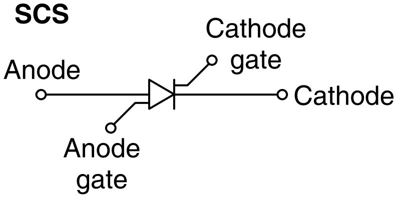
Vidyalankar

S.Y. Diploma : Sem. IV [ET/EN/EX/EJ/DE/ED/EI/IS/IC/IE/IU]

Power Electronics

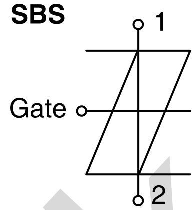
Prelim Question Paper Solution

1. (a) (i) (1) SCS



(SCS)

(2) SBS

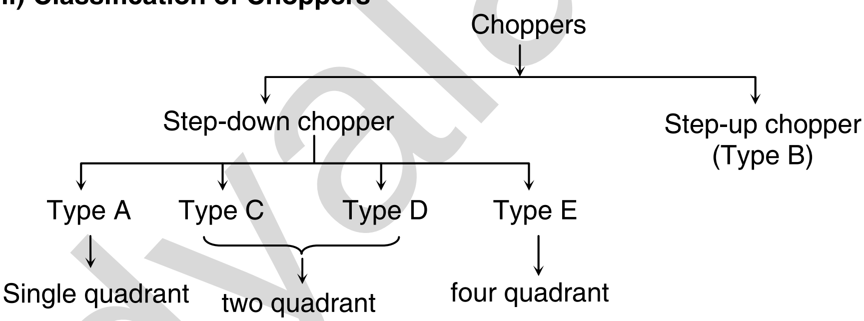


(SBS)

1. (a) (ii) Advantages of GTO

- GTO can be used at higher switching frequencies.
- GTO needs only a short duration pulse to turn ON.
- Reduced size, weight and cost.
- Efficiency of converters using GTO is better than that using conventional SCR′s.

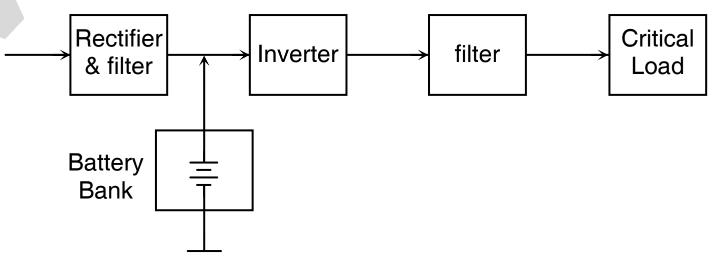
1. (a) (iii) Classification of Choppers



1. (a) (iv) Advantages of poly-phase rectifier

a) Higher output voltage
b) Higher efficiency
c) Higher TUF
d) Low ripple component hence reduces the use of filter circuit.

1. (a) (v) Block diagram of UPS



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1. (a) (vi) Turn-ON methods of SCR

- By raising the temperature (Thermal triggering)
- By focusing light (optical triggering)
- By applying high voltage (forward voltage triggering)
- By applying voltage at high dv / dt (dv / dt triggering)

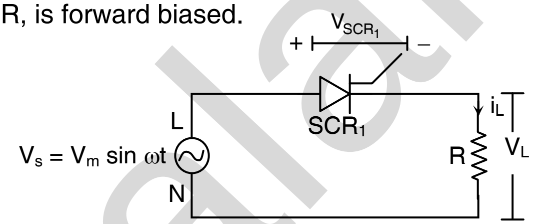
1. (a) (vii) Commutation and natural commutation

- The process of turning off of a conducting SCR is known as "Commutation".
- When SCR is turned off, due to its forward current going Glow the holding current, naturally, it is said to be naturally commutated.

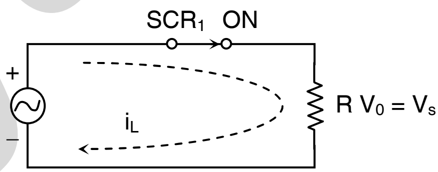
1. (a) (viii) Need of inverter

- Portable consumer devices that allow the user to connect a battery or a set of batteries to the device to produce AC power to run various electrical appliances.
- Use in power generation system.
- Use within larger electronic system.

1. (b) (i) From the circuit diagram, during the positive half cycle of the ac supply, the thyristor SCR, is forward biased.

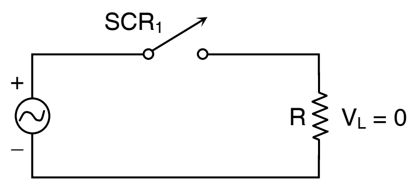


When it is turned ON at wt = a the thyristor acts like a closed switch and the input ac voltage appears at it is across the load.



Due to the resistive nature of the load, the load current is in phase with the load voltage. The instantaneous value of load current is equal to the ratio of supply X R. As the load voltage decreases, load current also decreases and as this current reduces Glow the holding current of SCR_1, it is commutated due to natural commutation.

In negative half cycle, the thyristor is reverse biased and acts like open switch. The load is disconnected from the input and hence voltage is zero across load.



Entire input voltage appears across the turned off SCR_1.

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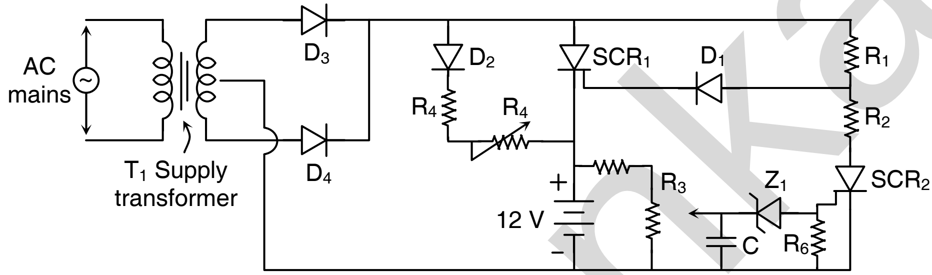
1. (b) (ii) Distortion Factor: Distortion factor is a measure of effectiveness in reducing the unwanted harmonics without having to specify the values of a second order load filters, DF is defined as,

$$DF = \frac{1}{Vo_1\ rms}\left[\sum_{n=2,3,...}^{\infty}\left(\frac{V_{on}\ rms}{n^2}\right)^2\right]^{1/2}$$

Lowest order Harmonic (LOH): LOH is that harmonic component whose frequency is the closest to the fundamental one and its amplitude is greater than or equal to 3% of the fundamental component.

1. (b) (iii) Battery Charger using SCR



2. (a) Three Phase Controlled Rectifier Circuit

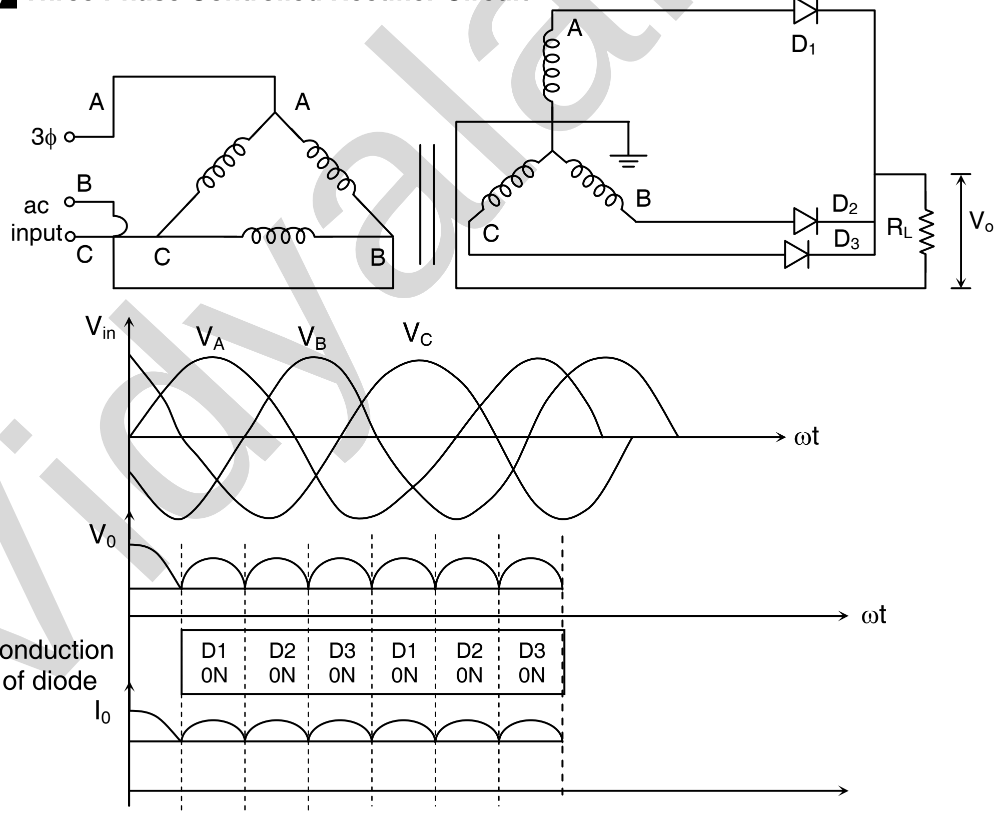
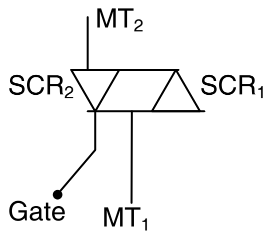


Fig. : Input and o/p voltage and current voltage waveforms of 3ϕ halfwave rectifier

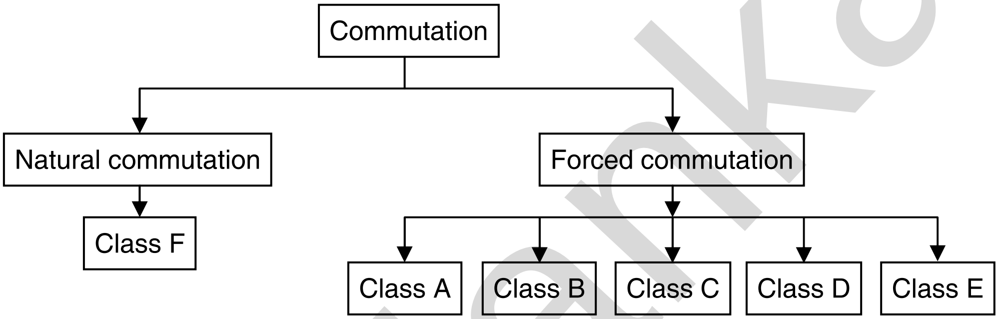
2. (b) TRIAC

Triac can be operated in 4 modes
i) I^+
ii) I^-
iii) III^+
iv) III^-

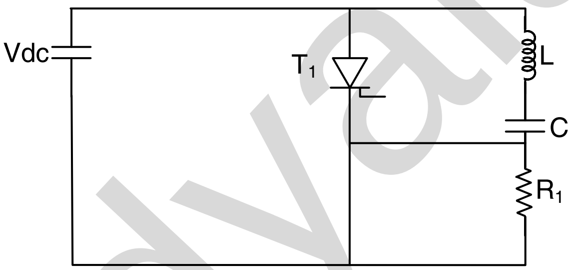


I^+ mode is the most sensitive modes of the triac as sensitive of a mode is defined as the minimum gate current required to turn ON a triac.

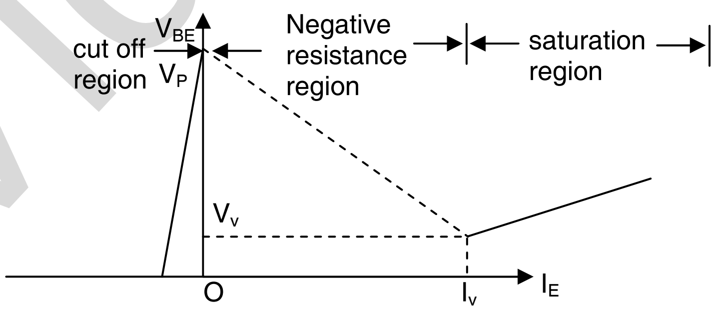
2. (c) Commutation methods of SCR



Class B commutation circuit



2. (d) V-I characteristics of UJT

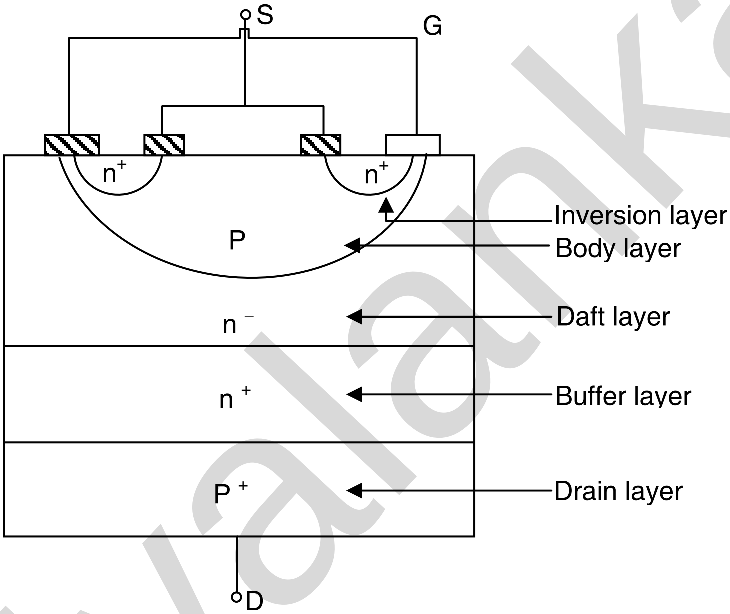


Cutoff region: In this region the base emitter junction is reverse biased. Only a small leakage current flows through the device. The device is said to be in off state.

Negative resistance region: The region from V_p to V_v is known as negative resistance region. In this region the base emitter junction is forward biased and the emitter injects holes into the base due to which emitter current increases and V_{BE} decreases.
Because of the presence of this region VJT can be used as a relation oscillator.

Saturation region: The region beyond V_v is known as saturation region. (Valley point). In this region the emitter current increases with almost constant V_{BE}. The device is said to be in saturation state or ON state.

2. (e) **Constructional diagram of N-channel IGBT**



2. (f) **Single Phase Half Bridge Inverter**
Sketch the diagram of single phase half bridge inverter? Why it is called as half bridge inverter.

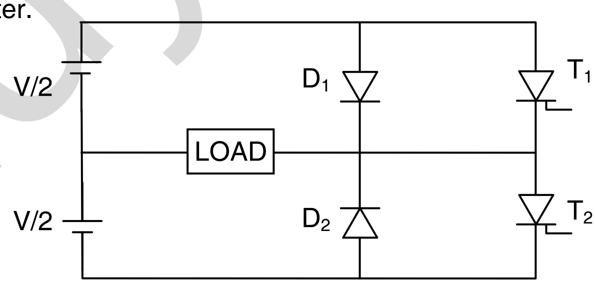


Fig. Single phase half bridge inverter

The above circuit diagram consists of only one pair of SCRs and one pair of diodes whereas the full bridge inverter consists of 2 pairs of SCRs and two pairs of diodes. Hence this circuit is called half bridge inverter.

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3. (a) **On-line UPS**

The configuration of an on line UPS system is as shown in Fig.

Operation of on line UPS

- In the on line UPS system the load is always connected to the inverter through the UPS static switch.

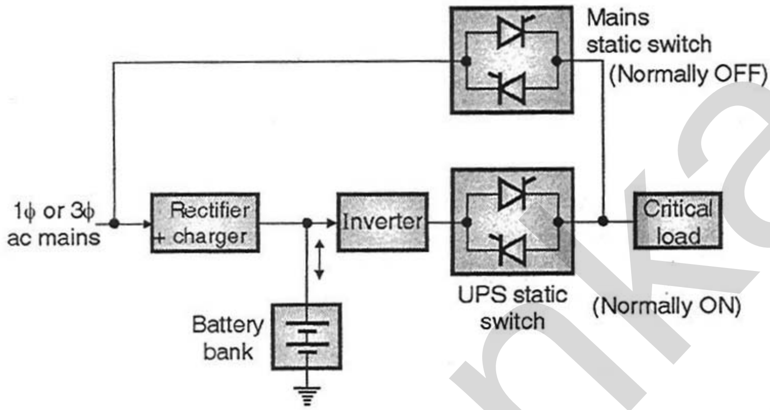
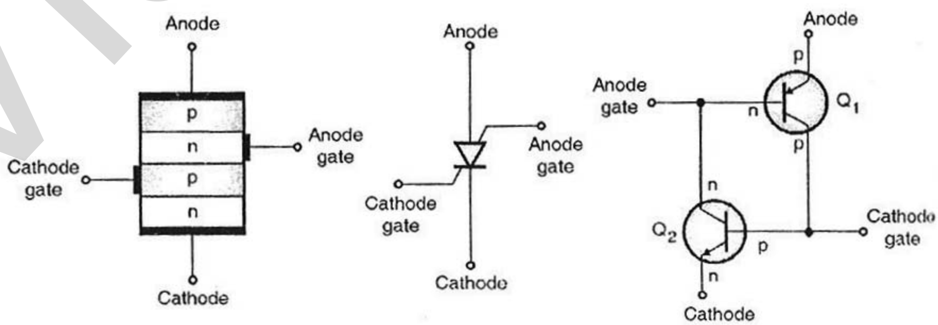


Fig. : ON line (inverter preferred) UPS system

- The UPS static switch in the Fig. is a "Normally ON" switch. It turns off only when the UPS system fails.
- In that case the "Mains static switch" is turned on to connect the ac mains directly to the load.
- This switch is a "Normally OFF" switch and used only when UPS is to be bypassed.
- A static switch consists of a pair of antiparallel SCRs. Therefore conduction through a static switch is bidirectional.
- Static switches are preferred over conventional mechanical switches because they can be activated electrically. Earthing and sparking does not take place while operating the static switches.

3. (b) **SCS**

- The difference between the SCS and SCR is that all the four layers are now available. This is due to the inclusion of the "anode gate" as shown in Fig.



(a) Construction **(b) Circuit symbol** **(c) Equivalent circuit**

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Effects of anode gate

- The anode gate connection can be used to turn on or turn off the SCS. The SCS can be turned on by applying a negative pulse to the anode gate whereas a positive pulse applied at the anode gate will turn off the conducting SCS.
- This can be explained with the help of the equivalent circuit of Fig. (c).
- A negative pulse applied at the anode gate will forward bias the base-emitter junction of Q_1, turning it on. This will result in a heavy-collector current I_{C1} which will turn on Q_2.
- This will result in regeneration and the device turns on and latches into the on state.
- A positive pulse applied at the anode gate will reverse bias the base-emitter junction of Q_1, turning it off. This will turn off the device.
- However the anode gate is not generally used to turn on the SCS, because the triggering gate current for the anode gate is larger in magnitude than the required cathode gate current.
- Thus SCS is turned on by applying a positive pulse to the cathode gate and it is turned off by applying a positive pulse at the anode gate.

3. (c) Full Wave Controlled Rectifier with Resistive Load using two SCR's

- One of the two fully controlled circuits is the midpoint configuration which is as shown in figure 1.
- It uses an input centre tapped transformer T_1, SCRs S_1 and S_2 and the load is connected between the common cathode point of the two SCRs (X) and the center tap (O) of the secondary winding of T_1.

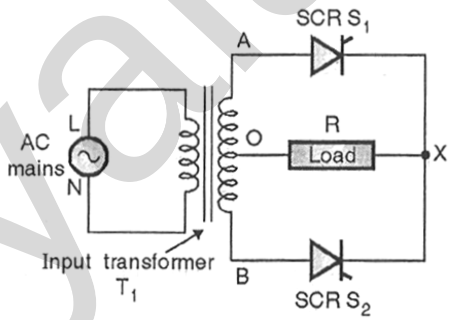
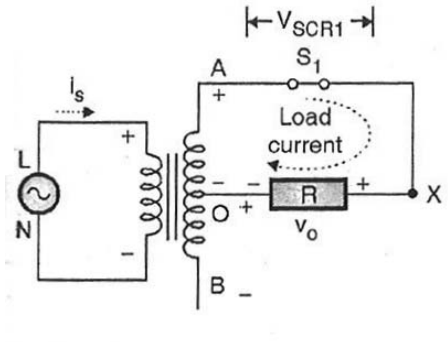


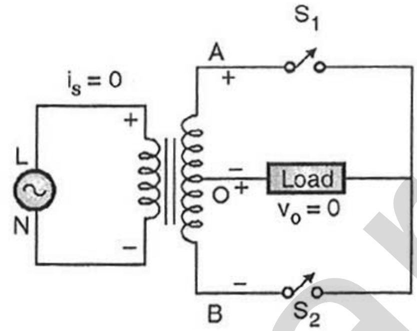
Fig. 1 : Midpoint configuration schematic diagram

- For simplicity, it is assumed that the turns ratio of the input transformer T_1 is 1 : 1 thus the primary and secondary voltages and Currents will be equal.
- The operation can be divided into four modes.
  They are as follows :

  Mode I ($\alpha \le \omega t \le \pi$)
- Mode I corresponds to the positive half cycle of the input supply. The polarity of ac mains supply is as shown in figure 2(a).
- This makes the secondary voltage V_{A0} positive and V_{B0} negative. This will forward bias SCR S_1 and reverse bias SCR S_2.
- Therefore SCR S_1 can be turned on at any value of α between 0 to 180°.
  Here SCR S_1 is turned on at $\omega t = \alpha$.



(a) Mode I (α to π) equivalent circuit



(b) Mode II equivalent circuit

Fig. 2

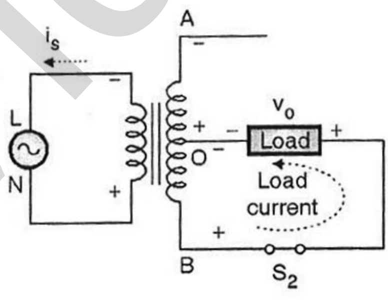
- This connects point A to the load as shown in figure 2(a).
- The load voltage is positive and equal to V_{A0}. Due to the fact that the transformer turns ratio is unity, V_{A0} = AC mains voltage $V_m \sin \omega t$
- Thus the load voltage is equal to the instantaneous ac mains voltage. At instant ωt = % radians SCR S_1 is turned off due to the natural commutation.

Mode II ($\pi \le \omega t \le \pi + \alpha$)

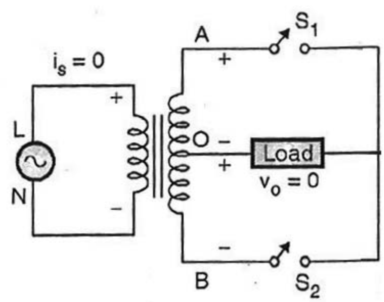
- At instant $\omega t = \pi$, S_1 is turned off. The negative half cycle of ac mains voltage begins. The polarities of the primary and secondary voltages are as shown in figure 2(b).
- This voltage will forward bias SCR S_2 and reverse bias SCR S_2 but SCR S_2 is still not turned on.
- Therefore in mode II both the SCRs are in the off state, the load voltage, load current and the supply current all are zero, mode II when S_2 is triggered at $\omega t = (\pi + \alpha)$.

Mode III ($\pi + \alpha \le \omega T \le 2\pi$)

- In the negative half cycle of the input ac supply, SCR S_2 is turned at instant $\omega t = \pi + \alpha$. Point B of the transformer secondary connected to the load through S_2.
- Thus the load voltage become positive and equal to the instantant ac mains voltages.



(c) Mode III ($\pi + \alpha$ to 2π)



(d) Mode IV (0 to α or 2π to $2\pi + \alpha$)

Fig. 2 : Equivalent circuits

- The load current is also positive. At $\omega t = 2\pi$, the supply voltage to zero, therefore load voltage goes to zero, the load current reaches a zero and S_2 is turned off due to natural commutation.

Mode IV (0 to α or 2π to $2\pi + \alpha$)

- S_2 is turned off at $\omega t = 2\pi$. The input ac mains voltage will reverse the polarities at $\omega t = 2\pi$.
- Therefore the secondary voltage polarities also are reversed as shown in figure 2(d).
- This will forward bias S_1 and reverse bias S_2. But as S_1 is yet to be turned on both the SCRs remain in the off state.
- The load voltage, load current and the supply current all are zero as shown in figure 2(d). At instant α, S_1 is turned on again and the operation repeats.

3. (d) Pulse Transformers

- Pulse transformers are used to couple pulses from a triggering device to a SCR. They provide electrical isolation between the two circuit.
- The pulse transformers usually used for SCR control are either two winding, or 1 : 1 : 1 three winding types. The three winding transformer is used to drive a pair of antiparallel SCRs are show figure 1.
- The most important requirement is that the efficiency of the pulse transformer must be high. Practically, some loss is to be expected and must be compensated by increasing the drive from the control circuit that drives the primary winding of the pulse transformer.

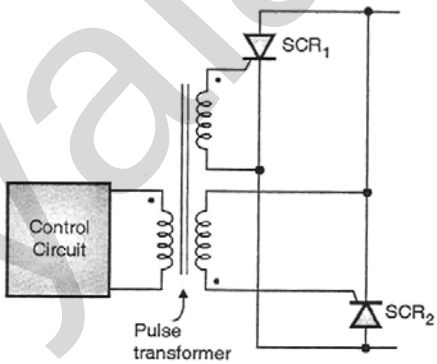


Fig. 1 : Use of pulse transformer to drive a pair of antiparallel SCRs

Some of the transformer design factors to be considered are :
Primary magnetizing inductance should be high enough so that magnetizing current is low, in comparison with the pulse current during the pulse time.

Since most of the times, a unidirectional current flows through the primary winding of the pulse transformer, the core saturation must be avoided.

Insulation between the windings must be adequate as per the requirements of various applications, including transients.
Interwinding capacitance is usually insignificant but may provide a path for undesirable stray signals at high frequencies.

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Coupling between the primary and secondary windings should be tight.

The effect of the frequency and pulse width on the output of a pulse transformer is as shown in figure 2. There are two operating conditions :

(a) When the operating frequency is large or the width of the input pulse (T) is small, then the same pulse appears at the output of pulse transformer.
(b) When T is large or frequency is low, derivative for the input pulse is obtained at the output.

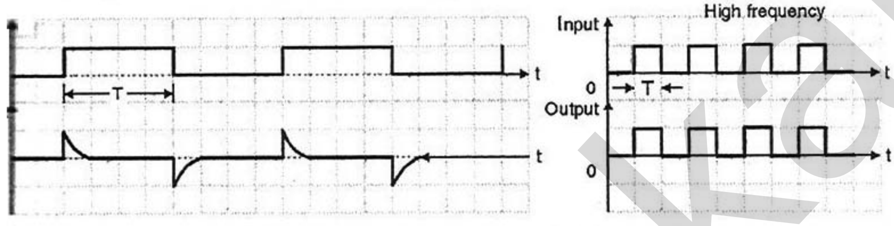
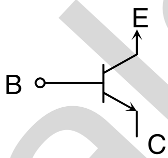
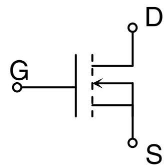
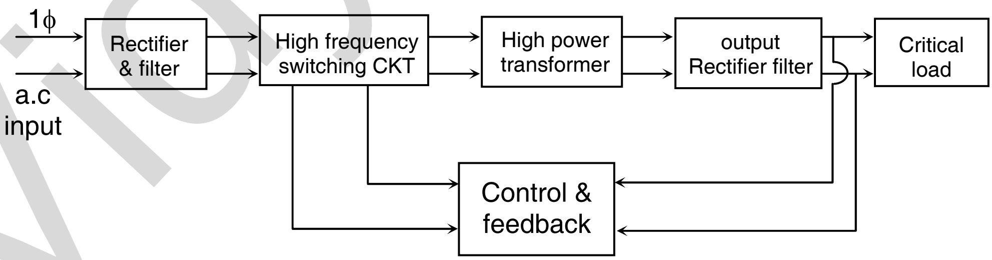


Fig. 2

3. (e) Comparison between Power transistor and Power MOSFET

Parameter	Power BJT	Power MOSFET
Symbol		
Switching speed	10 KHz	100 KHz
SiO_2 layer	absent	Present
On state Losses	less	More compare to Power BJT

3. (f) Comparison AM and FM



Rectifier filter Block
This circuit converts the a.c. input to pulsating d.c. & filtered to get pure d.c.

High Frequency switching circuit
This circuit uses a high frequency switching device like MOSFET or power BJT to convert the pulsating d.c. into a square wave.

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High power transformer
This transformer isolated the output & steps up or steps down to a desired voltage level.

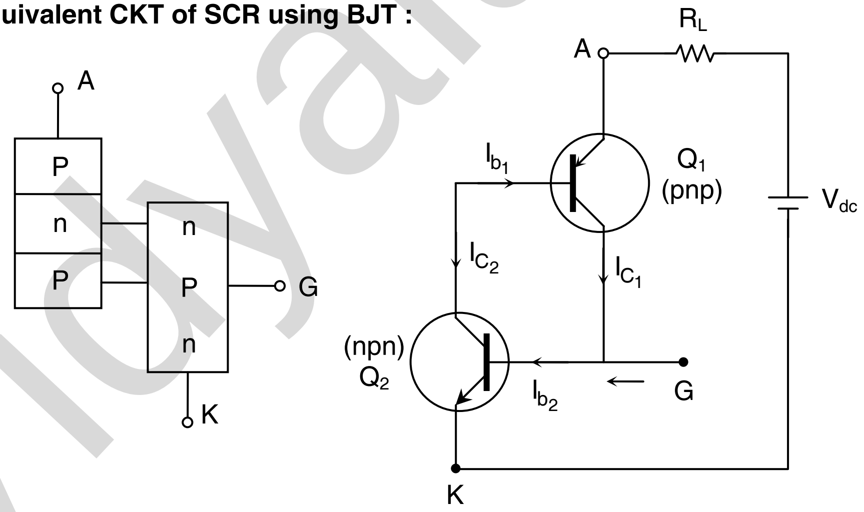
Output rectifier & filter circuit
This rectifier is different from the first rectifier as this rectifier deals with the high frequency here the diodes such as schottky diodes are used for the rectification.

Control & feedback
This block consists of a pulse width modulator which varies the duty cycle of the output pulse by pulse to provide the constant dc voltage to the load.

4. (a) Application
i) Induction motor speed control application.
ii) Synchronous motor speed control.
iii) Induction heating.
iv) Emergency lighting

Need of inverter
- Portable consumer devices that allow the user to connect a battery or a set of batteries to the device to produce AC power to run various electrical appliances.
- Use in power generation system.
- Use within larger electronic system.

4. (b) Equivalent CKT of SCR using BJT :



SCR can be considered as a combination of two transistors one pnp and the other npn. The transistors Q_1 & Q_2 are connected such that the base of Q_1 is connected to collector of Q_2 & vice versa as shown above.

Initially when Ig is provided at the gate terminal it acts a base current of Q2 and Q_2 comes into conduction. Now Q_2 produces the collector current (I_{C_2} – $B_2 I_g$) which acts as the base into conduction, now the collector current of Q_1

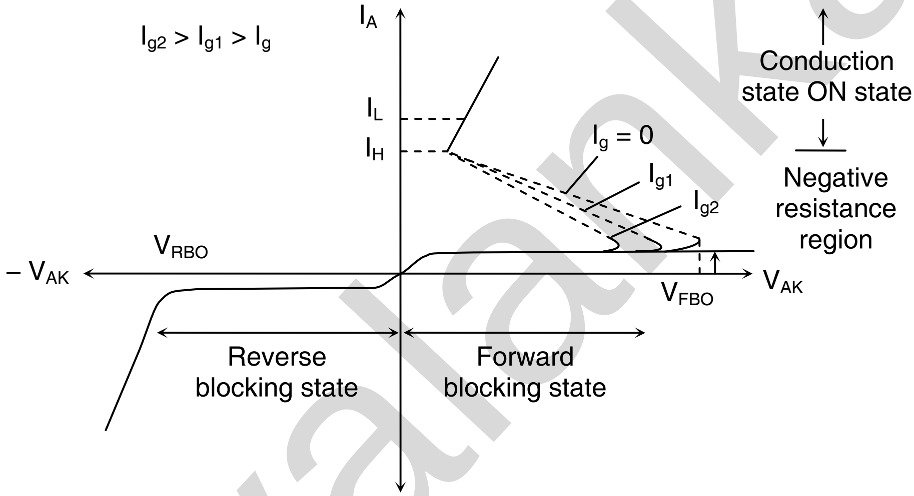
(I_{C_1} = B, B_2 I_g) acts as a base current along with I_g. Due to this the collector current of Q_2 increases as a result collector current of Q_1 also increases.

This is called current multiplication (or) regenerative feedback. Due to this current multiplication inside the PNPN

Structure both the transistors Q_1 & Q_2 goes into saturation & acts as a closed switch.

When once the device comes into conduction even though if we remove the gate current, the device remains in conduction.

4. (c) V–I Characteristics of SCR



(i) Holding current (I_H) : It is the minimum anode current required to maintain the SCR in the ON State. If the current flowing through the SCR falls below the holding current SCR turns off.

(ii) Latching current (I_L) : It is the minimum anode current required to latch the SCR from OFF state to ON state immediately after the removal of gate. Latching current is greater than the holding current usually,

I_L = 2 to 3 times I_H

4. (d) Series Resonant Commutation Circuit for SCR

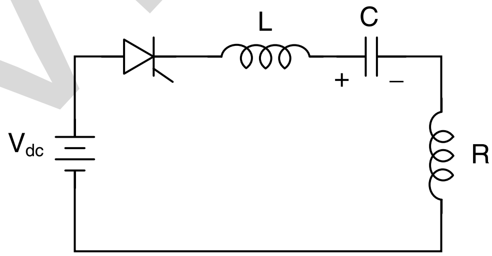


Fig. (a)

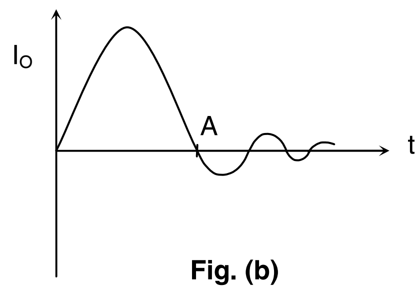


Fig. (b)

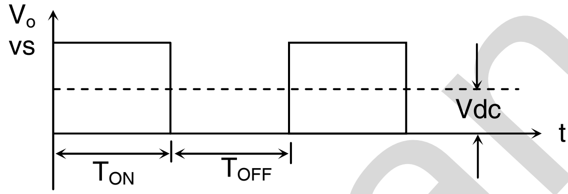
The circuit diagram for series resonant communication CKT is as shown above. Here the R–L–C components are selected such that they form an under damped resonant circuit ($R^2 < 4L$) due to which the current flowing through the CKT is as shown in the fig (b).

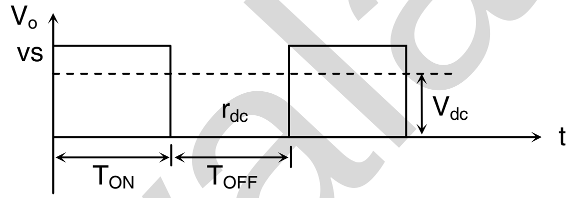
When the SCR is turned ON the current flowing through the SCR becomes zero at point A. Hence the SCR goes into OFF state.

4. (e) Polyphase Rectifier
A rectifier which operates on 3ϕ supply is known as polyphase rectifier.

Need of Polyphase rectifier
The output of the single phase rectifier is only upto 2 KW of there is a power requirement of more than 2KW there is a necessity of polyphase rectifiers …..

4. (f)





The ratio of on time to total time period is known as duty cycle (δ)

$$\text{duty cycle } (\delta) = \frac{T_{on}}{T}$$

where T_{on} – on time period
T – total time period ($T_{on} + T_{off}$)

The average d.c. output voltage of the chopper is given by

$$V_{dc} = \frac{1}{T}\int_0^{T_{on}} V_s dt$$

$$= \frac{1}{T} V_S . T_{on}$$

$$= \frac{T_{on}}{T} \cdot V_S \qquad = \delta V_S$$

$$\therefore \quad V_{dc} = \delta \cdot V_S$$

Therefore by varying duty cycle (δ) from 0 to 1 the output of the chopper can be varied from zero to V_S.

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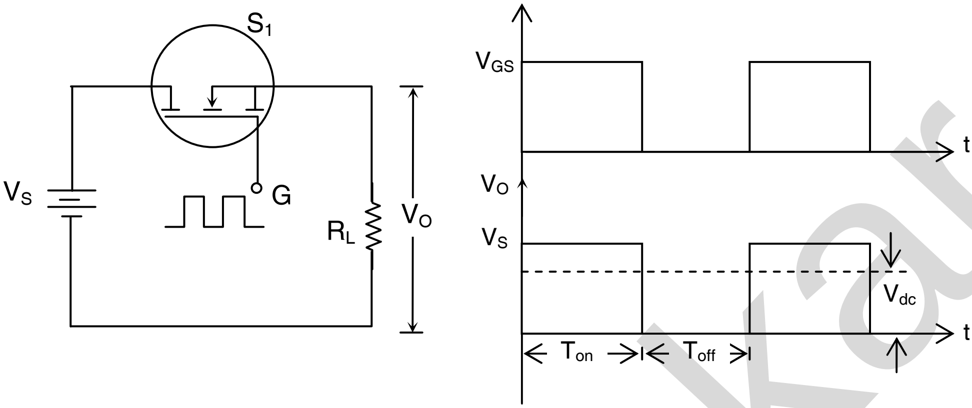
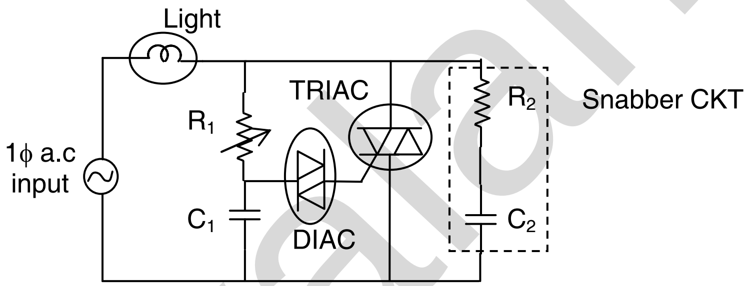
5. (a) **Class B Chopper**
This Chopper is also called as step down chopper.

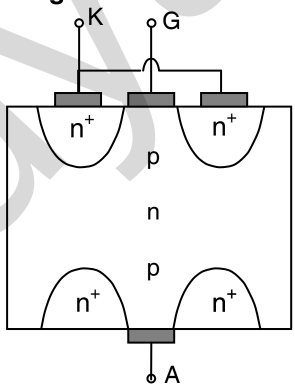


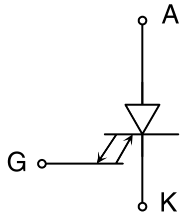
Input and output voltage waveforms of step down chopper.

5. (b) **Light Dimmer Circuit using DIAC and TRIAC.**



5. (c) **Constructional diagram of GTO**





Symbol

Merits of GTO over SCR:

- Higher switching speed hence can be used for high power switching applications.
- No commutation circuit are used to turn OFF the conducting GTO.
- Efficiency of converter using GTO is better than that of using SCR.
- High voltage blocking capability.

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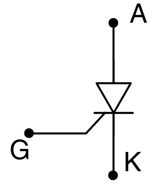
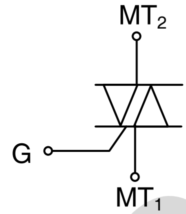
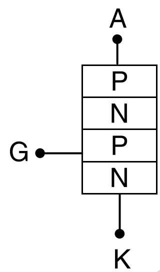
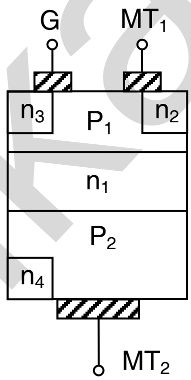
5. (d) Difference between SCR and TRIAC

Parameter	SCR	TRIAC
Symbol		
Layered diagram		
Operating Quadrant	I^{st} quadrant of operation.	I^{st} and III^{rd} quadrant of operation.
Applications	Controlled rectifiers, Inverters, Choppers etc.	Light dimmers, AC Flasher circuits, Fan Speed control etc.

5. (e) Different operating regions of power transistor

Primary Break down : This region is similar to the avalanche break down in the normal logic level transistor. This region is due to the reverse bias of the collector base function. This region should be avoided because of the associated high power dissipation.

Secondary Break down: From the above V.I. characteristics of the power BJT At larger values of I_C, V_{CE} reduces.

This increase in collector current increases the power dissipation. This power dissipation is not evenly distributed throughout the volume of the device instead it is concentrated at localized regions. Due to this the temperatre of these regions increases and the device may get damaged. This is called second break down.

Second breakdown can be avoided by
(i) Operating the device within the SOA (Sage Operating area) specified by the manufacture.
(ii) Avoiding the non-uniform current densities especially during turn ON and Turn OFF.

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5. (f)
- One common application of UJT is in triggering of SCRs. The basic elements of such a circuit are shown in figure 1(a).
- This is basically the UJT relaxation oscillator.
- The waveforms of emitter voltage V_E and the triggering pulses for SCR are shown in figure 1(a). The equivalent circuit have also been shown.

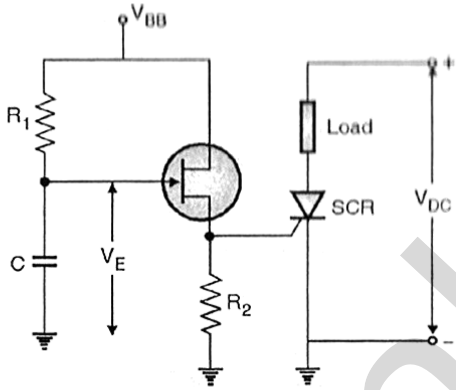


Fig. 1(a) : Triggering circuit of SCR using UJT

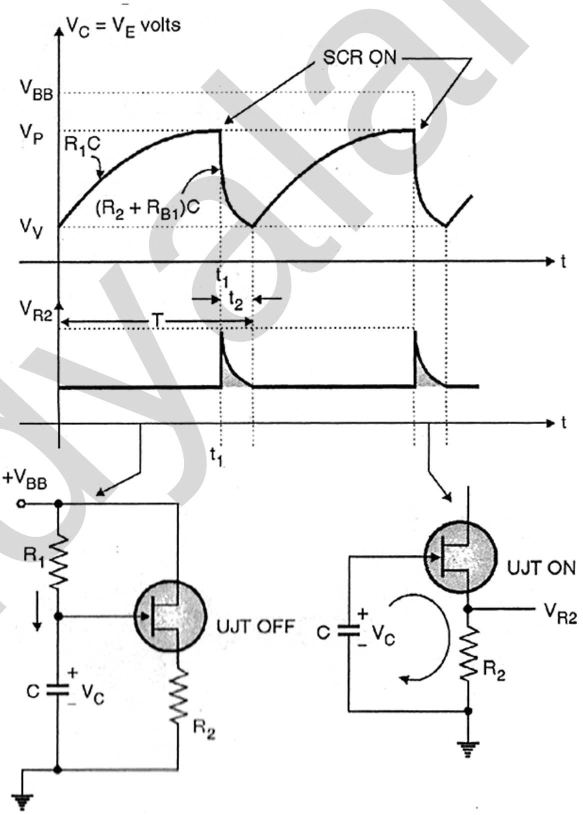


Fig. 1(b) : Voltage waveforms and equivalent circuits for triggering circuit using UJT

$$= V_{BB} - (V_{BB} - V_V)e^{-t/R_1C}$$

- The capacitor C will determine the time interval between triggering pulses and the time span of each pulse. At the instant the dc supply voltage V_{BB} is applied, the voltage across the capacitor i.e. V_C will increase from V_V towards V_{BB}.
- The charging of the capacitor takes place through resistance R_1 therefore the charging time constant is $T = R_1C$. (See figure 1(b)).
- When $V_C = V_E - V_P$ the UJT will enter the conduction state and the capacitor will discharge through R_{B1} and R_2 at a rate determined by the time constant $(R_{B1} + R_2)$ C.

6. (a) Given Data

1ϕ Full wave controlled rectifier

$V = 230 \sin 314t \qquad \alpha = 45° \qquad R_L = 100\ \Omega$

$\therefore \quad V_m = 230\text{ V} \qquad \therefore \cos\alpha = 0.707$

The average output voltage $E_{dc} = \dfrac{E_m}{2\pi}[1+\cos\alpha]$

$$= \frac{230}{2\pi}[1 + 0.707]$$

$$\therefore \quad E_{dc} = 62.48\text{ V}$$

average output current $I_{dc} = \dfrac{E_{dc}}{R_L} = \dfrac{62.48}{100}$

$$\therefore \quad I_{dc} = 6.248\text{ A}$$

6. (b) Circuit diagram of 2-Quadrant chopper and its working

- The circuit diagram and the output voltage and current waveforms of a step down chopper are as shown in figure 1(a) and (b) respectively.
  When SCR S_1 is closed for a time T_{ON}, the input voltage V appears across the load. If the SCR remains off for a period T_{OFF}, the voltage across the load is zero.
- Practically any power device can be used as switch. These devices have finite voltage drop ranging from 0.5 to 2 volt but for the sake of simplicity we shall neglect the voltage drops of these power semiconductor devices, and assume the switch S to be an ideal switch.

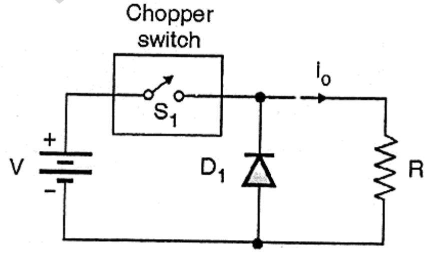


Fig. 1(a) : Step down chopper

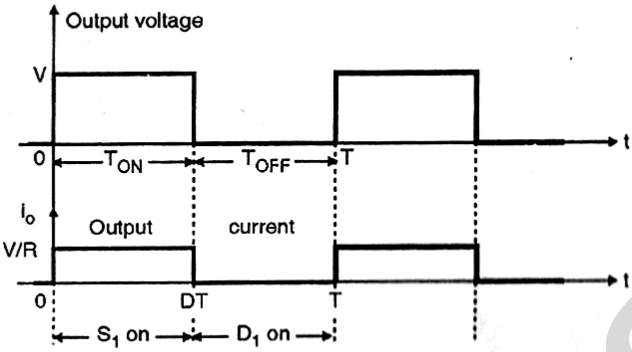


Fig. 1(b) : Load voltage and load current waveforms with resistive load

6. (c) Four applications of Power MOSFET

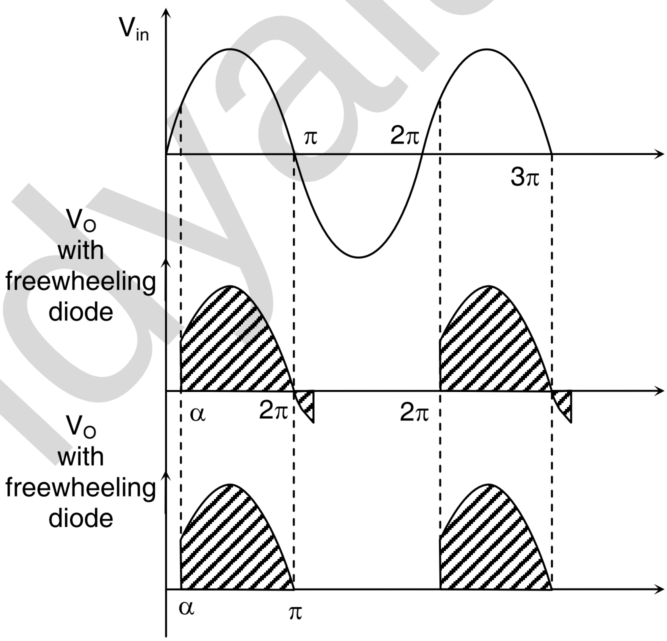
Application

i) Inverters
ii) AC motor control
iii) SMPS
iv) Converters

Thermal runaway does not take place in Power MOSFET because

Thermal run does not take place in power MOSFET because it is a voltage control device and it has a positive temperature co-efficient as temperature increases resistance increases.

6. (d) The effect of free-wheel diode with waveform in controlled rectifier



When the load is inductive the stored energy in the inductor maintains the SCR on for a part of the –ve half cycle due to which the output the rectifier reduces.

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To improve this free wheeling diode is connected across the inductive load. This will serve the following main two purposes.

i) Transfers the energy stored in the inductor away from the rectifier allowing it to regain its blocking state when the supply voltage is reversed.
ii) It improves the power factor of the system.

6. (e) Distortion Factor (DF)

It is a measure of effectiveness in removing the unwanted harmonics without specifying the second order load filter. It is given by

$$D.F. = \frac{1}{V_{o_{1rms}}}\left[\sum_{n=2,3\ldots}^{\infty}\left(\frac{V_{on\,rms}}{n^2}\right)^2\right]^{1/2}$$

where V_{01rms} is the rms voltage of fundamental frequency.

$V_{on\,rms}$ is the rms voltage of ‘n’th harmonic.

Lowest Order Harmonic (LOH)

It is the harmonic whose frequency is closest to the fundamental component and its amplitude is equal to or greater than 3% of its fundamentals one.

6. (f) Comparison between Linear regulator with SMPS

	Linear regulator	SMPS
i)	Size is large	Size is small.
ii)	Maintenance cost is less.	Maintenance cost is more.
iii)	High switching frequency circuit absent.	High switching frequency circuit present.
iv)	Noise is more.	Noise is less.
v)	IC’s are not used.	IC are used for controlling.

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