LEARNING MATERIAL

OF

POWER ELECTRONICS & PLC

(5TH SEM)

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BHUBANESWAR

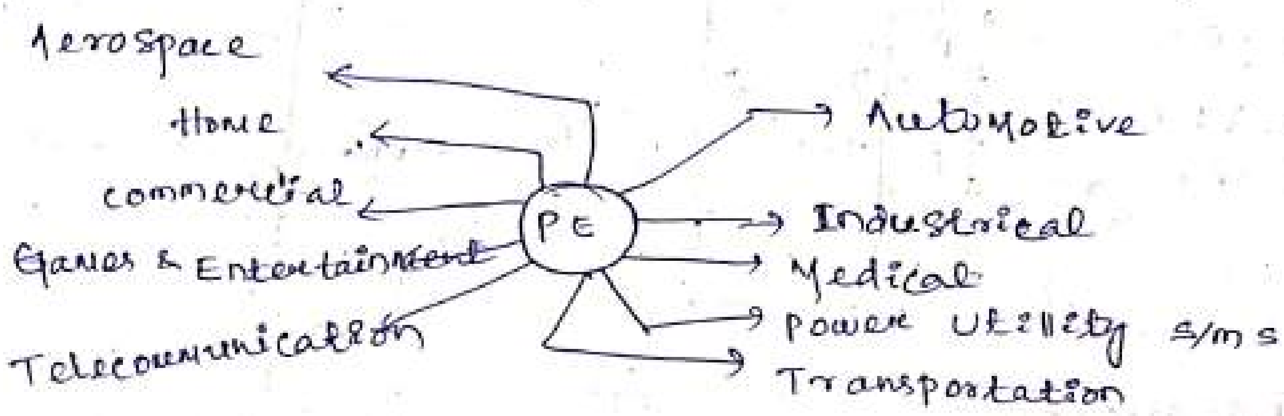
chapter-1

more +ve than A1

Power Electronics

What is power Electronics:-

It is the application of Electronics and circuits to control the conversion of Electric power from one form to another.

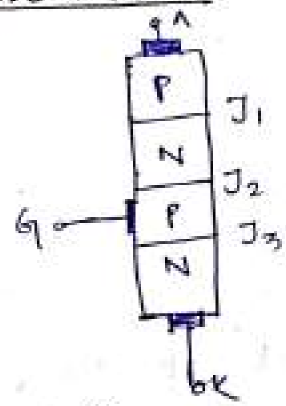


SCR

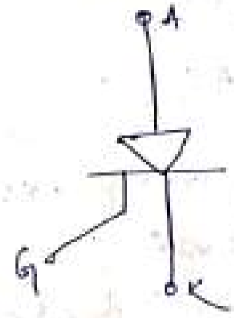
Sillicon controlled Rectifier → Three terminal Four layer device.

→ control → Ac to Dc

construction:-



Symbol

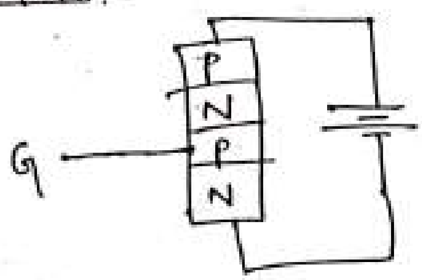


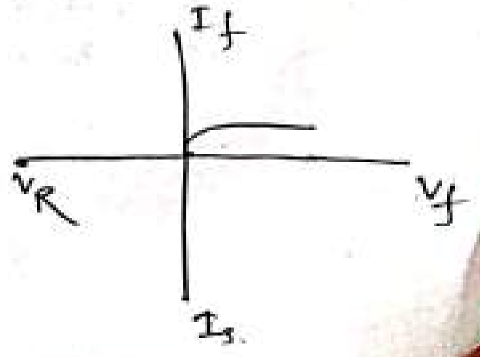
working:-

- → Forward blocking Mode
- → Forward conduction Mode
- → Reverse blocking Mode

Forward blocking Mode:-

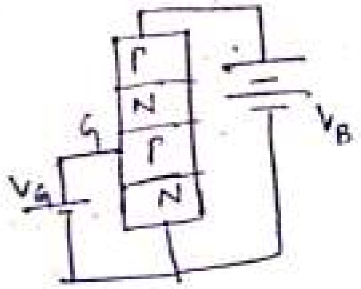
$J_1 \rightarrow$ F.B
$J_2 \rightarrow$ R.B
$J_3 \rightarrow$ F.B

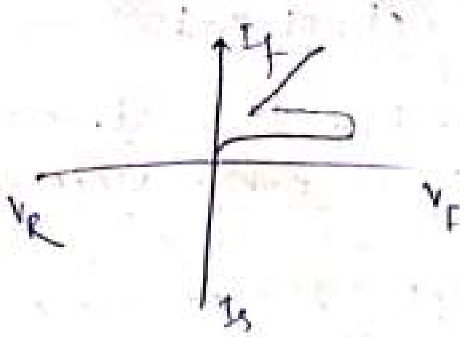




...uction Mode:-

$J_2 \rightarrow$ FB
$J_3 \rightarrow$ F.B



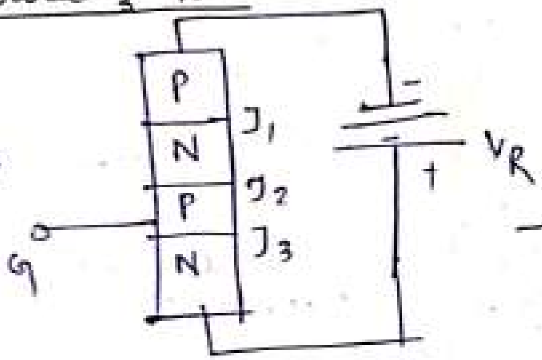


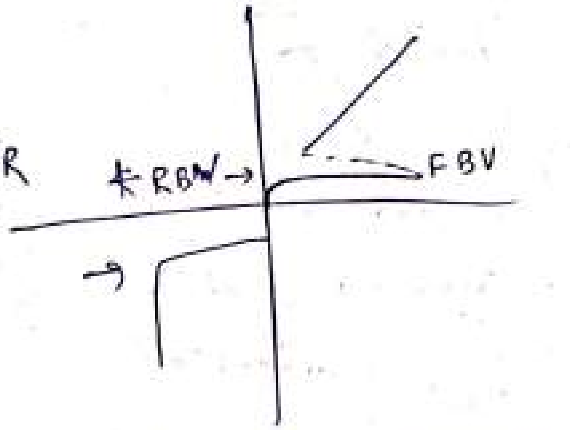
Reverse blocking Mode:-

$J_1 \rightarrow$ R.B

$J_2 \rightarrow$ F.B

$J_3 \rightarrow$ R.B





RBV → Reverse Breakdown Voltage

FBV → Forward Breakdown vtg

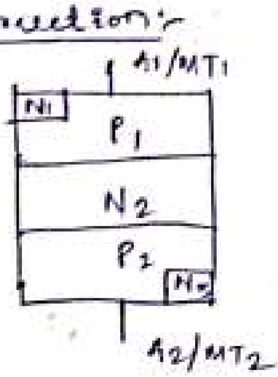
Application:-

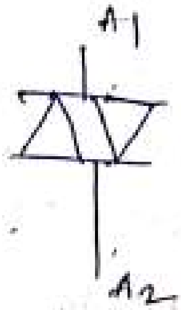
→ AC voltage stabilizer
→ used as Switch
→ " " Inverter
→ Motor speed control
→ DC ckt breaker

DIAC

→ Diode for Alternating current.
→ Bidirectional device
→ combination of two diodes in Anti Parallel

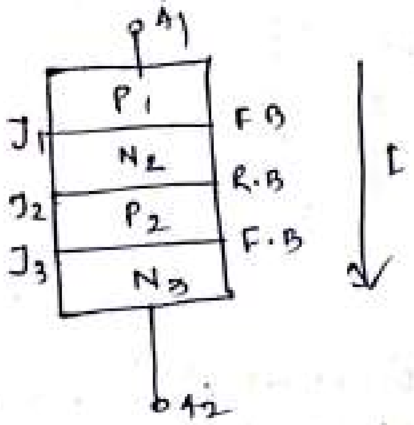
construction:-



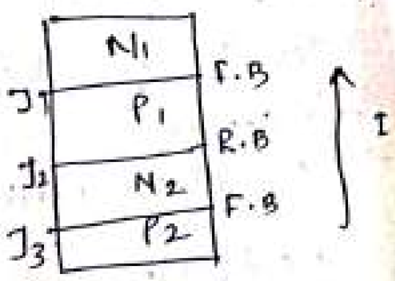


Working:-

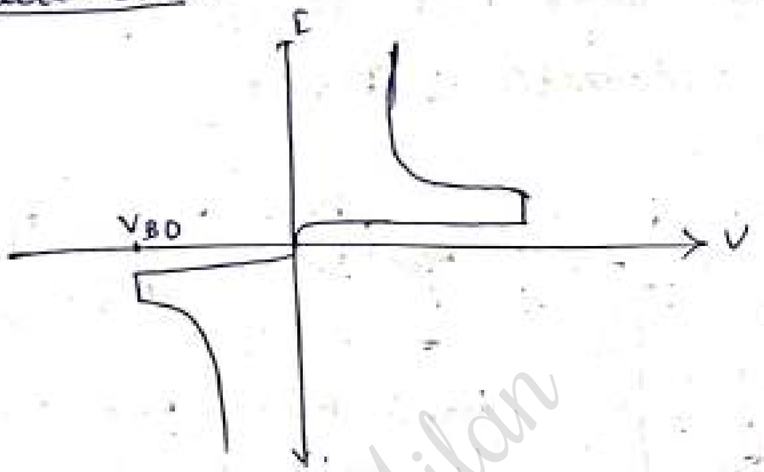
A_1 is more +ve than A_2



A_2 is more +ve than A_1



VI characteristics:-



Application:-

→ Using SCR/TRIAC to Trigger

→ Large power control

→ Heat control ckt

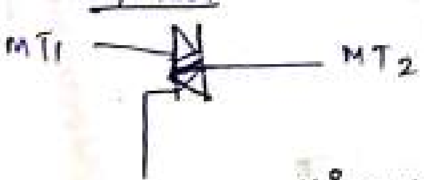
TRIAC (TRIode for Alternating current)

TRIAC → controlling terminal

→ Two SCR connected in Anti-parallel

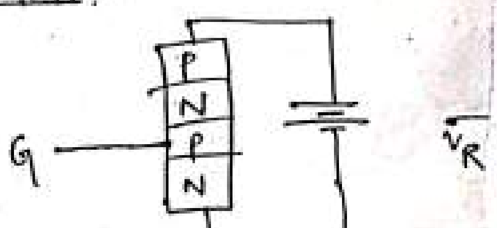
→ TRIAC can Trigger in both direction

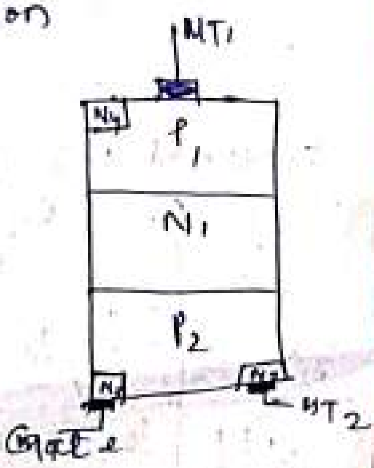
Symbol



→ used as a switch

ing Mode:-





Application :-

→ Lamps control

→ Speed control

→ chopper

→ AC phase control

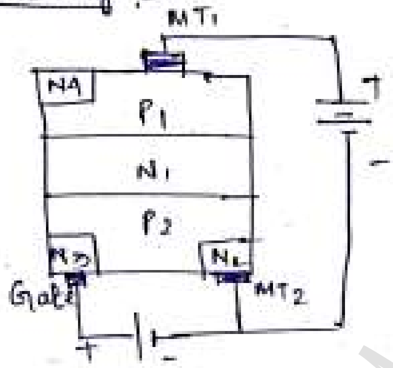
Definition

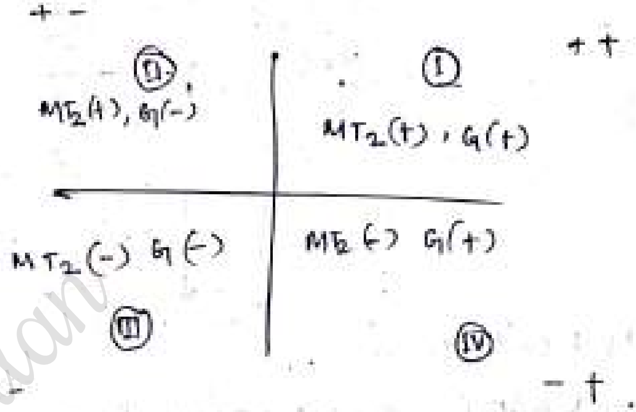
TRIAC is a three terminal electronic component that conduct current in either direction when triggered.

→ A TRIAC can work both direction

→ It is a bi-directional device

working :-





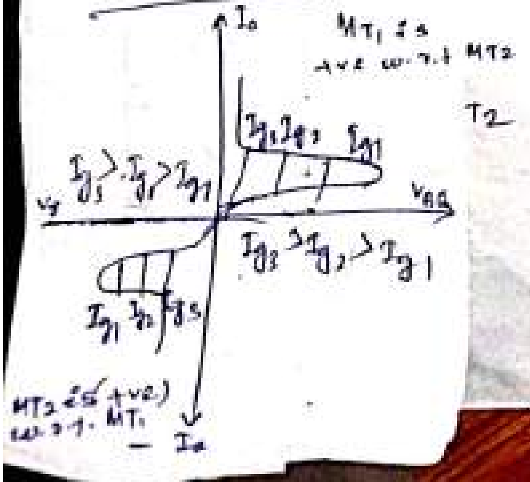
Qudrant-I :- is the Most sensitive (i.e least gate current) required to turned on the device)

Qudrant-II :- MT₂. G - Moderate

Qudrant-III

MT₂(-) G(-) is the least sensitive(Most gate current required to turned on the device)

Qudrant (IV) MT₂(-) G(-)

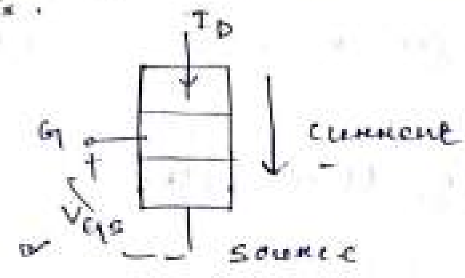


FET (Field Effect Transistor)

→ It is a 3 terminal device, which control the flow of current through the device.

→ Most of the I.C including the computers are design of these FETs.

→



→ current flows from Drain to Source.

→ This current can be controlled by the Gate-Source voltage. (V_{GS}).

(Voltage controlled current source)

→ controlling the electric field we control the ~~field~~ flow of current.

→ That is known as it is Field Effect Transistor.

BJT | **FET**

→ Unipolar Devices (Either free electron or holes)
→ voltage controlled

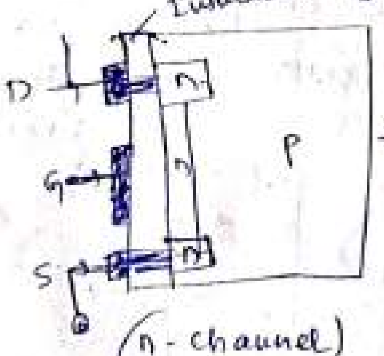
Application :— → Amplifier
→ Analog switch
→ Integrated circuits
→ Buffer Amplifier
→ oscillators

(The path through charge carrier flows is known as channel)

FET
- JFET — Junction Field Effect Transistor
  - n-channel
  - P-channel
- ✓ MOSFET (IGFET) Insulated Gate Field Effect Transistor
  - n-ch
  - P-ch

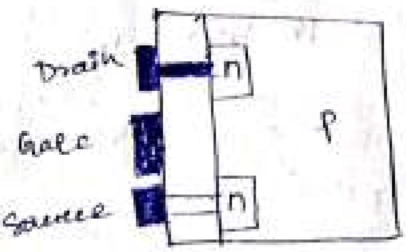
MOSFET

Insulated layer (SiO_2 → silicon dioxide)



(Depletion type)

(n-channel)



Enhancement type

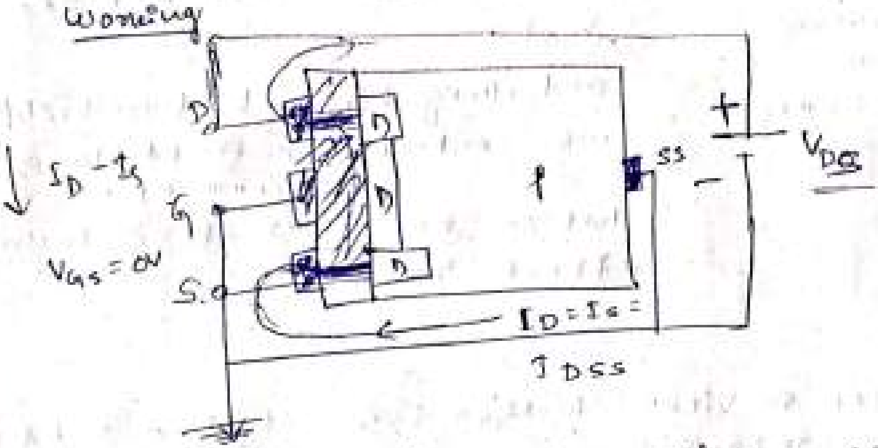
Depletion type MOSFET

→ Gate terminal is not directly connected to n-channel it is isolated by insulated layer (SiO_2)

→ Due to the insulating layer the lower current is flow from gate.

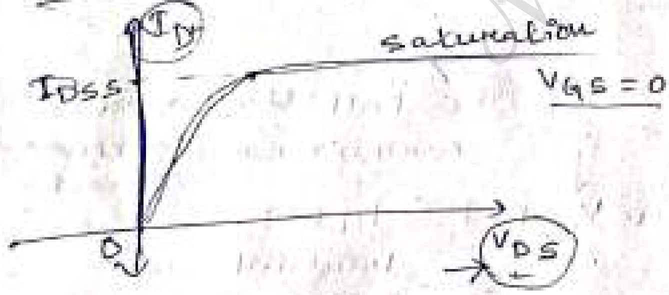
→ Very high input impedance than JFET

Working

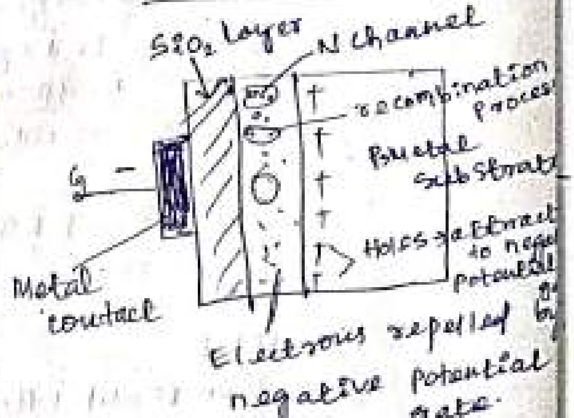


→ Initially $V_{GS} = 0$, and +ve voltage is applied Drain & source terminal.

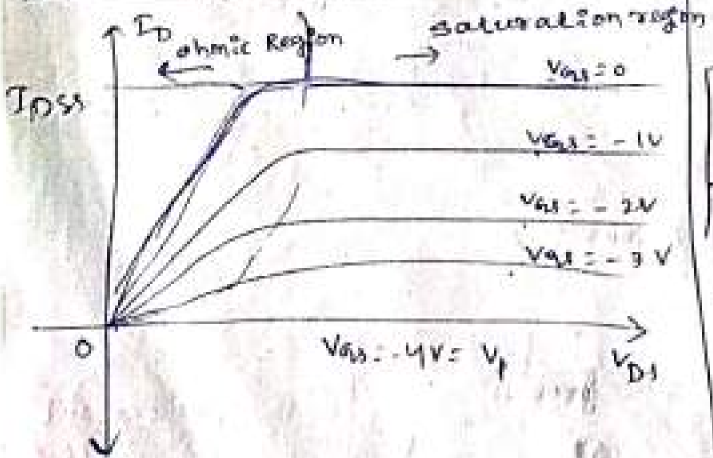
O/P characteristics



When V_{GS} is negative



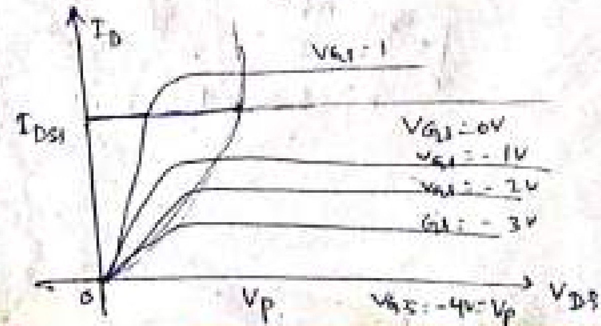
(−ve)



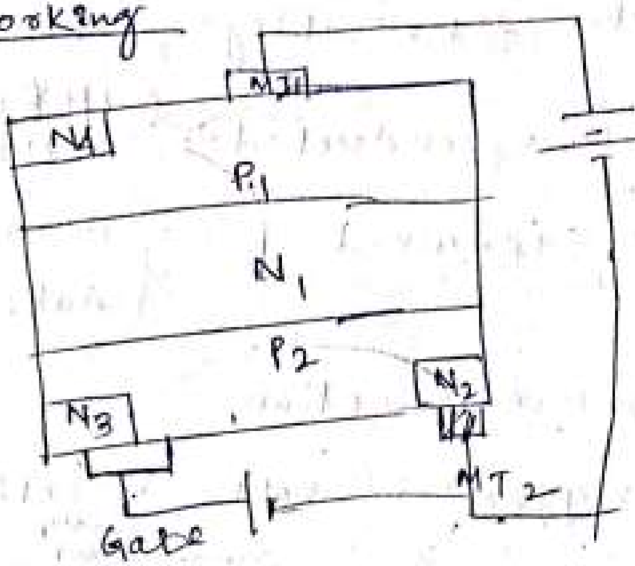
As −ve voltage ↑, rate of recombination also ↑. Then reduces free electron available in this ∴ n-channel

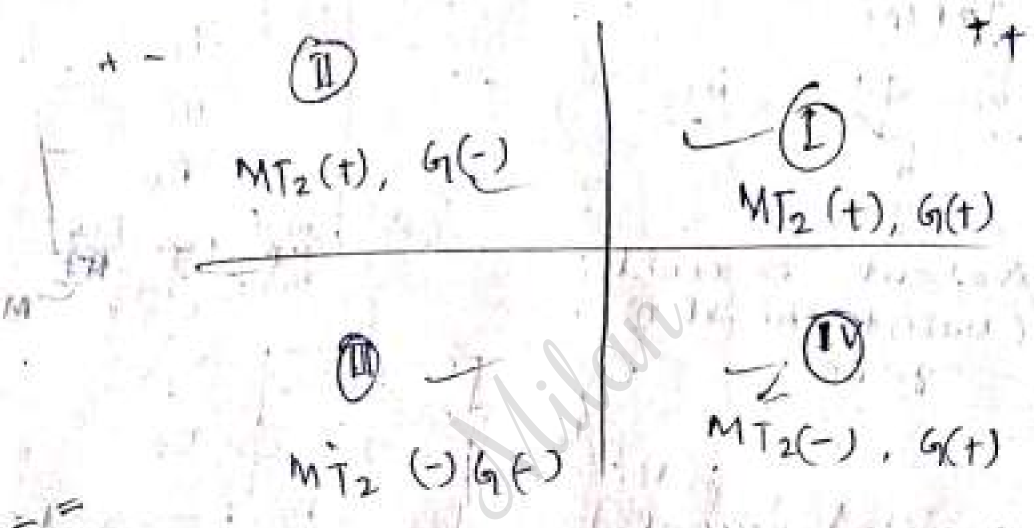
→ effective it reduced the flow of electrons

+ve



(*) Working





(*) Quadrant I is the most sensitive (i.e. least gate current required)

(*) Quadrant IV is the least sensitive (most Gate current required)

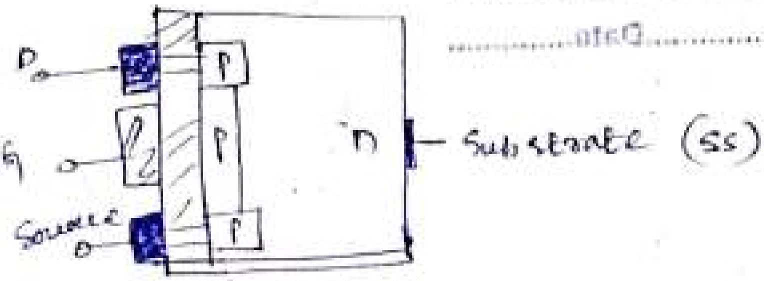
Quadrant II

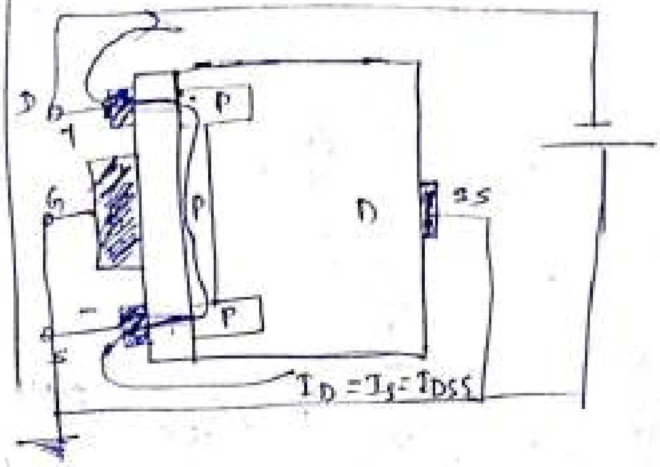
M_2 is + G -

②

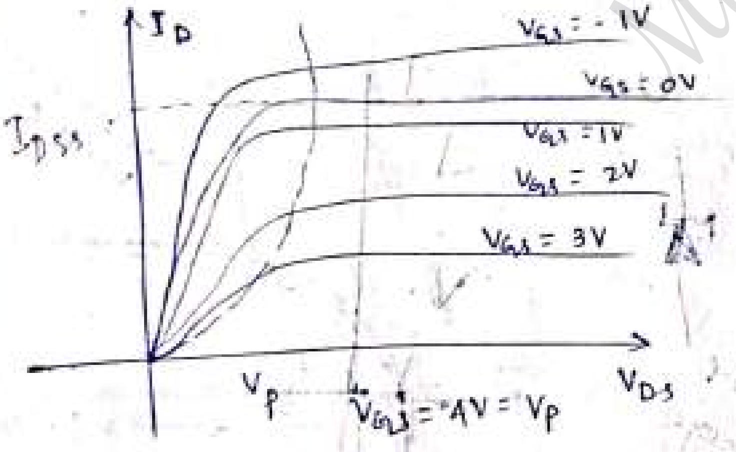
$$I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2$$

P- Channel (Depletion)



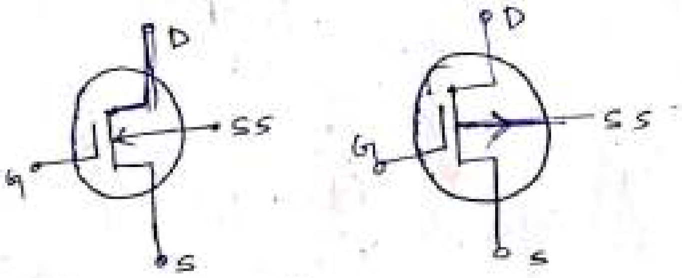


O/P characteristics

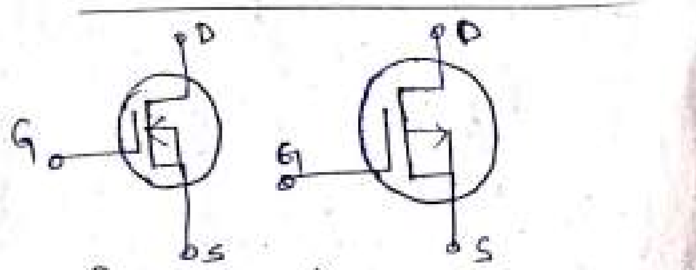


$V_{GS} = 0$

n-Channel | p-channel



Depletion type MOSFET



(n-channel) (P-channel)

(*) GTO (Gate Turn off Thyristor)

(*) conventional thyristors (CTs) are nearly ideal switches for their use in power electronics application. It can easily turned on by positive gate current. In on state, gate losses control.

→ Then to overcome these drawbacks in thyristors has led to development of GTOs.

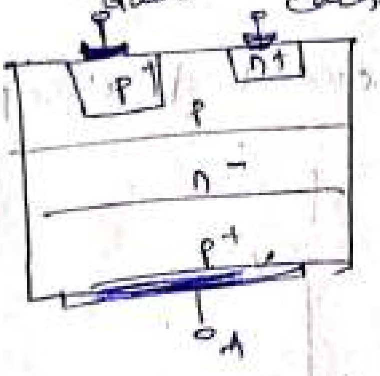
→ Symbol.

→ GTO is a pnpn device that can be turned on by a positive gate current and turned off by a negative gate current at its gate cathode terminals.

→ GTO is fully controllable switch which can be turned on & turn off by Gate signal.

→ It is active semiconductor device.

GTO Structure



→ Working
→ Turn on (+ve Gate curr)
Turn on is not as reliable as SCR.

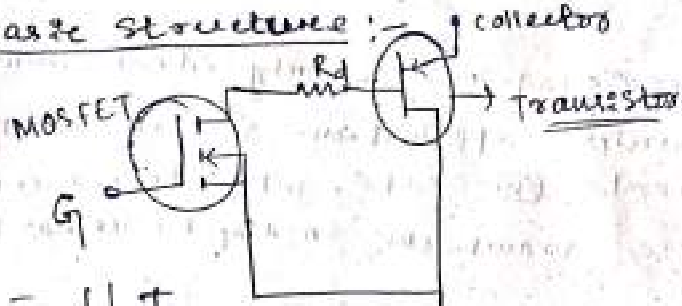
→ GTO is 10 times faster than SCR.

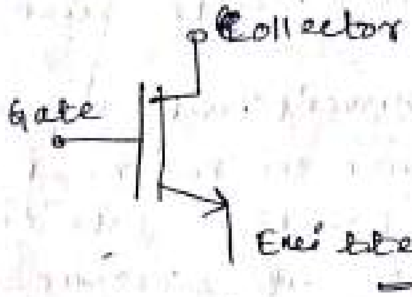
IGBT (INSULATED GATE BIPOLAR TRANSISTOR)

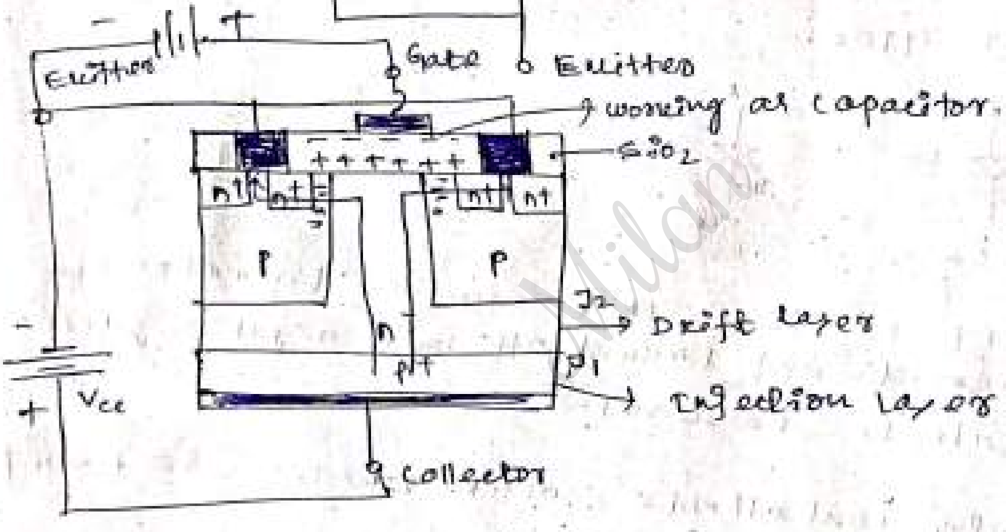
→ IGBT has been developed by combining into it the best qualities of both BJT and PMOSFET. Thus an IGBT possess high input impedance like a PMOSFET and has low on-state power loss as in a BJT.

→ IGBT is free from second breakdown problem present in BJT. All these merits have made IGBT very popular amongst power electronics engineers.

Basic Structure :-

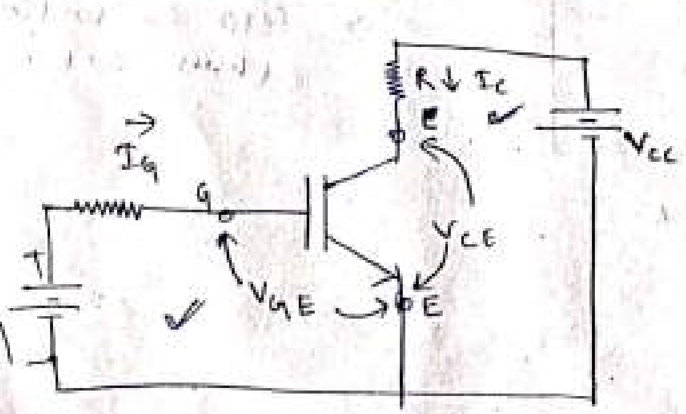




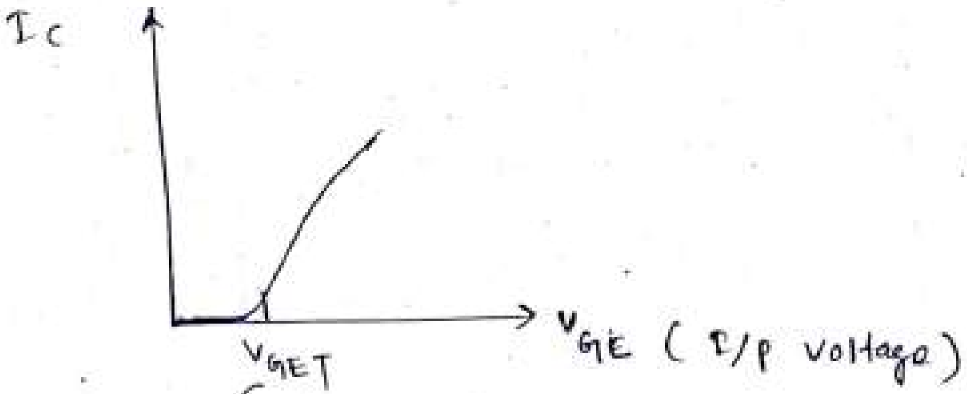


→ Collector is +ve w.r.t Emitter J_1 is forward biased
J_2 Reversed biased
→ current is not flow from collector to emitter

Gate voltage ↑
→ bcz of the SiO_2 is created as capacitor

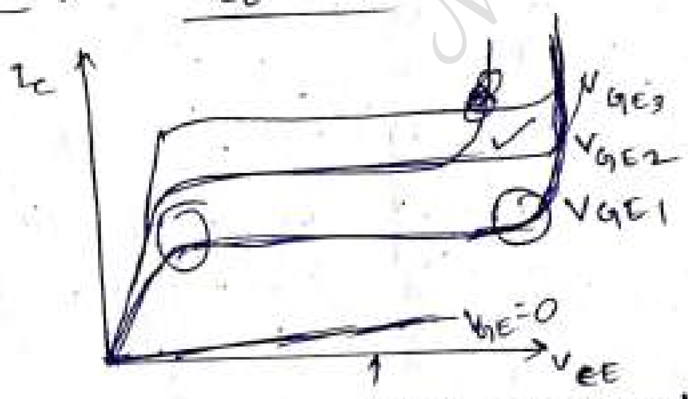


Transfer characteristics ($V_{GE} \sim I_C$)



Gate excitation there around 1V (SI)

O/P chacs → $V_{CE} \sim I_C$

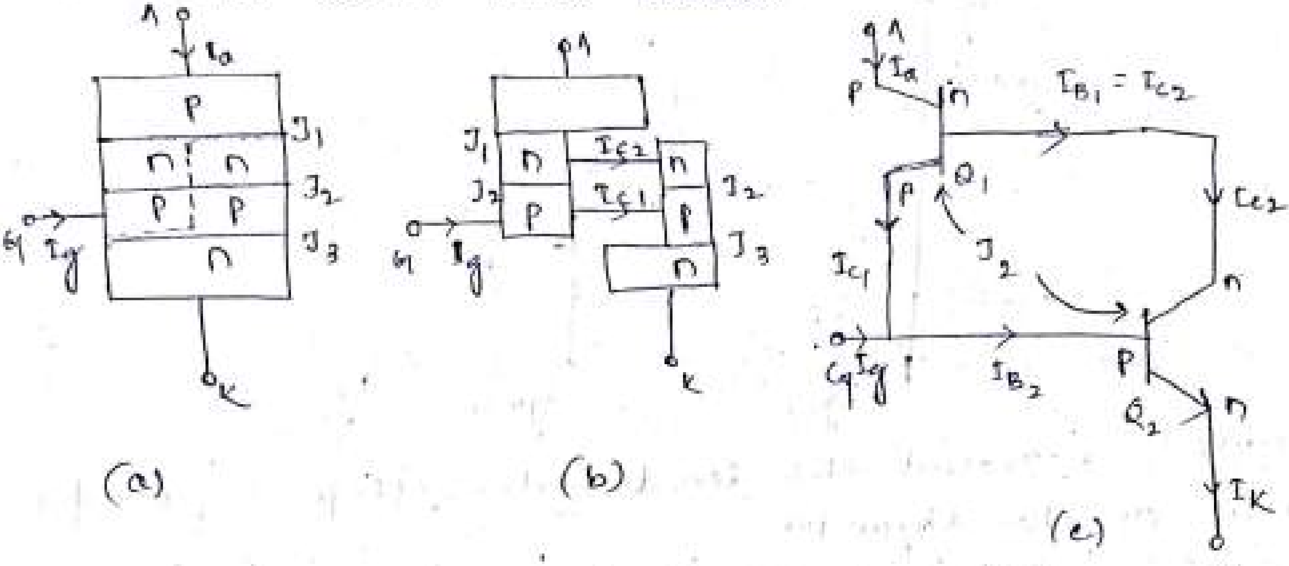


$V_{GE3} > V_{GE2} > V_{GE1} > V_{GE}$

Here current is their due to minority charge carrier.

(*) Two Transistor Model of a Thyristor / Two Transistor Analysis

→ A Thyristor can be considered as two complementary Transistors, one pnp Transistor Q_1 & another npn Transistor Q_2 as show below.



(a) (b) (c)

→ The collector current I_C is related to emitter current I_E as $I_C = \alpha I_E + I_{CBO}$ —(1)

→ Where α → common base current gain

I_{CBO} → common base leakage current of collector base junction of a transistor.

$\Rightarrow \alpha = \frac{I_C}{I_E}$

→ For Transistor Q_1 : $I_E = I_A$ and $I_C = I_{C1}$

$I_{C1} = \alpha_1 I_A + I_{CBO1}$ —(2)

α_1 → common base current gain of Q_1

I_{CBO1} → common base leakage current of Q_1

(*) Last point
$\alpha_1 + \alpha_2 = 0$
$I_a = \infty$, which turns on the device.

(*) For Transistor Q_2 . $I_{C2} = \alpha_2 I_K + I_{CBO2}$ —(3)

α_2 → common base current gain of Q_2.

I_{CBO2} → common Leakage current Q_2.

We know that $I_A = I_{C1} + I_{C2}$

$= \alpha_1 I_A + I_{CBO1} + \alpha_2 I_K + I_{CBO2}$ —(4)

When gate current is applied $I_K = I_a + I_g$ (equ^n 4)

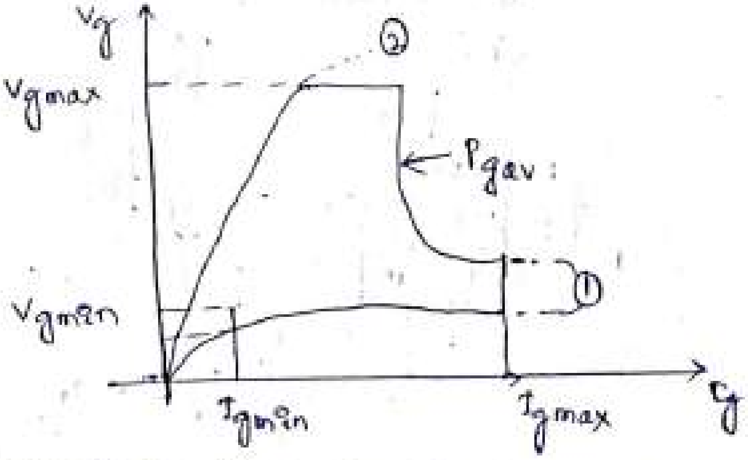
$I_a = \alpha_1 I_A + I_{CBO1} + \alpha_2 (I_a + I_g) + I_{CBO2}$

$$I_a = \frac{\alpha_2 I_g + I_{CBO1} + I_{CBO2}}{1 - (\alpha_1 + \alpha_2)}$$

$$I_a = \frac{\alpha I_g}{1 - (\alpha_1 + \alpha_2)}$$ neglecting leakage current

Gate characteristics of SCR :-

The graph between gate voltage and gate current of a thyristor is known as gate characteristics



curve-1 :→ Represent the lowest gate voltage required to turn-on the thyristor.

curve-2 :→ Represent the Maximum gate votage that may be safely applied to turn on the SCR.

→ I_{gmax} – Max. gate current

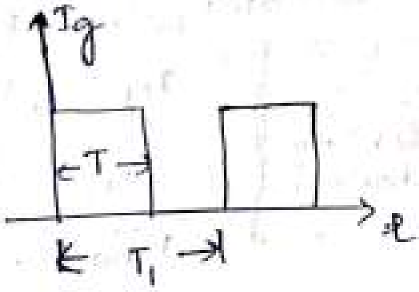
→ I_{gmin} – Min. gate current

→ V_{gmax} – Max. gate voltage

→ V_{gmin} – Min gate voltage

→ $P_{g(av)}$ – gate power dissipation Limit curve

$$\delta = \frac{T}{T_1} = f \cdot T$$



→ where δ = duty cycle

T = Time period

f = frequency of firing in Hz

→ Duty cycle is defind as the ratio of pulse on peri to the periodic time of pulse.

→ The relation between P_{gmax} & P_{gavg} is —

$$P_{gmax} = \frac{P_{gavg}}{\delta}$$

→ where P_{gmax} = maximum gate power

P_{gavg} = Average gate power

→ Higher the Magnitude of gate current pulse, Lesser is the time for turning on the Thyristor.

Prob - A thyristor is triggered by a pulse - train of 5kHz. The duty ratio is 0.4. If the allowable average power is 100W. What is the Maximum allowable gate drive power.

Given $f = 5\,kHz$, $\delta = 0.4$, $P_{gav} = 100W$

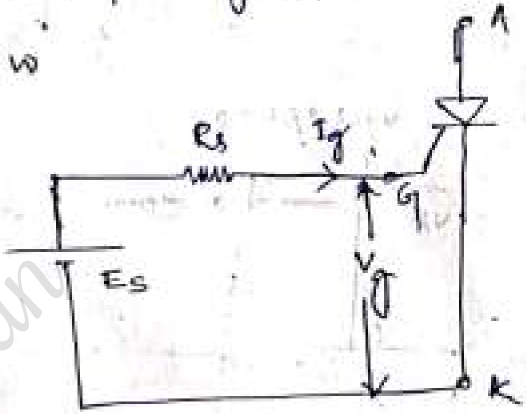
$P_{gmax} = ?$

We know $\frac{P_{gav}}{\delta} = P_{gmax} \Rightarrow \frac{100}{0.4} = P_{gmax}$

$\Rightarrow P_{gmax} = 250\,W$

Design of Gate ckt

$$E_s = V_g + R_s I_g$$



* Switching characteristics of SCR during turn on & turn off

* Switching characteristics during Turn on -

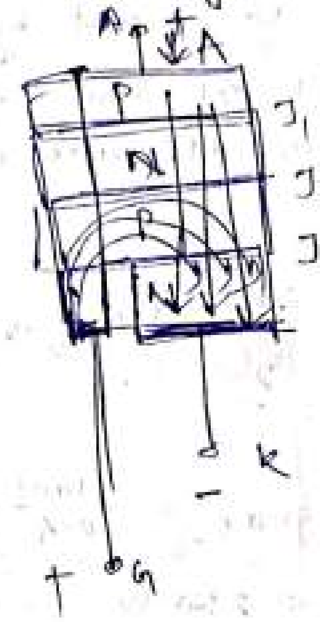
→ A forward biased thyristor is usually turned on by applying a positive gate voltage b/w gate and cathode. There is, however, a transition time from forward off-state to forward on state. This transition time, called thyristor turn-on time, is defined as the time during which it changes from forward blocking state to final on-state.

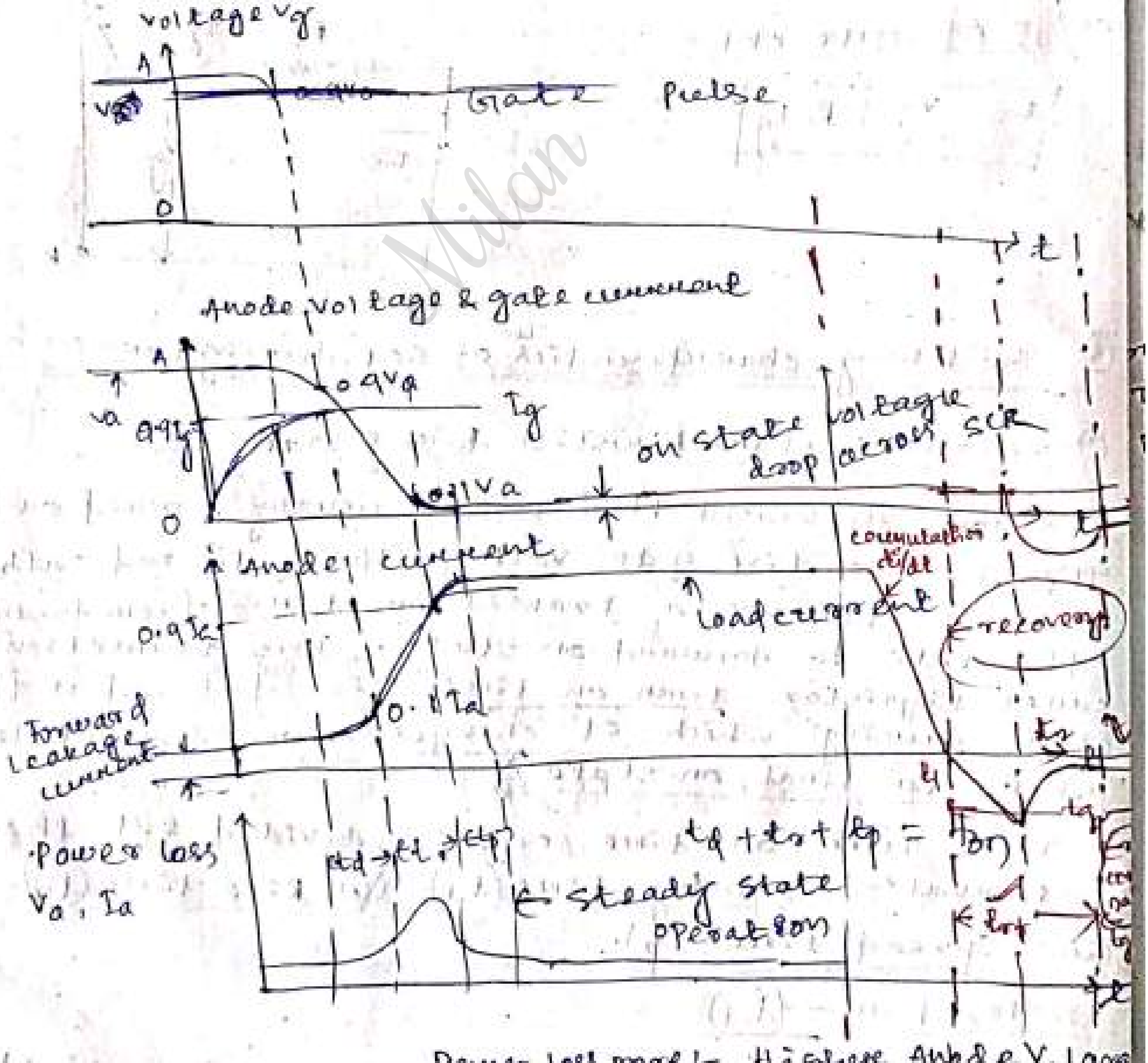
→ Total Turn-on time can be divided into three intervals (i) Delay time (t_d), (ii) Rise time (t_r), (iii) Spread time (t_p).

Delay time:- (t_d)

Delay time measure from the instant at which Gate current reach $0.9\,I_g$ to the instant at which anode current reach $0.1\,I_a$.

The delay time define as time during which anode voltage Fall from V_a to $0.9V_a$ where V_a is initial value of anode voltage.





Power loss more: Higher Anode V, Large Anode I.

$t_r \propto \frac{1}{\text{magnitude of gate current}}$

*) switching characteristics during Turn off :-

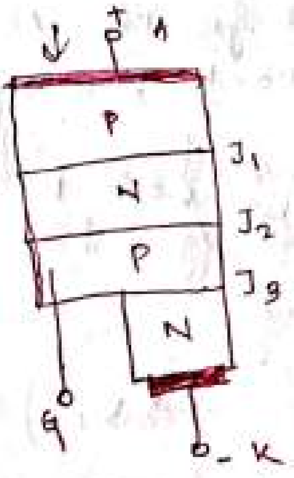
→ Thyristor turn off Means that SCR has change from on to off state and capable to blocking forward voltage. This dynamic process of the SCR from conduction state to forward blocking state is called commutation process or turn off process

1 → Reverse recovery time (t_{rr})

2 → Gate recovery time (t_{gr})

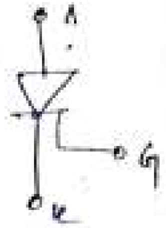
3 → Turn off time (t_q)

Turn off time = Reverse recovery time (t_{rr}) + gate recovery time (t_{gr})



(8) Turn on methods of SCR / Thyristor Turn-on Methods:-

When anode is positive w.r.t cathode, a thy[ristor] can be turned on by any one of the following -



1. Forward voltage triggering
2. Gate triggering
3. $\frac{dv}{dt}$ triggering
4. Temperature Triggering
5. Light triggering

(1) Forward voltage Triggering:→

→ When anode is +ve w.r.t cathode & gate circuit open, Junction J_1 & J_3 are forward biased and J_2 is reverse bia[sed].

→ When Anode to cathode forward voltage is increased Junction J_2 will break. This is known as avalanche break[down] and the voltage at which avalanche occurs is called Forward breakover voltage (V_{BO}). At this votage, thyristor changes from off state to on state.

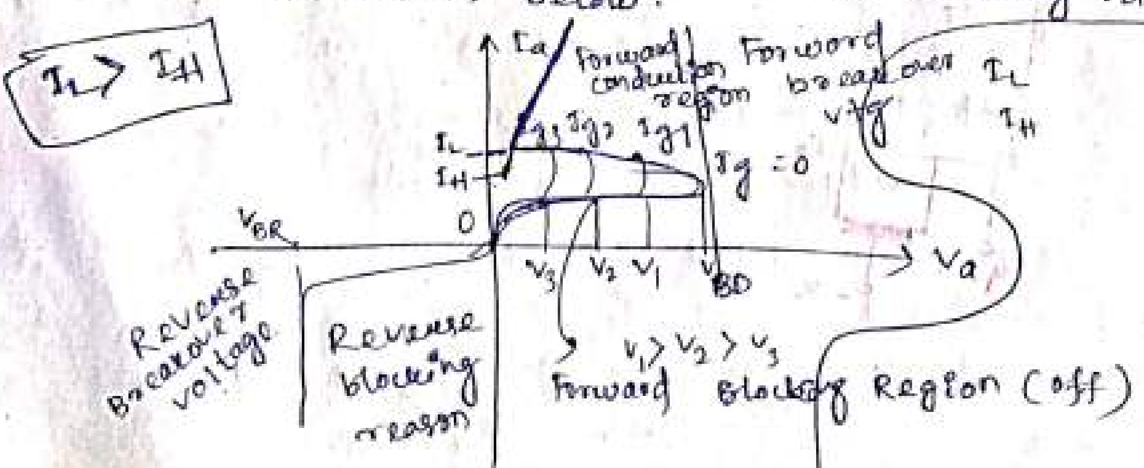
→ In Practice the transition from off-state to onstate obt[ained] by exceeding V_{BO} is never employed as it may destroy the device.

→ The Magnitude of forward breakover and Reverse break down voltage are nearly the same and both are temperat[ure] dependent. In Practice, it is found that V_{BR} is slightly more than V_{BO}.

→ Therefore, Forward breakover voltage is taken as the Final voltage rating of the device during the desi[gn] of SCR applications.

(2) Gate Triggering:-

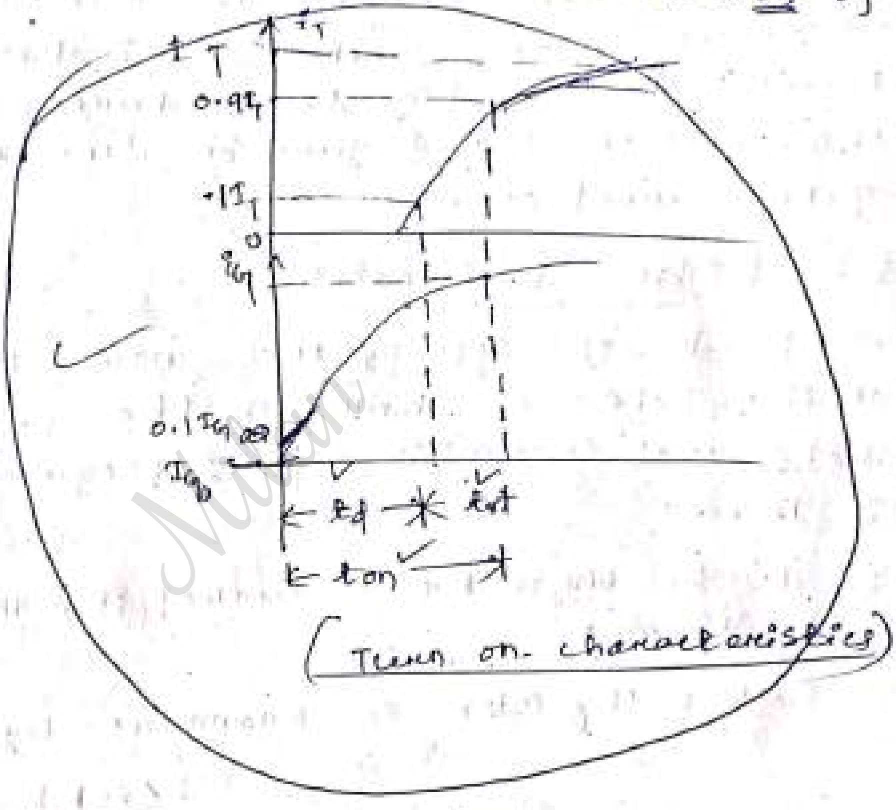
→ If the thyristor is forward biased the injection of Gate current by applying positive gate voltage between gate & cathod terminal turns on the thyristor. As the gate current is increased, the forward blocking voltage is decreased as shown below.



→ The gate signal should be removed after the thyristor is turned on. A continuous gating signal would increase the power loss in the gate junction.

→ When the SCR is reverse biased, there should be no gate signal, otherwise, the thyristor may fail due to an increased leakage current.

→ The width of gate pulse t_G must be longer than the time required for the anode current to rise to holding current. In practice, the pulse width t_G is normally made more than the turn on time t_{on} of the thyristor.



(Turn on characteristics)

$\frac{dv}{dt}$ Triggering :

→ We know that, with forward voltage across the anode and cathode of device, junction J_1 & J_3 are forward biased where as junction J_2 becomes reverse biased. This reverse biased junction J_2 has the characteristics of capacitor due to charges existing across the junction.

→ If the voltage impressed across the device is denoted by 'V_a', the charge by Q and the capacitance by C_j, then the charging current

$$i_c = \frac{dQ}{dt} = \frac{d}{dt}(C_j V)$$

$$C_j \frac{dV}{dt} + V\frac{dC_j}{dt} \rightarrow 0$$ → Junction capacitance always constant

$$i_c = C_j \frac{dv}{dt}$$

→ If $\frac{dv}{dt}$ is high; changing current i_c will be more. The changing current turn on the thyristor even when the gate signal is zero.

(4) Temperature Triggering :—

→ During forward blocking, most of the applied voltage appears across reverse biased Junction J_2. This voltage across J_2 associated with leakage current, would raise the temp. of this Junction. With increase in temperature, width of depletion layer decreases.

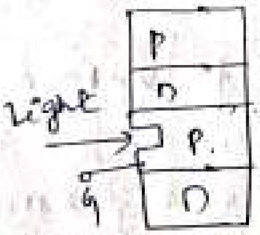
→ This further leads to more leakage current and therefore, more Junction temperature. With the cumulative process, at some high temperature, depletion layer of this reverse biased junction vanishes and the device gets turned on.

(5) Light Triggering :—

→ Light of appropriate wave-length is incident on the hole as shown in the figure, the electron-hole pairs increase and subsequently reverse Junction J_2 breaks.

→ So the thyristor is turned on. This is called light triggering.

→ Such a thyristor is known as light-activated SCR (LASCR)



Holding current :— The Max^m Anode to cathode current below which SCR will forward blocking state.

$I_{AK} < I_H$, SCR-off

→ ~~concept~~ Related to turning off

→

Latching current (I_L)

→ It is the Min^m Anode to cathode current above which SCR will forward conduction state.

$I_{AK} \geq I_L$ SCR → ON

→ Latching current related to turning on

→ Concept of latching current is used for determined the Gate pulse width, reqd for Turn on of SCR.

Thyristor Turn off:-

→ For the purpose of power control or power conditioning a conducting thyristor must be turn off. Than turn off a thyristor means bringing the device from forward conducting state to forward blocking state. The thyristor turn off requires that its anode current (forward current) falls below the holding current. commutations is defind as the process of turning-off a thyristor.

commutation (The process for which SCR is turn off)

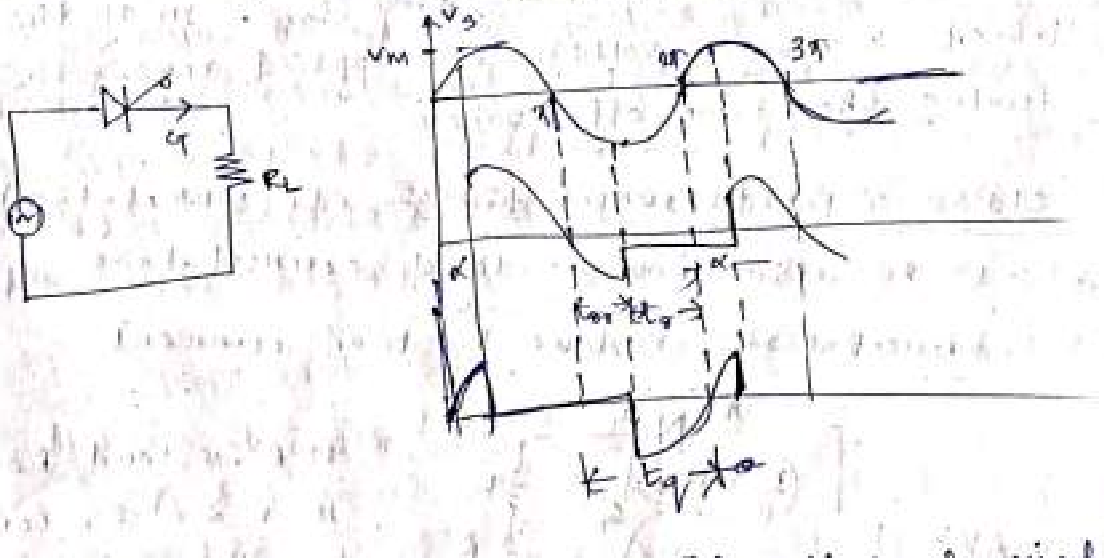
- Natural (or) Line commutation [AC] → Class F
- Forced commutation [DC]
  - Class A (load commutation)
  - Class B (Resonant pulse commutation)
  - Class C (Impulse/complimentary)
  - Class D (voltage commutation)
  - Class E

Natural commutation:-

→ It is a turn off process the scR gets into off state whenever the supply voltage passes through natural zero. This may be obtained whenever an ac input is given.

→ Additional commutation circuit is not required for this natural commutation.

→ This type of commutation process is used in ac vtg regulators, step down cycloconverters.



Note → once thyristor is turned on it can't be turned off as gate losses its control.

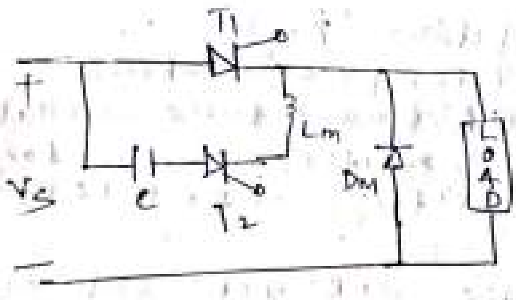
→ There is no off switch

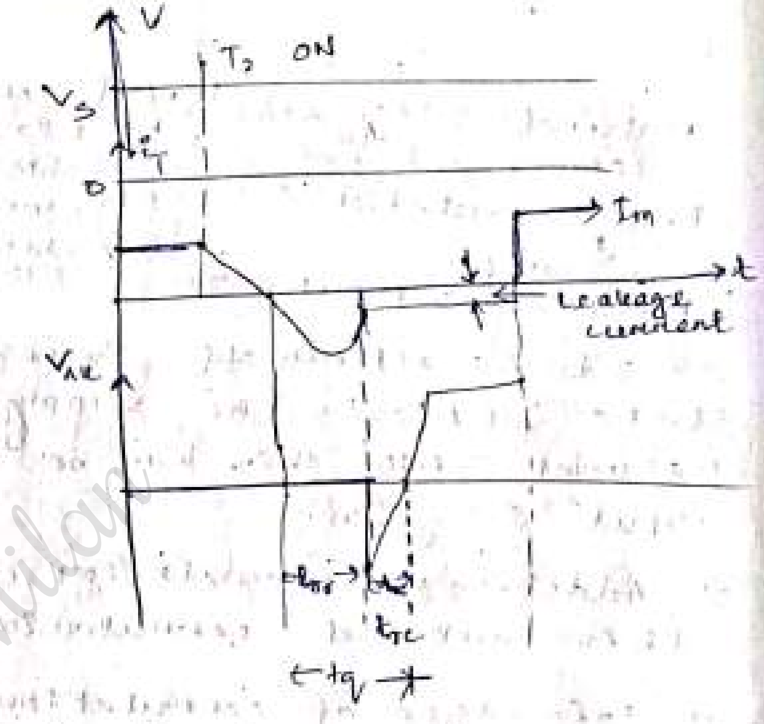
→ Hence use external means to turn it off.

Forced commutation :-

→ It is a turn-off process where the SCR gets into turn off state whenever the current flowing through the SCR is made zero for sometime by using external circuit.

→ The commutating elements generally employed are inductor and capacitor. This type of commutation process is used for DC input circuits.



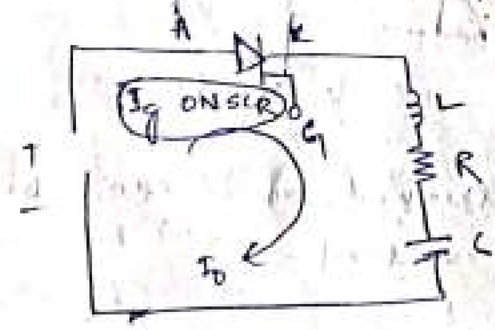


→ The turn-off time t_q is the sum of reverse recovery time (t_{rr}) and recombination time (t_{rc}). In all the commutation method, a reverse voltage is applied across the thyristor during the turn-off process.

Class A / Load commutation (self commutation)

→ It is also known as load commutation.

→ Commutation is done by load current.

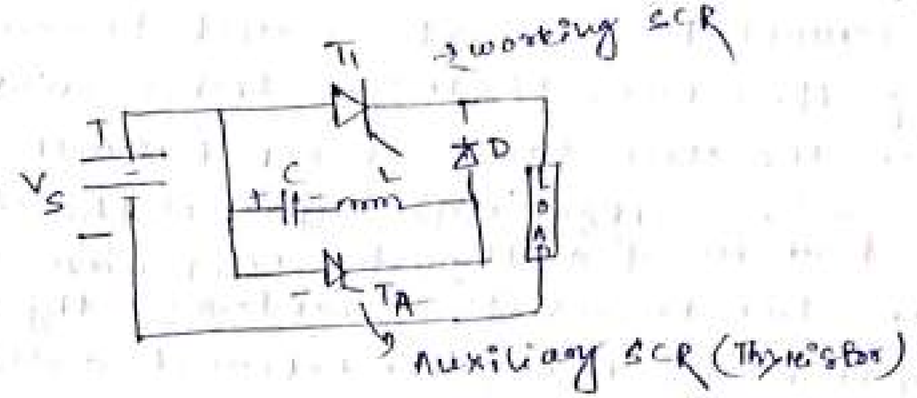


- R is Load Resistance.
- L & C is commutating elements of SCR.

$I_o = \frac{V(s)}{R}$

→ Turn off SCR, $I_A < I_H$

(f) Resonant pulse / current pulse commutation:-



Assumptions

↳ Load current is constant

→ LC circuit is Resonating in nature

Protection of SCR

→ Reliable operation of a thyristor demands that at it's specified ratings should not be exceeded practice a thyristor may be subjected to over voltage or over currents. During SCR turn on, $\frac{di}{dt}$ may be large. There may be false triggering of SCR, high value of $\frac{dv}{dt}$. A specious signal across Gate - cathode terminals may lead to unwanted turn on.

→ A thyristor must be protected all such abnormal conditions for satisfactory and reliable operation of SCR circuits and the equipments. Ri are very delicate device, their protection against abnormal operating conditions is essentials.

→ $\frac{di}{dt}$ protection (20 - 500) A/μsec

→ $\frac{dv}{dt}$ protection (20 - 500) $\frac{V}{\mu sec}$

→ over voltage protection

→ over current protection

→ Gate protection

Over voltage protection:-

→ A thyristor may be subjected to overvoltage due to bad commutation, short circuit, transient due to switching operation, lightning strokes, overvoltage transient are the main cause of SCR failure. Transient overvoltages cause either maloperation of the circuit by unwanted turn on of a thyristor or permanent damage to the device due to reverse breakdown. A thyristor may be subjected to internal or external overvoltages.

→ The former is caused by the thyristor operation whereas the latter comes from the supply lines or the load circuit.

(*) Internal overvoltages:-

→ Large voltages may be generated internally during the commutation of a thyristor. After thyristor anode current reduces to zero, anode current reverse due to stored charges. This reverse recovery current rises to a peak value at which time the SCR begins to block.

→ After this peak, reverse recovery current decays abruptly with large $\frac{di}{dt}$. Because of the series inductance L of the SCR circuit, large transient voltage $L\frac{di}{dt}$ is produced. As this internal overvoltage may be several times the breakover voltages of the device the thyristor may be destroyed permanently.

(*) External overvoltages:-

→ External overvoltages are caused due to the interruption of current flow in an inductive circuit and also due to lightning strokes on the lines feeding the thyristor systems.

→ When a thyristor converter is fed through a T/F, voltage transients are likely to occur when the T/F primary is energised or de-energised. Such overvoltages may cause random turn on of a thyristor.

→ As a result, the overvoltages may appear across the load causing the flow of large fault currents.

→ overvoltages may also damage the thyristor by an inverse breakdown. For reliable operation, the overvoltage must be suppressed by adopting suitable techniques.

Overcurrent protection:-

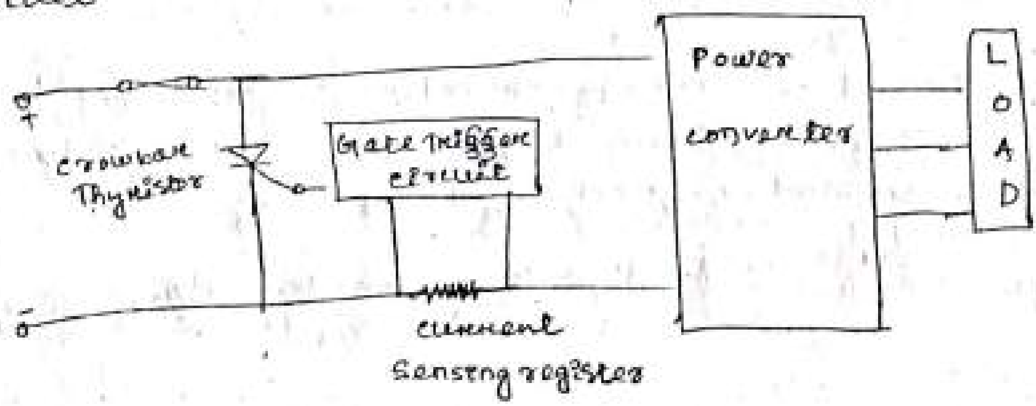
→ Thyristors have small thermal time constants. Therefore, if a thyristor is subjected to overcurrent due to faults, short circuits or surge currents; its junction temperature may exceed the rated value and the device may be damaged. There is thus a need for the overcurrent protection of SCRs. As in other electrical systems, over current protection in thyristor ckt is achieved through the use of circuit breaker and fast acting switching.

→ The type of protection used against overcurrent depends upon whether the supply system is weak or stiff.

→ In a weak supply network, fault current is limited by the source impedance below the multi-cycle surge current rating of the thyristor.

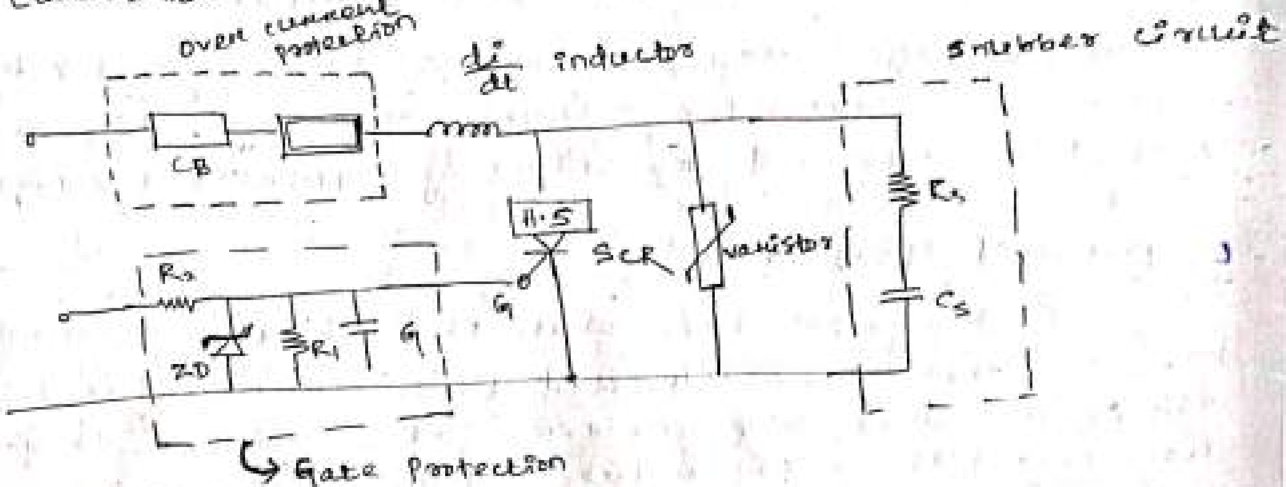
→ If the supply is ~~stiff~~ overload; current is limited by the source and motor impedance.

→ over current can be interrupted by conventional fuses and circuit breakers.



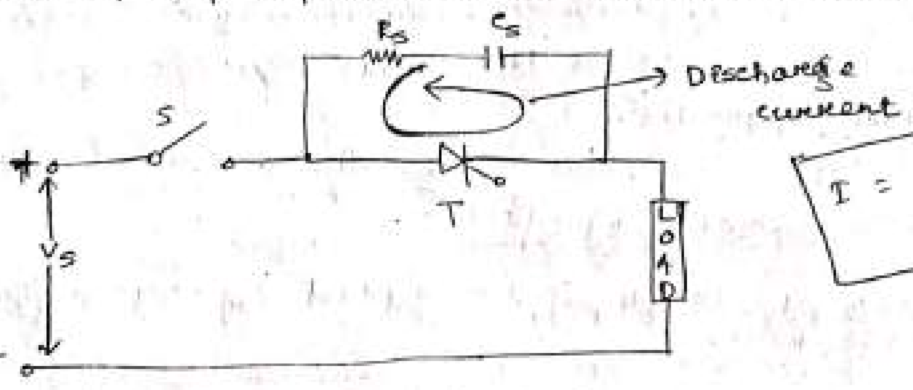
* Gate protection:-

→ Gate circuit should also be protected against overvoltages and overcurrents. overvoltages across the gate circuit can cause false triggering of the SCR. overcurrent may raise junction temperature beyond specified limit leading to its damage. Protection against over-voltages is achieved by connecting a zener diode ZD across the Gate circuit. A Resistor R_2 connected in series with the Gate circuit provides protection against over currents.



Design of snubber circuit

→ A snubber circuit consists of a series combination of Resistance R_s and capacitance C_s in parallel with the thyristor.



$$I = \frac{V_s}{Resistance}$$

→ snubber circuit is energy absorbing circuit use to suppress the voltage spikes cause by the the circuit inductance when a switch, electrical or mechanical open.

→ Device is sufficient prevent unwanted dv/dt triggering of the SCR.

(*) switch close, sudden voltage appears across the ckt. capacitor C_s behaves like a short circuit, therefore voltage across SCR is zero.

(*) with the passage of time, voltage across C_s builds up at a slow rate such that $\frac{dv}{dt}$ across C_s and therefore across

SCR is less than the specified Maximum $\frac{dv}{dt}$ rating of the the device.

→ Why R_s is connected Series to C_s.

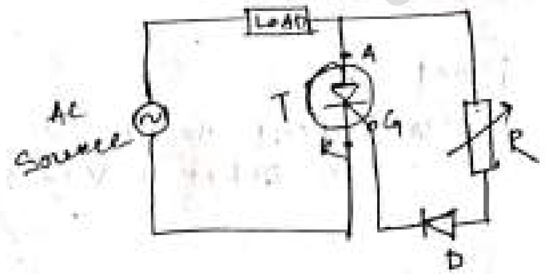
→ Before SCR is fired by gate pulse, C_s charges to Full Vtg V_s. When the SCR is turned on, capacitor discharges through the SCR and sends a current equal to V_s/(resistance of local path formed by C_s and SCR). As this 'R' is quite low, the turn on $\frac{di}{dt}$ will tend to be excessive and as a result, SCR may destroyed.

→ In order to limit the magnitude of discharge current, a resistance R_s is inserted in series with C_s. Now, when SCR is turned on, Initial discharge current $\frac{V_s}{R_s}$ is relatively small and turn-on $\frac{di}{dt}$ is reduced.

Firing circuits

R Firing circuits or Resistance triggering circuit:-

→ In R-Firing method, the variable 'R' is used to control the gate current

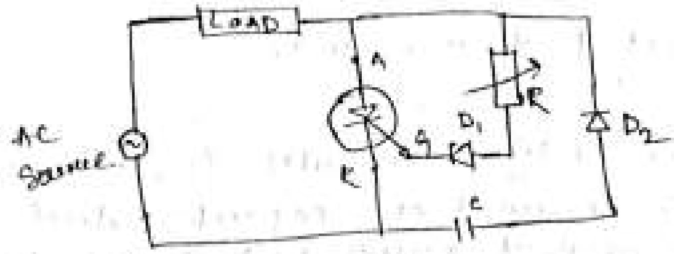


→ Depending upon the value of R, when the magnitude of the gate current reaches the sufficient value (latching current of the device) the SCR starts to conduct.

→ The diode (D) is called as blocking diode. It prevents the gate cathode junction from getting damaged in the negative half cycle.

→ By considering that the gate circuit is purely resistive, the gate current is in phase with the applied voltage. By using this method we can achieve Max^m Firing angle up to 90°.

RC - Firing circuit :— (R-C Triggering ckt)



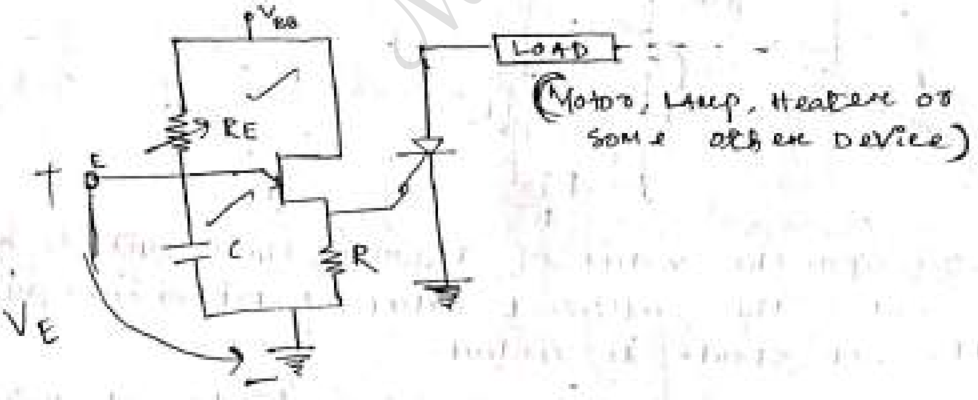
→ By using this Method we can achieve Firing angle more than 90°.

→ In +ve half cycle, the 'C' is charged through the variable Resistance R up to the peak value of the applied voltage. The variable 'R' controls the charging time of capacitor. Depends upon the voltage across the capacitor, when sufficient amount of gate current will flow in the circuit, SCR start to conduct.

→ In -ve half cycle, the capacitor 'C' is charged up to the -ve Peak value through the D_2. D_1 is used to prevent the Reverse break down of gate cathode junction in the -ve half cycle.

UJT Pulse triggering circuit:-

→ common Application of Uni Junction Transistor is the triggering of the other devices such that SCR, TRIAC etc.



→ The Resistor R_E is chosen so that the load line determined by R_E passes through the device characteristics in the -ve Resistance region. that is, to the right of the peak point but to the left of the valley point. If the load line does not pass to the right of the peak point P, the device can't turn on.

→ For ensuring turn-on of UJT, $R_E < \frac{V_{BB} - V_P}{I_P}$

consider the peak point at which $I_{RE} = I_P$ and $\boxed{V_E = V_P}$

Than $V_E = V_{BB} - I_{RE} R_E$

So, $R_E(MAX) = \frac{V_{BB} - V_{BE}}{I_{RE}} = \frac{V_{BB} - V_P}{I_P}$ at the peak point

→ At the valley point point, V

$I_E = I_V$ and $V_E = V_V$ so that $\boxed{V_E = V_{BB} - I_{RE} R_E}$

→ At $R_E(MIN) = V_{BB} - \frac{V_E}{I_{RE}} = V_{BB} - \frac{V_V}{I_V}$ (or) For ensuring turn off

$R_E > = V_{BB} - \frac{V_V}{I_V}$

So, the range of resistor R_E is given as

$$V_{BB} - \frac{V_P}{I_P} > R_E > V_{BB} - \frac{V_V}{I_V}$$

→ The resistor R is chosen small enough so as to ensure that SCR is not turned on by voltage V_R when emitter terminal E is open or ($I_E = 0$).

→ The voltage $V_R = RV_{BB}/R + R_{BB}$ for open-emitter terminal.

① The capacitor C determines the time interval between triggering pulses and the time duration of each pulse. By varying R_E, we can change the time constant $R_E C$ and alter the point at which the UJT fires. This allows us to control the conduction angle of the SCR, which means the control of load current.

Semi - converter

→ A semi converter is a one quadrant converter and it has one polarity of o/p vtg and current. It contains a mixture of diodes and thyristors allowing more limited control over the dc o/p voltage level than the full controlled rectifier. It is cheaper.

→ It permits power flow from AC system to DC load. It is also known as half-wave controlled converter.

Full ~~Dual~~ - converter:-

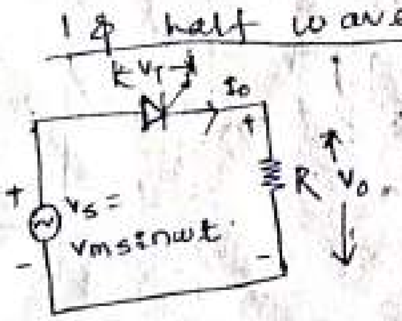
→ A full-converter is a two-quadrant converter and the polarity of its o/p voltage can be either +ve or -ve. However the o/p current of full-converter has one polarity only. Here power can be transmitted from AC side to DC side (conversion) and from DC side to AC side (inversion).

→ It uses only thyristor as rectifying elements.

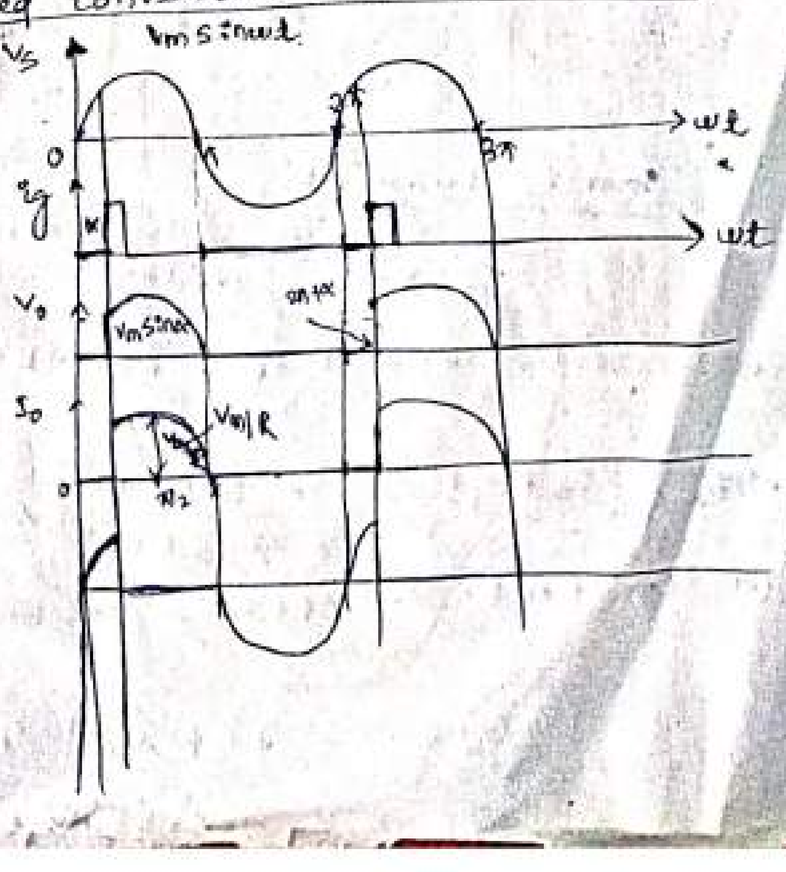
Dual-converter:-

If two full converters are connected back to back they form a dual converter. It can operate in four quadrants and both the o/p voltage & current can be either +ve or -ve. Normally these are used in high power application.

(*) 1φ half wave controlled converter with 'R' loads:-



$$V_s = V_T + V_o$$



* circuit turn off time $t_c = \pi/\omega$ sec ($\omega = 2\pi f$)

(*) Average o/p voltage, $V_0 = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_m \sin\omega t \cdot d(\omega t)$

$$\frac{V_m}{2\pi}(1+\cos\alpha)$$

(*) Average load current $I_0 = \frac{V_0}{R} = \frac{V_m}{2\pi R}(1+\cos\alpha)$

(*) rms value of load voltage = $V_{or} = \left[\frac{1}{2\pi}\int_{0}^{\pi} V_m \sin\omega t \cdot d(\omega t)\right]^{1/2}$

$$= \frac{V_m}{2\pi}\left[(\pi-\alpha)+\frac{1}{2}\sin 2\alpha\right]^{1/2}$$

(*) RMS o/p current $I_{or} = \frac{V_{or}}{R}$

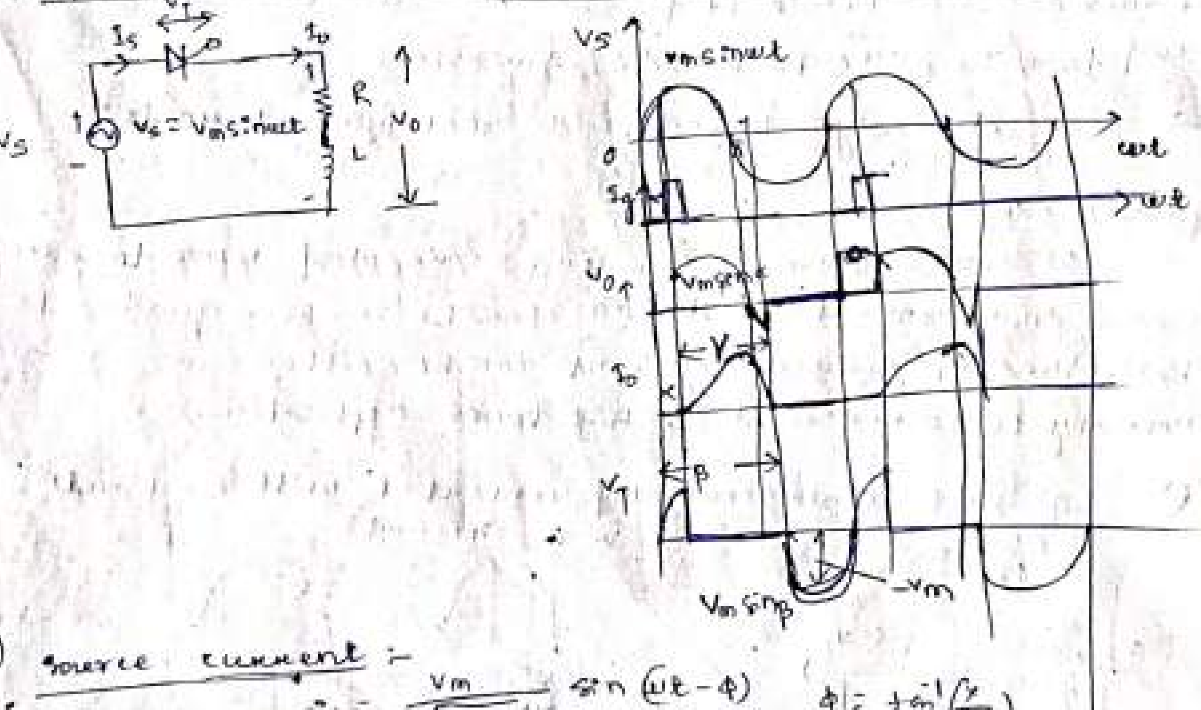
(*) power deliver to resistive load = (RMS load voltage)(RMS load current)

$= V_{or} \cdot I_{or} = V_{or}^2 / R = I_{or}^2 r$

(*) Input power factor:

$$pf = \frac{1}{\sqrt{2}\pi}\left[(\pi-\alpha)+\frac{1}{2}\sin 2\alpha\right]^{1/2}$$

(*) 1φ half wave controlled converter with R-L load:



(*) source current :-

$i_s = \frac{V_m}{\sqrt{R^2+x^2}}\sin(\omega t-\phi)$ $\phi = \tan^{-1}\left(\frac{x}{R}\right)$, $x = \omega L$

(*) Transient component i_t = $R i_t + L\frac{di}{dt} = 0$ $i_t = A e^{-(R/L)t}$

(*) $i_0 = i_s + i_t = \frac{V_m}{Z}\sin(\omega t-\phi) + A e^{-(R/L)t}$ $Z = \sqrt{R^2+x^2}$

(*) constant A obtain from boundary condition $\omega t = \alpha$

$t = \alpha/\omega$, $i_0 = 0$

$0 = (V_m/Z)\sin(\alpha-\phi) + A e^{-R\alpha/L\omega} \Rightarrow A = \frac{-V_m}{Z}\sin(\alpha-\phi) \cdot e^{R\alpha/L\omega}$

$$i_0 = \frac{V_m}{Z}\sin(\omega t-\phi) - V_m/Z\,\sin(\alpha-\phi)\,\exp.\left(-R/\omega L\,(\omega t-\alpha)\right)$$

(*) We also seen from wave form $\omega t = \beta$, $i_0 = 0$

$$= \sin(\beta-\phi) = \sin(\alpha-\phi)\,\exp.\ -R/\omega L(\beta-\alpha)$$

(*) Avg o/p voltage $V_0 = \frac{1}{2\pi}\int_{\alpha}^{\beta} V_m \sin\omega t \cdot d(\omega t)$

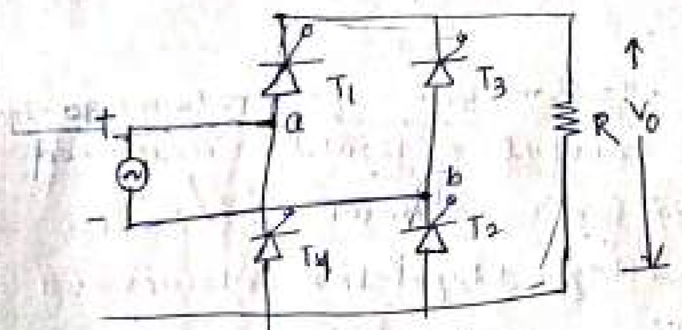
$$V_0 = \frac{V_m}{2\pi}(\cos\alpha - \cos\beta)$$

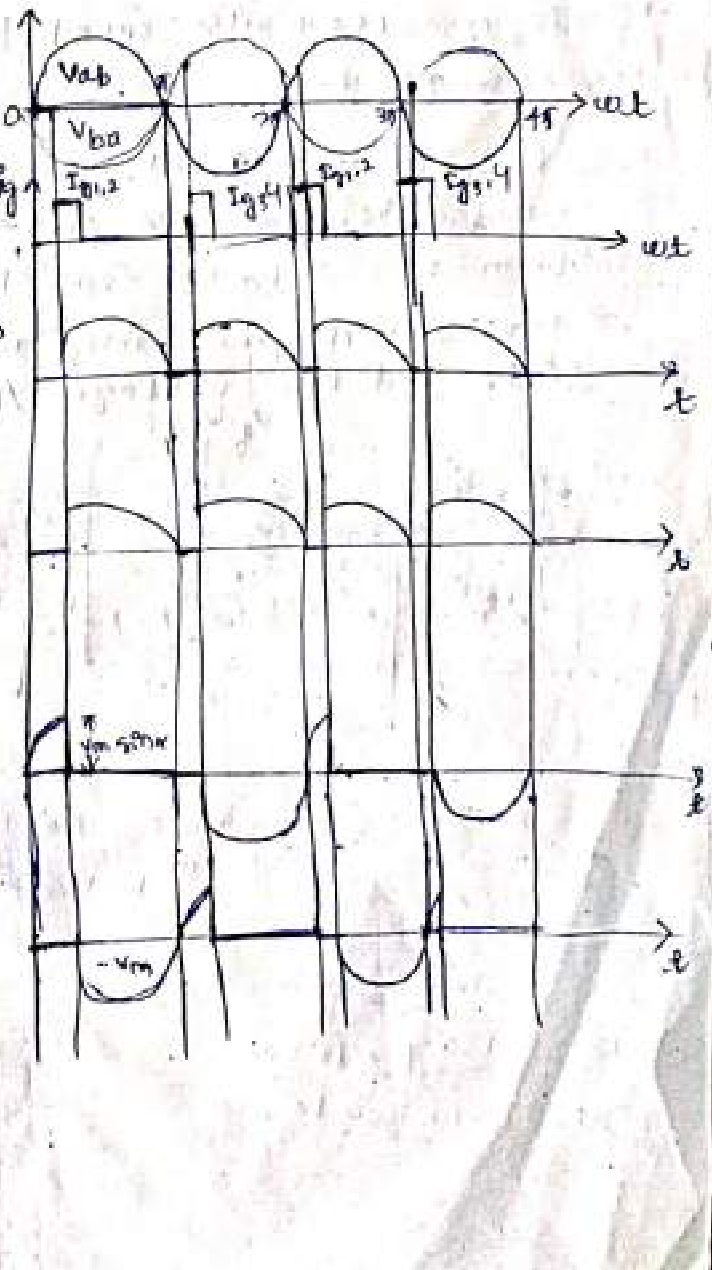
Avg load current $I_0 = \frac{V_0}{R} = \frac{V_m}{2\pi R}(\cos\alpha - \cos\beta)$

rms value of load voltage $V_{or} = \left[\frac{1}{2\pi}\int_{\alpha}^{\beta} V_m^2 \sin^2\omega t \cdot d(\omega t)\right]^{1/2}$

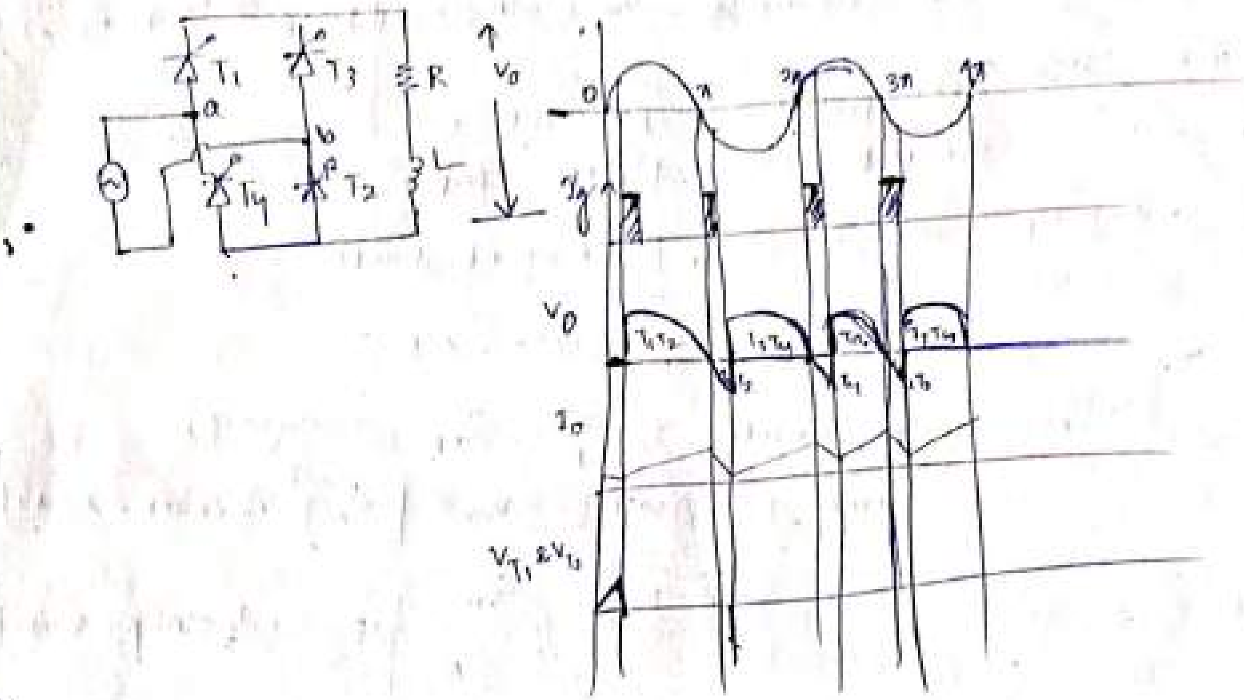
$$\frac{V_m}{2\sqrt{\pi}}\left[(\beta-\alpha) + \frac{1}{2}\sin 2\beta - \sin 2\alpha\right]^{1/2}$$

Single phase Full controlled converter with R L (Bridge)





④ Single phase Full converter with RL Load:-

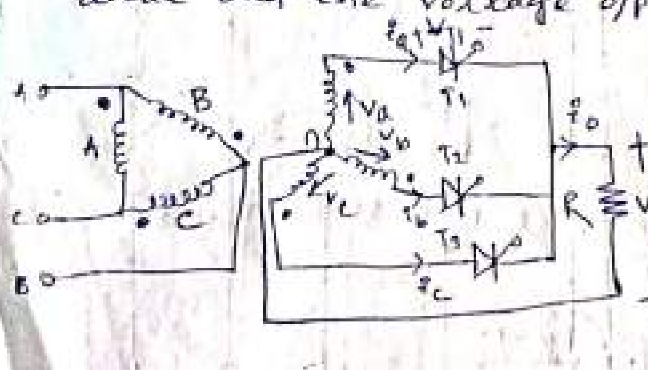


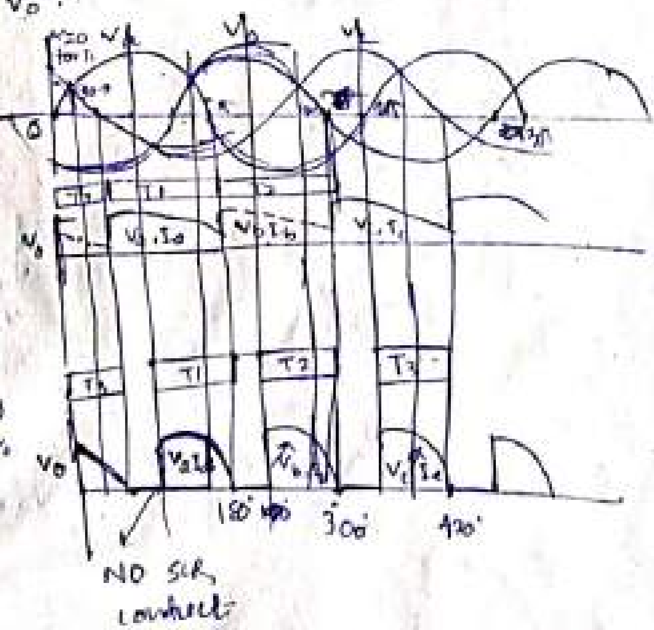
⑤ 3φ half wave controlled converter with R Load

→ This converter also called 3-phase 3 pulse converter or 3 phase M3 converter.

→ SCR T_1 conducting $\omega t = 30° - 150$, T2 from 150 – 270, T3 from 270–390. Firing angle for this controlled converter would be measured from $\omega t = 30°$ for T_1, from $\omega t = 150°$ for T_2, from $\omega t = 270°$ for T_3.

→ For zero degree firing angle delay, thyristor behaves as a diode and the voltage o/p V_o.





→ α < 30° (Each SCR conducts 120°) The waveform of i_o & v_o identical.

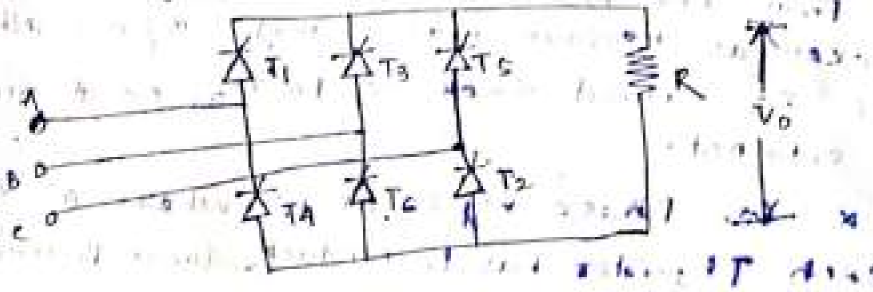
→ α > 30°

T_1 → 30° + α to 180°

T_2 → 150° + α to 300

T_3 → 270° + α to 120

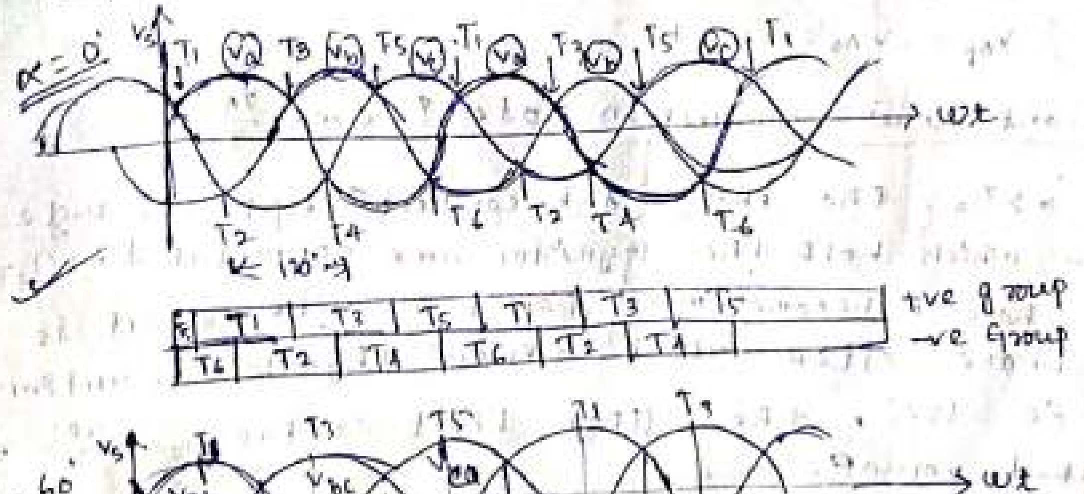
3φ fully controlled converter with 'R' Load

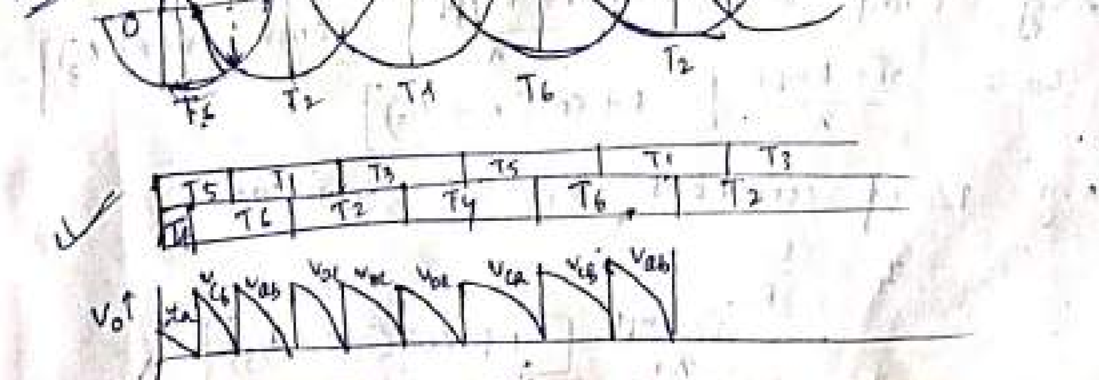


→ In the case of fully controlled bridge rectifier, there are six thyristors where T1, T3, T5 forms positive group of thyristors, T2, T4, T6 forms negative group of thyristors.

→ It consists of 3φ T/F where the primary side is delta connected & secondary is connected in Y or Δ. The purpose of T/F is for isolation of the o/p from the supply source and also for higher o/p requirements. This circuit is mainly for large power drives. The positive group thyristors are turned on when the supply voltage is +ve and -ve group of thyristors are turned on when the supply voltage is -ve.

→ In the case of bridge rectifier, two thyristors must be turned on at any instant of time. One from the upper arm and other from the lower arm. Each thyristor in the +ve and negative group conducts for a length of rad.





*) **Continuous conduction mode ($0 \le \alpha \le \pi/3$)**

From the phase cross over point, the reference point is taken as minimum firing angle $\alpha = 0°$. When the firing angle is varied from 0° to $\pi/3$, continuous mode of operation is obtained.

→ α = 60 phase vtg is at 90°; where as V_L = 120°. Since each Thyristor has to conduct for a period of 60°, it has chance to conduct from 120° to 180°.

The Avg o/p vtg = $\frac{3\sqrt{3}\, E_{mph}}{\pi} \cos\alpha$

(*) Avg load current $I_o = \frac{E_o}{R}$

$$I_o = \frac{3\sqrt{3}\, E_{mph}}{\pi R} \cos\alpha$$

(*) Avg Thyristor current is given as

$$I_{th} = \frac{1}{3} I_o$$

(*) RMS Thyristor current $I_{Th\,rms} = \frac{I_o}{\sqrt{3}}$

(*) Transformer secondary current

$$I_s = \sqrt{2}\, I_{Th\,rms}$$

$$= \sqrt{\frac{2}{3}}\, I_o$$

(*) PIV = $\sqrt{2}E$ (E → line voltage)

(*) VA rating of the T/F is given as

$$VA_p = VA_s = \sqrt{3}\, E I_a$$

(*) **Discontinuous conduction mode ($\frac{\pi}{3} < \alpha < \frac{2\pi}{3}$)**

→ When $\alpha > \pi/3$, the phasor A-B conducts upto the angle π after which both the thyristor are commutated i.e (T_1, T_6) because phase B becomes more positive with respect to other phase after $\omega t = \pi$. Since, thyristor conduction period is 120°, the upper limit is taken as $\frac{2\pi}{3}$. ~~associated voltage and~~

1. Avg Load vtg = $\frac{3\sqrt{3}\, E_{mph}}{\pi}\left[\cos\pi - \cos(\alpha + \pi/3)\right]$

(or) $E_o = \frac{3\sqrt{3}\, E_{mph}}{\pi}\left[1 + \cos(\alpha + \pi/3)\right]$

2. Avg Load current (I_o) is given as

$$I_o = \frac{E_o}{R}$$

$$= \frac{3\sqrt{3}\, E_{mph}}{\pi R}\left[1 + \cos(\alpha + \pi/3)\right]$$

1ϕ AC Regulator :—

→ 1ϕ AC Regulator is voltage converter.

AC - AC converter (change V & f)

- ACVR (V = variable, f = constant)
- cycloconverter: V = variable, f = variable

Application

→ speed control of AC motor → fans

→ Room heater (voltage ↑↓)

→ voltage control (power S/m)

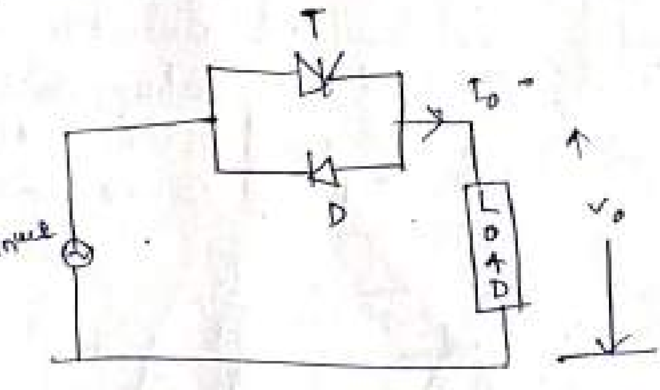
→ Reactive power compensation.

AC power → ACVR → AC power

V = fixed ✓
f = fixed ✓

variable controlled voltage, constant frequency (RMS Vtg)

(*)



(1) During +ve

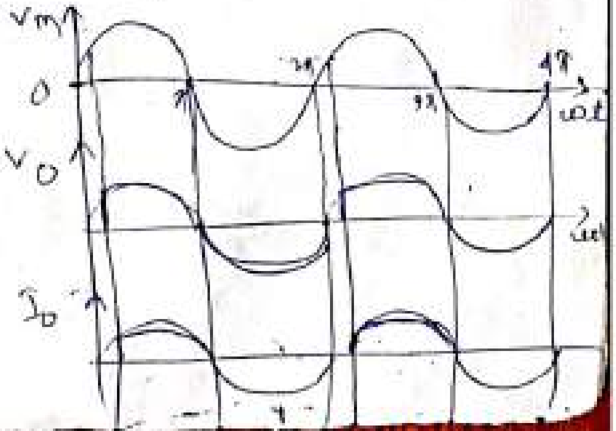
$0 < wt < 180$

$wt > \alpha$: T → ON (F.B) conducts after firing pulse ✓

(2) During -ve :—

$180 < wt < 360$.

D is F.B → immediately conducts



K.Haribabu

DC-DC converter [chopper]

→ It is a static PE ckt which converts ~~DC~~ fixed DC to variable D.C i.e variation in magnitude voltage

→ It has 3 types

(a) Buck converter (step down chopper) ($V_0 < V_s$).

(b) Boost converter (step up chopper) ($V_0 > V_s$)

(c) Buck-Boost converter (step up. down) ($V_0 = V_s$)

~~(*) step up~~

Uses

→ It provides smooth speed control

→ Losses are low, high efficiency because of single state power conversion.

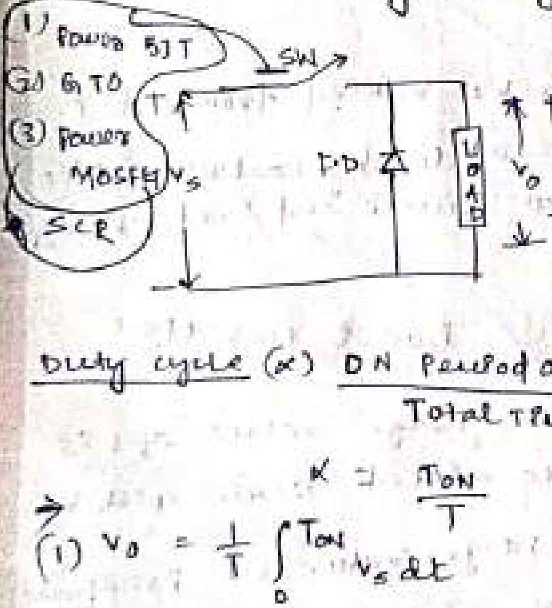
→ Fast dynamic response

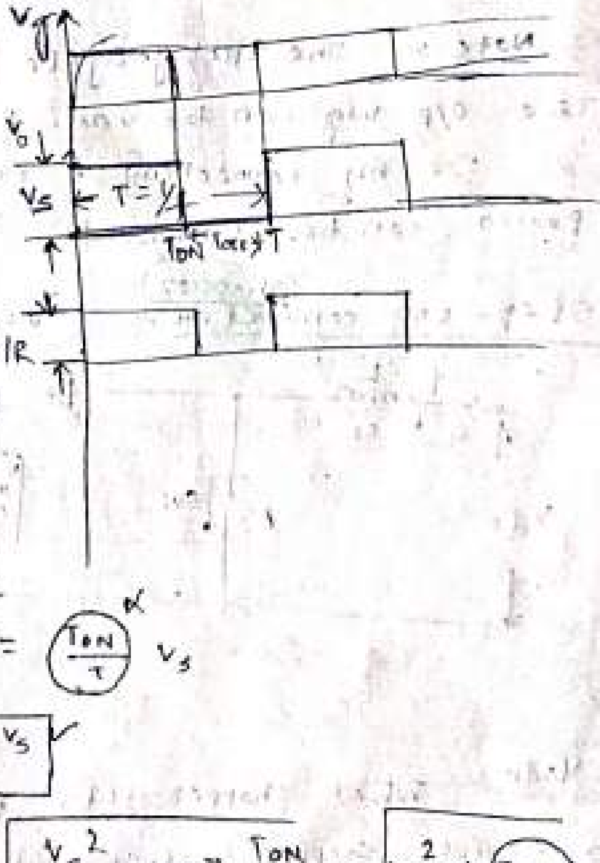
→ Regeneration capability when applied in drive control.

→ Saving in power and small size

(*) **Step down chopper / Buck converter:-**

Step down is a circuit in which the o/p voltage is less than the supply voltage V_{dc}.





Duty cycle (α) $= \dfrac{\text{ON Period of chopper}}{\text{Total time period}}$

$$\alpha = \frac{T_{ON}}{T}$$

→ (1) $V_0 = \frac{1}{T}\int_0^{T_{ON}} V_s\,dt$

$$\frac{V_s}{T} * t\Big]_0^{T_{ON}} = \frac{V_s}{T} * T_{ON} = \left(\frac{T_{ON}}{T}\right) V_s$$

$$\Rightarrow \boxed{V_0 = \alpha V_s}$$

(2) $V_{0R} = \sqrt{\frac{1}{T}\int_0^{T_{ON}} V_s^2\,dt} = \sqrt{\frac{V_s^2}{T} * t\Big]_0^{T_{ON}}} = \sqrt{V_s^2 * \left(\frac{T_{ON}}{T}\right)}$

$$\boxed{V_{0R} = V_s\sqrt{\alpha}}$$

$\Rightarrow I_0 = \frac{V_0}{R}$

$\Rightarrow I_{or} = \frac{V_{or}}{R}$

⇒ RMS value of O/P voltage is more than avg O/P voltage.

→ When the switch (SW) is closed for a time period (T_{ON}), the current starts flowing through the load resistance R. The load current direction is given as V_{dc}^+ - SW - R - V_{dc}^-

→ During the ON-period, the source voltage is transferred to the load side, neglecting the voltage drop across the switch. The voltage drop across the switch may vary b/w 0.5V to 1V.

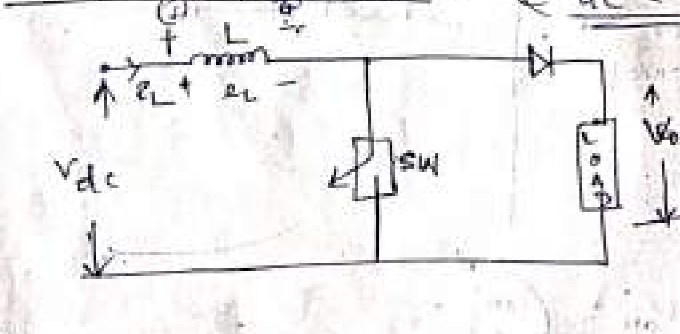
→ When the switch is OFF, by using a forced commutation ckt, the load O/P voltage is disconnected from the source. The O/P vtg is zero and no current will flow during the OFF period (T_{OFF}) of the chopper.

$$P_0 = \frac{I_0^2}{R}\alpha = \frac{E_{dc}^2}{R} * \alpha$$

$$\boxed{R_i = R/\alpha}$$

Note :- The duty cycle 'α' can be varied from 0 to T. The O/P vtg can be varied from 0 to V_{dc} by controlling the 'α' i.e by connecting a switch b/w source and load, the O/P power can be controlled.

Step-up converter (Chopper) :- ($V_{dc} < V_0$) / Boost converter



→ Large value of L is connected series with V_s.

→ Larger value of 'L' preferred for getting lesser ripple in the O/P vtg & to get continuous current.

Mode-1 When chopper gets turned on, inductor 'L' gets connected to series supply voltage and hence it stores energy during ON period T_{ON}.

Now, the closed current path is given as V_{dc}^+ - L - CH - V_{dc}^-

Mode - 2

→ When the chopper gets turned OFF, the inductor current is forced to flow through diode and hence load, for a period of T_{OFF}. Polarity of the inductor gets changed, the current tends to flow in the same direction. Which exceeds the V_{dc}. The inductor vtg gets add vdc, in that way stored energyes released to load.

DC applied a pure L

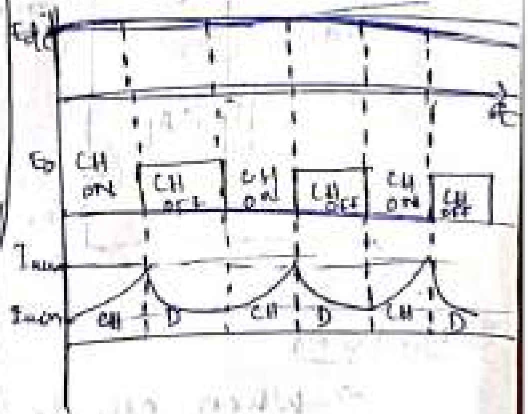
$$V_s = L\frac{di}{dt}$$

$$\int di = \int \frac{V_s}{L} dt$$

$$i = \frac{V_s}{L} t + K$$ At $t = 0^+, i = 0$

$$0 = 0 + K$$

$K = 0$ $\quad$ $i = \frac{V_s}{L} t$



(4)

→ During the ON time (T_{ON}), the energy stored in the inductor → $W_i = V_{dc} I_s T_{ON}$.

→ During the OFF time (T_{OFF}), the energy release by Inductor:

$$W_o = (V_o - V_{dc}) I_s T_{OFF}$$

Steady state condⁿ (lossless)

$$V_{dc} I_s T_{ON} = (V_o - V_{dc}) I_s T_{OFF}$$

$T = T_{ON} + T_{OFF}$

$T_{OFF} = T - T_{ON}$

$$\Rightarrow V_o T_{OFF} - V_{dc} T_{OFF} = V_{dc} T_{ON}$$

$$\Rightarrow V_o T_{OFF} = V_{dc} T_{ON} + V_{dc} T_{OFF}$$

$$\Rightarrow V_o = \frac{V_{dc}(T_{ON} + T_{OFF})}{T_{OFF}}$$

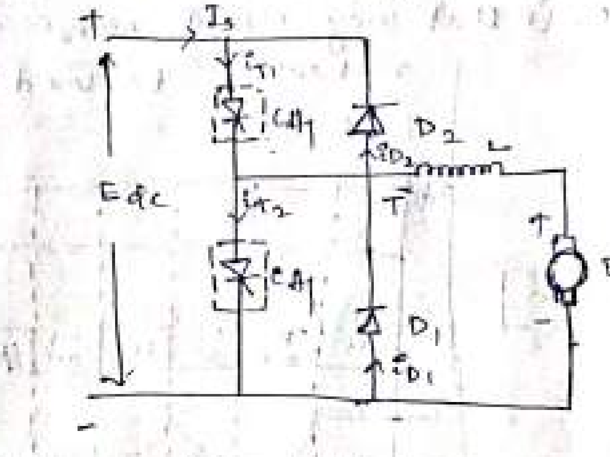
$$V_o = \frac{V_{dc}}{1 - \alpha}$$

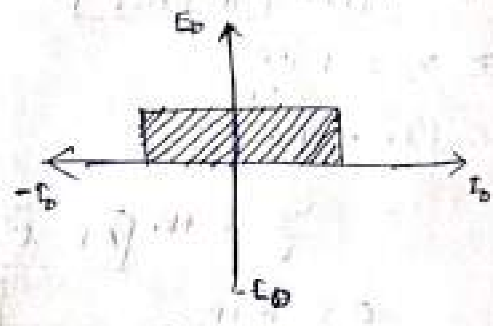
When $\alpha = 0$, $V_o = V_{dc}$

When $\alpha = 1$, $V_o = \infty$

Type C chopper or Two Quadrant Type A Chopper.

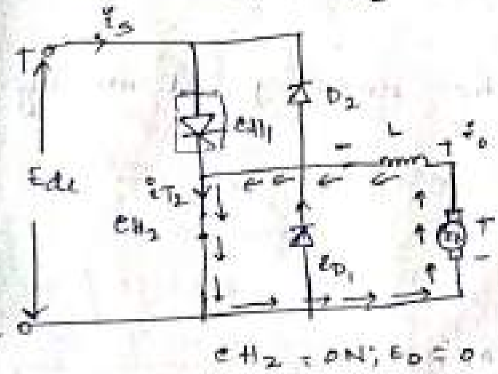
→ In the case of 'C' type chopper, type-A and type-B chopper are connected in parallel. Due to the presence of the free wheeling diode, the o/p voltage (E_0) becomes positive always.



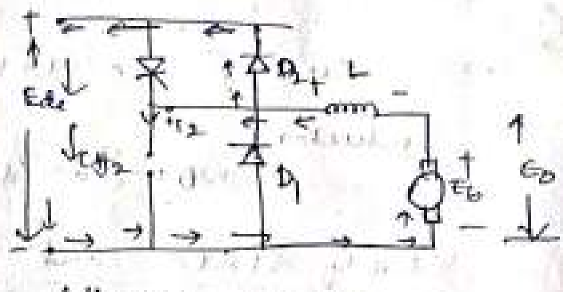


Mode-1

→ When CH_2 is turned on, E_b will drive the power who path is given as $E_b^+ - L - CH_2 - E_b^-$. The o/p voltage across the load zero. The energy will be stored in the inductor during the on-p of the chopper CH_2.



$CH_2 = ON; E_0 = 0$

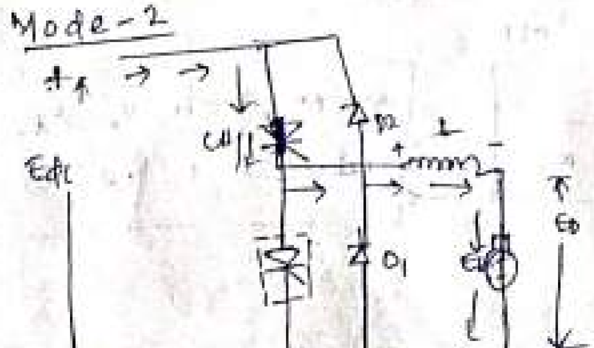


CH_2 OFF, $E_0 = Edc$

→ When CH_2 is turned off, the stored energy in the inductor reverses its polarity, and makes the diode (D_2) forward biased. Now current flowing $E_b+ - L - D_2 - Edc+ - Edc- - E_b^-$

→ power transferred from the load to source.

Mode-2

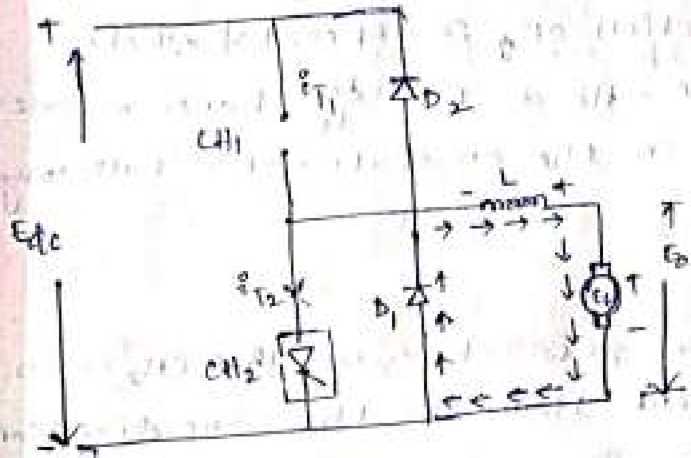


$CH_1 - ON;\ E_0 = Edc$

→ When the chopper CH_1 is turned on power will flow from source to the load. The power flow direction will be $Edc_+ - CH_1 - L - E_{b+} - E_{b-} - Edc_-$.

→ The o/p voltage will be $E_0 = Edc$.

→ During CH_1 ON, there will be some stored energy in the inductor.

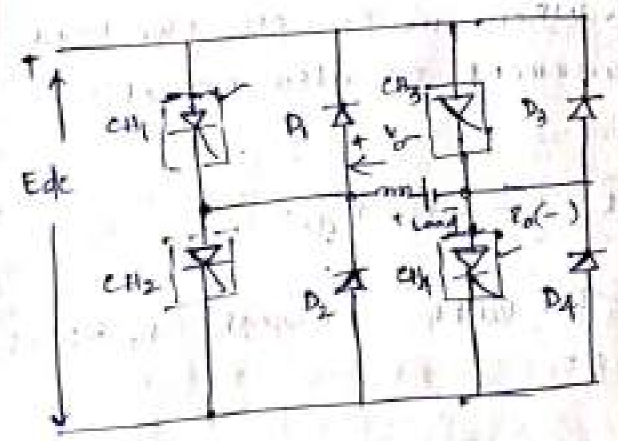


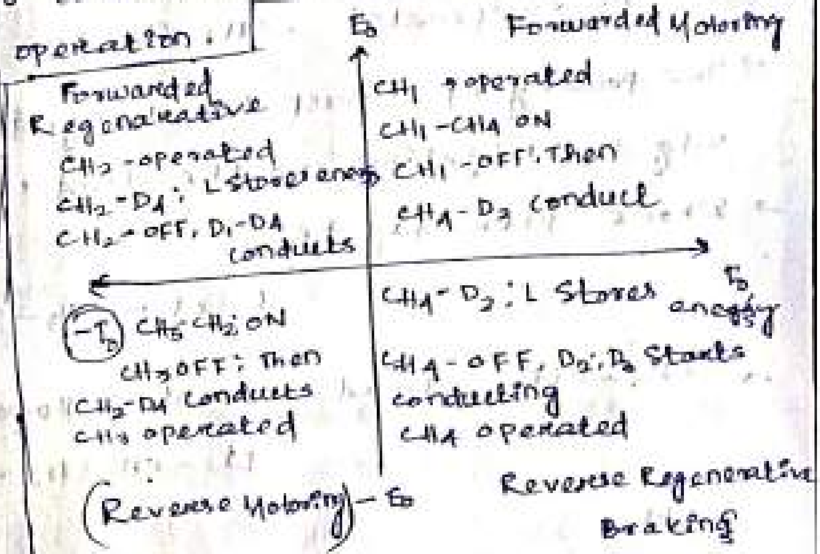
CH_1 - OFF; $E_0 = 0$

→ When CH_1 is turned off, the stored energy in the inductor tries to change its polarity and maintain the current in the same direction. During this period D_1 is forward biased and the load o/p voltage $E_0 = 0$.

(4) Four quadrant chopper or type E chopper :- (K. Harikabu)

→ It consists of four semiconductor switches known as choppers namely CH_1, CH_2, CH_3 and CH_4. It also consists of four diodes D_1, D_2, D_3 and D_4 for four quadrant chopper operation.





(1)

→ For the first quadrant operation, CH_1 is operated where CH_4 is in the ON state and CH_3, CH_2 are turned OFF state. The load current follows the path

$$Edc^+ - CH_1 - L - E - CH_4 - Edc$$

→ Both load voltage and load current are positive and hence the power flows from source side to load side.

→ When CH_1 is turn OFF, the load current follows the same path by reversing the polarities of the inductor through the conducting diode D_2. The load current path

$$L^+ - E - CH_4 - D_2 - L^-$$

2nd

→ For the second quadrant operation CH_2 is operated while CH_1, CH_3, CH_4 are in the OFF state. Here $E > \frac{Ldi}{dt}$. Hence reverse current flows whenever CH_2 is in the on state. It's path may be given as.

$$E^+ - L - CH_2 - D_4 - E_-$$

→ During this period, the inductor gets charged. When CH_2 is in the OFF state, the load current flows in the same direction

$$L^+ - D_1 - E_{dc}^+ - E_{dc}^- - D_4 - E - L^-$$

→ Power is fed back from load to source as voltage

$$E + \frac{Ldi}{dt} > E_{dc}$$

3rd

→ CH_3 is operated, CH_1, CH_4 are OFF, CH_2 is in ON.

→ The polarity of E must be changed. When CH_3 is on the load vtg is negative and the load current is also negative

→ Whose path may be

$$E_{dc}^+ - CH_3 - E - L - CH_2 - E_{dc}^-$$

→ CH_3 - OFF, load current follows the path through CH_2 & diode D_4

$$L^+ - CH_2 - D_4 - L^-$$

4th

→ CH_4 operated, CH_1, CH_3, CH_4 OFF. Here also, the chopper operates only when polarity of E is reversed.

→ The load current $E^+ - CH_4 - D_2 - L - E^-$

→ The current direction is +ve, whereas load vtg -ve. Whenever CH_4 is OFF, the load current follows the path as shown by conducting diode D_2 and D_3

$$L^+ - E - D_3 - E_{dc}^+ - E_{dc}^- - D_2 - L^-$$

→ The power is fed back to source from load.

Inverters

Inversion:- The Process of converting D.C power to AC power

Inverter:- The device which converts DC power to AC power at a certain o/p vtg and frequency or at a certain current level and Frequency.

Industrial applications of Inverter

1. variable speed AC Motor drives.
2. Induction heating.
3. Uninterruptible power supplies.
4. Stand by aircraft power supplies
5. HVDC Transmission lines.

Classification of Inverters:-

1. Line commutated Inverters
2. Forced commutated Inverters.
3. Load commutated Inverters.
4. Voltage source Inverters.
5. current source Inverters.

Inverters are also classified as, depending upon the connection of commutating components with the Main circuit.

a. Series Inverters
b. parallel Inverters
c. Bridge Inverters.

1) Line commutated:- Line commutated Inverters are those devices where the phase controlled converters operates in an inversion Mode i.e (90<α<180) In the case of AC ckt. AC line vtg is available across the device. Whenever the current through the thyristor passes the natural zero value. it gets turned off. This process of commutation is known as line commutation or natural commutation.

2 Forced commutated:-
→ In the case of D.C circuits

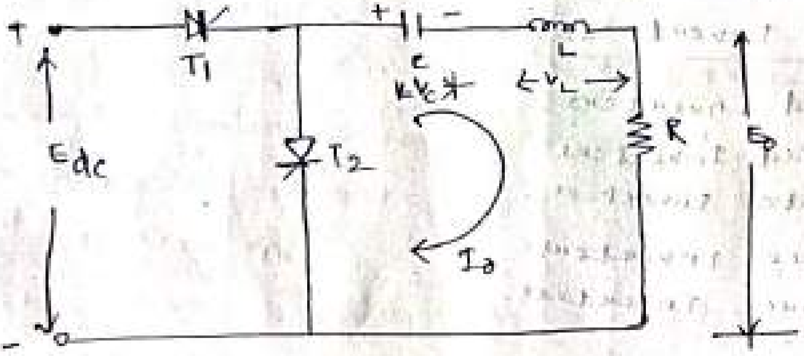
→ Inverters are also classified, depending upon the connection of commutating components with the Main circuit.

(a) Series Inverters
(b) Parallel Inverters
(c) Bridge Inverters → 1 φ half bridge Inverters.
→ 1 φ Full bridge Inverters.

Series Inverters

→ Series Inverters are those Inverters in which the commutating elements L and C are connected in series with the load. This circuit consists a series R-L-C resonance circuit. Produced high O/P freq range 200 Hz - 100 kHz.

→



Construction / (Circuit Description)

→ It consists of two thyristors which are used to produce the +ve and -ve half cycles respectively in the o/p. The commutating elements L and C are connected in series with the load. The value of L & C are selected that they form an under damped circuit, to produced the required oscillations.

→ $R^2 < \frac{4L}{C}$ the above condition full filled, where the values of L and C are selected by satisfying the above relation.

Working :-

Mode-1

→ Th T_1 is triggered by giving a gate signal to it. Th T_1 start conducting. As results current flowing through R-L-C, and capacitor gets charged up to Ec. Load current flows through the path $E_{dc}^{+} - T_1 - C - L - R - E_{dc}^{-}$

→ The load current produced is of alternating in nature which is due to the underdamped ckt formed by commutating elements.

→ When the load current reaches its peak value, the voltage across the capacitor is given as Edc.

→ Ec is the initial voltage across the capacitor when T_1 triggered. When the load current reaches a zero value, SCR T_1 gets turned off.

Mode-2

→ During this Mode, the load current remains constant for a sufficient period of a time before SCR T_2 is triggered. It is necessary to Maintain load current constant in order to prevent dead short circuit of supply.

→ Which may be caused when both the SCRs are in the conducting Mode. During this Mode, both T_1 and T_2 are in off State. Here the capacitor vtg remains constant.

Mode-3

→ When T_2 is triggered, it start conducting and the capacitor 'c' gets discharged through it. Here the load current direction is opposite to that of the load current direction of Mode(1)

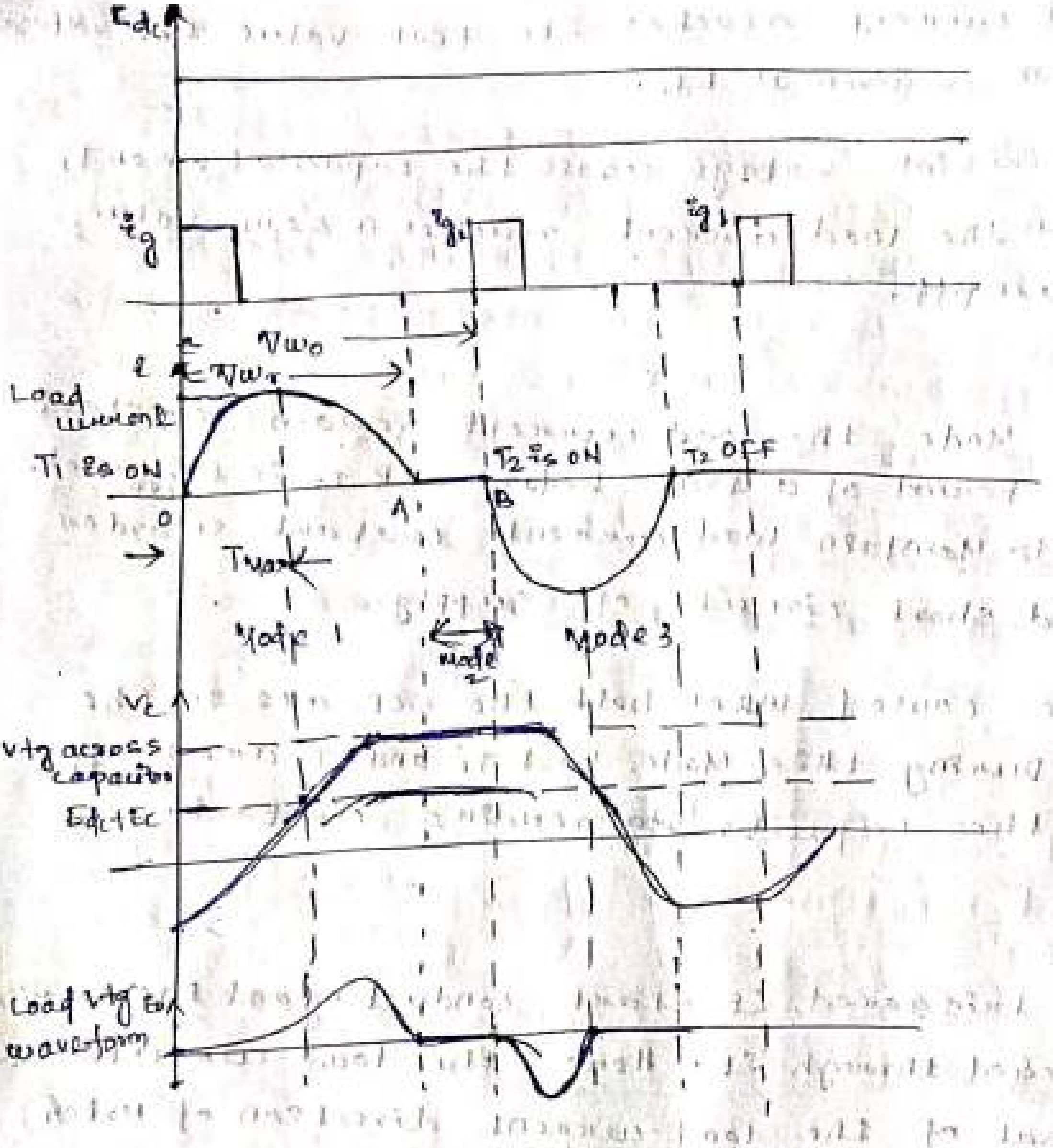
→ The load current flows through the path.

$$c^+ - T_2 - R - L - c^-$$

→ This current builds up to the negative Maximum and then reaches a zero value. When the load current reaches a zero value, T_2 get turned off. Depending upon the values of R, L and c the voltage across the capacitor gets reversed to some value.

→ After some time, again T_1 triggered and the above Process is Repeated. Hence alternating o/p which is of sinusoidal in nature is obtained.

→ The current has been drawn from supply for +ve alternation of AC o/p whereas it is drawn from capacitor, for -ve alternation of A.C o/p.



CONS:-

→ Power Flow From the dc suppy is discontinuous.

→ The dc supply will have a high peak current and hence contains harmonics.

→ If proper time delay is not ensured b/w the turn off process of thyristor T_1 and turn on process of Thyristor T_2, short circuit of supply voltage takes place.

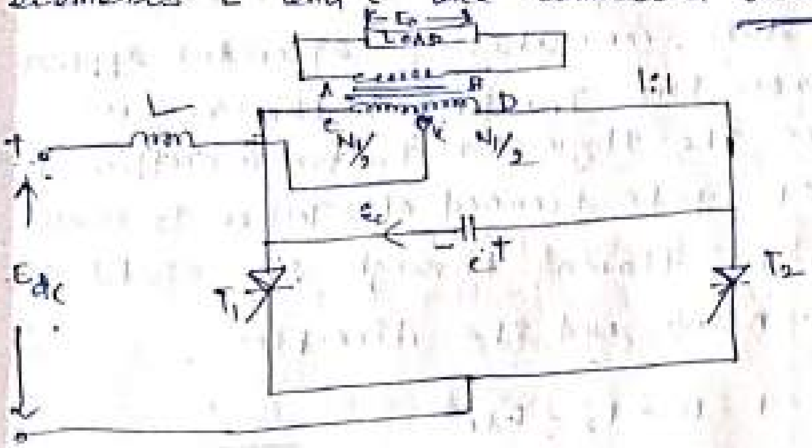
→ As the current drawn from dc source is discontinuous, more ripples are present in it.

→ Load ckt parameters determine the peak amplitude and duration of load current which results the poor output regulation of an inverter.

→ The ratings of the commutating elements must be high because these components carry load current continuously and the capacitor supplies the load current in every alternate half cycle.

Parallel Inverter:-

→ Parallel inverter are those inverters where the commutating elements L and C are connected across the load.



Construction/ Circuit Description:-

→ It consists of two thyristors T_1 & T_2 connected to the primary of the transformer. The capacitor is connected across load via T/F. Hence it is known as parallel inverter.

→ The function of L is to make source current constant at I_0 and in order to prevent the instant discharge of capacitor 'c' whenever thyristor switching occurs. Parallel inverter is generally used to produce a square wave from the D.C source.

Mode-1

→ At the instant t=0, T_1 is turned on. The current starts flowing through the leftside of the primary winding, and its direction is given by

$$E_{dc}^{+} - L - K - C - T_1 - E_{dc}^{-}$$

→ As a result, supply voltage E_{dc} appears across the left half of the T/F primary. Bcz of the closely coupled coil and same number of turns the voltage across the DK is also E_{dc}. By the dot convention, the voltage across KC = $+E_{dc}$ voltage across DK = E_{dc}.

→ On the secondary side of the T/F $2E_{dc}$ is induced. Hence the capacitor gets charged to a voltage of $2E_{dc}$ with the polarity!

Mode-2

→ At the instant $t = T_0$, Thyristor T_2 is triggered. When T_2 is conduction state, commutating capacitor applies a voltage 2Edc across the T_1. Due to the reverse voltage drop across the thyristor T_1 for a sufficient amount of Time, it gets turned off. When T_2 is on the current starts flowing through the right side of the primary winding and its direction

$$E_{dc}^{+} - L - K - D - T_2 - E_{dc}^{-}$$

→ voltage across KD = E_{dc}, voltage across CK = E_{dc}.

→ During this Mode, a voltage of $2E_{dc}$ appears across T/F secondary and the commutating capacitor has reverse polarity. As a result, -ve cycle of the o/p voltage is obtained.

Mode-3

→ At the instant, $t = 2T_0$, Thyristor T_1 triggered and hence T_2 gets turned off by above process. Here this way of triggering pulses are given at regular intervals of time to the alternate thyristor, approximately rectangular voltage waveform may be obtained

Pros:-

→ The circuit is simple.

→ Small in size and less expensive

→ It employs complementary voltage commutation.

Cons:-

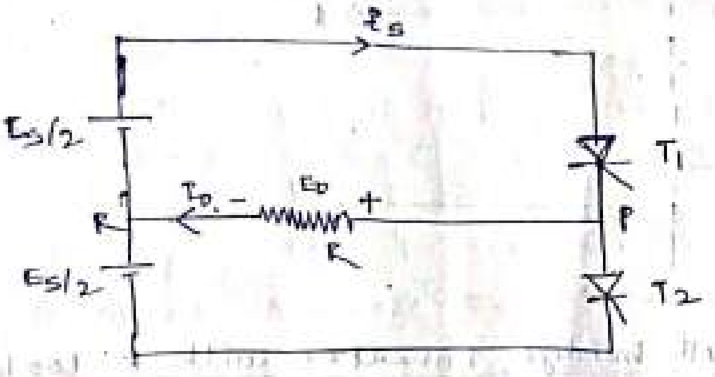
→ Whenever the circuit is operated at low frequencies. T/F's core get saturated which is an undesirable result. This is because, at low frequencies each thyristor conducts for higher duration which saturates the T/F's core.

(*) Single-phase bridge Inverters:-

1. Single phase half bridge Inverters
2. Single phase full bridge

(*) Single phase half-bridge inverter:- (R-Load)

→ It consists of two SCRs and resistive load. The two Thyristors T_1 & T_2 which are in series connected across the source.



Operation:-

→ When Thyristor T_1 is turned on for a time period of $T_0/2$, the instantaneous voltage across the load E_0 is $E_s/2$. At this instant $t = T_0/2$, thyristor T_1 gets commutated and T_2 is turned on.

→ When T_2 conducts for a period of $T_0/2$, the instantaneous voltage across the load is given as $-E_s/2$. Hence voltage across load is an alternating one whose amplitude is given by $E_s/2$ with a frequency $1/T_0$ Hz.

→ By controlling the time period 'T_0' frequency of the inverter O/P voltage may be varied. Here, conduction period of each SCR is equal to the gate pulse-period. As soon as the gate pulse is removed, the thyristor gets commutated.

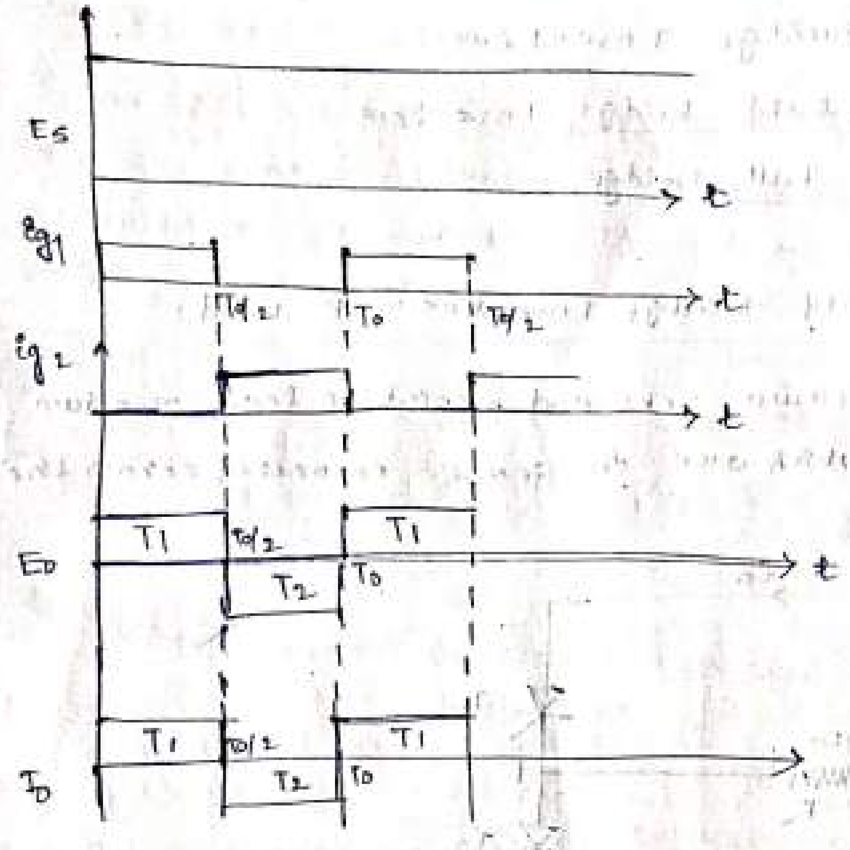
(*) Avg O/P vtg $E_0 = \frac{E_s}{2}$ for $0 < t \leq T_0/2$

$E_0 = -\frac{E_s}{2}$ for $T_0/2 < t \leq T_0$

(*) Avg O/P current $i_0 = \frac{E_0}{R} = \frac{E_s}{2R}$ $0 < t < T_0/2$

$i_0 = \frac{E_0}{R} = -\frac{E_s}{2R}$ $T_0/2 < t < T_0$

(*) RMS O/P vtg $= \frac{E_s}{2}$

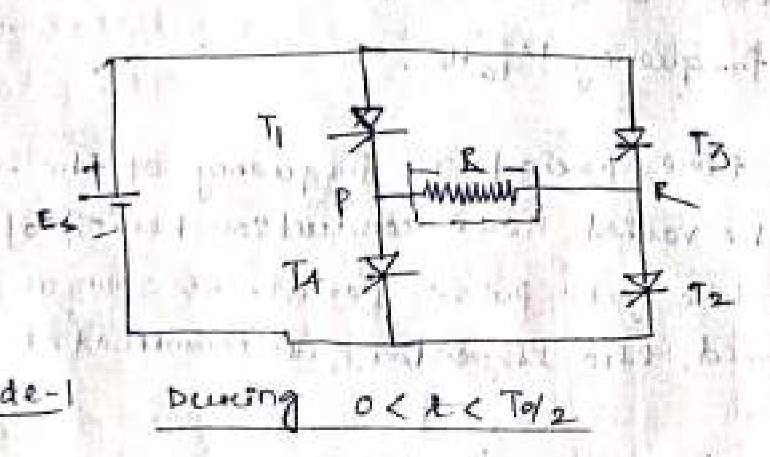


⊛ Single Phase Full bridge Inverter with R-Load:-

→ Single phase full bridge inverter with R load consists of 4 Thyristors. Thyristor T_1, T_4 and T_3, T_2 are in series and they are connected across the supply voltage.

→ It must be ensured that during inverter operation, two thyristors of same leg don't conduct simultaneously which lead to the direct short circuit of load.

→



Mode-1 During $0 < t < T_0/2$

When Thyristors T_1 and T_2 are turned 'ON' simultaneously, the I/P voltage E_s appears across the load whose load current direction $E_s^+ - T_1 - \text{Load} - T_2 - E_s^-$

Mode-2 During the interval $T_0/2 < t < T$

→ When the source voltage reaches $T_0/2$, load voltage becomes zero and thyristor T_1 & T_2 are forced commutated at this instant. When the gate signals are given to thyristor T_3 & T_4.

→ They get turned on and load voltage becomes $-E_s$.

The load current direction

$$E_s^+ - T_3 - \text{Load} - T_4 - E_s^-$$

→ At instant $t = T_0$, thyristor T_3 & T_4 are forced commutated and thus the above process repeats.

(*) Avg o/p vtg $E_0 = E_s \quad (0 < t < T_0/2)$

$E_0 = -E_s \quad (T_0/2 < t < T_0)$

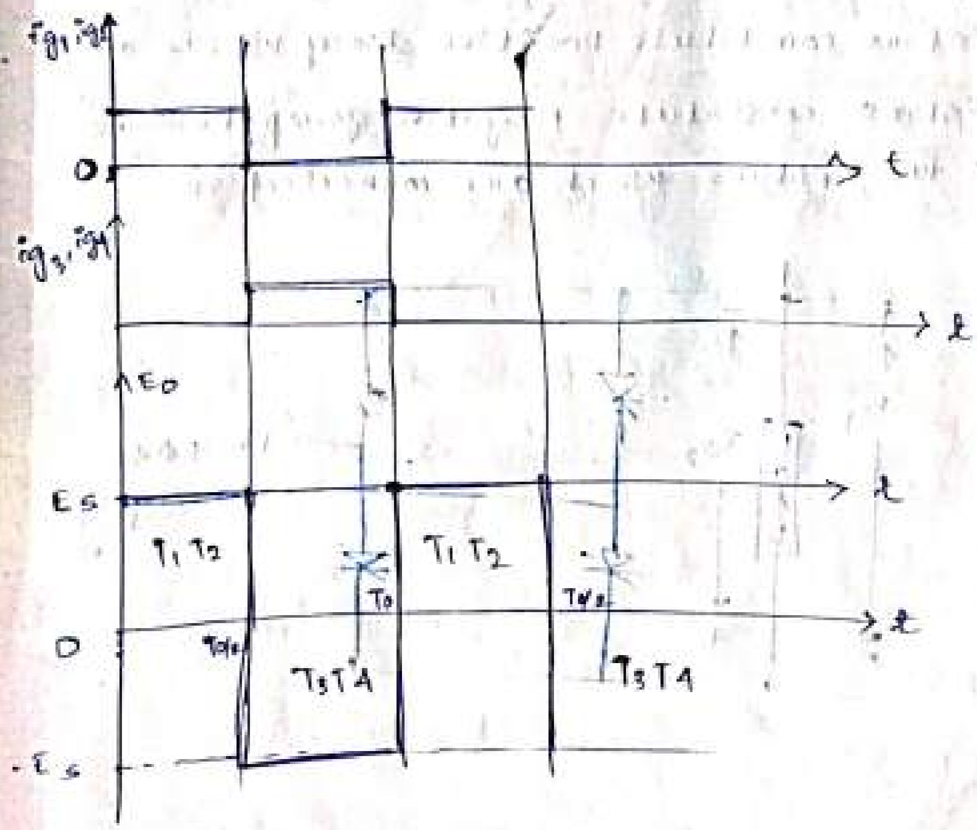
(*) Avg o/p current $I_0 = E_s/R \quad (0 < t < T_0/2)$

$-E_s/R \quad (T_0/2 < t < T_0)$

(*) RMS o/p vtg $= E_s$

(*) RMS o/p current $I_{0RMS} = \frac{E_{0RMS}}{R}$

$$\boxed{I_{0RMS} = \frac{E_s}{R}}$$



cyclo-converter

→ A circuit which converts i/p power at one frequency to o/p power at a different frequency with one-stage conversion is called a cycloconverter. A cycloconverter is thus a one-stage frequency changer.

→ Basically cycloconverters are 2 types
(i) step-down cycloconverters ($f_o < f_s$)
(ii) step-up cycloconverter. ($f_o > f_s$)

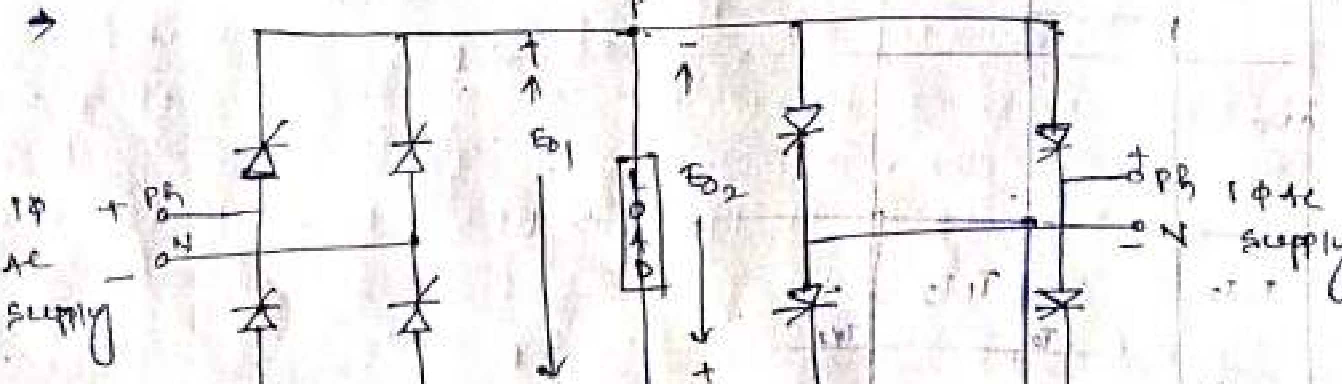
Applications of cycloconverters:-

→ Speed control of high-power AC drives
→ Induction heating
→ Static VAr compensation
→ For converting variable speed alternator voltage to constant frequency o/p vtg for use as power supply in aircraft or shipboards.

Bridge Type step up cycloconverters:-

→ The SCRs are arranged in a bridge type and hence it is known as bridge type cycloconverter consisting of 8 SCRs. P_1, P_2, P_3, P_4 thyristors constitute positive group whereas N_1, N_2, N_3, N_4 thyristors constitute negative group. Load is connected b/w the two bridges which are connected in antiparallel.

→



Operation principle :-

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

→ During the positive half cycle of the supply voltage P_1, P_2, N_3, N_4 are forward biased. From $\omega t = 0$ to π. Initially P_1 & P_2 thyristor triggered. The load voltage now follows the positive envelope of the supply voltage. The circuit completes its path through.

$$Ph - P_1 - P - Load - S - P_2 - N$$

→ At the instant ωt_1, P_1 & P_2 are turned off due to forced commutation. Now, N_3 & N_4 triggered which already in forward biased condition during +ve half cycle. The load o/p vtg traces the negative envelope of the supply voltage. The direction of current Ph - N_3 - S - Load - P - N_4 - N

→ At ωt_2, N_3 & N_4 are forced commutated and P_1 and P_2 are turned ON. The load voltage is now positive and follows the positive envelope. This process continues for positive half cycle of source voltage till $\omega t = \pi$ rad.

Mode-2 $\pi < \omega t < 2\pi$

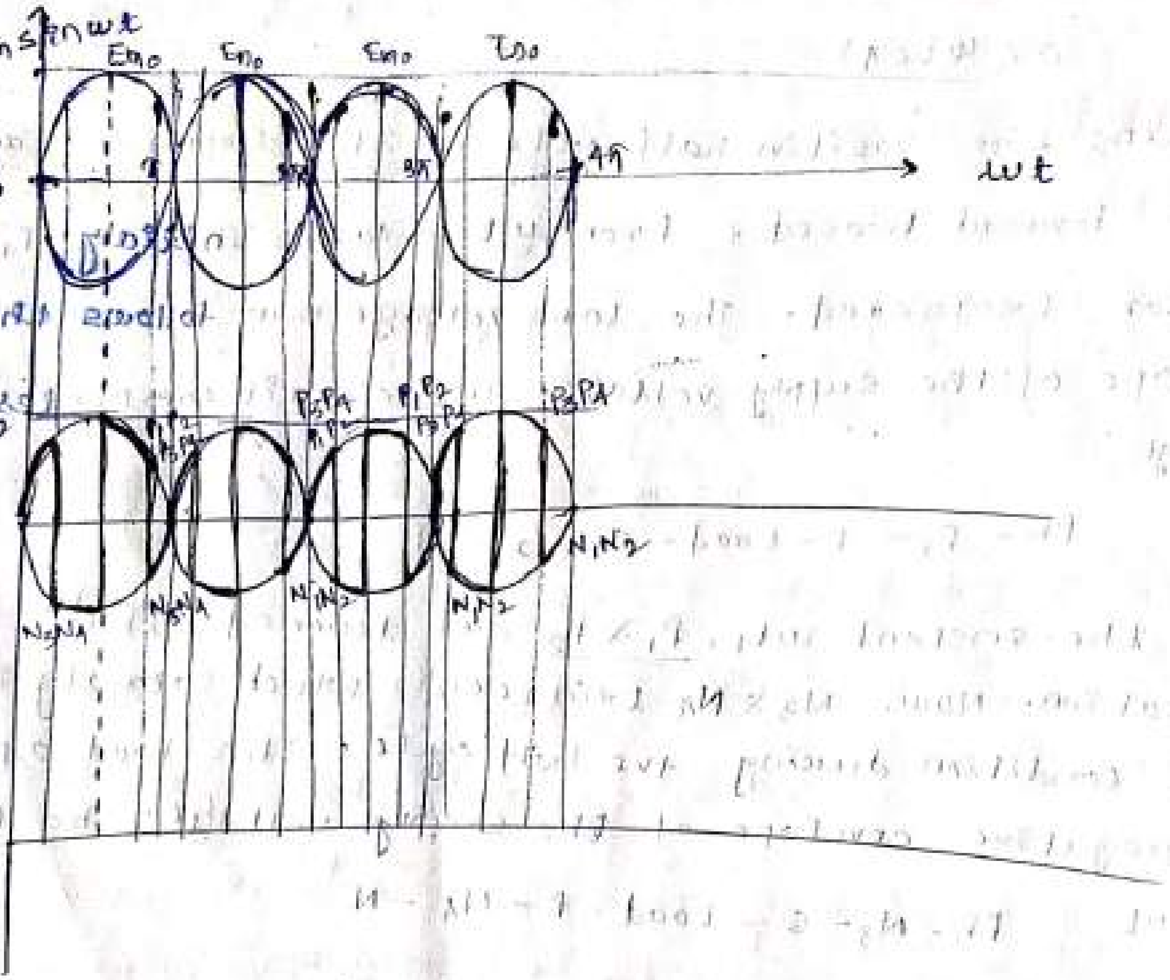
→ During the negative half cycle of the source voltage, thyristors P_3, P_4, N_1, N_2 are forward biased. Give the gate signal to P_3 & P_4 thyristors where the load voltage follows the +ve envelope of the supply voltage. The circuit completes path

$$N - P_3 - P - Load - S - P_4 - Ph$$

→ At the instant ωt_4. P_3 and P_4 are forced commutated. Give the gate signal to thyristors N_1 & N_2 which are already in forward biased condition. Now the o/p traces the negative envelope of the supply voltage. The circuit completes its path as

$$N - N_1 - S - Load - P - N_2 - Ph$$

→ At $\omega t = \omega t_5$, N_1 & N_2 are forced commutated. Its associated waveforms.


Es = Em sin ωt
ωt
0
4π
P1P2
P3P4
N1N2
N3N4

Bridge type cycloconverter with R-L Load:-

1 ϕ to 1 ϕ step down cycloconverter:-

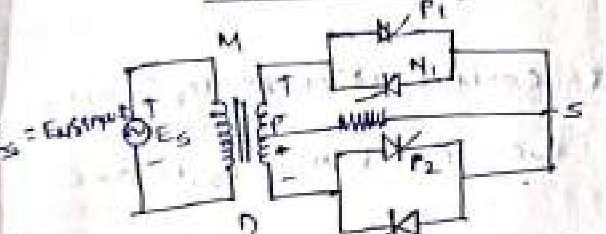
→ step down cycloconverter does not require forced commutation. It undergoes natural or line commutation which is provided by the ac supply.

(a) Mid point type

(b) bridge type

~~1 ϕ to 1 ϕ step down~~

Mid point type



Mode-1 (0 < ωt ≤ π)

→ When 'm' is positive with respect to 'n' during the positive half cycle of supply voltage thyristors P_1 and N_2 are forward biased. Give the gate signal to thyristor 'P_1'. Load current starts building up in the positive direction from M to n.

m - P_1 - S - Load - O

→ At ωt = π, source voltage becomes zero and hence, load voltage becomes zero. Since, load current is the ratio of load voltage to the resistance, it becomes zero.

Mode-2 (π ≤ ωt < 2π):-

→ During the negative half cycle of the supply voltage, terminal 'n' is positive with respect to 'm'. Now, thyristors P_2, N_1 are in the forward biased condition. When P_2 is triggered, load current starts building up in the positive direction from n to O. The path direction is as follows,

n - P_2 - S - Load - O.

At $\omega t = 2\pi$, source voltage becomes zero and hence load vtg and load current becomes zero. So thyristor P_2 is said to be naturally commutated as load current passes through zero.

(*) In +ve half cycle m is +ve w.r.t n. P_1 & N_2 is forward biased. When P_1 is OFF, N_2 is alone forward biased condition as seen above.

→ The load current starts building up in the -ve direction whose path is given below -

O - load - S - N_2 - n

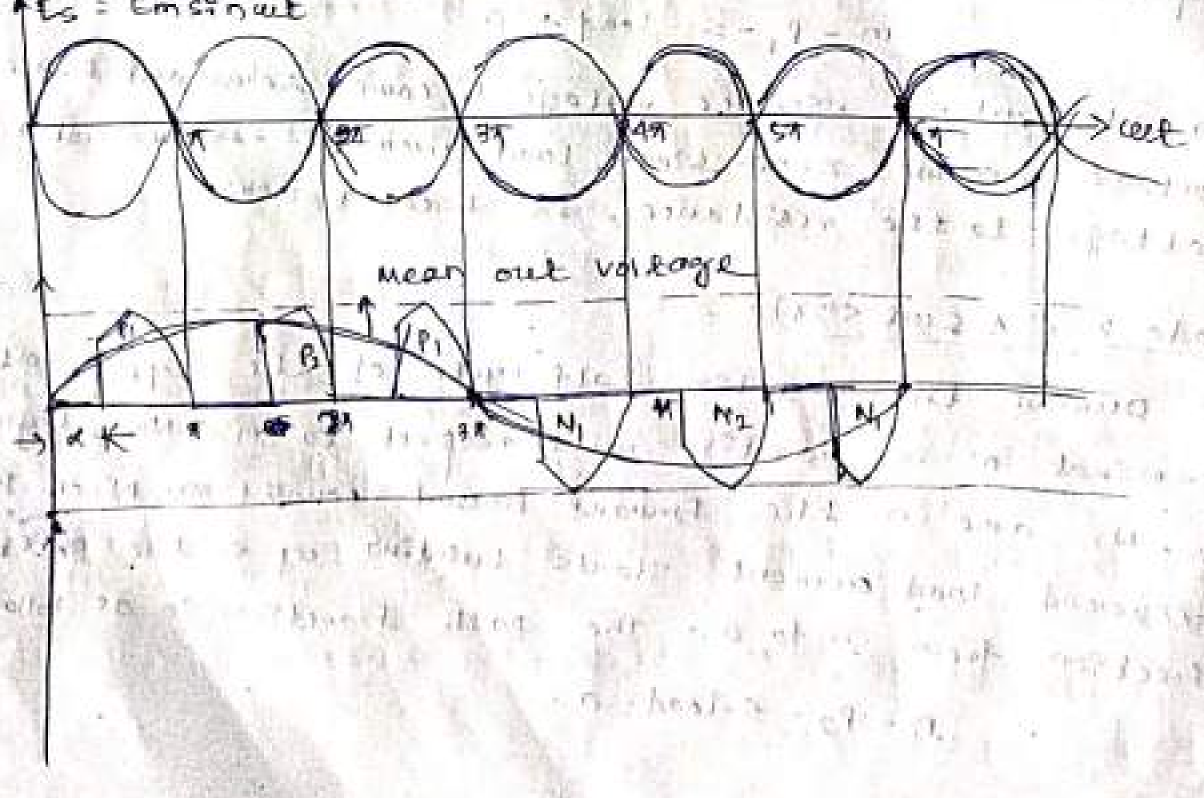
(*) At $\omega t = 3\pi$, N_2 is natural commutation or N_2 is OFF.

(*) In -ve half cycle n is +ve w.r.t m. P_2, N_1 are forward biased.

When P_2 is OFF only N_1 is turned on. The load current traces the negative envelope of the source voltage whose path is

O - load - O S - N_1 - m.

→ At $\omega t = 4\pi$, thyristor N_1 gets turned OFF naturally. Its associated waveforms.



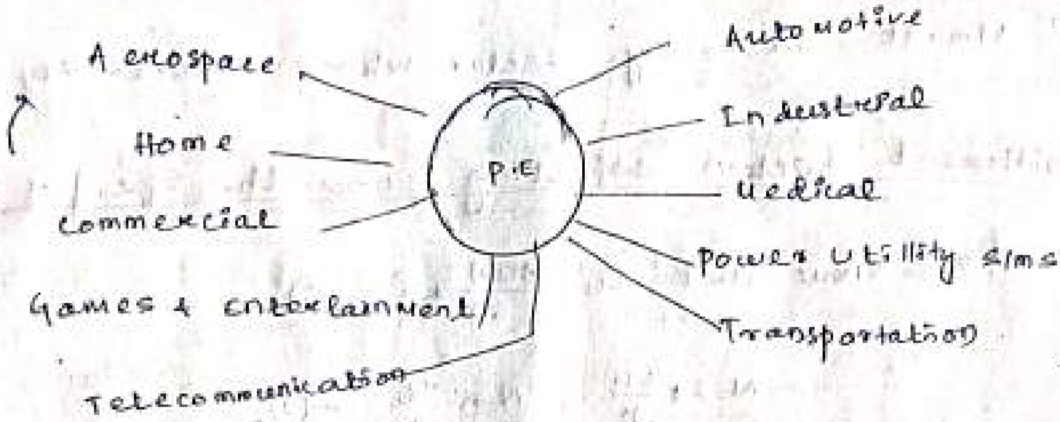
CH-04

(*) List application of power electronics circuits -

* Note

What is power Electronics

It is the application of Electronics and circuits to control the conversion of Electric power from one form to another.



(*) HOME :-

- Refrigerator
- Air conditioner
- Lighting
- Vacuum cleaner
- Television
- cooking appliances

(*) Aerospace

- Aero-plane power s/m
- space vehicle power s/m
- satellite power s/m
- Space exploration robot power s/m

(*) AUTOMOTIVE

- Electric vehicle drivetrain
- Electric vehicle charging s/m
- Battery Management s/m
- Auxiliary electric supply s/m

(*) Industrial

- Fan / blower
- pumps
- Induction furnace
- Electromagnet
- UPS

(*) Medical

- MRI scanner
- fitness M/C
- LASER supply
- power supply to various monitoring s/ms

(*) Power Utility s/ms

- ~~LASER~~
- STATCOM
- power-factor correctors
- VAR compensators
- static circuit breakers
- HVDC converters

(*) Transportation:-

→ Electric locomotive
→ maglev
→ Motor drives

(*) Telecommunication

→ mobile
→ wireless communication.
→ power supply for Transmitter and receiver

Note

(*) Almost in every sector where electricity is present.

Different factors affecting upon the speed of D.C Motor:-

we know that $E_b = \frac{\phi Z N}{60} * \frac{P}{A}$ — (1)

$N = K \frac{E_b}{\phi}$, $N \propto \frac{E_b}{\phi}$ — (2)

where $K = \frac{60 A}{P Z}$ = Proportional constant

so that $N \propto E_b$, $N \propto \frac{1}{\phi}$

And 'E_b' is also can be expressed as

$E_b = V - I_a R_a$ — (3) From eqn $E_b \propto N\phi$

$N\phi \propto V - I_a R_a$

$N = \frac{V - I_a R_a}{\phi}$

→ Here we also seen that 'N' again depends upon supply voltage & the Armature current.

$N \propto V$ but $N \propto \frac{1}{I_a}$

→ Hence overall speed of a d.c Motor depends upon E_b, ϕ, I_a, supply vtg etc.

→ ~~increase~~ to speed above the normal speed → Field Flux Method.

→ speed control below the rated speed → Armature voltage control method is used.

→

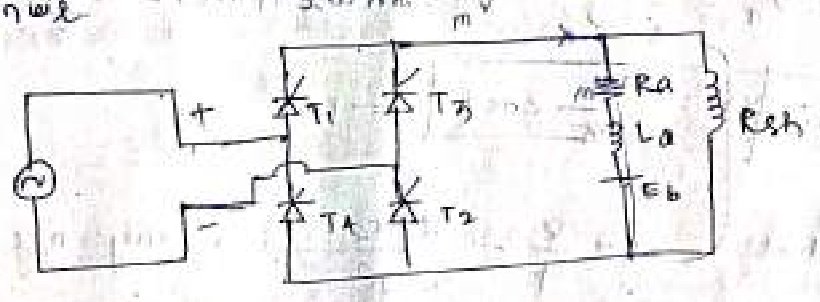
Speed control by using converter ckt:-

→ For Shunt Motor

→ we know that D.C shunt Motor is a constant speed Flux Motor like separated excited DC Motor, So that the speed control Method for D.C shunt Methods is very similar to speed control of separated Excited D.C series Motor

→ Let take a 1ϕ Full wave converter for the control of speed by using Armature voltage control Methods, which is given below:-

$V = V_m \sin \omega t$



(b) Here 4 Thyristor are used for control the speed of D.C Motor. At a time 2 Thyristor are operated.

(a) Mode-1 (For +ve Half cycle) :-

→ During +ve half cycle T_1 & T_2 are conducted with proving gate pulse, so that the current Flows through Armature wdg as well as field wdg.

→ The Armature current is controlled by using external Resistance similarly the Field current is controlled by using external Resistance their own.

→ For this Mode the line current path is

$V_s^+ \rightarrow T_1$ – Armature & Field wdg $\rightarrow T_2 - V_s^-$

Mode - 2

During negative half cycle T_3 & T_4 are conducted (Forward Biased) give to proper gate pulse. The current passed through both Armature wdg & Field wdg.

→ Again the both current values are controlled by their Respective external Resistance.

<u>For Any D.C Motor</u>

$$N = \frac{V - I_a R_a}{\phi} = \frac{V}{\phi} - \frac{I_a R_a}{\phi}$$

& $T \propto \phi I_a \Rightarrow I_a = \frac{T_a}{\phi}$

$$\boxed{N = \frac{V}{\phi} - \frac{T_a R_a}{\phi^2}} \quad \text{or} \quad \boxed{N \propto \frac{V}{\phi} - \frac{T_a R_a}{\phi^2}}$$

<u>and For continuous conduction Mode</u>

$$V_a = \frac{1}{\pi} \int_{\alpha}^{\pi+\alpha} V_m \sin\omega t \, d(\omega t) = \frac{2V_m}{\pi} \cos\alpha$$

$$\Rightarrow \boxed{V_a = \frac{2V_m}{\pi} \cos\alpha} \quad \text{— 1}$$

So that $N = \frac{V}{\phi} - \frac{R_a T_a}{\phi^2}$ For any D.C Motor

but for DC shunt Motor ϕ is constant, Hence

$$\boxed{N = \frac{V}{K} - \frac{R_a T_a}{K^2}} \quad \text{— 2}$$

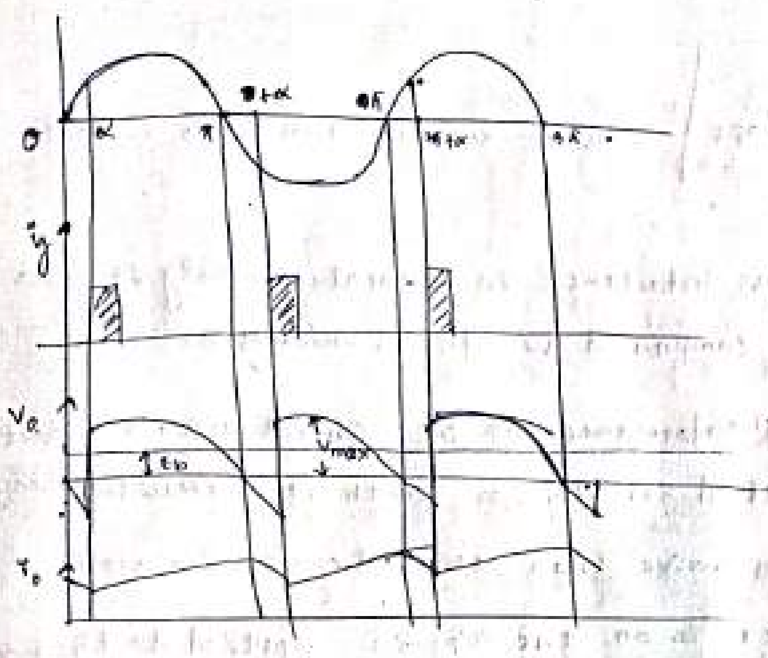
$$\Rightarrow \boxed{N = \frac{2V_m}{K\pi} \cos\alpha - \frac{R_a T_a}{K^2}} \quad \text{— 3}$$

⇒ So that, at $0 < \alpha \leq \pi/2$ then speed of D.C shunt Motor $N = \frac{V_{max}}{K}$ only

or if $\pi/2 \leq \alpha \leq \pi$, then the speed of D.C shunt Motor $N = \frac{V_{max} \sin\alpha}{K}$

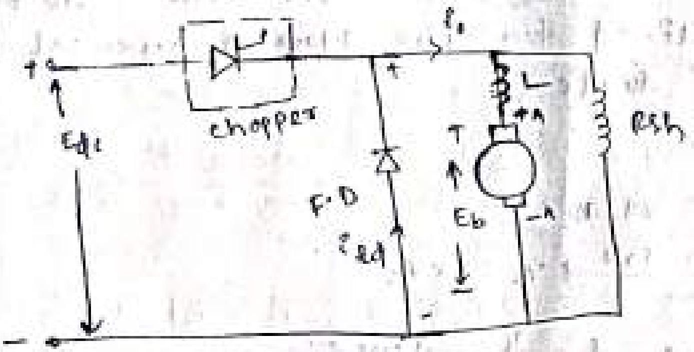
→ Here Let $\frac{V_m \sin\alpha}{K}$ take $\frac{2V_m}{\pi}$ = max. Avg Terminal voltage of D.C shunt Motor this voltage value equal to rated terminal supplied voltage.

Wave form

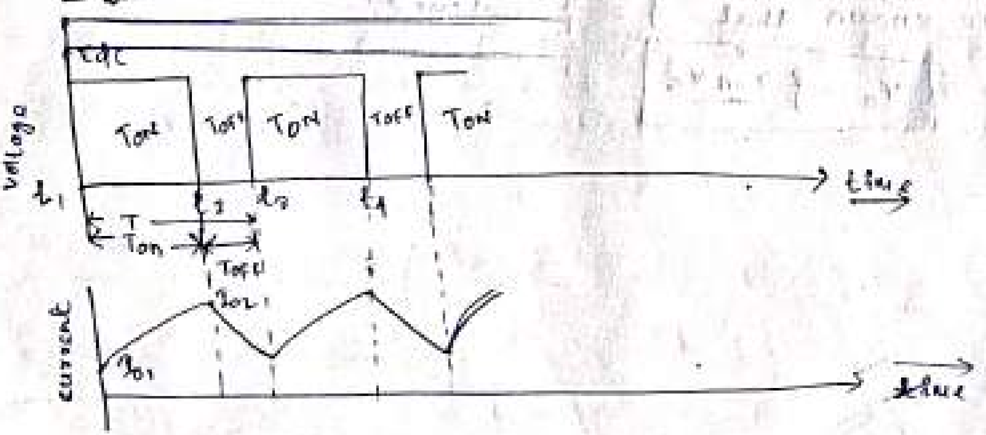


(continuous conduction mode)

Speed control of DC shunt motor using chopper:-



(*) Transistor
SCR → 10 kHz High frequency, F. 200kW, 3 rating
(*) chopper → 1kHz, High Power
(*) Forced commutation



→ continuous current conduction $T_{ON} > T_{OFF}$

→ Discontinuous current conduction $T_{ON} < T_{OFF}$

(*) Armature current increases in exponentially.

(*) To increase the duty cycle we, change the speed of the d-c Motor.

→ $\alpha \uparrow$, speed ↑

→ $\alpha \downarrow$, speed ↓

$$\boxed{\alpha = \frac{T_{ON}}{T_{ON} + T_{OFF}}}$$

That means $T_{ON} \uparrow$, ∴ $\delta \uparrow$, speed ↑.

Note

(*)→ The motor has less inductance in armature wdg it gives poor performance as compared to d.c series motor.

→ To improve the performance of D.C shunt motor an additional inductance is connected in series with the armature wdg.

→ Hence it is expensive than the d.c series motor.

→ When the chopper is on, the o/p is applied to the motor and the energy will be stored in the inductance which is connected in series with the armature winding.

→ During the OFF period of the chopper, the inductance energy will be utilised for the flow of current through the free wheeling diode.

(*) The avg motor voltage

$$V_0 = V_L = \frac{T_{ON}}{T} \times V_S = \alpha V_S$$

we known that $f = \frac{1}{T}$, Hence

$$\boxed{V_0 = f\, T_{ON} V_S}$$

④ List of the Factor affecting speed of A.C Motor:-

For Induction Motor:-

The speed of an Induction Motor is given by

$N_r = (1-s) N_s$ & $N_s = \frac{120f}{P}$

$\Rightarrow$ $N_r = (1-s) \times \frac{120f}{P}$ —— ①

→ From Eqn we can varied the speed of an I.M by varing frequency (f), No. of (poles) of an I.M. & anther Method to control the speed of an I.M :-

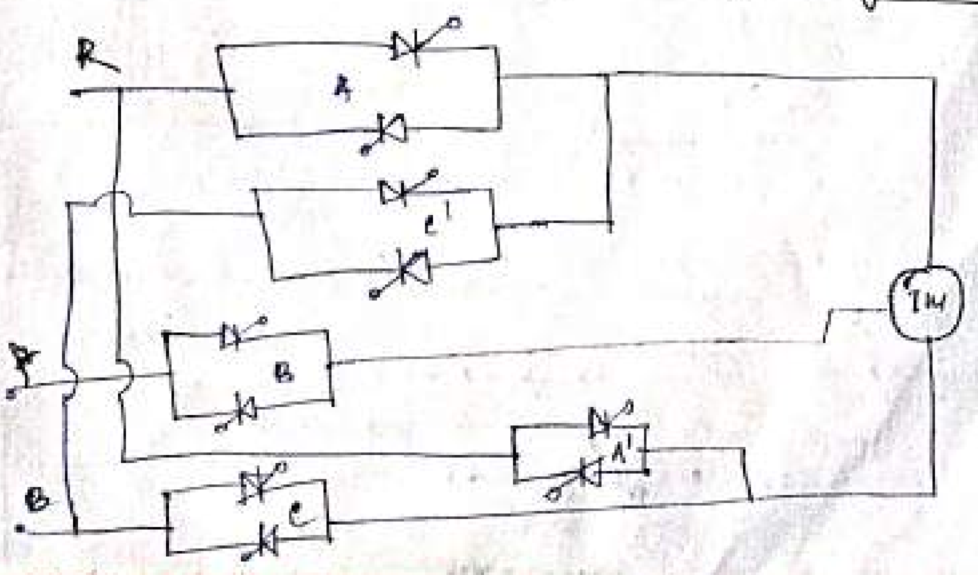
(1) pole changing
(2) stator voltage control
(3) supply ~~voltage~~ frequency control
(4) Rotor Resistance "
(5) slip energy Recovery

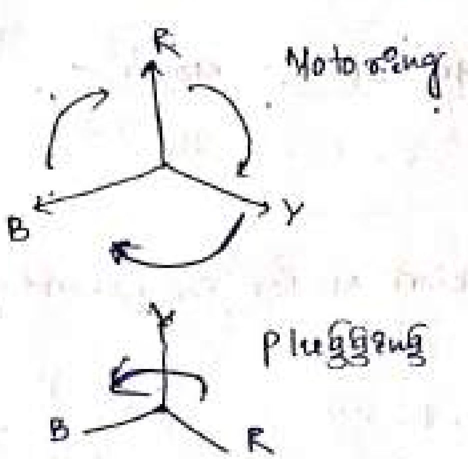
For synchronous Motor:-

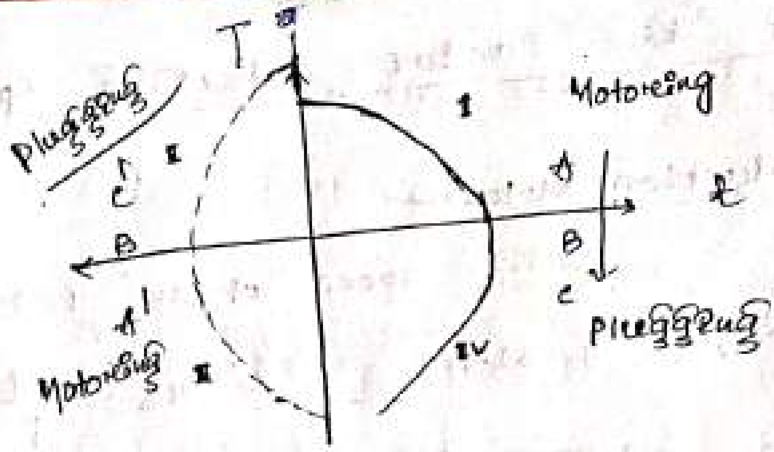
N_s = Motor speed = $\frac{120f}{P}$ —— (2)

→ Common method to control the speed of the synchronous Motor is supply frequency control method.

⑥ Speed control of the I.M by using A.C Voltage Regulator.







→ Here Four quadrant operation with plugging is obtained by the using of the circuit given above.

→ Thyristor pairs A, B, C provide operation in quadrant I & IV. Where as A' B C' Thyristor pair provides II & III quadrant operation of the Induction Machine.

→ While changing from one set of thyristor pairs to another, that is from ABC to A'BC' & vice versa, there should be taken to ensure that the incoming pair is activated only after the outgoing pair is fully turned off.

Some CONS –

→ O/P voltage depends upon both delay angle & period of the current flow, which are detected by load p.f. That is why, if load changes then the o/p voltage of the controller changes contineously.

→ Due to flucting the voltage & current then harmonics are present, which may cause eddy current in the core, which causes the over heat of the I.M.

Battery charger :-

(*) Now a day, batteries are used in a wide variety of applications.

→ For the starting of vehicles like scooters, cars, buses & trucks.

→ In UPS & Inverter circuits for illumination purpose or for running other household gadgets.

→ In electric vehicles.

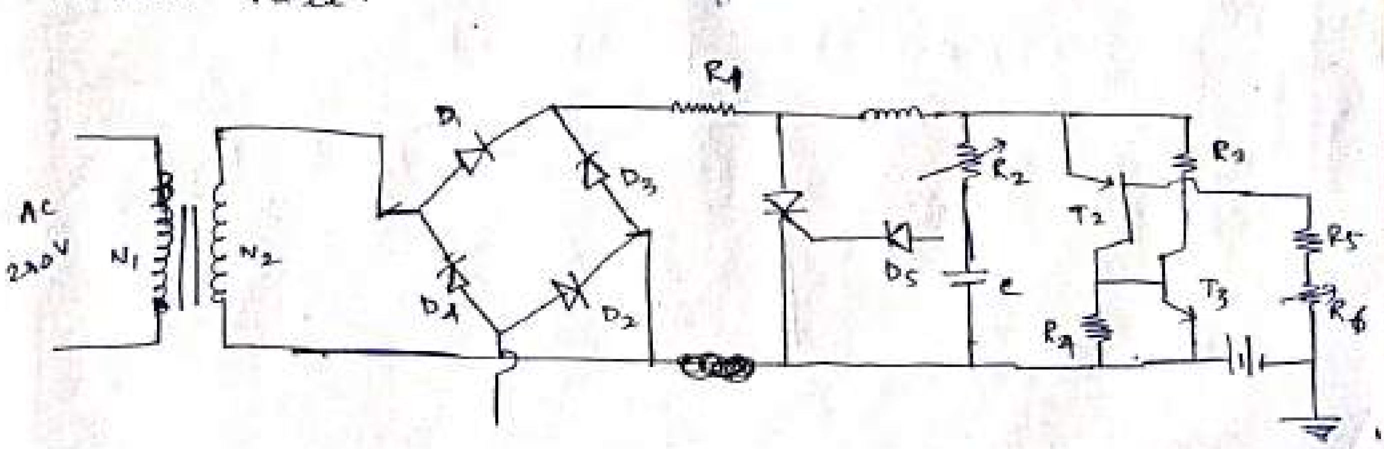
→ In telephone s/m etc.

(*) It is necessary to charge a battery to restore it's fully charged condition. During charging a current is sent through the battery in a direction opposite to that when the battery is being used.

(*) The charging current is generally obtained from bridge rectifier. The ckt should given an indication that the charging is over, in addition provision for Trickle charging should also exist.

(*) Trickle charging means charging at a slow rate to keep the battery in fully charged condition.

(*) The battery is permanently connected to the load as well as to the charger & is continuously charged at a slow rate.



(*) Generally the battery charger has a 'quick charge' setting and trickle charge setting.

→ After a heavy discharge, the charger is put on 'quick charge' to charge the battery quickly.

→ After quick charging is over, the battery is again put on trickle charge setting.

→ For charging a 12V battery the T/F Turns ratio N_1/N_2 is 11.5:1. The bridge rectifier converts low voltage ac to dc. This rectifier ckt generally uses diodes because charging current is requirement.

→ Diode D_5 triggers the Tyristor (SCR) T_1 & the charging current flows thyristor into the battery.

→ The voltage to the battery is to be charged can be adjusted by adjusting resistance R_6.

→ The Resistance R_1 is high power resistance because it carries fully charging current.

→ When the battery becomes fully charged, transistors T_1 & T_2 starts conducting. The capacitor C discharge through the low impedance path through T_1 & T_2.

→ After the battery is charged, a small current continues to flow through the neon lamp which starts glowing. This small current is the trickle charge current for the battery.

CH-05 Programmable logic controllers (R. Dick Morley, 1964)

5.1 Introduction:-

- A PLC (Programmable logic controller) is a device that was invented to replace the necessary sequential relay circuits for machine control.
- The PLC works by looking at its inputs and depending upon their state, turning on/off outputs. The user enters a program, usually via software, that gives the desired results.

PLC Example:-

- Let's assume that when a switch turns on we want to turn a solenoid on for 5 seconds and then turn it off regardless of how long the switch is on for.
- We can do this with a simple external timer. But what if the process included 10 switches and solenoids? we would need 10 external timers. What if the process also needed to count how many times the switches individually turned on? we need a lot of external counters.

PLC Need:-

→ The bigger the process the more is need for a PLC.

→ Simply program the PLC to count its inputs and turn the solenoids on for the specified time.

→ The primary reason for designing PLC was eliminating the large cost involved replacing the complicated relay based machine control systems.

Inside PLC:-

→ The PLC mainly consists of

→ A CPU

→ Memory Areas, and

→ Appropriate circuits to receive input/output data

→ We can actually consider the PLC to be a box full of hundreds or thousands of separate relays, counters, timers and data storage locations.

Definition and History of the PLC:-

→ A PLC is a user-friendly, Microprocessor-based specialized computer that carries out control functions of many types and levels of complexity.

→ Its purpose is to Monitor crucial process parameters and adjust process operations accordingly.

→ Used extensively because the PLC
- Is easy to set up and program
- Behaves predictably
- Ruggedized.

→ It can be programmed (to a degree) controlled, and operated by a person unskilled in operating (programming) computers.

→ Essentially, a PLC's operator draws the lines and devices of ladder diagrams with a keyboard/Mouse onto a display screen.

→ The resulting ladder diagram is converted into computer M/c language and run as a program.

Example:-

→ Allen-Bradley PLC5.

→ Allen-Bradley SLC500.

→ Allen-Bradley Micrologix.

→ Allen-Bradley Picocontroller.

PLC Basics:-

- Some PLCs are:-
  - → Integrated into a single unit (Picocontroller).
  - → Whereas others are Modular (PLC5, SLC500)
  - → The Micrologix Product lies somewhere B/W the PLC5 and the Picocontroller.
- Integrated PLCs:-

Integrated PLCs are sometimes called brick PLCs because of their small size

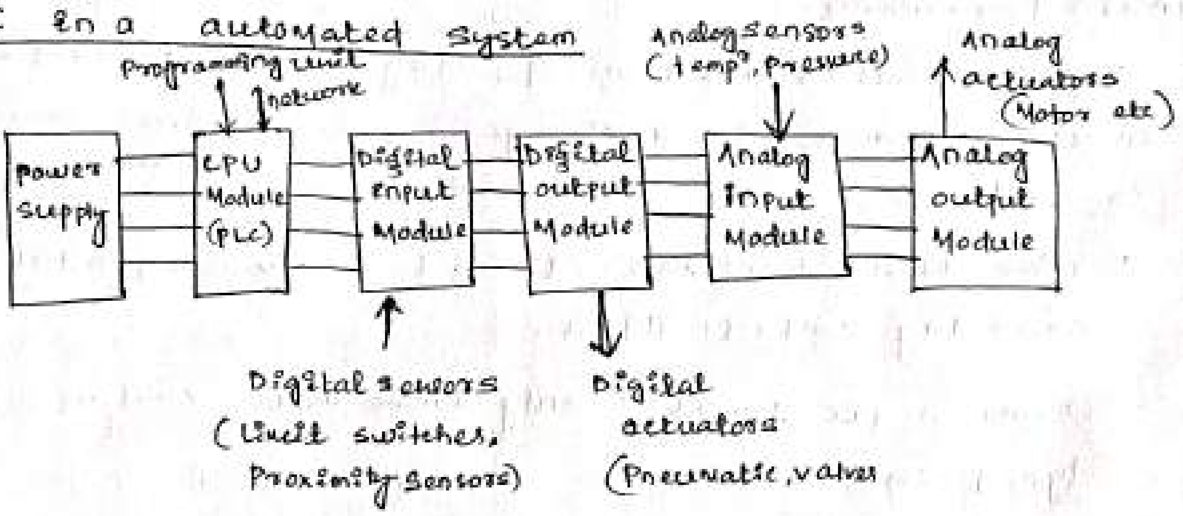
→ These PLCs ~~because~~ have embedded I/O (i.e the I/O is a part of the same unit as the controller itself.

→ Modular PLCs have extended I/O.

Components in a PLC system

- CPU Module containing the processor and memory
- Input and output modules to allow the PLC to read sensors and control actuators.
  - → A wide variety of types are available
- Power supply for the PLC and often sensors and low power actuators connected to I/O modules
- A rack or bus so the PLC can exchange data with I/O modules.

PLC in a automated system



5.3 (*) PLC Advantages

(a) Flexibility

→ In the past, each different electronically controlled production machine required its own controller, 15 machine might require 15 different controllers.

→ Now it is possible to use just one model of a PLC to run any one of the 15 machines.

→ Furthermore, you would probably need fewer than 15 controllers, because one PLC can easily run many machines.

→ Each of the 15 machines under PLC control would have its own distinct program (or a portion of one running program)

(b) Implementing changes and correcting Errors:-

→ With a wired relay-type panel, any program alterations require time for rewiring of panels and devices.

→ When a PLC programming circuit or sequence design change is made, the PLC program can be changed from a keyboard sequence in a matter of minutes.

→ No rewiring is required for a PLC-controlled system.

→ Also, if a programming error has to be corrected in a PLC control ladder diagram, a change can be typed in quickly.

(c) Large Quantities of contacts:-

→ The PLC has a large number of contacts for each coil available in its programming.

→ Suppose that a panel-wired relay has four contacts and all are in use when a design change requiring three more contacts is made.

- Time would have to be taken to procure and install a new relay or relay contact block.

→ Using a PLC, however, only three more contacts would be typed in.

- contacts are now a "software" component.

(d) Lower cost:-

→ Increased technology makes it possible to condense more functions into smaller and less expensive packages.

→ Now you can purchase a PLC with numerous relays, timers, and counters, a sequencer, and other functions for a few hundred dollars.

(e) Pilot Running:-

→ A PLC programmed circuit can be evaluated in the lab. The program can be typed in, tested, observed, and modified if needed, saving valuable factory time.

(f) Visual observation:-

→ A PLC circuit's operation can be seen during operation directly on a CRT screen.

→ The operation or mis-operation of a ckt can be observed as it happens.

→ Logic paths light up on the screen as they are energized.

→ Troubleshooting can be more quickly during visual observation.

(g) Ladder or Boolean Programming Method:-

→ The PLC programming can be accomplished in the ladder mode by an engineer, electrician or possibly a technician.

→ Alternatively, a PLC programmer who works in digital or Boolean control systems can also easily perform PLC programming.

(i) Reliability and Maintainability:-

→ Solid-state devices are more reliable, in general, than mechanical systems or relays and timers. consequently, the control system maintenance costs are low and downtime is minimal.

(j) Documentation:-

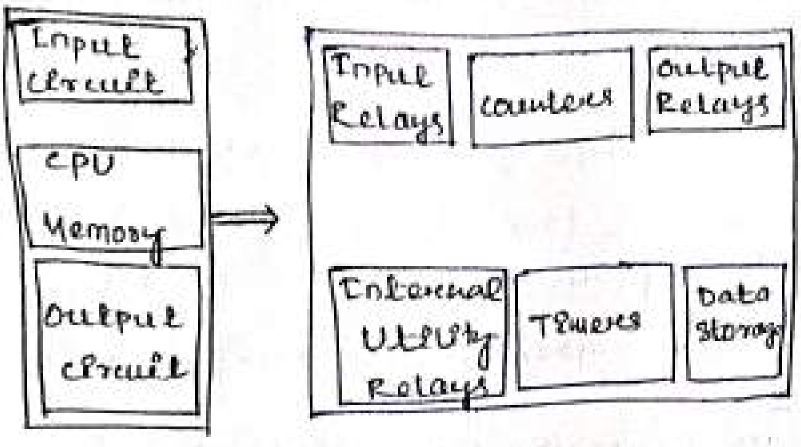
→ An immediate printout of the true PLC circuit is available in minutes, if required.

→ There is no need to look for the blueprint of the circuit in remote files.

→ The PLC prints out the actual circuit in operation at a given moment.

→ Often, the file prints for relay panels are not properly kept up to date

(Various parts of PLC) BLOCK DIAGRAM:-



• Input Relays (contacts):-

→ These are connected to the outside world. They physically exist and receive signals from switches, sensors, etc. Typically they are not relays but rather they are transistors.

• Internal Utility Relays:-

→ These do not receive signals from the outside world nor do they physically exist. They are simulated relays and are what enables a PLC to eliminate external relays.

→ There are also some special relays that are dedicated to performing only one task. Some are always on while some are always off. Some are on only once during power-on and are typically used for Initialising data that was stored.

• Counters:-

→ These again do not physically exist. They are simulated counters and they can be programmed to count pulses. Typically these counters can count up, down or both up and down.

• Timers:-

→ These also do not physically exist. They come in many varieties and increments. The most common type is on-delay type. others include off-delay and both retentive and non retentive types. Increments vary from 1ms through 1s.

• Output Relays (coils)

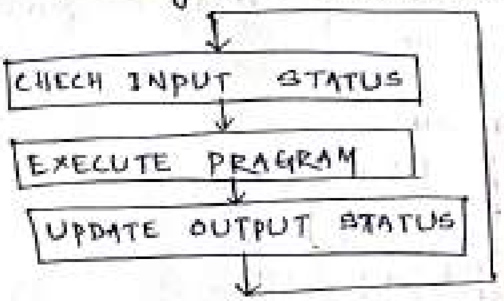
→ These are connected to the outside world. They physically exist and send on/off signals to solenoids, lights. They can be transistors, relays, or triacs depending upon the model chosen.

- **Data Storager**

→ Typically there are registers assigned to simply store data. They are usually used as temporary storage for math or data manipulation. They can also typically be used to store data when power is removed from the PLC. Upon power up they will still have the same contents as before power was removed.

PLC Operation/working :-

→ A PLC works by continually scanning a program. We can think of this scan cycle as consisting of 3 important steps.



→ Step-1:- CHECH I/P Status:-

→ First the PLC takes a look at each input to determine if it is on or off. In other words, is the sensor connected to the first input on? How about the second I/P? How about the third ... It records this data into its memory to be used during the next step.

→ Step- 2 - EXECUTE PRAGRAM:-

→ Next the PLC executes program one instruction at a time. May be program said that if the first input was on then it should turn on the first output. Since it already knows which inputs are on/off from the previous step it will be able to decide whether the first O/P should be turned on based on the state of the ~~first~~ first input. It will store the execution results results for use later during the next step.

→ Step - 3 - UPDATE OUTPUT STATUS:-

→ Finally the PLC updates the status of the outputs. It updates the O/P based on which inputs were on during the first step and the results of executing your program during the second step. Based on the example in step - 2 it would now turn on the first O/P because the first I/P was on and your program said to turn on the first output when this condition is true.

After the third step the PLC goes back to step one and Repeats the steps continuously. one scan time is defined as the time it takes to execute the 3 steps listed above.

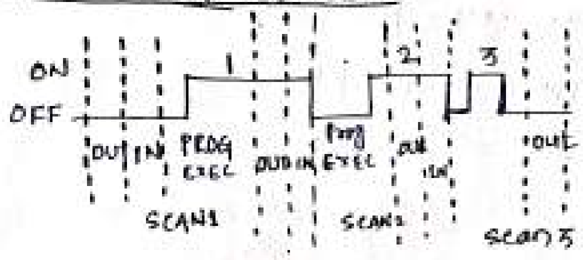
PLC - Response:-

→ The total response time of the PLC is fact we have to consider when purchasing a PLC.

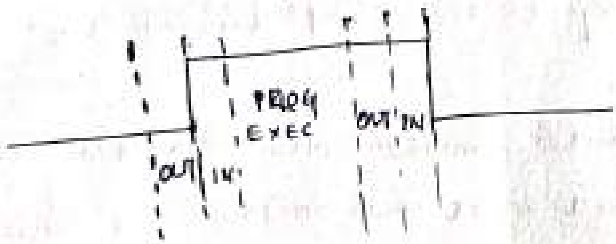
→ PLC takes a certain amount of time to react to changes. In many applications speed is not a concern, in others though.....

→ Input Response Time, Program Execution Time, Output Response Time = Total Response Time

PLC - RESPONSE TIME CONCERN:-



- Input 1 is not seen until scan 2.
- Input 2 is not seen until scan 3.
- Input 3 never seen by PLC.

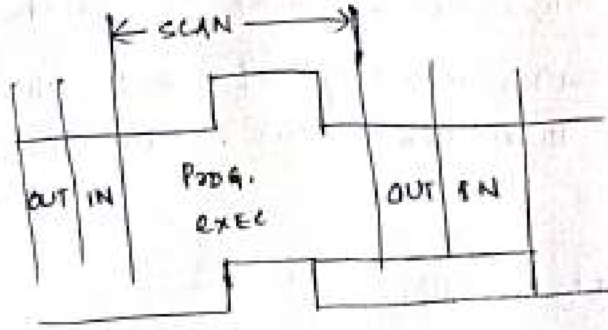


→ To Avoid this we say that the i/p should be ON for at least 1 input delay time + one scan time.

→ But what if it was not possible for the iput to be on this long? Then the PLC doesn't see the input turn on.

PULSE STRETCH FUNCTION:-

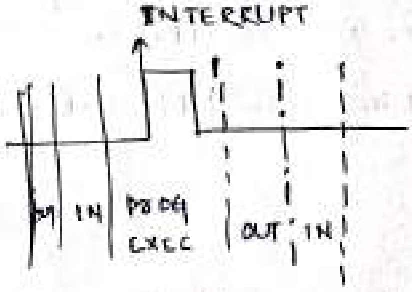
→ This function extends the length of the i/p signal until the PLC looks at the inputs during the next scan (it stretches the duration of the pulse).



PULSE STRETCH

(7) Interrupt Function:-

- This function interrupts the scan to process a special routine. i.e As soon as the input turns on, regardless of where the scan current is, the PLC immediately stops what its doing and executes an interrupt routine.
- An interrupt rot routine can be through of as a mini program outside of the main program. After its done executing the interrupt routine, it goes back to the point it left off at and continues on with the normal scan process.



(8) Relays:-

→ we understand how the PLC processes inputs. outputs, and the actual program.

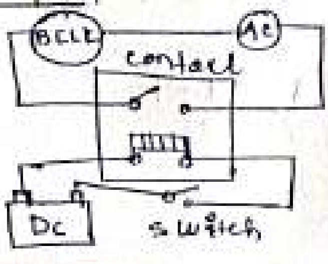
→ Now Lets see How a relay actually works. After all, the main purpose of a PLC is to replace "real world" relays.

→ we can think of a relay as an electromagnetic switch.

→ Apply a voltage to the coil and a magnetic field is generated. This magnetic field sucks the contacts of the relay in, causing them to make a connection.

→ These contacts can be considered to be a switch. They allow current to flow between 2 points there by closing the circuit.

Relays - a real example:-



→ Here we simply turn on a bell whenever a switch is closed.

→ we have 3 real-world parts: A switch, a relay and a bell. whenever the switch closes we apply a current to a bell causing it to sound.

⊛ Replacing Relays:-

→ Lets use a PLC in place of the relay.

→ The first thing that's necessary is to create what is called a Ladder diagram.

→ we have to create one of these because, unfortunately, a PLC doesn't understand a schematic diagram it only recognises code.

→ Most PLCs have software which convert diagrams into code.

Ladder Diagram:-

- First step:- Translate all of the items were using into symbols the PLC understands.

- Second step:- we must tell the PLC where everything is located. In other words we have to give all the devices an address.

- Final step:- we have to convert the schematic into a logical sequence of events.

⊛ APPLICATIONS OF PLC:-

(*) Because of the versatility of PLC, it is used in various places for automation. In Industries various processes needs to be controlled at every instant of time such as valve control, pressure control, robotic etc.

(*) It becomes tedious and infeasible for humans to control all such activities on their own. Thus Relays were used to perform these activities. However, a relay can be used only for a specific and limited operation. Which makes their use bulky and uneconomic.

(*) On the contrary PLC having the ability to perform number of tasks by simply modifying the program has become a prominent device for automation of such activities.

→ Robotic arm in car manufacturing
→ Air compressors
→ Airport runway lighting control.
→ Traffic signal control
→ Smoke alarm control
→ Process valve control
→ Textile equipments
→ Vaccum Pump system.