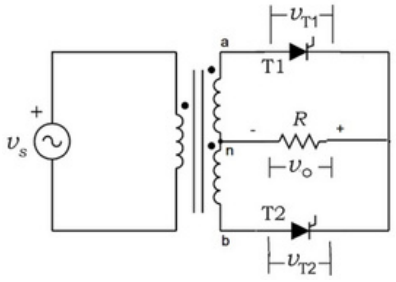
   Its value is thus decided by the external resistors RB1 & RB2. It means by properly choosing these resistors (programming), we can fix its value, hence termed as Programmeable-UJT (PUT). 2 marks for explanation

3. The anode is held at capacitor voltage. Initially, the capacitor voltage is zero, hence the anode-gate junction is reverse biased and device remains off.
4. As soon as the supply voltage VBB is connected to the circuit, the capacitor begins to charge towards VBB volt. So far anode voltage is less than gate voltage, device remains off.
5. When the anode voltage reaches to peak-point voltage VP, the anode voltage becomes higher that gate voltage. The anode-gate junction is forward biased, gate current flows, regeneration starts and device is turned on. The capacitor then discharges through the device to valley-point voltage VV.
6. During discharging of capacitor, a pulse of current flows through the cathode resistor RK and we get pulse voltage across it, as shown in the waveform.
7. At the end of discharging, the device is turned off due to very low current. The capacitor then starts charging and the cycle repeats.
8. The capacitor voltage waveform is saw-tooth in nature, whereas the voltage across RK is in the form of pulses.

3 c) Explain with sketch the operation of single-phase fully controlled midpoint configuration with R load.

Ans:

Midpoint converter with resistive load:

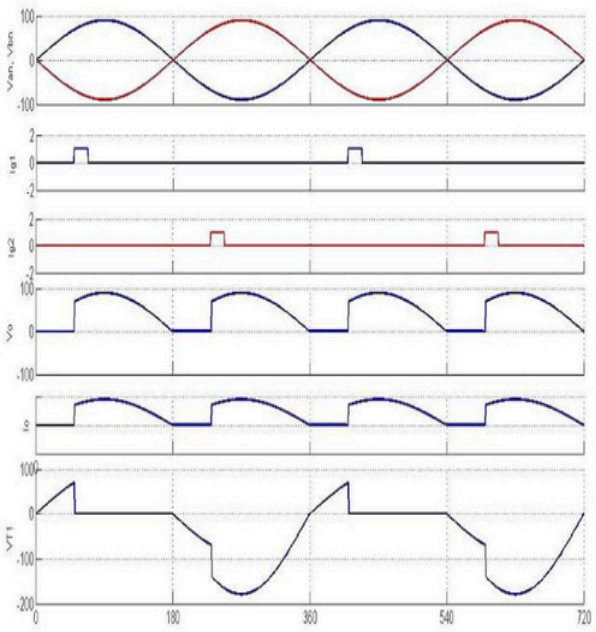


1 mark

Explanation:-

1) During positive half cycle of AC supply, A is positive with respect to B ,this makes T1 forward biased and T2 is reverse biased. But since no triggering pulse is applied, both are in off state. When SCR T1 is triggered at firing angle α, current flows through load from A, T1 and back to centre tap of the transformer. This current flow is continuous till angle π when the line voltage reverses the polarity and T1 is turned off. 2 marks
2) During negative half cycle of AC supply, B is positive with respect to A ,this makes T2 forward biased and T1 is reverse biased. But since no triggering pulse is applied, both are in off state. When SCR T2 is triggered at firing angle α+π, current flows

through load from B, T2 and back to centre tap of the transformer. This current flow is continuous till angle 2π, when the line voltage reverses the polarity and T2 is turned off. The operation is as shown in waveforms**.**

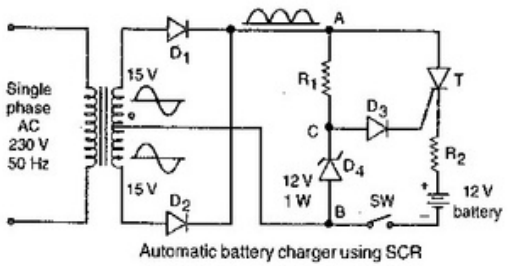


1 mark

3 d) Give the operation of battery charger using SCR with a neat diagram.

Ans:

Battery charger circuit using SCR:



Automatic battery charger using SCR

The figure shows the battery charger circuit using SCR. A 12V discharged battery is connected in the circuit and switch SW is closed. The single-phase 230V supply is stepped down to (15-0-15) V by a centre-tapped transformer. The diodes D1 and D2 forms full wave rectifier and pulsating DC supply appears across terminals A and B. When SCR is off, its cathode is held at the potential of discharged battery. During each positive half-cycle, when the potential of point C rises to sufficient level so as to forward bias diode D3 and gate-cathode junction of SCR, the gate pulse is provided and SCR is turned on. When SCR is turned on, the charging current flows through battery. Thus during each positive half-cycle of pulsating DC supply, voltage across A-B, SCR is fired and charging current is passed till the end of that half-cycle. Due to Zener diode D4, the maximum voltage at point C is held at 12V. Due to the charging process, the battery voltage rises and finally attains full value of 12V. When the battery is fully charged, the cathode of SCR is held at 12V. So the diode D3 and gate-cathode junction of SCR cannot be forward biased, since the potential of point C can reach up to 12V. Therefore, no gate current is supplied and SCR is not fired. In this way, after full charging, further charging is

2 marks for circuit diagram

2 marks for operation (Marks may please be awarded to any other valid battery charging scheme)

Model Answers
Winter – 2018 Examinations
Subject & Code: Fundamentals of Power Electronics (22326)

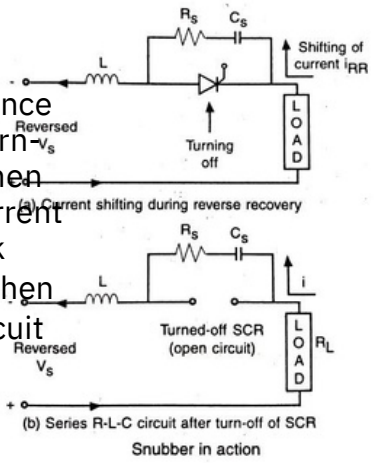
4 Attempt any THREE of the following. 12

4 a) Explain the operation of snubber protection circuit with diagram.

Ans:

Operation of Snubber protection circuit:

The snubber circuit is used to provide protection against high dv/dt. During turn-on of thyristor, it is switched from high impedance state to low impedance state and current is suddenly increased. During turn-off, the forward current is first reduced to zero, then due to storage charges at the junctions, reverse current flows. This reverse recovery current reaches to peak value IRR and then it is abruptly reduced to zero. When current is reduced abruptly (very high rate), the circuit inductance which includes load inductance, stray inductance and di/dt inductance cause high emf (Ldi/dt) that appears at high rate (dv/dt) across the thyristor. A snubber circuit having series RC combination is used to limit this high dv/dt as well as peak reverse voltage appearing across thyristor. As prior to turn-off, thyristor was conducting, voltage across it and also across snubber R-C circuit was negligibly small. The capacitor voltage at this instant therefore can be assumed to be zero. Thus when thyristor turns-off abruptly, the reverse recovery current IRR is transferred through snubber R-C circuit. The uncharged capacitor initially acts as short-circuit and hence at this instant the voltage appearing across thyristor is only because of drop in resistance RS i.e. RS IRR. Once the thyristor is turned-off, the snubber circuit R-C and circuit inductance with load impedance forms a series RLC circuit. After turn-off, the capacitor charges slowly and limits dv/dt across thyristor. The reverse voltage to which the capacitor be charged and the rate (dv/dt) at which it is charged, is determined by the circuit parameters R, L and C.



2 marks for circuit diagram

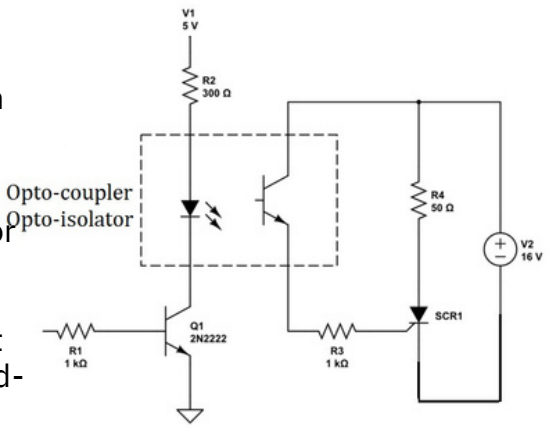
2 marks for explanation

4 b) Explain the operation of opto-coupler based triggering circuit with diagram.

Ans:

Opto-coupler based triggering circuit:

A simple opto-coupler based triggering circuit for SCR is shown in the figure. An opto-coupler or opto-isolator is a combination of light source and light-sensitive device enclosed in a compartment. The light source is LED or infra-red LED (IRLED) and light-sensitive device may be photo-diode or photo-transistor. Referring to the circuit diagram, when the SCR is to be turned-on, a voltage is applied to base of Q1 through R1. The base current flows and Q1 is turned on. The collector current flow and voltage appears across the LED of opto-coupler. The light emitted by LED falls on the photo-transistor and it is turned-on. When photo-transistor is turned-on. It carries the



2 marks for circuit diagram

2 marks for explanation

current, which flows through R3 and acts as gate current for the SCR. Thus gate current is provided to SCR and it is ultimately turned-on. The firing circuit is electrically
isolated from SCR circuit but optically coupled.

OR

(Any other equivalent valid circuit and explanatiobn)

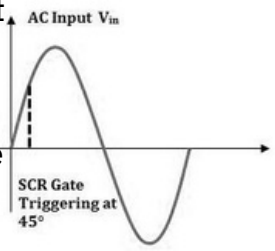
4 c) Give the concept of firing angle and conduction angle with a neat waveform.

Ans:

Firing Angle( ):

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

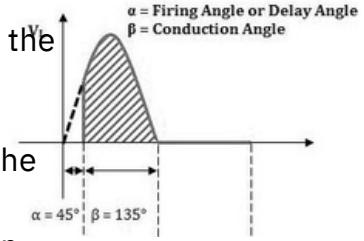
Firing angle or delay angle can be defined as the angle measured from the angle that gives maximum average output voltage to the angle when the SCR is actually triggered or fired by gate pulse.



Conduction Angle ():

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

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



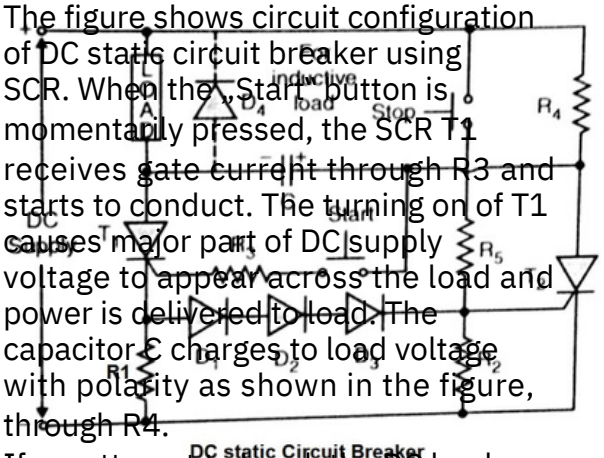
1 mark for each description and 1 mark for each waveform = 4 marks

4 d) Draw the circuit diagram of DC static circuit breaker and give its operation.

Ans:

DC Static Circuit Breaker:

The figure shows circuit configuration of DC static circuit breaker using SCR. When the „Start" button is momentarily pressed, the SCR T1 receives gate current through R3 and starts to conduct. The turning on of T1 causes major part of DC supply voltage to appear across the load and power is delivered to load. The capacitor C charges to load voltage with polarity as shown in the figure, through R4.



2 marks for circuit diagram

If we attempt to break the DC load current i.e switch off the load, using mechanical contact type switch, since current is DC, heavy arcing may damage the switch. Instead, if we use this circuit configuration, the load current can be interrupted by turning off the SCR T1. When „Stop" button is

2 marks for explanation

pressed momentarily, SCR T2 receives gate current through R5 and it is turned on. The turning on of T2 causes the charged capacitor C to place across conducting SCR T1. The capacitor provides reverse bias across T1 and discharges quickly through T2, resistance and T1. The discharge current is reverse current for T1 and it is turned off. The load current is then continued through C and T2. The capacitor C first discharges and then charges with reverse polarity to supply DC voltage. At this instant, the load current falls to zero, and further since current falls below holding current level, T2 is turned off naturally. Thus manual firing of T2 by pressing „Stop" button interrupts load current through T1.

The load current can be automatically interrupted under overload condition. With T1 on and carrying load current, if overload occurs, the voltage drop across R1 exceeds the forward voltage drop of string of diodes D1, D2, D3 and gate-cathode junction of T2.

Therefore, gate current is provided to T2 and it is turned on. Turning on of T2 immediately causes turning off of T1 as mentioned above. The load current is

4 e) interrupted and thus over-load protection is provided. Since no moving contact type mechanism is used for interruption of load current, this circuit configuration is called DC static circuit breaker. By proper selection of R1 and number of diodes in string and replacing „Stop" button by NO relay contact in fault sensing circuit, the circuit can be obtained using emergency lighting system that works on DC supply. A very simple single source emergency lighting system which is most suitable for household application is shown in the figure. The input 230v AC supply is stepped down to 6-0-6V AC supply by transformer. The diodes D1 and D2 form full wave rectifier and convert 6-0-6V AC supply into 6V DC supply for 6V lamp. When AC supply is available, 6V DC supply appears across lamp & it glows. The pulsating current also flows through D3, R1 to trickle charge the battery. Thus battery charging is carried out when AC supply is availabl;e. The capacitor C get charged with upper plate positive to some voltage less than 6V. due to capacitor voltage, gate-cathode junction of thyristor T get reverse biased. The anode is at battery voltage and cathode is at rectifier output voltage, which is slightly higher, hence thyristor is reverse biased and can not conduct. The lamp glows due to rectifier output DC voltage.

When AC supply fails, rectifier output DC voltage is reduced to zero. The capacitor C then discharges through lamp and R2. After discharging, due to battery, it charges

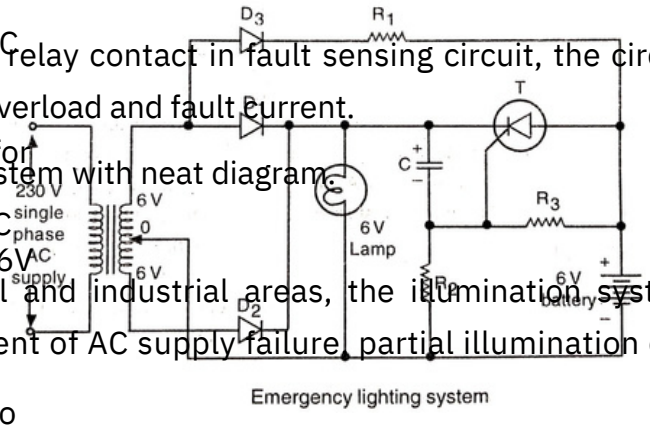
Describe emergency lighting system with neat diagram. 2 marks for circuit diagram

Ans:

Emergency lighting system:

In the residential, commercial and industrial areas, the illumination system work with available AC supply. In the event of AC supply failure, partial illumination can be obtained by using emergency lighting system that works on DC supply. A very simple single source emergency lighting system which is most suitable for household application is shown in the figure. The input 230v AC supply is stepped down to 6-0-6V AC supply by transformer. The diodes D1 and D2 form full wave rectifier and convert 6-0-6V AC supply into 6V DC supply for 6V lamp. When AC supply is available, 6V DC supply appears across lamp & it glows. The pulsating current also flows through D3, R1 to trickle charge the battery. Thus battery charging is carried out when AC supply is availabl;e. The capacitor C get charged with upper plate positive to some voltage less than 6V. due to capacitor voltage, gate-cathode junction of thyristor T get reverse biased. The anode is at battery voltage and cathode is at rectifier output voltage, which is slightly higher, hence thyristor is reverse biased and can not conduct. The lamp glows due to rectifier output DC voltage.

When AC supply fails, rectifier output DC voltage is reduced to zero. The capacitor C then discharges through lamp and R2. After discharging, due to battery, it charges



Emergency lighting system

2 marks for explanation

through R3 and lamp with lower plate positive. Due to capacitor voltage, gate-cathode junction get forward biased and gate current flows. Since the anode is now at higher potential than cathode, thyristor T is turned-on. The lamp get connected across battery through thyristor and therefore, it glows. In rthis way, on failure of AC supply, light is obtained from DC supply.

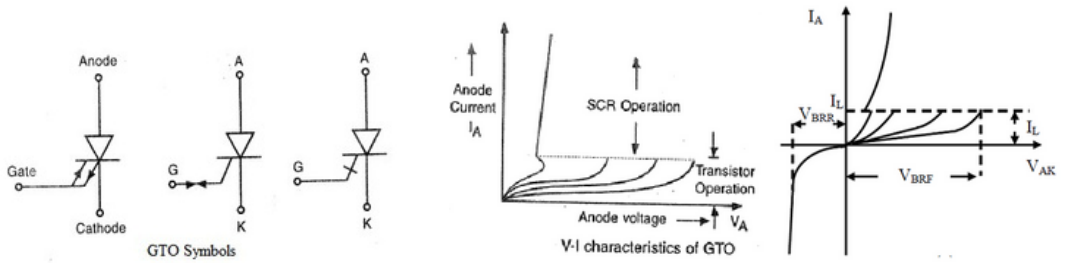
OR
(Any other equivalent valid circuit and explanatiobn)

5 Attempt any TWO of the following: 12

5 a) Draw a symbol and neat labeling V-I characteristics of GTO and explain its operation.

Ans:

Symbol and V-I characteristics of GTO:



1 mark for any one symbol

Operation of GTO:

2 marks for v-i characteristic

i) As the applied anode to cathode voltage is increased above zero, very small current (leakage current) flows through the device. Under this condition the GTO is said to be off. It will be continued till the applied voltage reaches the forward Breakover voltage (VBRF).

3 marks for explanation

ii) If the anode-cathode (applied) voltage exceeds the breakover voltage, the device conducts heavily and the GTO is turned ON. The anode to cathode voltage decreases quickly because, the GTO offers very low resistance when it is ON, hence it drops very low voltage across it.

iii) At this stage the GTO allows more current to flow through it. The amplitude of the current is depending upon the supply voltage and load resistance connected in the circuit.

iv) If the value of the gate current Ig is increased above zero, the GTO turns ON even at lower anode-cathode voltage (less than forward breakover voltage, VBRF).

v) If the polarity of applied voltage is reversed, we get the reverse characteristics.

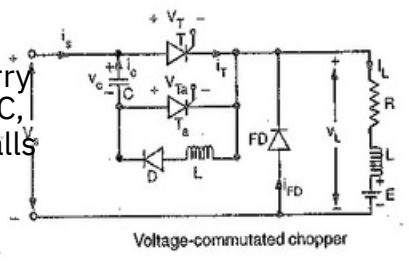
vi) In reverse direction GTO breaks down at very low voltage (VBRR). The reverse breakdown voltage is of the order of 20 to 30 volt only.

5 b) Explain auxiliary commutation with a neat diagram. Also draw its waveform.

Ans:

Auxiliary Commutation

At start, the Ta is triggered and turned on to carry the load current. Due to the resonant circuit R-L-C, the current initially rises, attains peak and then falls to zero. This turns off the auxiliary SCR Ta. This current charges the capacitor C with upper plate positive. The capacitor thus forward biases the



2 marks for circuit diagram

main SCR T. When main SCR T is triggered, it is turned on and charged capacitor C is placed across Ta so as to apply reverse bias across it. The load current now flows through T. The capacitor continues to discharge through T, L and D. Since this LC is resonant combination, the capacitor discharges completely first and then charges with opposite polarity till the current falls to zero. The capacitor current cannot reverse because of diode D. Now the oppositely charged capacitor forward biases the auxiliary SCR Ta. Thus when Ta is triggered, T is turned off and the same cycle is repeated. In this configuration, the firing of auxiliary SCR commutates the main SCR, hence name is auxiliary commutation.

4 marks for stepwise operation

5 c) Explain in detail over-voltage protection.

Ans:

Over-voltage protection:

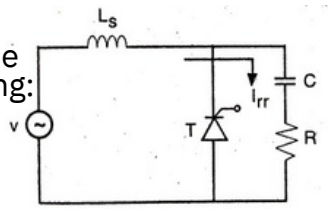
Over-voltage protection to the thyristor is provided using:

i) R-C Snubber circuit

ii) Non-linear resistor "Thyrector"

A) Snubber Circuit:

It is basically a series r-C circuit which is connected across the device to be protected. The snubber circuit helps to minimize the effects of internal or external overvoltages by following ways:



Equivalent circuit showing circuit condition for single SCR in converter

3 marks for snubber circuit

i) Internal over-voltages are generated by interruption of reverse recovery current IRR during turn-off of device. With snubber circuit, the IRR is diverted through R-C after SCR has blocked the reverse current. If LS, R, and c are suitably chosen, the voltage across thyristor can be limited to suitable safe value.

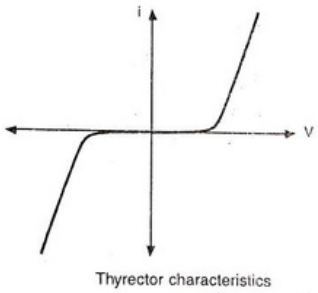
ii) At the time of external over-voltages, the capacitor charges through R at slow rate, hence does not allow the voltage to change at high rate. Thus transient voltage spikes are damped and also rate of rise of forward voltage dv/dt across SCR is reduced.

iii) The resistance R of snubber circuit causes power loss at the time of energy transfer oscillations between snubber circuit capacitance C and stray circuit inductance, therefore the oscillations are damped and over-voltage transients are reduced.

iv) The snubber circuit can be connected directly across secondary winding of transformer to suppress the over-voltages caused by switching on or off the primary winding.

B) Non-linear resistor (Thyrector):

Thyrector is a non-linear resistor device having v-I characteristic as shown in the figure. Under normal working voltage it offers very high resistance and draws very small leakage current. However, under over-voltage conditions, its resistance is reduced, it draws heavy current and maintains safe voltage across it. Thus its resistance depends upon voltage



Thyrector characteristics

3 marks for thyrector

across it. This device is therefore used as surge diverter. At the time of over- voltage surge, it conducts heavy current, causing virtual short-circuit. This protects the device from increased impedance, by which the SCR volatge is maintained to safe low value. After the surge energy is dissipated in thyrector, the thyrectyior returns to its high resistance state. Thyrector is normally placed across the supply terminals.

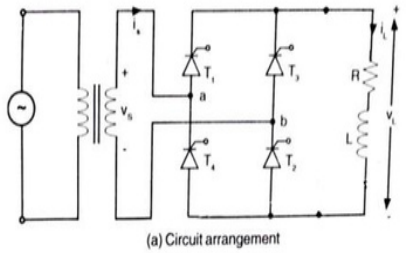
6 Attempt any TWO of the following: 12

6 a) Give the operation of single phase full wave bridge controlled converter with RL load with a neat diagram. Also draw its waveform.

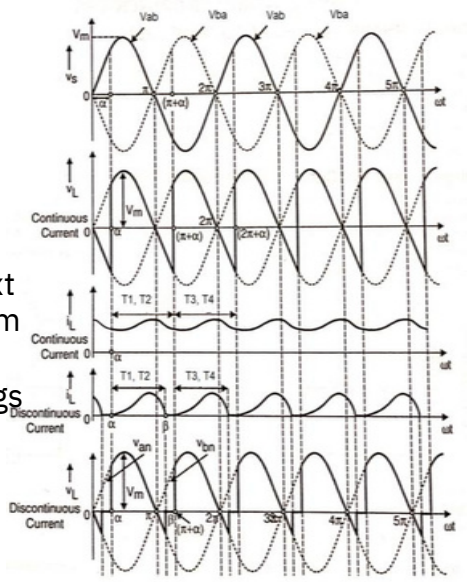
Ans:

Single phase fully control bridge converter with RL load:

1. During positive half cycle of input voltage, T1 and T2 are forward biased and during negative half cycle, T3 and T4 are forward biased. Therefore, T1-T2 pair and T3-T4 pair are fired alternately in positive and negative half cycles of input voltage respectively, as shown in the waveform figure (b).



(a) Circuit arrangement



(b) Waveforms

2 marks for description

2 marks for circuit diagram

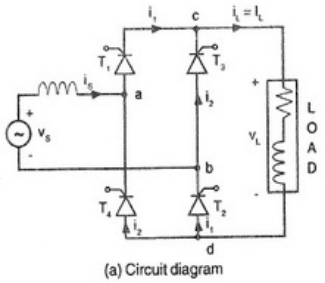
2 marks for waveforms

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

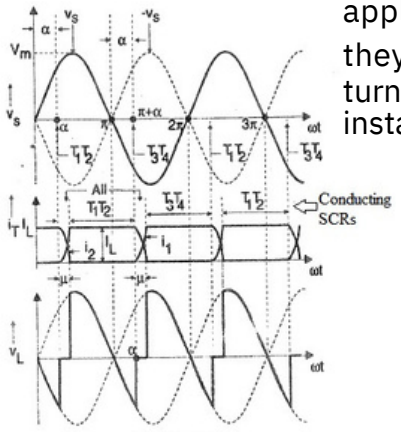
6 b) Give the effect of source impedance on converter operation.

Ans:

Effect of source impedance on converter operation:



(a) Circuit diagram



(b) Waveforms

Effect of Source Inductance on the performance of 1-ph full converter.

For single-phase fully controlled bridge converter, the SCRs are triggered in pairs alternately. During positive half-cycle of input, SCRs T1 and T2 are triggered whereas during negative half-cycle, SCRs T3 and T4 are triggered. When T1 and T2 are conducting, T3 and T4 are off. On the reversal of supply voltage, firing of T3 and T4 causes application of reverse bias across T1 and T2 and they are turned off. The current shifts from T1 T2 to T3 T4. The instantaneous current shift is possible only when the voltage source has no internal impedance. In practice, the source always possesses some internal impedance may be due to the transformer on supply side.

1 mark circuit diagram

2 marks for waveforms

1 mark for effect of source resistance

1) If the source impedance is purely resistive, then voltage drop across it causes reduction in input voltage and ultimately in the output voltage of converter.

2 marks for effect of source inductance

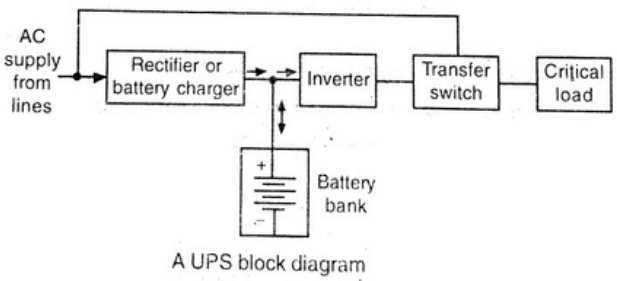
2) If the source impedance is largely inductive, then source current cannot change instantly. The current cannot get transferred immediately from outgoing SCRs to incoming SCRs. The commutation of SCRs is delayed. During current transfer, both pairs of SCRs conduct simultaneously and load voltage appears zero. As both pairs of SCRs conduct simultaneously, this commutation period is called “overlap period (□)”. The output dc voltage is given by,

As source inductance (Ls) increases, the commutation period (overlap angle □) increases and as a consequence, the output dc voltage decreases.

6 c) Explain the operation of UPS with a neat block diagram.

Ans:

Uninterruptible-Power-Supplies (UPS):



A UPS block diagram

2 mark for block diagram

A block diagram of UPS system is shown in figure. It essentially consists of four major

components:
i)Rectifier (or battery charger) ii) Battery bank
iii) Inverter vi) Transfer switch

i) Rectifier (or battery charger):

Its function is to convert available AC supply at input line into DC supply and then to feed DC power to inverter and also to battery bank to keep it charged. It is designed to handle the total current supplied to inverter and battery bank.

1 mark for each block explanation = 4 marks

ii) Battery bank:

It consists of number of batteries in series. The rating and number of units in the bank depends upon the following factors: Input voltage required by inverter, Back-up time requirement of UPS, Efficiency of inverter and load power.
When the line voltage is present, the battery trickle charged to compensate for the slight self-discharge. The battery continuously draws a small amount of current to maintain itself in a fully charged state.
When AC input fails, battery supplies DC power to inveter, wherein it is converted into AC and then fed to load. During this period, the battery discharges. On recovery of AC mains supply, the battery charging starts.

iii) Inverter:

It is used to convert DC supply available at its input terminals into AC supply. The filter is normally used at the output of inverter to minimize the harmonic distortion. Most of the loads are highly non-linear and inject large harmonic currents into the UPS.

iv) Transfer switch:

It is a change over switch. When AC supply is available, the transfer switch connects load to AC supply directly. However, when AC supply from line is not available and load demands for AC supply, the transfer switch can be placed to connect inverter output AC supply to the load. Due to fast action requirement, transfer switch can be implemented by fast acting semiconductor devices.

11920

22326

3 Hours / 70 Marks

Seat No. | | | | | | | | |

Instructions :

(1) All Questions are compulsory.

(2) Answer each next main Question on a new page.

(3) Illustrate your answers with neat sketches wherever necessary.

(4) Figures to the right indicate full marks.

Marks

1. Attempt any FIVE of the following : 10

(a) Define (i) Holding current, (ii) Latching current of SCR. 2

(b) Draw circuit diagram of Class B commutation. 2

(c) State classification of Phase controlled rectifiers. 2

(d) Define (i) Conduction angle, (ii) Firing angle. 2

(e) Draw circuit diagram of symmetrical configuration of bridge converter. 2

(f) State the advantages of SMPS. (any two) 2

(g) State the need of UPS. 2

2. Attempt any THREE of the following : 12

(a) Describe with neat sketch the constructional details of IGBT. 4

(b) Explain two transistor analogy of SCR with neat diagram. 4

(c) With neat diagram explain synchronized UJT triggering circuit. 4

(d) Explain working of static A.C. circuit breaker. 4

3. Attempt any THREE of the following : 12

(a) Give comparison of SCR & TRIAC. (any four points) 4

(b) Explain the thermal triggering method of SCR. Enlist different triggering methods of SCR. 4

(c) Draw single phase full wave mid-point converter for inductive load. Draw input and output waveforms for it. 4

(d) Draw the circuit diagram of battery charger using SCR and explain it's working. 4

4. Attempt any THREE of the following : 12

(a) Draw I-V characteristics of power transistor. Show different regions. 4

(b) With reference to GTO answer the following : 4

(i) State advantage of GTO over SCR.

(ii) Draw construction of GTO.

(c) Explain triggering of SCR using opto-coupler. State its advantages. 4

(d) Describe the operation of single phase fully controlled bridge converter with R-load. 4

(e) Explain the working principle of SMPS with neat diagram. 4

5. Attempt any TWO of the following : 12

(a) With neat sketch explain four modes of operation of a TRIAC. 6

(b) Explain with neat circuit diagram and input output waveforms, single phase half wave converter with R-L load. Give significance of freewheeling Diode. 6

(c) Describe working of online UPS. List any two applications of UPS. 6

6. Attempt any TWO of the following : 12

(a) Draw symbols and V-I characteristics of the following devices : 6

(i) LASCR (ii) DIAC

(iii) PUT (iv) SCS

(b) For a class D commutation, answer the following : 6

(i) Explain the operation with a circuit diagram.

(ii) Interpret with waveforms.

(c) A 1-ϕ half controlled rectifier supplied with voltage V = 300 sin 314 t, and load resistance is 100 Ω. Find : 6

(i) Average output DC voltage.

(ii) Load current.

(For $\alpha = 60^\circ$ and $\alpha = 100^\circ$)

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MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC-27001-2005 Certified)

Winter – 2019 Examinations

Model Answer

Subject & Code: FUNDAMENTALS OF POWER ELECTRONICS (22326)

Important Instructions to examiners:

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

1 a) **Attempt any FIVE of the following:** **10**

1 a) Define: (i) Holding Current (ii) Latching Current of SCR

Ans:

1 Mark for each definition = 2 Marks

(i) Holding Current:

Holding current is defined as the minimum anode current required to maintain conducting SCR in the on-state.

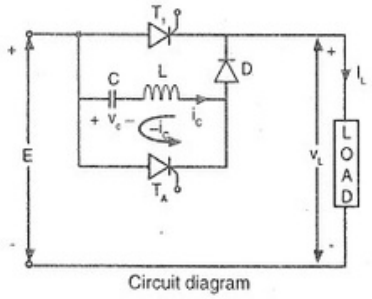
(ii) Latching Current:

Latching current is defined as the minimum anode current required to maintain the SCR in the on-state immediately after the SCR has been turned on and the gate signal has been removed.

1 b) Draw circuit diagram of Class B commutation.

Ans:

Class B: Resonant Pulse Commutation:



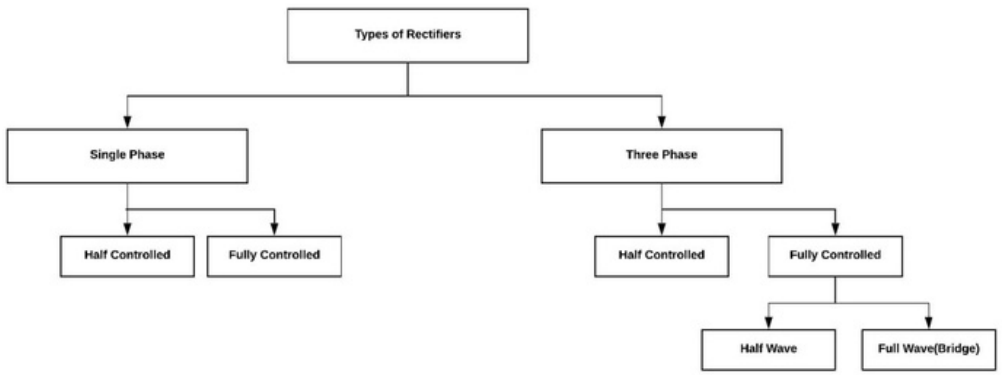
Circuit diagram

2 Marks for labeled circuit diagram

1 c) State classification of Phase controlled rectifiers.

Ans:

Classification of phase controlled rectifiers:



2 Marks

1 d) Define: (i) conduction angle (ii) firing angle.

Ans:

(i) Conduction Angle ():

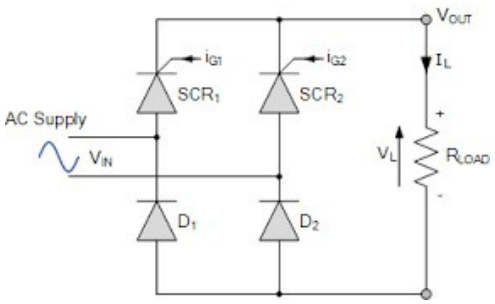
Conduction angle is defined as the angle between the instant the SCR is triggered or turned on and the instant at which the SCR is turned off. Assuming that the SCR is turned off naturally at the end of positive half cycle, the relation between the firing or delay angle ( ) and conduction angle () can be expressed as:

1 Mark for each definition = 2 Marks

(ii) Firing Angle( ):

Firing angle is defined as the angle between the instant the SCR would conduct if it would be a diode and the instant it is triggered or fired. Firing angle or delay angle can be defined as the angle measured from the angle that gives maximum average output voltage to the angle when the SCR is actually triggered or fired by gate pulse.

1 e) Draw circuit diagram of symmetrical configuration of bridge converter.
Ans:



2 Marks for circuit diagram

1 f) State the advantages of SMPS. (any two)
Ans:
Advantages of SMPS:

1. High Efficiency, more than 94%.
2. Easy maintenance and servicing.
3. High modularity and redundancy.
4. Lower power dissipation.
5. Wide AC input voltage range.
6. Less cost.

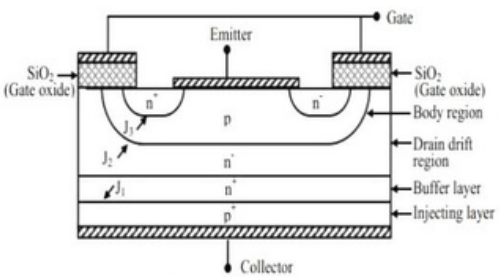
1 Mark for each of any two = 2 Marks

1 g) State the need of UPS.
Ans:
Need of UPS:
1) An Uninterruptible Power Supply (UPS) is used to protect critical loads from mains supply problems including spikes, voltage dips, fluctuations and complete power failures using a dedicated battery.
2) A UPS system can also be used as standby system when AC mains is failed.

1 Mark for each point = 2 Marks

2 Attempt any <u>THREE</u> of the following: 12

2 a) Describe with neat sketch the constructional details of IGBT.
Ans:
Construction:



Construction of IGBT

2 marks for construction diagram

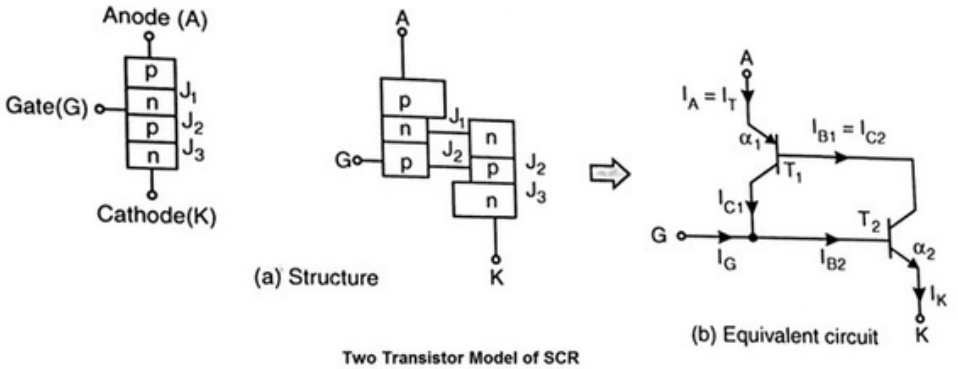
Insulated gate bipolar transistor or IGBT, is a solid state devices primarily used as an electronic switch which, as it was developed, came to combine high efficiency and fast switching. The insulated gate bipolar transistor (IGBT) is a three terminal semiconductor device combines the benefits of both MOSFET and BJT. So, an insulated gate bipolar transistor (IGBT) has input impedance like that of a MOSFET and low ON state power loss as in a BJT. It is also called as metal oxide semiconductor insulated gate transistor (MOSIGT) and other name to this device are insulated gate transistor (IGT), conductivity modulated field effect transistor (COMFET). It is similar to that of a double-diffused power MOSFET (DMOS) except for a p+ layer at the bottom. This layer forms the IGBT collector and a pn junction with n-drift region, where conductivity modulation occurs by injecting minority carriers into the drain drift region of the vertical MOSFET. Therefore, the current density is much greater than a power MOSFET and the forward voltage drop is reduced. The p+ substrate, n- drift layer and p+ emitter constitute a BJT with a wide base region and hence small current gain.

2 marks for description

2 b) Explain two transistor analogy of SCR with neat diagram.

Ans:

Two-transistor Analogy of SCR:



Two Transistor Model of SCR

1 mark for (a)
1 mark for (b)
= 2 marks for diagram

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

where, = common-base current gain
= leakage current from collector to base with emitter open
For transistors T1 and T2, we can write,
and
From KCL applied to T1, we can write

From KCL applied to entire equivalent circuit,
and substituting in above equation,

[ ]

2 marks for mathematical treatment

[ ]

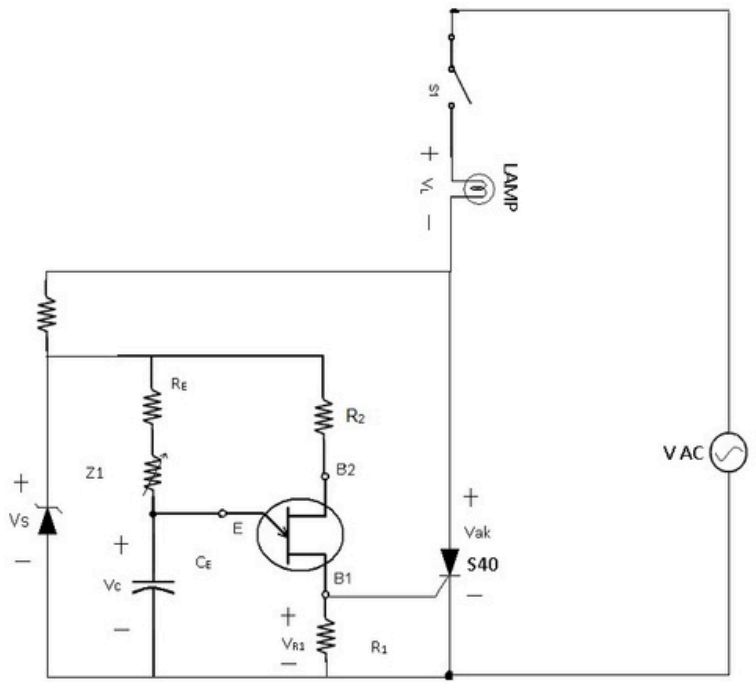
From this equation it is clear that the anode current depends on the gate current, leakage currents and current gains.

If tends to be unity, the denominator [ ] approaches zero, resulting in a large value of anode current and SCR will turn on. The current gains vary with their respective emitter currents. When gate current is applied, the anode current is increased. The increased , being emitter current of T1, increases the current gain . The gate current and anode current together form cathode current, which is emitter current of T2. Thus increase in cathode current increases current gain increase the anode current and the anode current further increases the current gains. The cumulative action leads to the loop gain to approach unity and the anode current drastically rises which can be controlled by external circuit only.

2 c) With neat diagram explain synchronized UJT triggering circuit.

Ans:

Line Synchronized UJT triggering circuit:



2 Marks for circuit diagram + 2 Mark for description = 4 Marks

The UJT is almost ideal as a firing device for SCRs. There are 2 main reasons for the compatibility between UJTs and SCRs. Firstly, the UJT produces a pulse-type output, which is excellent for accomplishing sure turn-on of an SCR without straining the SCR's gate power dissipation capability. Secondly, the UJT firing point is inherently stable over a wide temperature range. This can compensate for the temperature instability of the SCR.

The usual method of triggering an SCR with a UJT is shown in Figure 1.

In this circuit, zener diode Z1 clips the Vs waveform at the zener voltage during the positive half-cycle of the ac line. During the negative half cyce, Z1 is forward biased and Vs is held near 0 V.

Once the dc voltage Vs has been established, which occurs immediately

after the ac line crosses zero, CE begins charging through resistor RE. When CE reaches the peak voltage of the UJT, the UJT then fires. This generates a voltage

pulse across R1 and results in the firing of the SCR. When the SCR is fired, current flows through it and the load. This makes the positive half cycle.

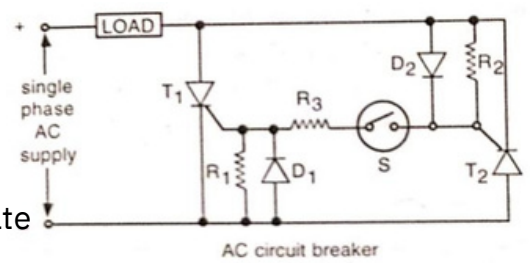
In this circuit, automatic synchronization between the firing pulse of the UJT and the SCR ensures that the SCR will be fired only when it is forward biased. This means that whenever the UJT delivers a pulse, the SCR is sure to have the right polarity between the anode and cathode for turning on.

2 d) Explain working of static AC circuit breaker.

Ans:

Static AC Circuit breaker:

The circuit configuration of static AC circuit breaker using SCR is shown in the figure. When switch 'S' is closed, the SCRs T1 and T2 are fired in positive and negative half cycles respectively.



AC circuit breaker

2 Marks for circuit diagram

During positive half-cycle, T1 receives gate current through D2 || R2, switch S and R3 and it conducts. At the end of positive half-cycle, T1 is turned off due to natural current zero. In the negative half-cycle, T2 receives gate current through D1 || R1, R3andswitch S and it conducts. It is turned off at the end of this negative half cycle due to natural current zero value. When the load current is required to be interrupted, the switch S is opened. It results in blocking of gate currents of both SCRs and hence both SCRs are maintained off. When sitch S is opened at any instant in a particular half-cycle, the load current continue to flow through conducting SCR till the end of this half-cycle, however in the next half-cycle the other SCR will not be fired due to non-availability of gate current. Thus the maximum time delay for breaking the circuit is one half-cycle.

2 Marks for operation

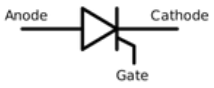
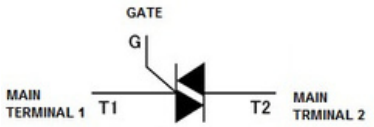
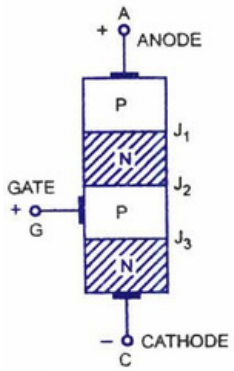
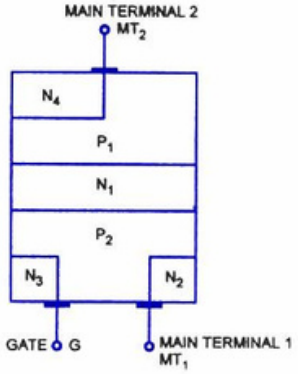
3 Attempt any THREE of the following **12**

3 a) Give comparison of SCR and TRIAC (any four points)

Ans:

SCR	TRIAC
It is an unidirectional device.	It is a bidirectional device.
It is turned-on by only positive gate current.	It can be turned-on by either positive or negative gate current.
Operates only in the first quadrant	Operates in either 1 or 3 quadrant.
Anti-parallel SCRs are used for bidirectional current flow.	TRIAC is equivalent to a pair of antiparallel connected SCRs.
It has better gate-current sensitivity.	It has poor gate-current sensitivity as compared to SCR.
It has lower turn-on & turn-off times as compared to TRIAC.	It has higher turn-on & turn-off times as compared to SCR.
For bidirectional current applications, two SCRs & two heat sinks require	For bidirectional current applications, one TRIAC & one

1 Mark for each of any four points = 4 Marks

more space.	heat sink require less space.
Firing circuit design is simple.	More careful firing circuit design is required.
Higher voltage & current ratings as compared to TRIAC.	Lower voltage & current ratings as compared to SCR.
	
	
It is employed in large power applications including large power supplies, DC motor drives, lighting and heating, Static VAR compensators, Electronic circuit breakers etc.	It is employed in low and medium power applications including lamp dimmer, heating control, zero voltage switched AC relay, small AC motor control etc.

3 b) Explain the thermal triggering method of SCR. Enlist different triggering methods of SCR.

Ans:

Types of Triggering:

1) Forward voltage triggering
2) Thermal triggering (Temperature triggering)
3) Radiation triggering (Light triggering)
4) dv/dt triggering
5) Gate triggering
   (i) D.C. Gate triggering
   (ii) A.C. Gate triggering
   (iii) Pulse Gate triggering

1 Mark for different methods + 3 Marks for thermal triggering = 4 Marks

Thermal Triggering :

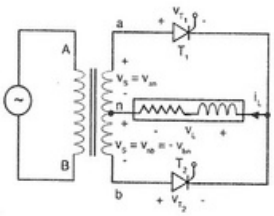
- If the temperature of a thyristor increases, there is an increase in the number of electron hole pairs. This will increase the leakage current. Therefore the value of α1 and α2 will increase. If (α1 + α2) tends to unity, then the thyristor may be turned on.
- This is called as thermal triggering of thyristor. It is an undesirable feature. The break over voltage goes on decreasing with increase in temperature.
- In short, due to increase in temperature the thermally generated leakage current increases. This current gets multiplied internally and thyristor is

turned on.

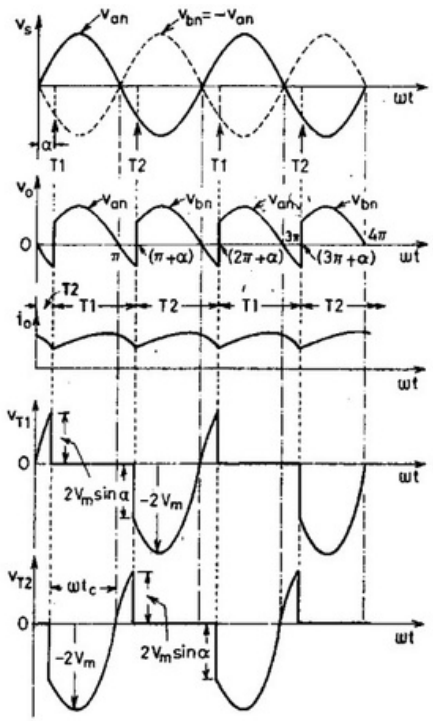
3 c) Draw single phase full wave mid-point converter for inductive load. Draw input and output waveforms for it.

Ans:

Circuit Diagram:



Waveforms:

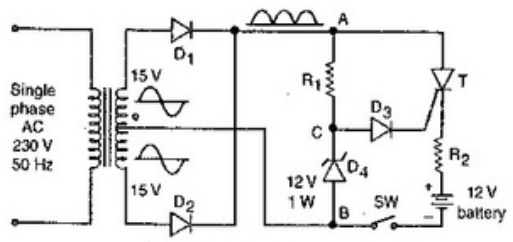


2 Marks for circuit diagram + 2 Marks for waveforms = 4 Marks

3 d) Draw the circuit diagram of battery charger using SCR and explain it's working.

Ans:

Battery charger circuit using SCR:

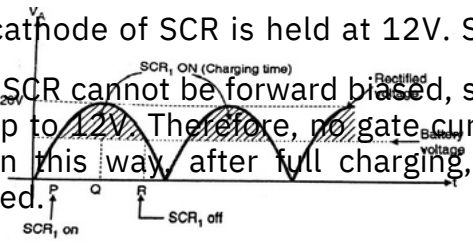


Automatic battery charger using SCR

The figure shows the battery charger circuit using SCR. A 12V discharged battery is connected in the circuit and switch SW is closed. The single-phase 230V supply is stepped down to (15-0-15) V by a centre-tapped transformer. The diodes D1 and D2 forms full wave rectifier and pulsating DC supply appears across terminals A and B. When SCR is off, its cathode is held at the potential of discharged battery. During each positive half-cycle, when the potential of point C rises to sufficient level so as to forward bias diode D3 and gate-cathode junction of SCR, the gate pulse is provided and SCR is turned on. When SCR is

2 Marks for circuit diagram + 2 Marks for explanation = 4 Marks

turned on, the charging current flows through battery. Thus during each positive half-cycle of pulsating DC supply, voltage across A-B, SCR is fired and
charging current is passed till the end of that half-cycle. Due to Zener diode D4,
the maximum voltage at point C is held at 12V. Due to the charging process, the
battery voltage rises and finally attains full value of 12V. When the battery is
fully charged, the cathode of SCR is held at 12V. So the diode D3 and gate-
cathode junction of SCR cannot be forward biased, since the potential of point C can reach up to 12V. Therefore, no gate current is supplied and SCR is not fired. In this way, after full charging, further charging is automatically stopped.



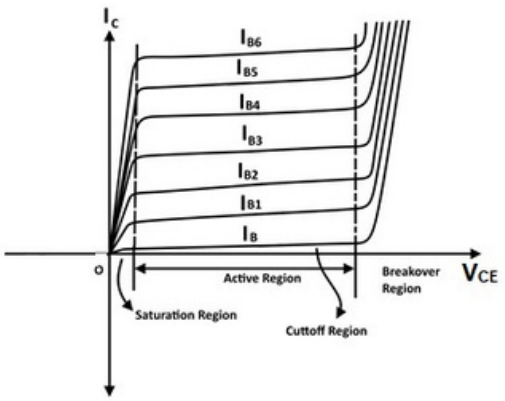
Waveform for battery charger circuit

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

4 a) Draw I-V characteristics of power transistor. Show different regions.

Ans:

I-V characteristics of power transistor:



4 marks for labeled diagram

2 mark for partially labeled diagram

No marks for unlabeled diagram

4 b) With reference to GTO answer the following:
i)State advantages of GTO over SCR
ii)Draw construction of GTO.

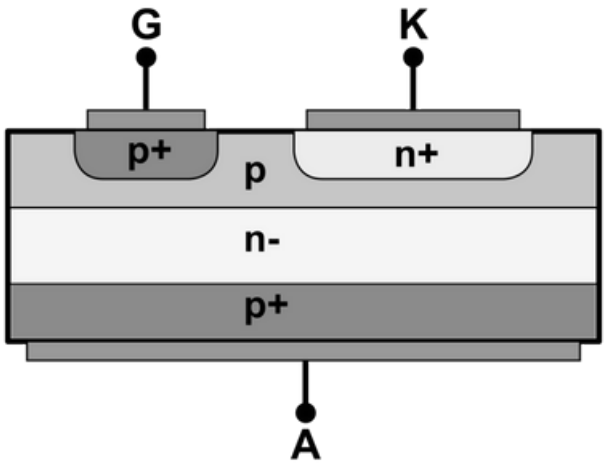
Ans:

I) Advantages of GTO over SCR:

i) It is turned-off by negative gate pulse.
ii) No commutation circuit required, reducing the cost, size, weight and volume of the circuit.
iii) As commutation choke is not used, the associated acoustic and electromagnetic noise (interference) is absent.
iv) Less turn off time permits high switching frequency.
v) It has higher di/dt rating at turn-off.

½ Mark for each of any four advantages = 2 Marks

II) Construction of GTO:



2 Marks for constructional sketch

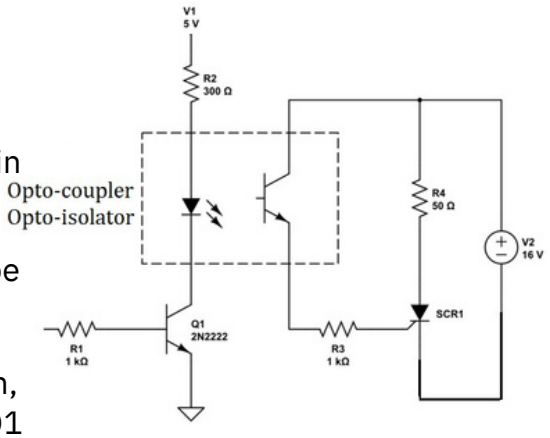
OR any other equivalent constructional sketch

4 c) Explain triggering of SCR using opto-coupler. State its advantages.

Ans:

Triggering of SCR using opto-coupler:

A simple opto-coupler based triggering circuit for SCR is shown in the figure. An opto-coupler or opto-isolator is a combination of light source and light-sensitive device enclosed in a compartment. The light source is LED or infra-red LED (IRLED) and light-sensitive device may be photo-diode or photo-transistor.



1 Mark for circuit diagram

2 Marks for explanation

Referring to the circuit diagram, when the SCR is to be turned-on, a voltage is applied to base of Q1 through R1. The base current flows and Q1 is turned on. The collector current flow and voltage appears across the LED of opto-coupler. The light emitted by LED falls on the photo-transistor and it is turned-on. When photo-transistor is turned-on. It carries the current, which flows through R3 and acts as gate current for the SCR. Thus gate current is provided to SCR and it is ultimately turned-on. The firing circuit is electrically isolated from SCR circuit but optically coupled.

OR

(Any other equivalent valid circuit and explanation)

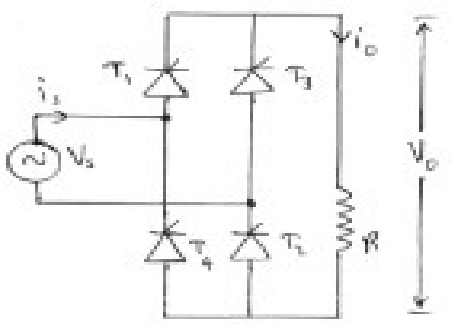
Advantages of Opto-Couplers i)Triggering circuits are well protected due to electrical isolation. ii)It is small size and light weight device. iii)Interfacing with logic circuits is easily possible.

1 Marks for two advantages

4 d) Describe the operation of single phase fully controlled bridge converter with R-load.

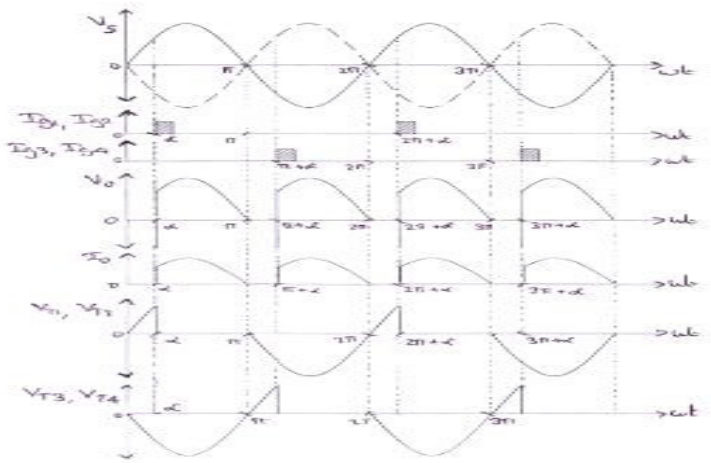
Ans:

Circuit Diagram:



1 Mark for circuit diagram

Waveforms:



1 Mark for waveforms

Explanation:

- During positive half cycle of Vs, SCRs T1 and T2 are fired, so that Vab appears across load.
- During negative half cycle of Vs, SCRs T3 and T4 are fired, so that Vba appears across load.

Thus alternate firing of SCR pairs results in repeated positive half cycles i.e pulsating DC across load.

The delayed firing of SCR pairs provides phase control and control over output voltage.

2 Marks for explanation

4 e) Explain the working principle of SMPS with neat diagram.

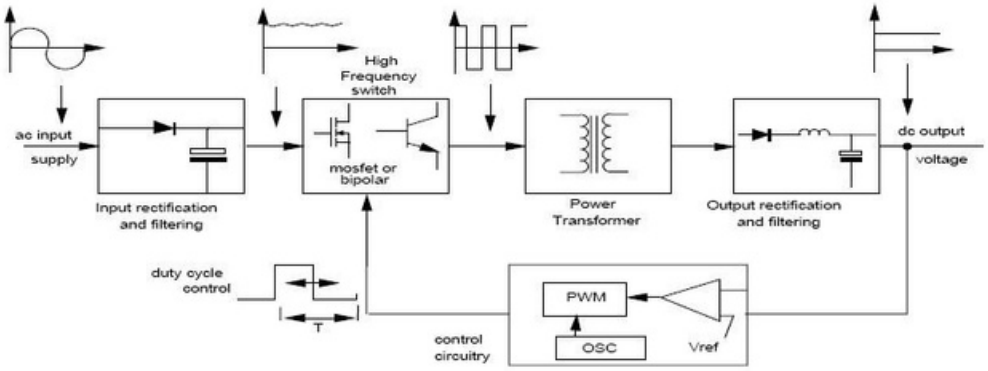
Ans:

Working principle of SMPS:

 SMPS converts unregulated AC or DC voltage into a regulated voltage.In case of AC it first converted into unregulated DC. This is fed to a high frequency switching element. The switch is operating at the high frequencies of 20 kHz to 1 MHz, chopping the d.c voltage into a high frequency square wave. This square wave is fed into power isolation transformer ,stepped down to a predetermined value and then

2 Marks for explanation

rectified and filtered to produce the required d.c output. A portion
- of this output is monitored and compared against the fixed reference voltage and the error signal is used to control the on-off times of the swich, thus regulating the output.



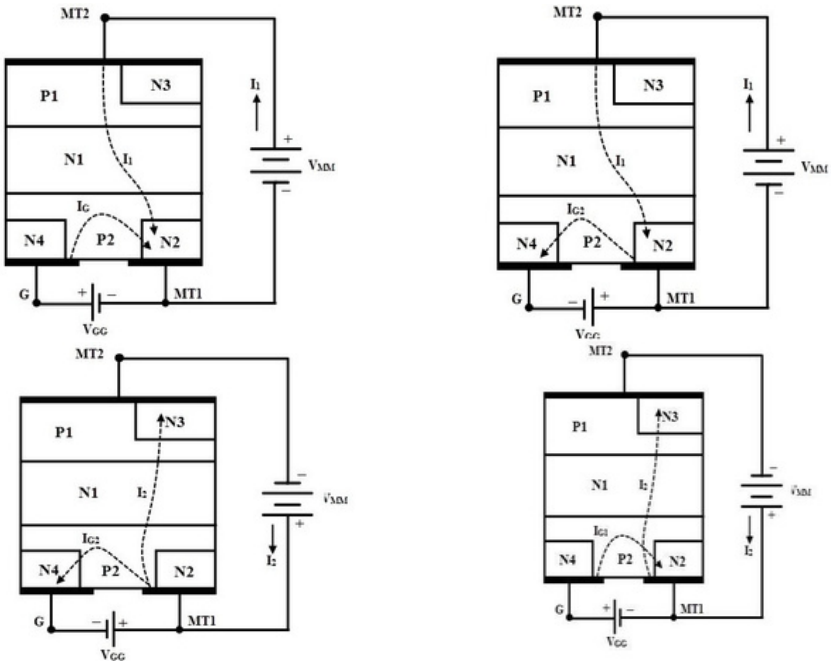
2 Marks for diagram

5 Attempt any TWO of the following: 16

5 a) With neat sketch explain four modes of operation of a TRIAC?

Ans:

Modes of operation of a TRIAC:



1 Mark for each of four diagrams

= 4 Marks

There are four different operating modes of TRIAC:

1) MT2 and gate are positive with respect to terminal MT1(Mode1) : Here terminal MT2 is positive with respect to terminal MT1 current flows through path P1-N1-P2-N2.The two junctions P1-N1 and P2-N2 are forward biased whereas junction N1-P2 is blocked. The TRIAC is now said to be positively biased. A positive gate with respect to terminal MT1 forward biases the junction P2-N2 and the breakdown occurs as in a normal SCR.

2 Marks for explanation

2) MT2 is positive but gate is negative with respect to terminal

MT1(Mode2):
Though the flow path of current remains the same as in mode 1 but now junction P2-N3 is forward biased and current carriers injected into P2 turn on the TRIAC.

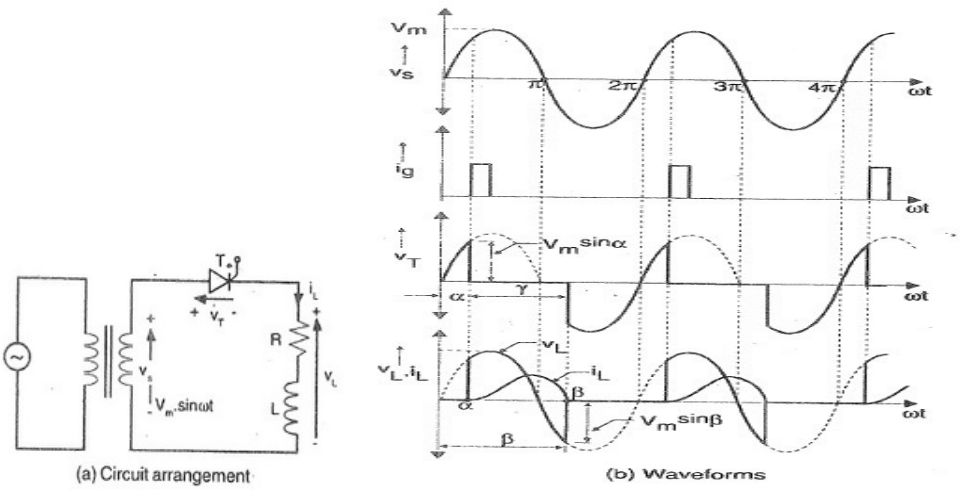
3) MT2 and gate are negative with respect to terminal MT1(Mode4)
: When terminal MT2 is negative with respect to terminal MT1, the current flow path is P2-N1-P1-N4. The two junctions P2-N1 and P1 – N4 are forward biased whereas junction N1-P1 is blocked. The TRIAC is now said to be negatively biased. A negative gate with respect to terminal MT1 injects current carriers by forward biasing junction P2-N3 and thus initiates the conduction.

4) MT2 is negative but gate is positive with respect to terminal MT1(Mode3) :
Though the flow path of current remains the same as in mode 3 but now junction P2-N2 is forward biased, current carriers are injected and therefore, the TRIAC is turned on.

5 b) Explain with neat circuit diagram and input output waveforms, single phase half wave converter with R-L load. Give significance of freewheeling diode.

Ans:

Single phase half wave converter with R-L load:



1 Mark for circuit diagram

2 Marks for waveforms

The circuit diagram of single-phase half-wave controlled rectifier with RL load
and without freewheeling diode is shown in Fig. (a). The SCR T is forward
biased only during positive half cycle whereas reverse biased during negative
half cycle. Therefore, it is triggered in positive half cycles only. When the gate
pulse is applied in positive half cycle with delay angle of as shown in waveform diagram (b), the SCR conducts and starts to carry the load current. Since the load is inductive (RL), the current lags behind the voltage. The load inductance maintains the load current and keeps SCR on even if the supply voltage is reversed. Thus every positive half cycle of load voltage is followed by some negative voltage till the current drops to zero. The negative voltage appearing across load reduces the average load voltage. For some sensitive loads, the negative voltage is undesirable. In such cases freewheeling diode is used to prevent the negative voltage across the load. Thus the use of

2 Marks for explanation

freewheeling diode helps to increase the average load voltage. **Mode 1:** (0 to α) (+ve half cycle)
SCR anode is positive w. r. t. cathode but gate pulse is not applied therefore
SCR is in off state though it is forward biased. The load current is zero & load
voltage is also zero.
Mode 2: (α to π) (+ve half cycle + gate signal is applied at α)
SCR is forward biased and gate signal is applied, therefore SCR turns on at α.
When SCR is triggered the load current will increase in a finite time through the
inductive load. The supplied voltage from this instant appears across the load.
Due to the inductive load the increase in current is gradual, energy is stored in
inductor during α to π .
Mode3: (π to 2 π) (negative half cycle) During this part of negative half cycle,
current continues to flow but falls and finally becomes zero when the energy
stored in the inductance is dissipated in the load resistor and a part of the energy
is feedback to the source, Hence due to energy stored in inductor, current
continues to flow up to instant ωt = 2π. Thus during interval from ωt = π to ωt
= 2π, the negative supply voltage appears across the load. When the load current becomes zero, due to negative supply voltage, the SCR is turnd off. At instant
ωt = π + α, when again pulse is applied, the SCR is turned on & the above cycle
is repeated.

a) Freewheeling diode is used across inductive loads such as coils, dc motor armature etc. to prevent voltage spikes across these loads when the switching device is turned off.
b) It is used to bypass the stored energy in inductive elements when the switching device is turned off.
c) In absence of FWD, the stored energy in inductance will maintain forward current through the power semiconductor device and prevent it from being turned off.
d) When the power semiconductor device in series with load is turned off, the free-wheeling diode is forward biased and the current in load is bypassed through FWD. Since load current is shifted from switching device, it is turned off easily and regain its blocking ability.

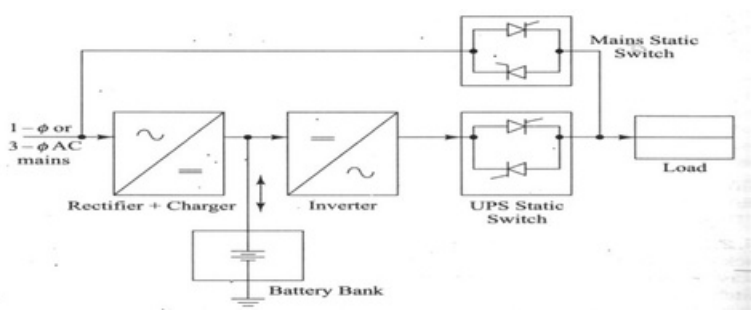
1 Mark for Significance of FD

5 c) Describe working of online UPS. List any two applications of UPS.

Significance of Freewheeling Diode (FWD):

Ans:

OnlineUPS:



2 Marks for block diagram

The block diagram of the on line UPS systems is as shown, where the load is

connected to the invertor through the UPS static switch. The UPS static switch is normally ON switch. It turns off only when the UPS system fails. In that case the mains static off switch is used only when UPS is to be bypassed. The various operating modes are **Mode 1:-**When the AC mains is on, the inverter circuit will supply the power to the inverter as well as to the battery. Therefore it acts as a rectifier cum charger .Hence its ratings are usually higher. The inverter o/p is connected to the load via UPS static switch. Battery will be charged in this mode. **Mode 2:-**If the supply fails suddenly, the rectifier o/p will be zero and hence the battery bank now supplies power to the inverter without any interruption and delay. There will not be any inverter as well as the load. After restoration of the line supply,the charger supplies the inverter and recharges the battery automatically first in constant current mode and then in constant potential mode. **Mode 3:-**In case if the inverter /UPS fails, then the normally OFF mains static switch is turned on which automatically transfers the ac line to the load in less than ¼ th of the cycle period with no phase discontinuity. **Applications of UPS:** 1) Data Centers 2) Banks and insurance 3) Industrials 4) Healthcare: hospitals, clinics and retirement homes 5) Telecommunications 6) Special projects (events)

2 Marks for working

1 Mark for each of any two applications = 2 Marks

Attempt any TWO of the following

Draw symbol & V-I characteristics of the following devices

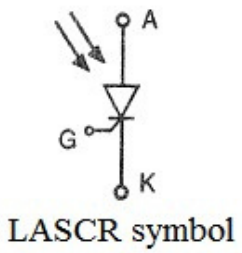
6 **12**

6 a)

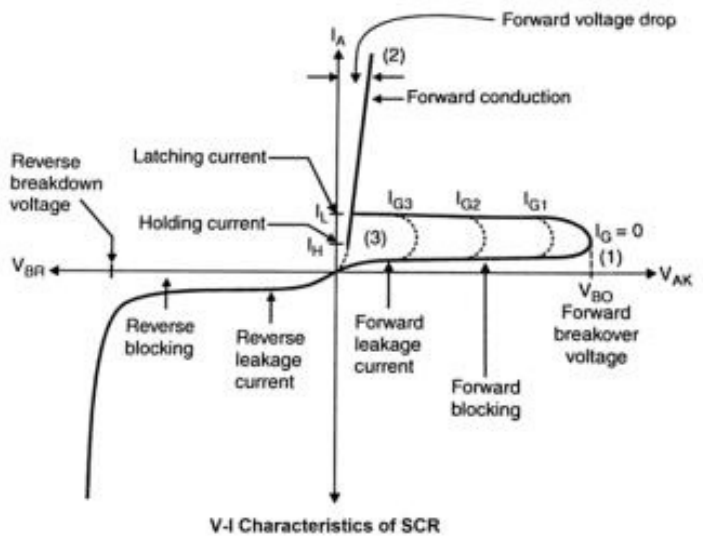
i)LASCR ii)DIAC iii)PUT iv)SCS

Ans:

i) LASCR:



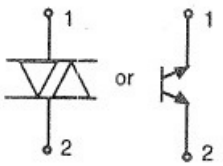
LASCR symbol



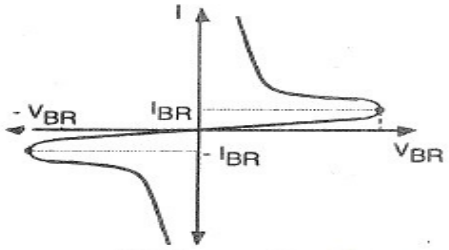
V-I Characteristics of SCR

½ Mark for symbol and 1 Mark for characteristic = 1½ for each bit

ii) DIAC:

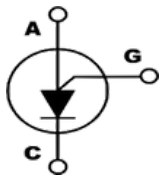


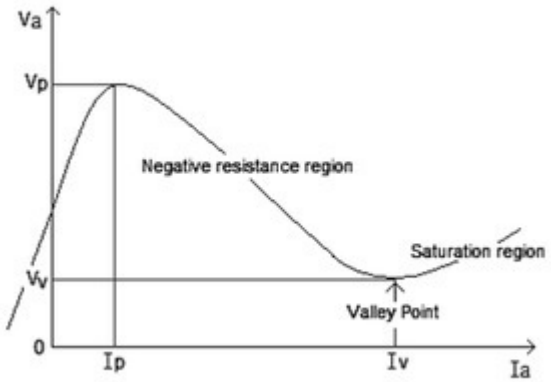
Symbol



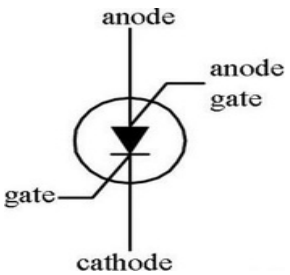
V-I Characteristics of DIAC

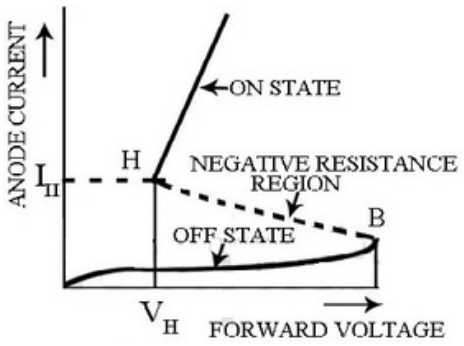
iii) PUT:





iv) SCS:





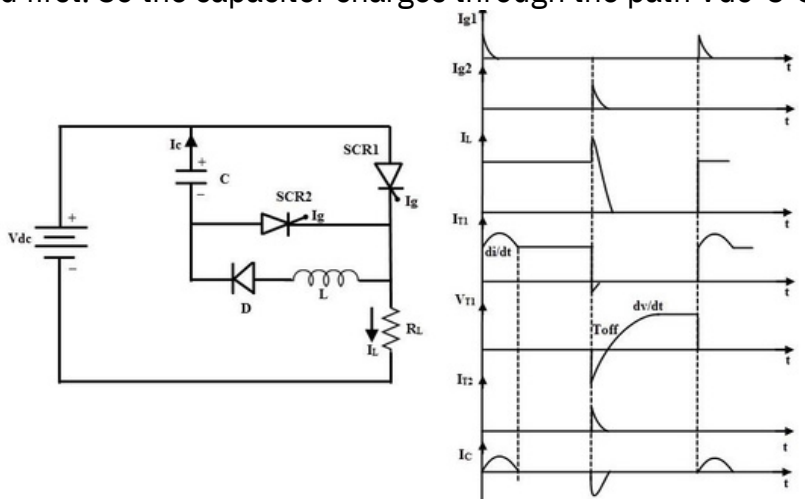
6 b) For a class D commutation, answer the following:
i) Explain the operation with circuit diagram.
ii) Interpret with waveforms.

Ans: Class D commutation:

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

When the supply voltage Vdc 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 Vdc-C-SCR2-RL-Vdc.



1 Mark for circuit diagram

2 Marks for explanation

2 Mark for waveforms

1 Mark for interpretation

When the capacitor is fully charged, the charging current becomes zero and the SCR2 is turned-off naturally.

The supply voltage Vdc as well as the charged capacitor C holds the SCR1 in forward bias condition. If the SCR1 is triggered, it is turned-on and two currents flow through it: one is the load current supplied by source, through path Vdc-SCR1 – RL – Vdc and another one is capacitor discharge current through path C – SCR1 – L – D - C. The capacitor while discharging supplies its energy to the inductor L. When the capacitor fully discharges, its voltage becomes zero at peak discharge current instant. Then the inductor L utilizes its energy to maintain the current through the same path and the capacitor charges with reversed polarity. When the inductor gives out its energy to the capacitor, the current naturally falls to zero and the capacitor charges fully with reversed polarity. Due to the presence of diode the reverse discharge is not possible. Thus after reverse charging of C, the SCR1 continues to carry only load current. The capacitor voltage maintains forward bias across SCR1, thereby it can be triggered at any instant.

Now when it is desired to turn-off SCR1 for load voltage control, the SCR2 is triggered. The charged capacitor (lower plate positive) then placed across conducting SCR1, applying reverse bias to SCR1. Also, the capacitor discharging starts through path C - SCR2- RL- Vdc - C. The load current is shifted from SCR1 to C – SCR2 path. When this discharging current becomes more than the load current the SCR1 is turned OFF. After turning off of SCR1, the reverse bias is maintained across it by capacitor voltage, which ensures the proper turn-off.

The capacitor discharges fully first and then starts charging with polarity of upper plate positive, through the SCR2 – RL to a supply voltage Vdc. When the capacitor fully charges, the charging current falls to zero and SCR2 is naturally turned off. The capacitor voltage as well as supply voltage make SCR1 forward biased and keep ready for next triggering. The above cyclic process is repeated.

6 c) A 1-phase Half controlled rectifier supplied with voltage v=300sin 314t, and load resistance is 100Ω. Find

i)Average output voltage ii)Load current (For α=60 and α=100)

Ans:

Data Given: Vm =300 volt, RL=100Ω

1) For α=60

i)Average output voltage:

=143.24V

Average output voltage = = 143.24 V 1½ Marks

ii) Load current:

1½ Marks

2) For α=100

i) Average output voltage:

Average output voltage = =71.61V 1½ Marks

ii) Load current:

Load current=0.789A 1½ Marks

11920

22326

3 Hours / 70 Marks

Seat No. | | | | | | | | |

Instructions :

(1) All Questions are compulsory.

(2) Answer each next main Question on a new page.

(3) Illustrate your answers with neat sketches wherever necessary.

(4) Figures to the right indicate full marks.

Marks

1. Attempt any FIVE of the following : 10

(a) Define (i) Holding current, (ii) Latching current of SCR. 2

(b) Draw circuit diagram of Class B commutation. 2

(c) State classification of Phase controlled rectifiers. 2

(d) Define (i) Conduction angle, (ii) Firing angle. 2

(e) Draw circuit diagram of symmetrical configuration of bridge converter. 2

(f) State the advantages of SMPS. (any two) 2

(g) State the need of UPS. 2

2. Attempt any THREE of the following : 12

(a) Describe with neat sketch the constructional details of IGBT. 4

(b) Explain two transistor analogy of SCR with neat diagram. 4

(c) With neat diagram explain synchronized UJT triggering circuit. 4

(d) Explain working of static A.C. circuit breaker. 4

3. Attempt any THREE of the following : 12

(a) Give comparison of SCR & TRIAC. (any four points) 4

(b) Explain the thermal triggering method of SCR. Enlist different triggering methods of SCR. 4

(c) Draw single phase full wave mid-point converter for inductive load. Draw input and output waveforms for it. 4

(d) Draw the circuit diagram of battery charger using SCR and explain it's working. 4

4. Attempt any THREE of the following : 12

(a) Draw I-V characteristics of power transistor. Show different regions. 4

(b) With reference to GTO answer the following : 4

(i) State advantage of GTO over SCR.

(ii) Draw construction of GTO.

(c) Explain triggering of SCR using opto-coupler. State its advantages. 4

(d) Describe the operation of single phase fully controlled bridge converter with R-load. 4

(e) Explain the working principle of SMPS with neat diagram. 4

5. Attempt any TWO of the following : 12

(a) With neat sketch explain four modes of operation of a TRIAC. 6

(b) Explain with neat circuit diagram and input output waveforms, single phase half wave converter with R-L load. Give significance of freewheeling Diode. 6

(c) Describe working of online UPS. List any two applications of UPS. 6

6. Attempt any TWO of the following : 12

(a) Draw symbols and V-I characteristics of the following devices : 6

(i) LASCR (ii) DIAC

(iii) PUT (iv) SCS

(b) For a class D commutation, answer the following : 6

(i) Explain the operation with a circuit diagram.

(ii) Interpret with waveforms.

(c) A 1-ϕ half controlled rectifier supplied with voltage V = 300 sin 314 t, and load resistance is 100 Ω. Find : 6

(i) Average output DC voltage.

(ii) Load current.

(For $\alpha = 60^\circ$ and $\alpha = 100^\circ$)

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MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC-27001-2005 Certified)

Winter – 2019 Examinations

Model Answer

Subject & Code: FUNDAMENTALS OF POWER ELECTRONICS (22326)

Important Instructions to examiners:

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

1 a) **Attempt any FIVE of the following:** **10**

1 a) Define: (i) Holding Current (ii) Latching Current of SCR

Ans:

1 Mark for each definition = 2 Marks

(i) Holding Current:

Holding current is defined as the minimum anode current required to maintain conducting SCR in the on-state.

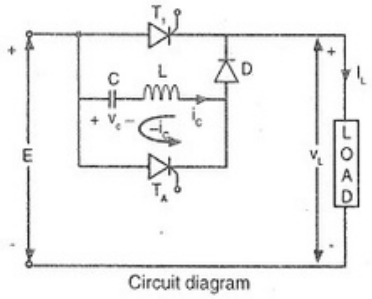
(ii) Latching Current:

Latching current is defined as the minimum anode current required to maintain the SCR in the on-state immediately after the SCR has been turned on and the gate signal has been removed.

1 b) Draw circuit diagram of Class B commutation.

Ans:

Class B: Resonant Pulse Commutation:



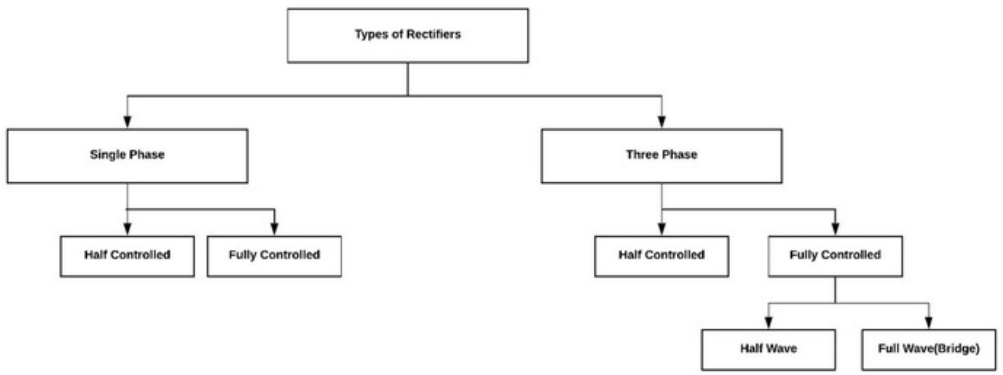
Circuit diagram

2 Marks for labeled circuit diagram

1 c) State classification of Phase controlled rectifiers.

Ans:

Classification of phase controlled rectifiers:



2 Marks

1 d) Define: (i) conduction angle (ii) firing angle.

Ans:

(i) Conduction Angle ():

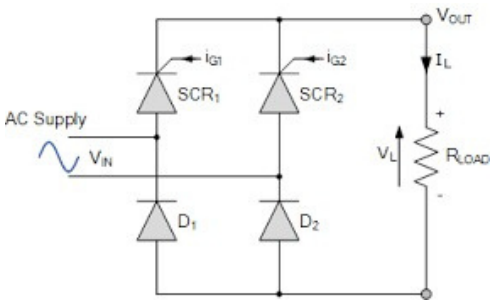
Conduction angle is defined as the angle between the instant the SCR is triggered or turned on and the instant at which the SCR is turned off. Assuming that the SCR is turned off naturally at the end of positive half cycle, the relation between the firing or delay angle ( ) and conduction angle () can be expressed as:

1 Mark for each definition = 2 Marks

(ii) Firing Angle( ):

Firing angle is defined as the angle between the instant the SCR would conduct if it would be a diode and the instant it is triggered or fired. Firing angle or delay angle can be defined as the angle measured from the angle that gives maximum average output voltage to the angle when the SCR is actually triggered or fired by gate pulse.

1 e) Draw circuit diagram of symmetrical configuration of bridge converter.
Ans:



2 Marks for circuit diagram

1 f) State the advantages of SMPS. (any two)
Ans:
Advantages of SMPS:

1. High Efficiency, more than 94%.
2. Easy maintenance and servicing.
3. High modularity and redundancy.
4. Lower power dissipation.
5. Wide AC input voltage range.
6. Less cost.

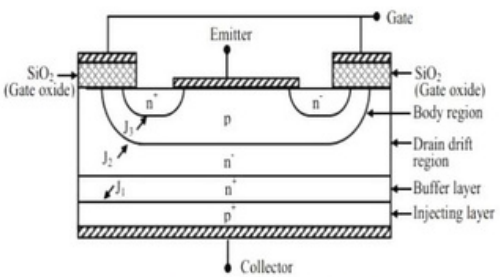
1 Mark for each of any two = 2 Marks

1 g) State the need of UPS.
Ans:
Need of UPS:
1) An Uninterruptible Power Supply (UPS) is used to protect critical loads from mains supply problems including spikes, voltage dips, fluctuations and complete power failures using a dedicated battery.
2) A UPS system can also be used as standby system when AC mains is failed.

1 Mark for each point = 2 Marks

2 Attempt any <u>THREE</u> of the following: 12

2 a) Describe with neat sketch the constructional details of IGBT.
Ans:
Construction:



Construction of IGBT

2 marks for construction diagram

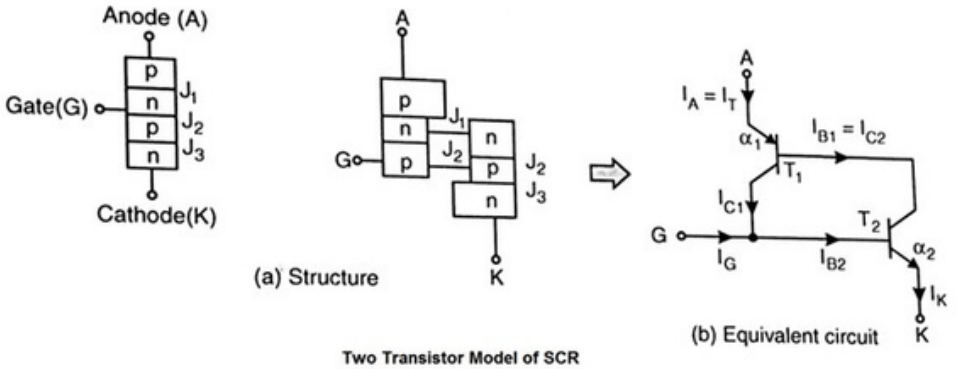
Insulated gate bipolar transistor or IGBT, is a solid state devices primarily used as an electronic switch which, as it was developed, came to combine high efficiency and fast switching. The insulated gate bipolar transistor (IGBT) is a three terminal semiconductor device combines the benefits of both MOSFET and BJT. So, an insulated gate bipolar transistor (IGBT) has input impedance like that of a MOSFET and low ON state power loss as in a BJT. It is also called as metal oxide semiconductor insulated gate transistor (MOSIGT) and other name to this device are insulated gate transistor (IGT), conductivity modulated field effect transistor (COMFET). It is similar to that of a double-diffused power MOSFET (DMOS) except for a p+ layer at the bottom. This layer forms the IGBT collector and a pn junction with n-drift region, where conductivity modulation occurs by injecting minority carriers into the drain drift region of the vertical MOSFET. Therefore, the current density is much greater than a power MOSFET and the forward voltage drop is reduced. The p+ substrate, n- drift layer and p+ emitter constitute a BJT with a wide base region and hence small current gain.

2 marks for description

2 b) Explain two transistor analogy of SCR with neat diagram.

Ans:

Two-transistor Analogy of SCR:



Two Transistor Model of SCR

1 mark for (a)
1 mark for (b)
= 2 marks for diagram

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

where, = common-base current gain
= leakage current from collector to base with emitter open
For transistors T1 and T2, we can write,
and
From KCL applied to T1, we can write

From KCL applied to entire equivalent circuit,
and substituting in above equation,

[ ]

2 marks for mathematical treatment

[ ]

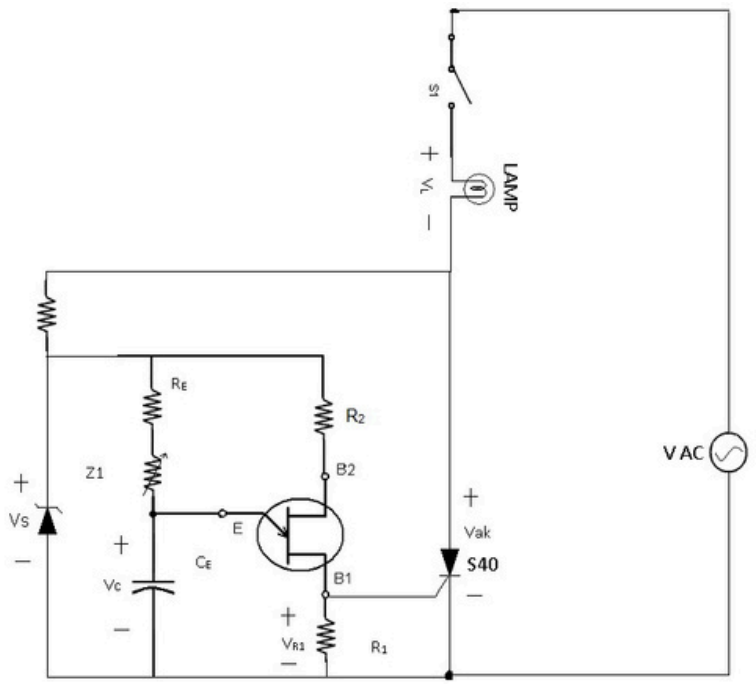
From this equation it is clear that the anode current depends on the gate current, leakage currents and current gains.

If tends to be unity, the denominator [ ] approaches zero, resulting in a large value of anode current and SCR will turn on. The current gains vary with their respective emitter currents. When gate current is applied, the anode current is increased. The increased , being emitter current of T1, increases the current gain . The gate current and anode current together form cathode current, which is emitter current of T2. Thus increase in cathode current increases current gain increase the anode current and the anode current further increases the current gains. The cumulative action leads to the loop gain to approach unity and the anode current drastically rises which can be controlled by external circuit only.

2 c) With neat diagram explain synchronized UJT triggering circuit.

Ans:

Line Synchronized UJT triggering circuit:



2 Marks for circuit diagram + 2 Mark for description = 4 Marks

The UJT is almost ideal as a firing device for SCRs. There are 2 main reasons for the compatibility between UJTs and SCRs. Firstly, the UJT produces a pulse-type output, which is excellent for accomplishing sure turn-on of an SCR without straining the SCR's gate power dissipation capability. Secondly, the UJT firing point is inherently stable over a wide temperature range. This can compensate for the temperature instability of the SCR.

The usual method of triggering an SCR with a UJT is shown in Figure 1.

In this circuit, zener diode Z1 clips the Vs waveform at the zener voltage during the positive half-cycle of the ac line. During the negative half cyce, Z1 is forward biased and Vs is held near 0 V.

Once the dc voltage Vs has been established, which occurs immediately

after the ac line crosses zero, CE begins charging through resistor RE. When CE reaches the peak voltage of the UJT, the UJT then fires. This generates a voltage

pulse across R1 and results in the firing of the SCR. When the SCR is fired, current flows through it and the load. This makes the positive half cycle.

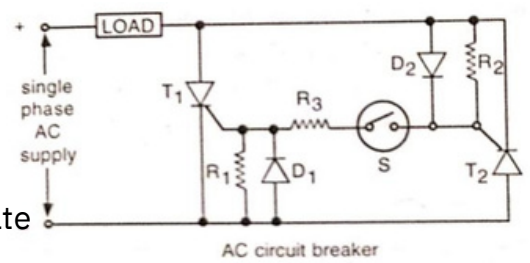
In this circuit, automatic synchronization between the firing pulse of the UJT and the SCR ensures that the SCR will be fired only when it is forward biased. This means that whenever the UJT delivers a pulse, the SCR is sure to have the right polarity between the anode and cathode for turning on.

2 d) Explain working of static AC circuit breaker.

Ans:

Static AC Circuit breaker:

The circuit configuration of static AC circuit breaker using SCR is shown in the figure. When switch 'S' is closed, the SCRs T1 and T2 are fired in positive and negative half cycles respectively.



AC circuit breaker

2 Marks for circuit diagram

During positive half-cycle, T1 receives gate current through D2 || R2, switch S and R3 and it conducts. At the end of positive half-cycle, T1 is turned off due to natural current zero. In the negative half-cycle, T2 receives gate current through D1 || R1, R3andswitch S and it conducts. It is turned off at the end of this negative half cycle due to natural current zero value. When the load current is required to be interrupted, the switch S is opened. It results in blocking of gate currents of both SCRs and hence both SCRs are maintained off. When sitch S is opened at any instant in a particular half-cycle, the load current continue to flow through conducting SCR till the end of this half-cycle, however in the next half-cycle the other SCR will not be fired due to non-availability of gate current. Thus the maximum time delay for breaking the circuit is one half-cycle.

2 Marks for operation

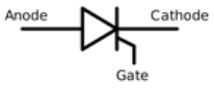
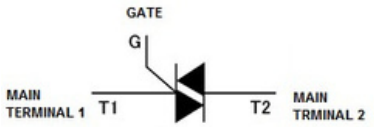
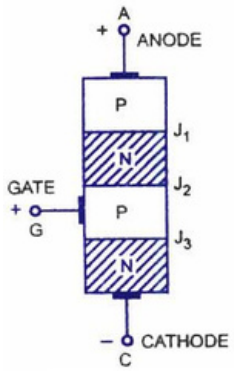
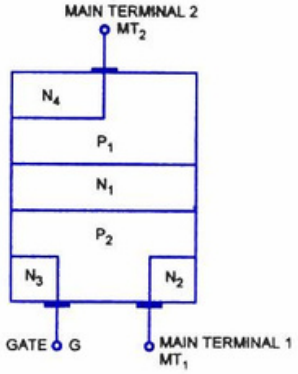
3 Attempt any THREE of the following **12**

3 a) Give comparison of SCR and TRIAC (any four points)

Ans:

SCR	TRIAC
It is an unidirectional device.	It is a bidirectional device.
It is turned-on by only positive gate current.	It can be turned-on by either positive or negative gate current.
Operates only in the first quadrant	Operates in either 1 or 3 quadrant.
Anti-parallel SCRs are used for bidirectional current flow.	TRIAC is equivalent to a pair of antiparallel connected SCRs.
It has better gate-current sensitivity.	It has poor gate-current sensitivity as compared to SCR.
It has lower turn-on & turn-off times as compared to TRIAC.	It has higher turn-on & turn-off times as compared to SCR.
For bidirectional current applications, two SCRs & two heat sinks require	For bidirectional current applications, one TRIAC & one

1 Mark for each of any four points = 4 Marks

more space.	heat sink require less space.
Firing circuit design is simple.	More careful firing circuit design is required.
Higher voltage & current ratings as compared to TRIAC.	Lower voltage & current ratings as compared to SCR.
	
	
It is employed in large power applications including large power supplies, DC motor drives, lighting and heating, Static VAR compensators, Electronic circuit breakers etc.	It is employed in low and medium power applications including lamp dimmer, heating control, zero voltage switched AC relay, small AC motor control etc.

3 b) Explain the thermal triggering method of SCR. Enlist different triggering methods of SCR.

Ans:

Types of Triggering:

1) Forward voltage triggering
2) Thermal triggering (Temperature triggering)
3) Radiation triggering (Light triggering)
4) dv/dt triggering
5) Gate triggering
   (i) D.C. Gate triggering
   (ii) A.C. Gate triggering
   (iii) Pulse Gate triggering

1 Mark for different methods + 3 Marks for thermal triggering = 4 Marks

Thermal Triggering :

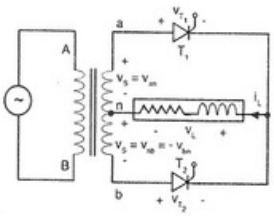
- If the temperature of a thyristor increases, there is an increase in the number of electron hole pairs. This will increase the leakage current. Therefore the value of α1 and α2 will increase. If (α1 + α2) tends to unity, then the thyristor may be turned on.
- This is called as thermal triggering of thyristor. It is an undesirable feature. The break over voltage goes on decreasing with increase in temperature.
- In short, due to increase in temperature the thermally generated leakage current increases. This current gets multiplied internally and thyristor is

turned on.

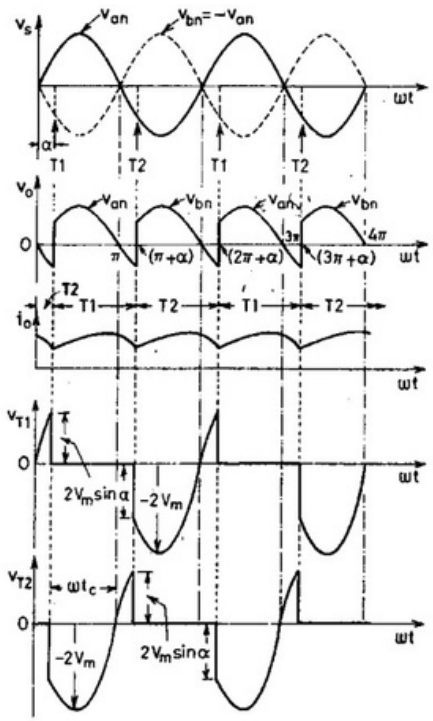
3 c) Draw single phase full wave mid-point converter for inductive load. Draw input and output waveforms for it.

Ans:

Circuit Diagram:



Waveforms:

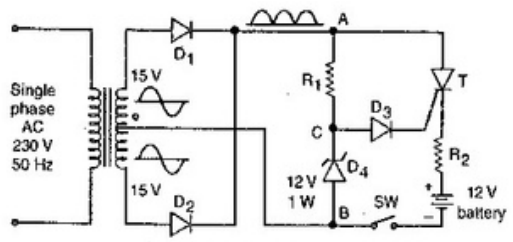


2 Marks for circuit diagram + 2 Marks for waveforms = 4 Marks

3 d) Draw the circuit diagram of battery charger using SCR and explain it's working.

Ans:

Battery charger circuit using SCR:

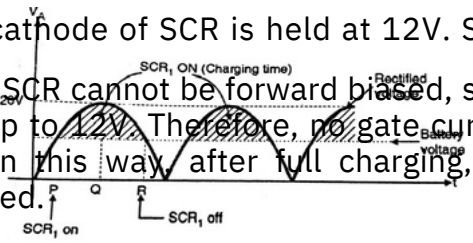


Automatic battery charger using SCR

The figure shows the battery charger circuit using SCR. A 12V discharged battery is connected in the circuit and switch SW is closed. The single-phase 230V supply is stepped down to (15-0-15) V by a centre-tapped transformer. The diodes D1 and D2 forms full wave rectifier and pulsating DC supply appears across terminals A and B. When SCR is off, its cathode is held at the potential of discharged battery. During each positive half-cycle, when the potential of point C rises to sufficient level so as to forward bias diode D3 and gate-cathode junction of SCR, the gate pulse is provided and SCR is turned on. When SCR is

2 Marks for circuit diagram + 2 Marks for explanation = 4 Marks

turned on, the charging current flows through battery. Thus during each positive half-cycle of pulsating DC supply, voltage across A-B, SCR is fired and
charging current is passed till the end of that half-cycle. Due to Zener diode D4,
the maximum voltage at point C is held at 12V. Due to the charging process, the
battery voltage rises and finally attains full value of 12V. When the battery is
fully charged, the cathode of SCR is held at 12V. So the diode D3 and gate-
cathode junction of SCR cannot be forward biased, since the potential of point C can reach up to 12V. Therefore, no gate current is supplied and SCR is not fired. In this way, after full charging, further charging is automatically stopped.



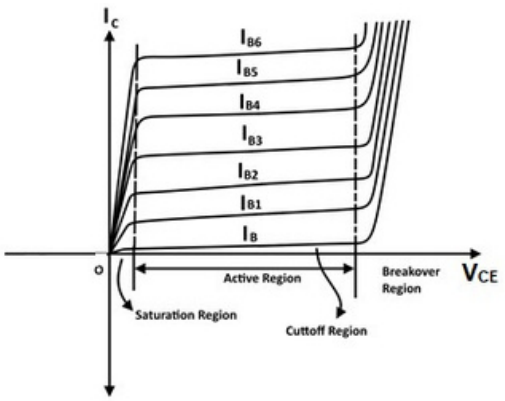
Waveform for battery charger circuit

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

4 a) Draw I-V characteristics of power transistor. Show different regions.

Ans:

I-V characteristics of power transistor:



4 marks for labeled diagram

2 mark for partially labeled diagram

No marks for unlabeled diagram

4 b) With reference to GTO answer the following:
i)State advantages of GTO over SCR
ii)Draw construction of GTO.

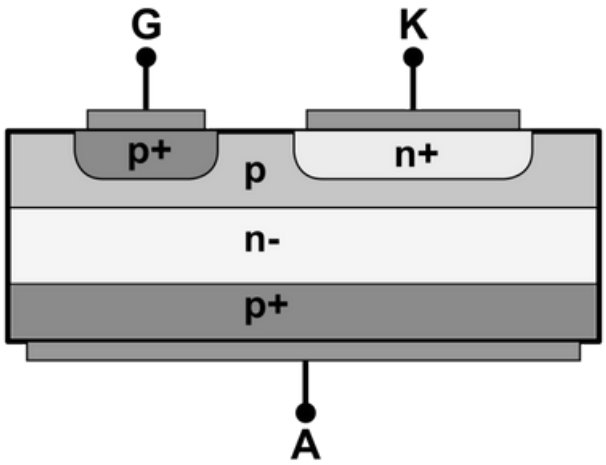
Ans:

I) Advantages of GTO over SCR:

i) It is turned-off by negative gate pulse.
ii) No commutation circuit required, reducing the cost, size, weight and volume of the circuit.
iii) As commutation choke is not used, the associated acoustic and electromagnetic noise (interference) is absent.
iv) Less turn off time permits high switching frequency.
v) It has higher di/dt rating at turn-off.

½ Mark for each of any four advantages = 2 Marks

II) Construction of GTO:



2 Marks for constructional sketch

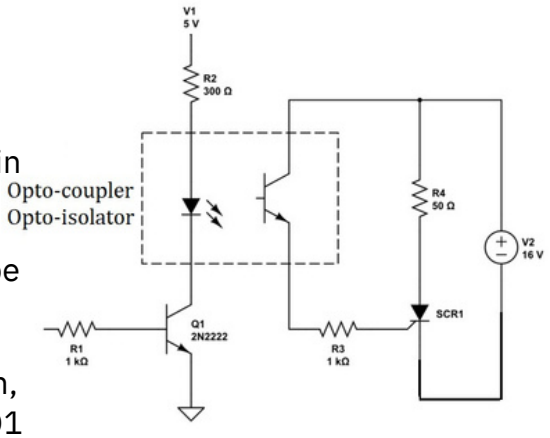
OR any other equivalent constructional sketch

4 c) Explain triggering of SCR using opto-coupler. State its advantages.

Ans:

Triggering of SCR using opto-coupler:

A simple opto-coupler based triggering circuit for SCR is shown in the figure. An opto-coupler or opto-isolator is a combination of light source and light-sensitive device enclosed in a compartment. The light source is LED or infra-red LED (IRLED) and light-sensitive device may be photo-diode or photo-transistor.



1 Mark for circuit diagram

2 Marks for explanation

Referring to the circuit diagram, when the SCR is to be turned-on, a voltage is applied to base of Q1 through R1. The base current flows and Q1 is turned on. The collector current flow and voltage appears across the LED of opto-coupler. The light emitted by LED falls on the photo-transistor and it is turned-on. When photo-transistor is turned-on. It carries the current, which flows through R3 and acts as gate current for the SCR. Thus gate current is provided to SCR and it is ultimately turned-on. The firing circuit is electrically isolated from SCR circuit but optically coupled.

OR

(Any other equivalent valid circuit and explanation)

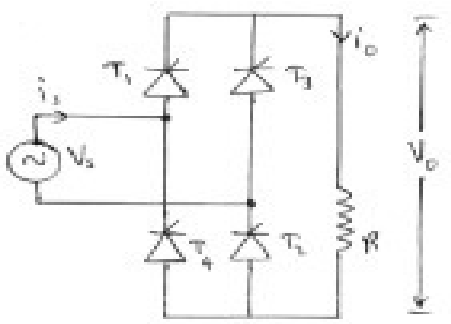
Advantages of Opto-Couplers i)Triggering circuits are well protected due to electrical isolation. ii)It is small size and light weight device. iii)Interfacing with logic circuits is easily possible.

1 Marks for two advantages

4 d) Describe the operation of single phase fully controlled bridge converter with R-load.

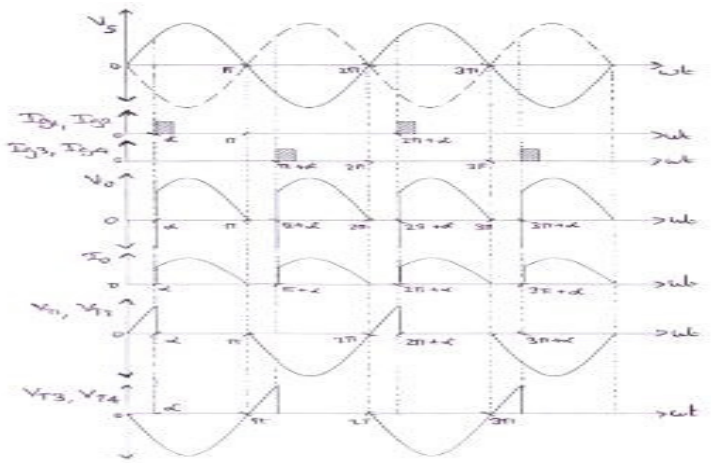
Ans:

Circuit Diagram:



1 Mark for circuit diagram

Waveforms:



1 Mark for waveforms

Explanation:

- During positive half cycle of Vs, SCRs T1 and T2 are fired, so that Vab appears across load.
- During negative half cycle of Vs, SCRs T3 and T4 are fired, so that Vba appears across load.

Thus alternate firing of SCR pairs results in repeated positive half cycles i.e pulsating DC across load.

The delayed firing of SCR pairs provides phase control and control over output voltage.

2 Marks for explanation

4 e) Explain the working principle of SMPS with neat diagram.

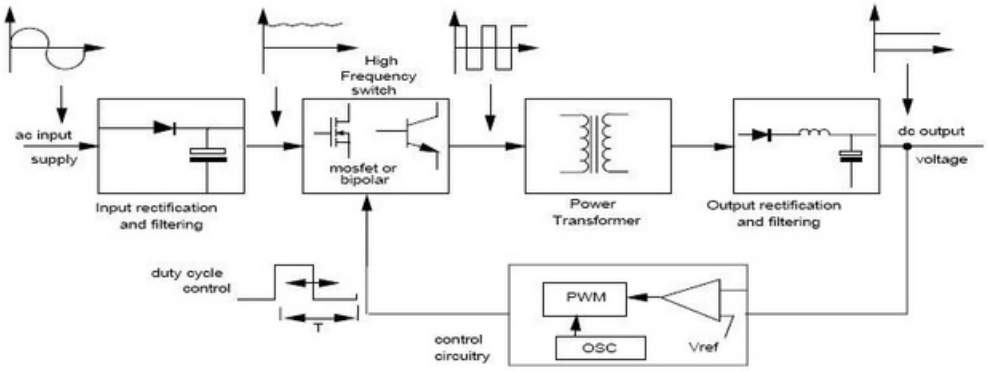
Ans:

Working principle of SMPS:

 SMPS converts unregulated AC or DC voltage into a regulated voltage.In case of AC it first converted into unregulated DC. This is fed to a high frequency switching element. The switch is operating at the high frequencies of 20 kHz to 1 MHz, chopping the d.c voltage into a high frequency square wave. This square wave is fed into power isolation transformer ,stepped down to a predetermined value and then

2 Marks for explanation

rectified and filtered to produce the required d.c output. A portion
- of this output is monitored and compared against the fixed reference voltage and the error signal is used to control the on-off times of the swich, thus regulating the output.



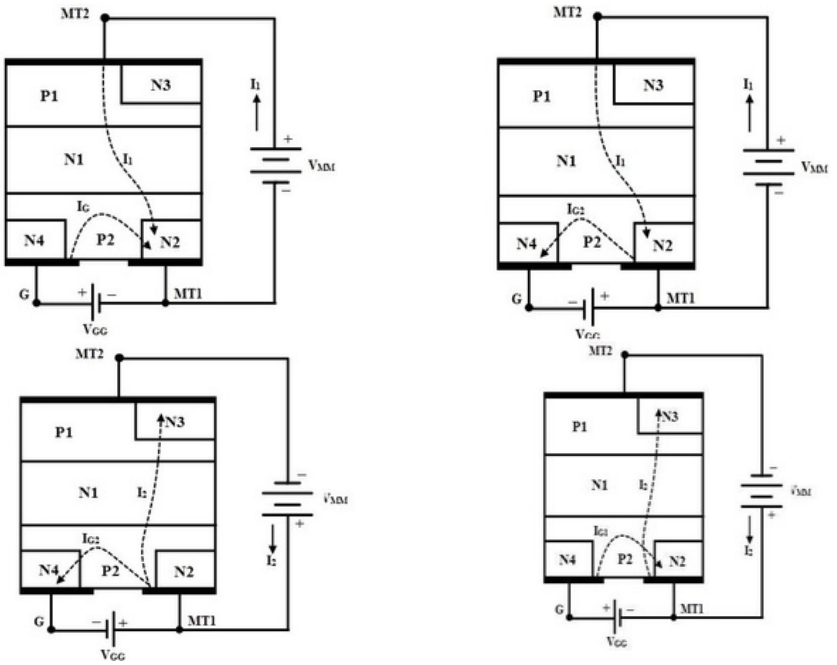
2 Marks for diagram

5 Attempt any TWO of the following: 16

5 a) With neat sketch explain four modes of operation of a TRIAC?

Ans:

Modes of operation of a TRIAC:



1 Mark for each of four diagrams

= 4 Marks

There are four different operating modes of TRIAC:

1) MT2 and gate are positive with respect to terminal MT1(Mode1) : Here terminal MT2 is positive with respect to terminal MT1 current flows through path P1-N1-P2-N2.The two junctions P1-N1 and P2-N2 are forward biased whereas junction N1-P2 is blocked. The TRIAC is now said to be positively biased. A positive gate with respect to terminal MT1 forward biases the junction P2-N2 and the breakdown occurs as in a normal SCR.

2 Marks for explanation

2) MT2 is positive but gate is negative with respect to terminal

MT1(Mode2):
Though the flow path of current remains the same as in mode 1 but now junction P2-N3 is forward biased and current carriers injected into P2 turn on the TRIAC.

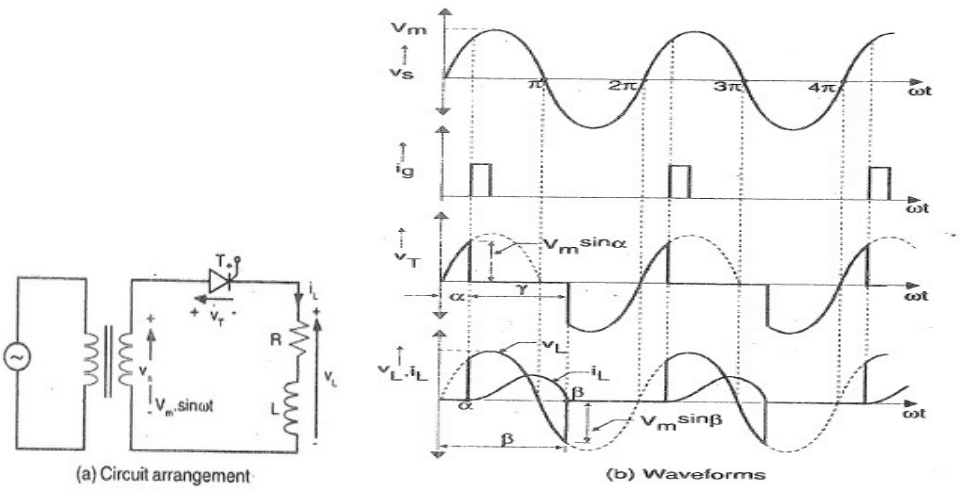
3) MT2 and gate are negative with respect to terminal MT1(Mode4)
: When terminal MT2 is negative with respect to terminal MT1, the current flow path is P2-N1-P1-N4. The two junctions P2-N1 and P1 – N4 are forward biased whereas junction N1-P1 is blocked. The TRIAC is now said to be negatively biased. A negative gate with respect to terminal MT1 injects current carriers by forward biasing junction P2-N3 and thus initiates the conduction.

4) MT2 is negative but gate is positive with respect to terminal MT1(Mode3) :
Though the flow path of current remains the same as in mode 3 but now junction P2-N2 is forward biased, current carriers are injected and therefore, the TRIAC is turned on.

5 b) Explain with neat circuit diagram and input output waveforms, single phase half wave converter with R-L load. Give significance of freewheeling diode.

Ans:

Single phase half wave converter with R-L load:



1 Mark for circuit diagram

2 Marks for waveforms

The circuit diagram of single-phase half-wave controlled rectifier with RL load
and without freewheeling diode is shown in Fig. (a). The SCR T is forward
biased only during positive half cycle whereas reverse biased during negative
half cycle. Therefore, it is triggered in positive half cycles only. When the gate
pulse is applied in positive half cycle with delay angle of as shown in waveform diagram (b), the SCR conducts and starts to carry the load current. Since the load is inductive (RL), the current lags behind the voltage. The load inductance maintains the load current and keeps SCR on even if the supply voltage is reversed. Thus every positive half cycle of load voltage is followed by some negative voltage till the current drops to zero. The negative voltage appearing across load reduces the average load voltage. For some sensitive loads, the negative voltage is undesirable. In such cases freewheeling diode is used to prevent the negative voltage across the load. Thus the use of

2 Marks for explanation

freewheeling diode helps to increase the average load voltage. **Mode 1:** (0 to α) (+ve half cycle)
SCR anode is positive w. r. t. cathode but gate pulse is not applied therefore
SCR is in off state though it is forward biased. The load current is zero & load
voltage is also zero.
Mode 2: (α to π) (+ve half cycle + gate signal is applied at α)
SCR is forward biased and gate signal is applied, therefore SCR turns on at α.
When SCR is triggered the load current will increase in a finite time through the
inductive load. The supplied voltage from this instant appears across the load.
Due to the inductive load the increase in current is gradual, energy is stored in
inductor during α to π .
Mode3: (π to 2 π) (negative half cycle) During this part of negative half cycle,
current continues to flow but falls and finally becomes zero when the energy
stored in the inductance is dissipated in the load resistor and a part of the energy
is feedback to the source, Hence due to energy stored in inductor, current
continues to flow up to instant ωt = 2π. This during interval from ωt = π to ωt
= 2π, the negative supply voltage appears across the load. When the load current becomes zero, due to negative supply voltage, the SCR is turnd off. At instant
ωt = 2π + α, when again pulse is applied, the SCR is turned on & the above cycle
is repeated.

a) Freewheeling diode is used across inductive loads such as coils, dc motor armature etc. to prevent voltage spikes across these loads when the switching device is turned off.
b) It is used to bypass the stored energy in inductive elements when the switching device is turned off.
c) In absence of FWD, the stored energy in inductance will maintain forward current through the power semiconductor device and prevent it from being turned off.
d) When the power semiconductor device in series with load is turned off, the free-wheeling diode is forward biased and the current in load is bypassed through FWD. Since load current is shifted from switching device, it is turned off easily and regain its blocking ability.

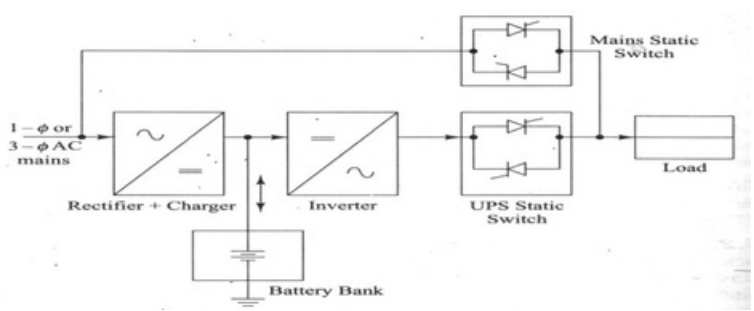
1 Mark for Significance of FD

5 c) Describe working of online UPS. List its applications of UPS.

Significance of Freewheeling Diode (FWD):

Ans:

OnlineUPS:



2 Marks for block diagram

The block diagram of the on line UPS systems is as shown, where the load is

connected to the invertor through the UPS static switch. The UPS static switch is normally ON switch. It turns off only when the UPS system fails. In that case the mains static off switch is used only when UPS is to be bypassed. The various operating modes are **Mode 1:-**When the AC mains is on, the inverter circuit will supply the power to the inverter as well as to the battery. Therefore it acts as a rectifier cum charger .Hence its ratings are usually higher. The inverter o/p is connected to the load via UPS static switch. Battery will be charged in this mode. **Mode 2:-**If the supply fails suddenly, the rectifier o/p will be zero and hence the battery bank now supplies power to the inverter without any interruption and delay. There will not be any inverter as well as the load. After restoration of the line supply,the charger supplies the inverter and recharges the battery automatically first in constant current mode and then in constant potential mode. **Mode 3:-**In case if the inverter /UPS fails, then the normally OFF mains static switch is turned on which automatically transfers the ac line to the load in less than ¼ th of the cycle period with no phase discontinuity. **Applications of UPS:** 1) Data Centers 2) Banks and insurance 3) Industrials 4) Healthcare: hospitals, clinics and retirement homes 5) Telecommunications 6) Special projects (events)

2 Marks for working

1 Mark for each of any two applications = 2 Marks

Attempt any TWO of the following

Draw symbol & V-I characteristics of the following devices

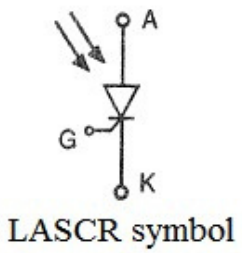
6 **12**

6 a)

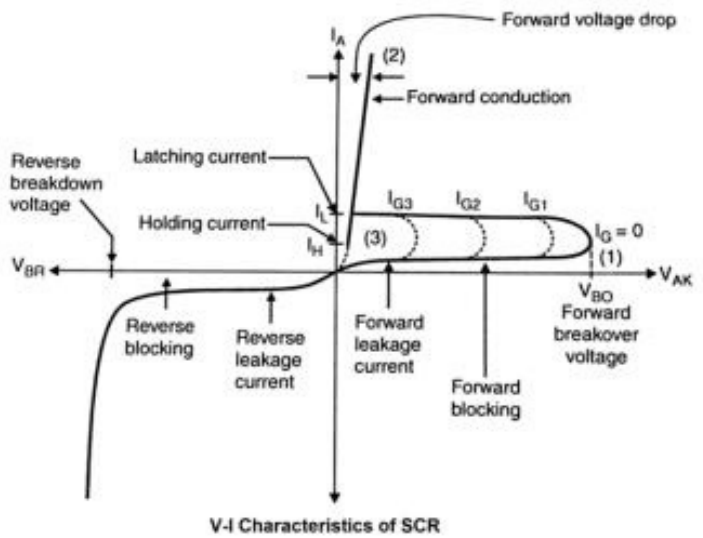
i)LASCR ii)DIAC iii)PUT iv)SCS

Ans:

i) LASCR:



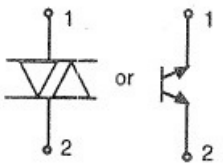
LASCR symbol



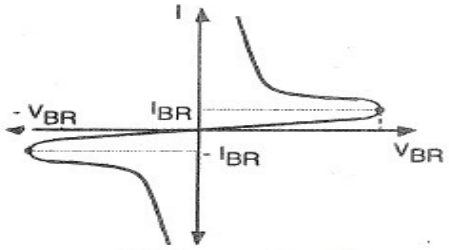
V-I Characteristics of SCR

½ Mark for symbol and 1 Mark for characteristic = 1½ for each bit

ii) DIAC:

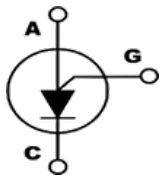


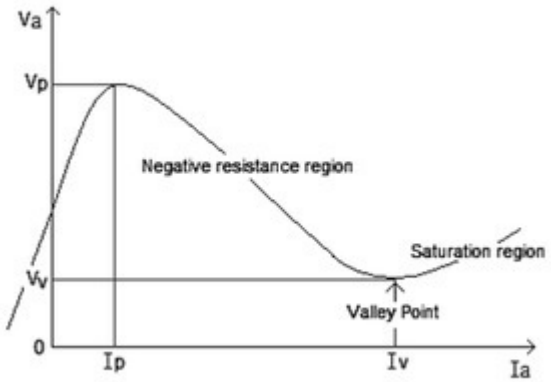
Symbol



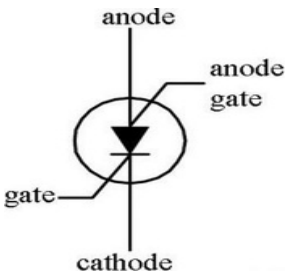
V-I Characteristics of DIAC

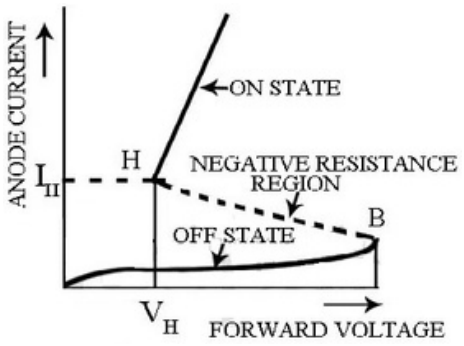
iii) PUT:





iv) SCS:





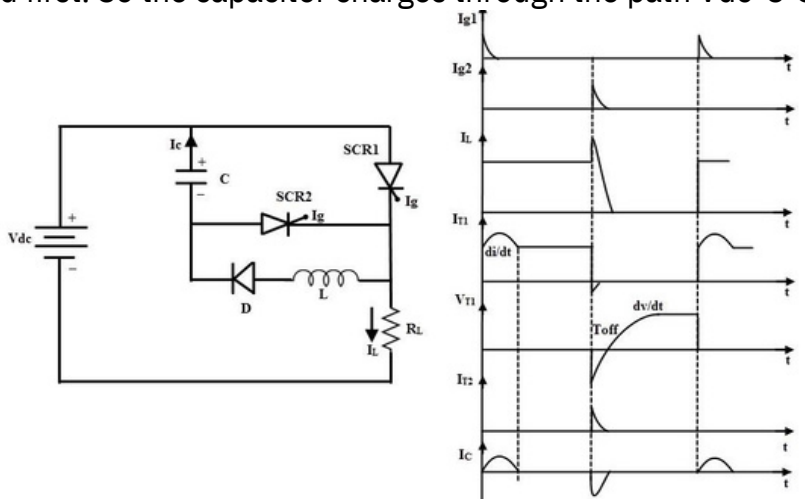
6 b) For a class D commutation, answer the following:
i) Explain the operation with circuit diagram.
ii) Interpret with waveforms.

Ans: Class D commutation:

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

When the supply voltage Vdc 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 Vdc-C-SCR2-RL-Vdc.



1 Mark for circuit diagram

2 Marks for explanation

2 Mark for waveforms

1 Mark for interpretation

When the capacitor is fully charged, the charging current becomes zero and the SCR2 is turned-off naturally.

The supply voltage Vdc as well as the charged capacitor C holds the SCR1 in forward bias condition. If the SCR1 is triggered, it is turned-on and two currents flow through it: one is the load current supplied by source, through path Vdc-SCR1 – RL – Vdc and another one is capacitor discharge current through path C – SCR1 – L – D - C. The capacitor while discharging supplies its energy to the inductor L. When the capacitor fully discharges, its voltage becomes zero at peak discharge current instant. Then the inductor L utilizes its energy to maintain the current through the same path and the capacitor charges with reversed polarity. When the inductor gives out its energy to the capacitor, the current naturally falls to zero and the capacitor charges fully with reversed polarity. Due to the presence of diode the reverse discharge is not possible. Thus after reverse charging of C, the SCR1 continues to carry only load current. The capacitor voltage maintains forward bias across SCR1, thereby it can be triggered at any instant.

Now when it is desired to turn-off SCR1 for load voltage control, the SCR2 is triggered. The charged capacitor (lower plate positive) then placed across conducting SCR1, applying reverse bias to SCR1. Also, the capacitor discharging starts through path C - SCR2- RL- Vdc - C. The load current is shifted from SCR1 to C – SCR2 path. When this discharging current becomes more than the load current the SCR1 is turned OFF. After turning off of SCR1, the reverse bias is maintained across it by capacitor voltage, which ensures the proper turn-off.

The capacitor discharges fully first and then starts charging with polarity of upper plate positive, through the SCR2 – RL to a supply voltage Vdc. When the capacitor fully charges, the charging current falls to zero and SCR2 is naturally turned off. The capacitor voltage as well as supply voltage make SCR1 forward biased and keep ready for next triggering. The above cyclic process is repeated.

6 c) A 1-phase Half controlled rectifier supplied with voltage v=300sin 314t, and load resistance is 100Ω. Find

i)Average output voltage ii)Load current (For α=60 and α=100)

Ans:

Data Given: Vm =300 volt, RL=100Ω

1) For α=60

i)Average output voltage:

=143.24V

Average output voltage = = 143.24 V 1½ Marks

ii) Load current:

1½ Marks

2) For α=100

i) Average output voltage:

Average output voltage = =71.61V 1½ Marks

ii) Load current:

Load current=0.789A 1½ Marks