



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



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

10

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

Ans:

(i) **Holding Current:**

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

(ii) **Latching Current:**

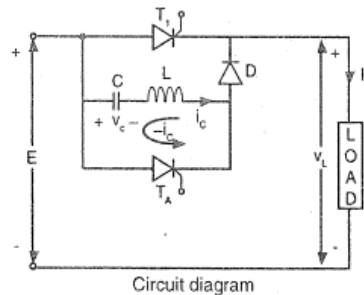
Latching current is defined as the minimum anode current required to maintain the SCR in the on-state immediately after the SCR has been turned on and the gate signal has been removed.

1 Mark for each definition
= 2 Marks

1 b) Draw circuit diagram of Class B commutation.

Ans:

Class B: Resonant Pulse Commutation:

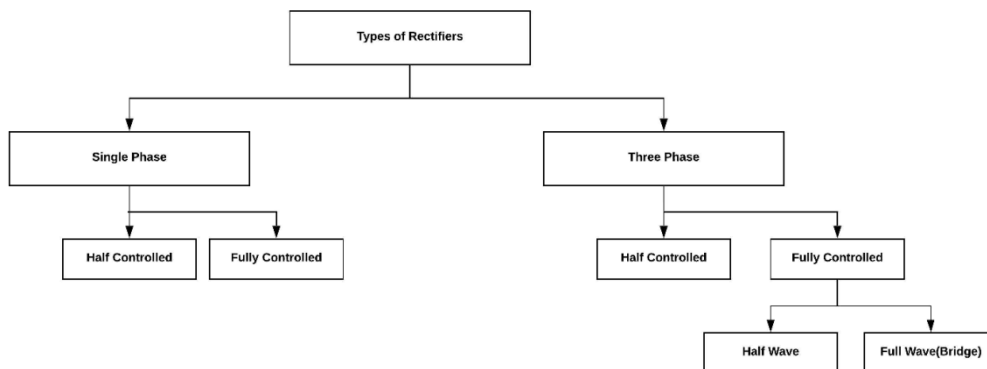


2 Marks for labeled circuit diagram

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 (β):**

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 (α) and conduction angle (β) can be expressed as:

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

(ii) **Firing Angle(α):**

1 Mark for each definition
= 2 Marks



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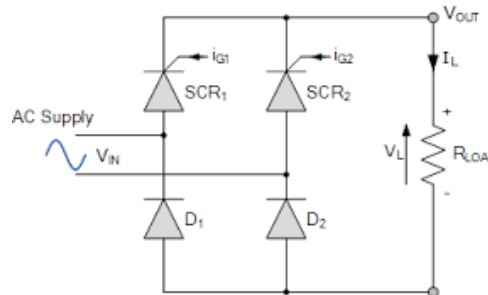
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Firing angle is defined as the angle between the instant the SCR would conduct if it would be a diode and the instant it is triggered or fired.

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.

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

Ans:



2 Marks for
circuit
diagram

1f) 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

1g) 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

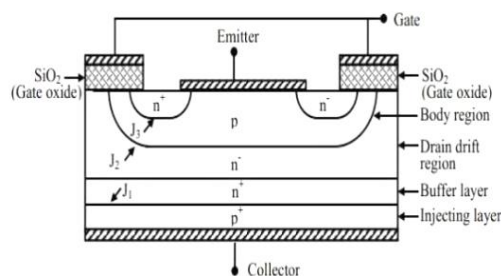
2 Attempt any **THREE** of the following:

12

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

Ans:

Construction:



Construction of IGBT

2 marks for
construction
diagram



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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.

2 marks for description

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.

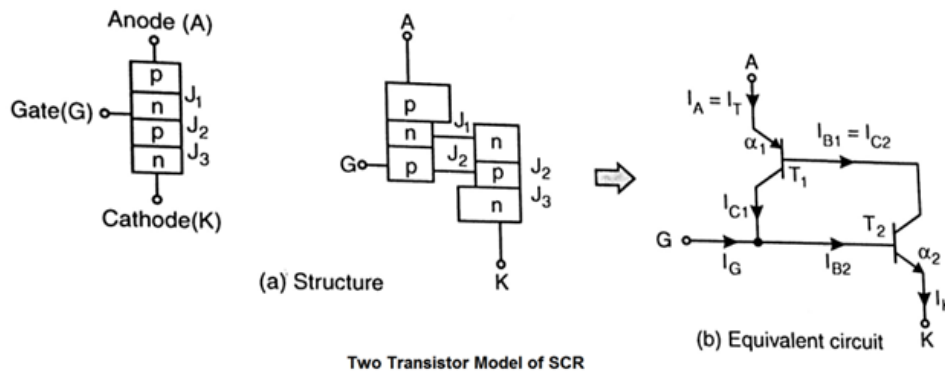
It is also called as metal oxide semiconductor insulated gate transistor (MOSIGT) and other name to this device are insulated gate transistor (IGT), conductivity modulated field effect transistor (COMFET).

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.

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

Ans:

Two-transistor Analogy 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:

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

where, α = common-base current gain

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

For transistors T₁ and T₂, we can write,

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

From KCL applied to T₁, we can write

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

From KCL applied to entire equivalent circuit,

$$I_K = I_A + I_G \quad \text{and substituting in above equation,}$$

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

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

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

2 marks for mathematical treatment



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

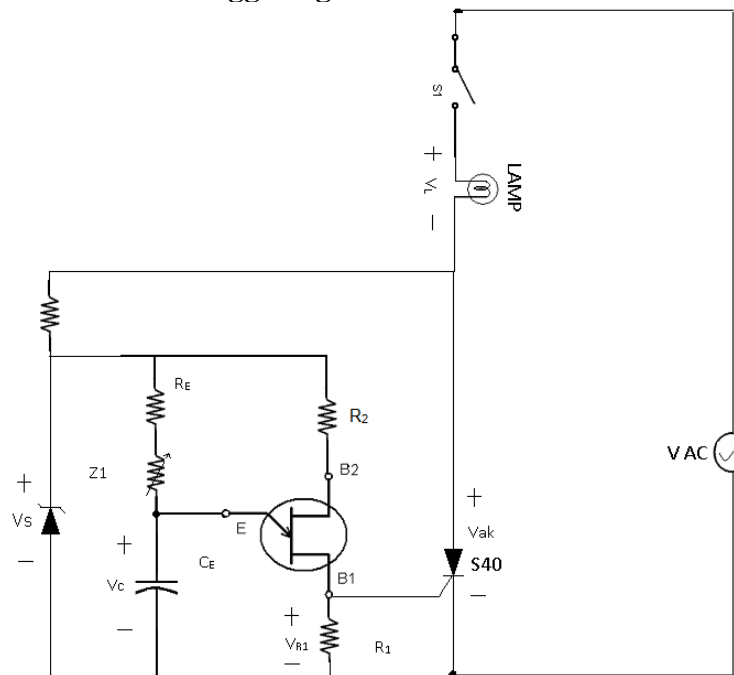
From this equation it is clear that the anode current depends on the gate current, leakage currents and current gains.

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

2c) 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 V_s waveform at the zener voltage during the positive half-cycle of the ac line. During the negative half cycle, Z1 is forward biased and V_s is held near 0 V.

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



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after the ac line crosses zero, C_E begins charging through resistor R_E . When C_E reaches the peak voltage of the UJT, the UJT then fires. This generates a voltage pulse across R_1 and results in the firing of the SCR. When the SCR is fired, current flows through the load for the rest of the positive half cycle.

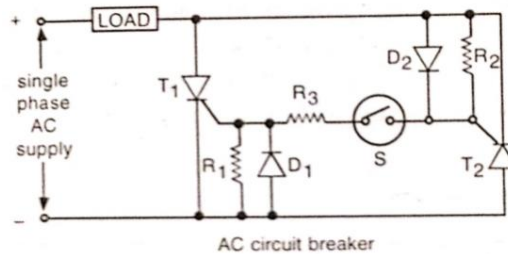
In this circuit, automatic synchronization between the firing pulse of the UJT and the SCR polarity is provided. This means that whenever the UJT delivers a pulse, the SCR is sure to have the right polarity between the anode and cathode for turning on.

2d) 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 T_1 and T_2 are fired in positive and negative half-cycles respectively. During positive half-cycle, T_1 receives gate current through $D_2 \parallel R_2$, switch S and R_3 and it conducts. At the end of positive half-cycle, T_1 is turned off due to natural current zero. In the negative half-cycle, T_2 receives gate current through $D_1 \parallel R_1$, R_3 and switch 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 switch S is opened at any instant in a particular half-cycle, the load current continues 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 circuit diagram

2 Marks for operation

3 Attempt any THREE of the following

12

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

Ans:

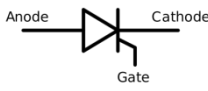
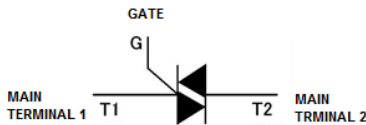
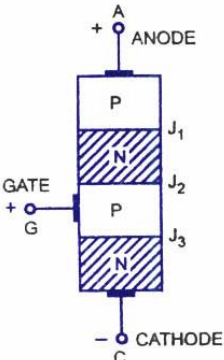
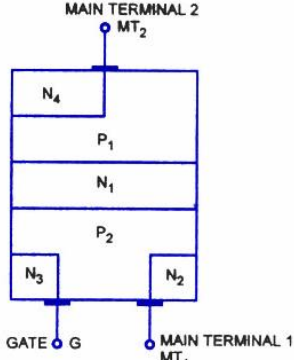
SCR	TRIAC
It is an unidirectional device.	It is a bidirectional device.
It is turned-on by only positive gate current.	It can be turned-on by either positive or negative gate current.
Operates only in the first quadrant	Operates in either 1 st or 3 rd quadrant.
Anti-parallel SCRs are used for bidirectional 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



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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.

3b) 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

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 α_1 and α_2 will increase. If $(\alpha_1 + \alpha_2)$ 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

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



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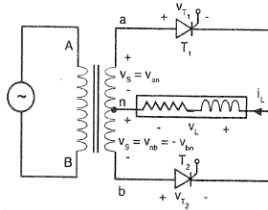
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turned on.

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

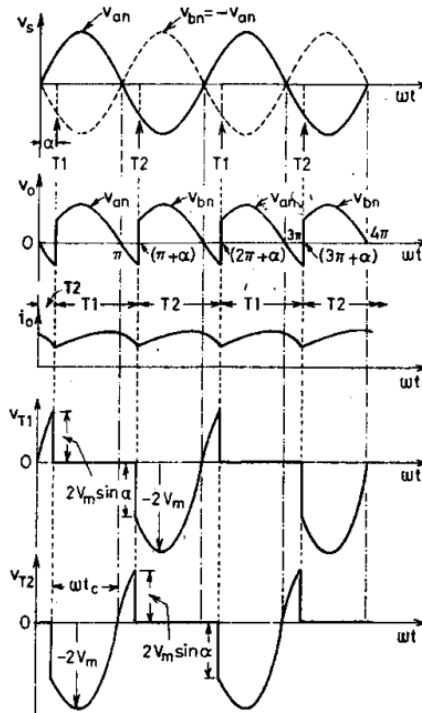
Ans:

Circuit Diagram:



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

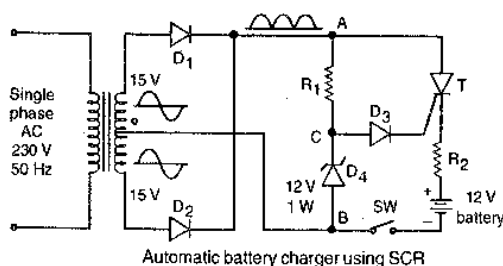
Waveforms:



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

Ans:

Battery charger circuit using SCR:



The figure shows the battery charger circuit using SCR. A 12V discharged battery is connected in the circuit and switch SW is closed. The single-phase 230V supply is stepped down to (15-0-15) V by a centre-tapped transformer. The diodes D₁ and D₂ forms full wave rectifier and pulsating DC supply appears across

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

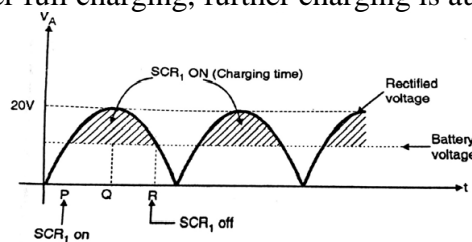
terminals A and B. When SCR is off, its cathode is held at the potential of discharged battery. During each positive half-cycle, when the potential of point C rises to sufficient level so as to forward bias diode D₃ and gate-cathode junction of SCR, the gate pulse is provided and SCR is turned on. When SCR is



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turned on, the charging current flows through battery. Thus during each positive half-cycle of pulsating DC supply, voltage across A-B, SCR is fired and charging current is passed till the end of that half-cycle. Due to Zener diode D_4 , the maximum voltage at point C is held at 12V. Due to the charging process, the battery voltage rises and finally attains full value of 12V. When the battery is fully charged, the cathode of SCR is held at 12V. So the diode D_3 and gate-cathode junction of SCR cannot be forward biased, since the potential of point C can reach up to 12V. Therefore, no gate current is supplied and SCR is not fired. In this way, after full charging, further charging is automatically stopped.



Waveform for battery charger circuit

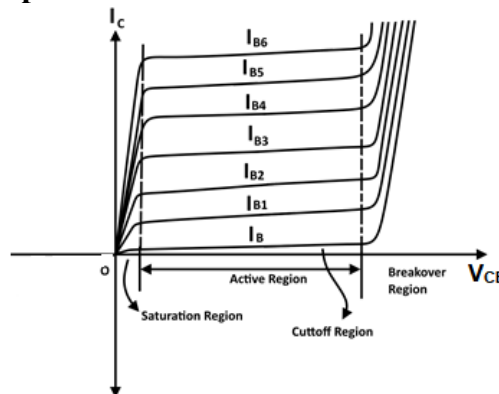
4 Attempt any **THREE** of the following:

12

4a) 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

4b) With reference to GTO answer the following:

- State advantages of GTO over SCR
- Draw construction of GTO.

Ans:

I) Advantages of GTO over SCR:

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

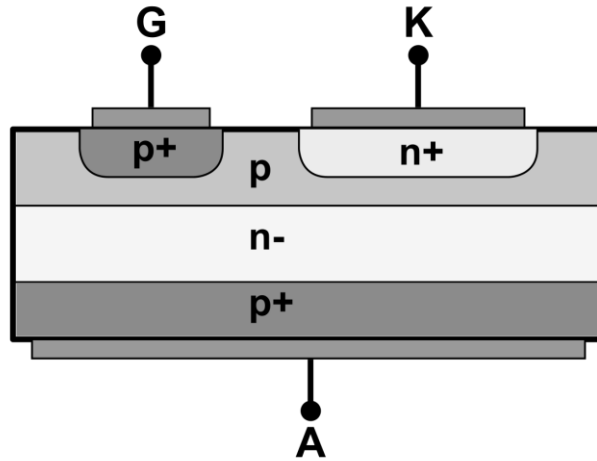
½ Mark for each of any four advantages = 2 Marks

II) Construction of GTO:



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2 Marks for
constructional
sketch

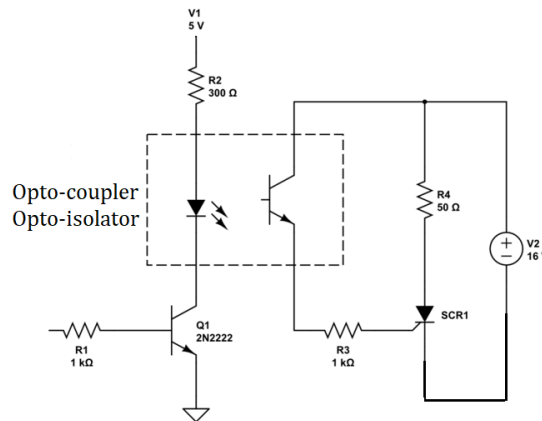
OR any other equivalent constructional sketch

4c) 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. Referring to the circuit diagram, when the SCR is to be turned-on, a voltage is applied to base of Q_1



1 Mark for
circuit
diagram

2 Marks for
explanation

through R_1 . The base current flows and Q_1 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 R_3 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

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

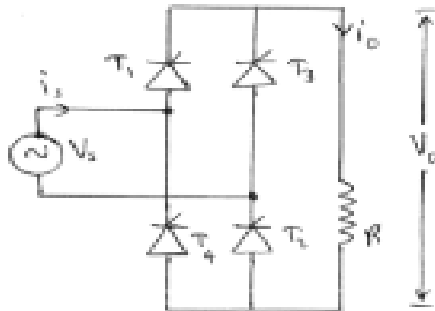
Ans:



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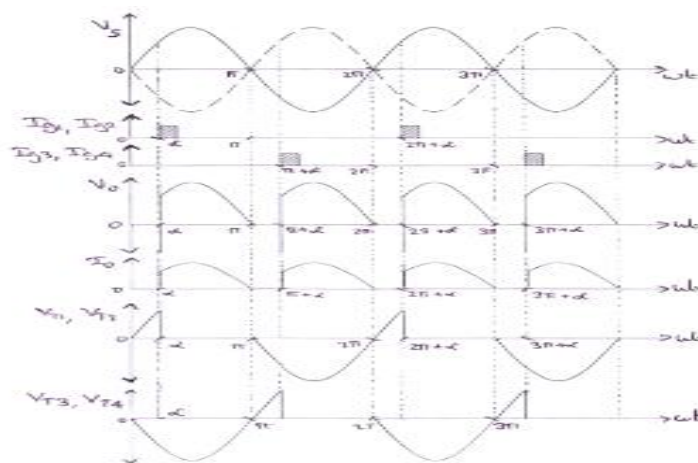
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Circuit Diagram:



1 Mark for circuit diagram

Waveforms:



1 Mark for waveforms

Explanation:

- During positive half cycle of V_s , SCRs T1 and T2 are fired, so that V_{ab} appears across load.
- During negative half cycle of V_s , SCRs T3 and T4 are fired, so that V_{ba} 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

4e) 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

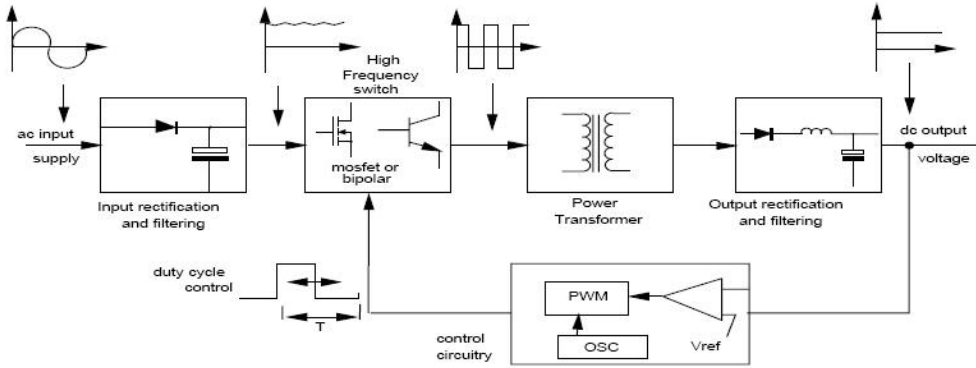


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rectified and filtered to produce the required d.c output.

- 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 switch, thus regulating the output.



2 Marks for diagram

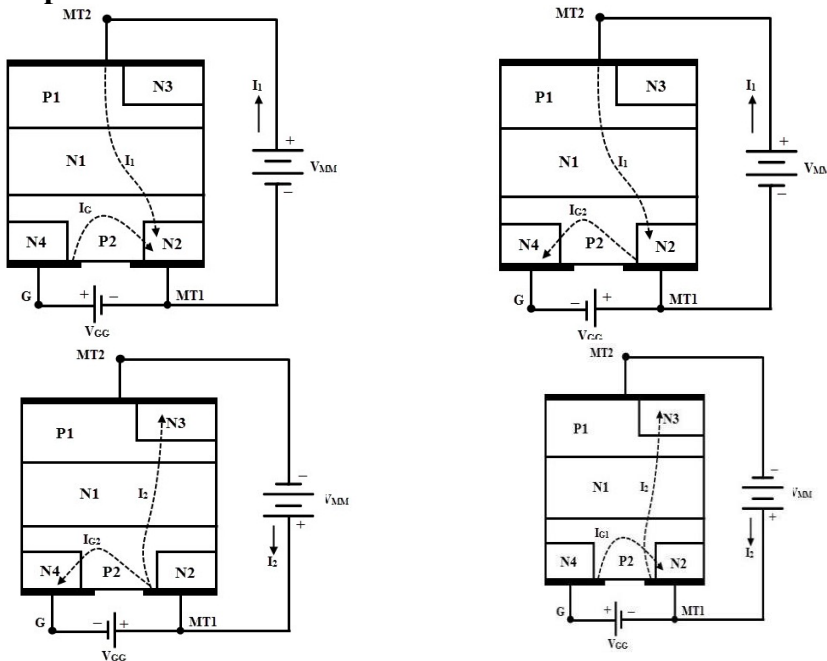
5 Attempt any TWO of the following:

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 (Mode 1)** : 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) **MT2 is positive but gate is negative with respect to terminal**

2 Marks for explanation



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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.

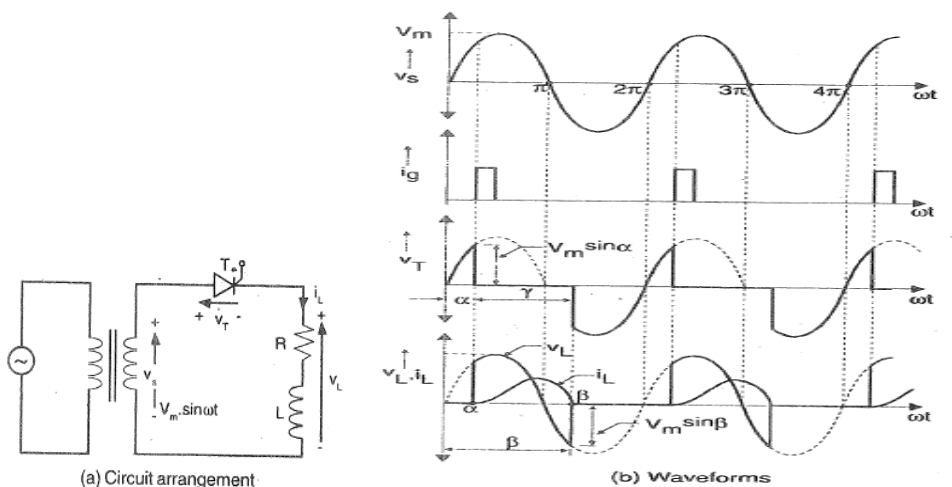
4) MT2 is negative but gate is positive with respect to terminal MT1(Mode3) :

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.

- 5b) 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 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. 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



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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 2π) (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 $\omega t = \beta$. Thus during interval from $\omega t = \pi$ to $\omega t = \beta$, the negative supply voltage appears across the load. When the load current becomes zero, due to negative supply voltage, the SCR is turned off. At instant $\omega t = \pi + \alpha$, when again pulse is applied, the SCR is turned on & the above cycle is repeated.

Significance of Freewheeling Diode (FWD):

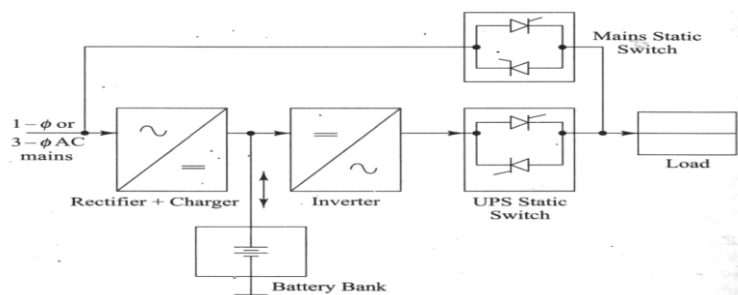
- Freewheeling diode is used across inductive loads such as coils, dc motor armature etc. to prevent voltage spikes across these loads when the switching device is turned off.
- It is used to bypass the stored energy in inductive elements when the switching device is turned off.
- In absence of FWD, the stored energy in inductance will maintain forward current through the power semiconductor device and prevent it from being turned off.
- 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

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

Ans:

Online UPS:



2 Marks for
block diagram

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



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connected to the inverter 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.

2 Marks for working

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 1/4 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)

1 Mark for each of any two applications = 2 Marks

6 Attempt any TWO of the following

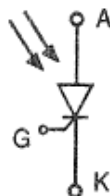
12

6a) Draw symbol & V-I characteristics of the following devices

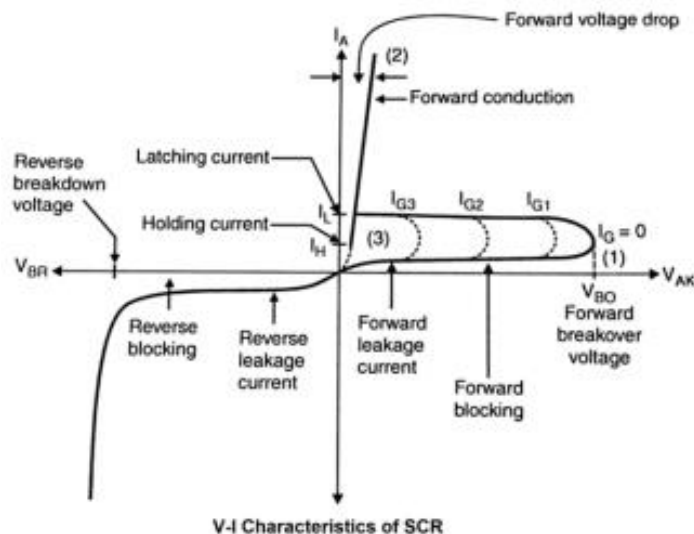
- i)LASCR ii)DIAC iii)PUT iv)SCS

Ans:

i) LASCR:



LASCR symbol



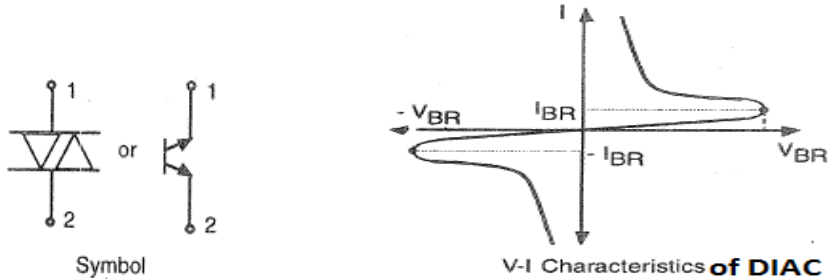
1/2 Mark for symbol and 1 Mark for characteristic = 1 1/2 for each bit

ii) DIAC:

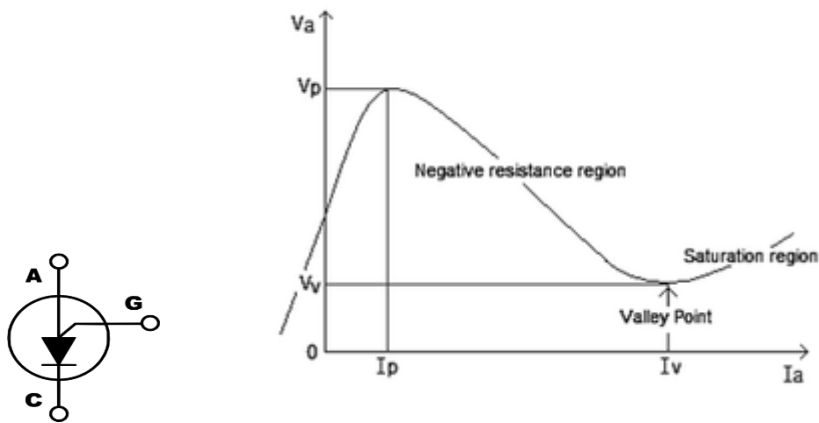


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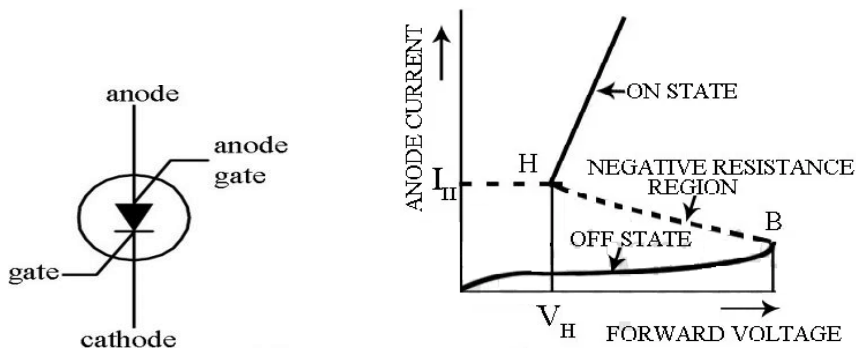
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iii) PUT:



iv) SCS:



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

- Explain the operation with circuit diagram.
- 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 R_L forms the power circuit while the diode D, inductor L, capacitor C and SCR2 forms the commutation circuit.

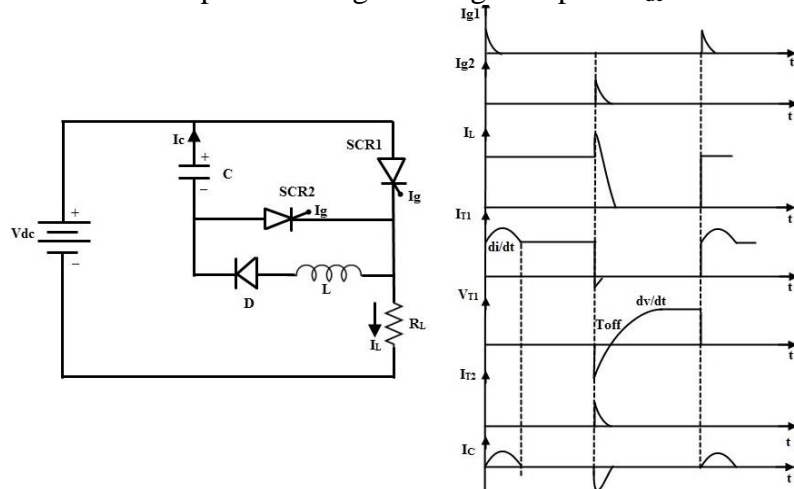
When the supply voltage V_{dc} is applied, both SCRs are in OFF state and hence the capacitor voltage is zero. In order to charge the capacitor, SCR2 must be



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triggered first. So the capacitor charges through the path $V_{dc}-C-SCR2-R_L-V_{dc}$.



1 Mark for circuit diagram

2 Marks for explanation

2 Mark for waveforms

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

The supply voltage V_{dc} 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 $V_{dc}-SCR1-R_L-V_{dc}$ 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.

1 Mark for interpretation

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 $C-SCR2-R_L-V_{dc}-C$. 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 $SCR2-R_L$ to a supply voltage V_{dc} . 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.

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



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i) Average output voltage ii) Load current (For $\alpha=60^\circ$ and $\alpha=100^\circ$)

Ans:

Data Given: $V_m=300$ volt, $R_L=100\Omega$

1) For $\alpha=60^\circ$

i) Average output voltage:

$$V_{dc} = \frac{V_m}{\pi} (1 + \cos\alpha)$$
$$V_{dc} = \frac{300}{\pi} (1 + \cos 60)$$
$$V_{dc} = 143.24V$$

Average output voltage = $V_{dc} = 143.24$ V

1½ Marks

ii) Load current:

$$I_L = \frac{V_{DC}}{R}$$
$$I_L = \frac{143.24}{100}$$
$$I_L = 1.4324 \text{ A}$$

1½ Marks

2) For $\alpha=100^\circ$

i) Average output voltage:

$$V_{dc} = \frac{V_m}{\pi} (1 + \cos\alpha)$$
$$V_{dc} = \frac{300}{\pi} (1 + \cos 100)$$

Average output voltage = $V_{dc} = 71.61$ V

1½ Marks

ii) Load current:

$$I_L = \frac{V_{DC}}{R}$$
$$I_L = \frac{71.61}{100}$$
$$I_L = 0.7161 \text{ A}$$

Load current = 0.7161 A

1½ Marks