INTRODUCTION

power Electronics is partly belongs to power engg & parc belongs to electronics engg.

(ii) power engg. is consult with generation, transmissi distribution & utilization of power or energy at high efficiency.

(iii) Electronics engg. deals with signal or data in distruction less, production, transmission & reception less in low power cable & efficiency.

Power Electronics is the branch of engg. that deals with the apparatus or equipment working on the principle of electronics but rated at power cable rather than signal cable.

(iv) Some family member of powerelectronics are

(i) SCR (iv) UJT
(ii) GTO (v) TRIAC
(iii) MOSFET (vi) DIAC .... etc

Application of P.E.

→ Aerospace (i) setlight power supply
(ii) Aircraft power supply

→ commertial (i) Heating
(ii) Air conditioning
(iii) Refrizeration
(iv) computers & office application
(v) uninterruptable power supply
(vi) Elebrealders
(vii) Light dimmers

→ Indrustial application: (i) forrnance
(ii) Cooling system
(iii) blowers
(iv) pump

(v) Compresure (viii) textile
(vi) Transformer tap changer (ix) cement meal
(vii) roling (x) welding

→ Residential application
(i) A.C
(ii) Refregirator
(iii) Swing machine
(iv) food mixture
(v) Computer
(vi) washing machine.

→ Telecomunication
(i) Battary charger & ups

→ Transpotation
(i) streat light
(ii) Truly
(iii) Electric ~~vach~~ vacles
(iv) Electric locomotive & traction System.

Utility system :-
(i) HVDC
(ii) Exitation System
(iii) VAR Compensation
(iv) Circcuit breakers. etc

Advantage & disadvantages of P.E.

(i) Heigh efficiency due to low loss in power semiconductor devices
(ii) heigh relability
(iii) Long life & less mentainance
(iv) first dinamic responce
(v) small size & less ~~prio~~ weight
(vi) Cost is less.

Disadvantages

(i) Generates harmonics in the system rectifier & cycloconverters operate at low input p.f.
(ii) Heavy low overload capacity
(iii) Regeneration of power is difficult.

power semiconductor devices

(i) Diode
(ii) Thyristor family (SCR, LASCR, MCT, RCT, GTO, TRIAC, SITH)
(iii) power transistor family (BJT, MOSFET, SIT, IGBT)

In 1957 silicon based semiconductor device called thyristor was introduced G.E.C. (USA) in bell labra

* TRIAC, DIAC, PUT → (programmable unijunction transistor)

GTO → (Gate turn off thyristor)

RCT → (Reverse conducting thyristor)

Etc are similar characters as thyristor.

So the whole family called as the thyristor family

→ The oldest family member of thyristor is silicon control rectifier (SCR) is the mostly used device now a days.

S.C.R.

THYRatron + tansISTOR = THYRISTOR

Thyristor is four layer 3junction p-n-p-n semiconductor switching device.

→ It has 3 terminal anode, cathode & gate.

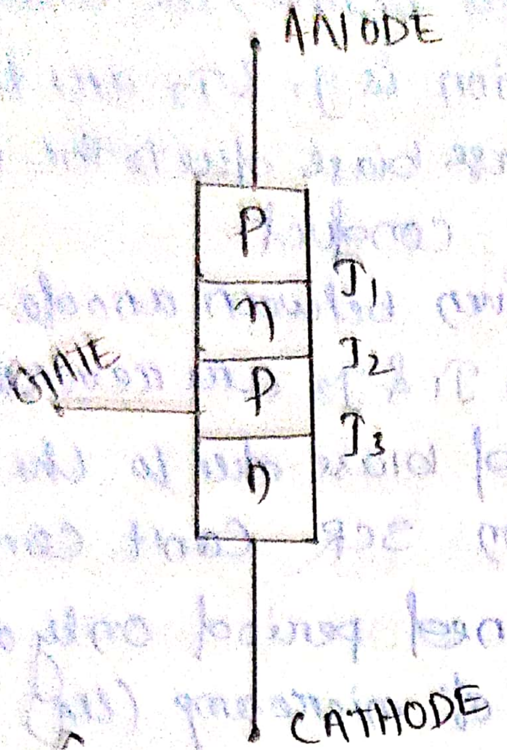
→ It has 4 layer of alternate p type & n type silicon materials, and the junction are $J_1 J_2 J_3$

→ Gate terminal is placed near the cathod terminal

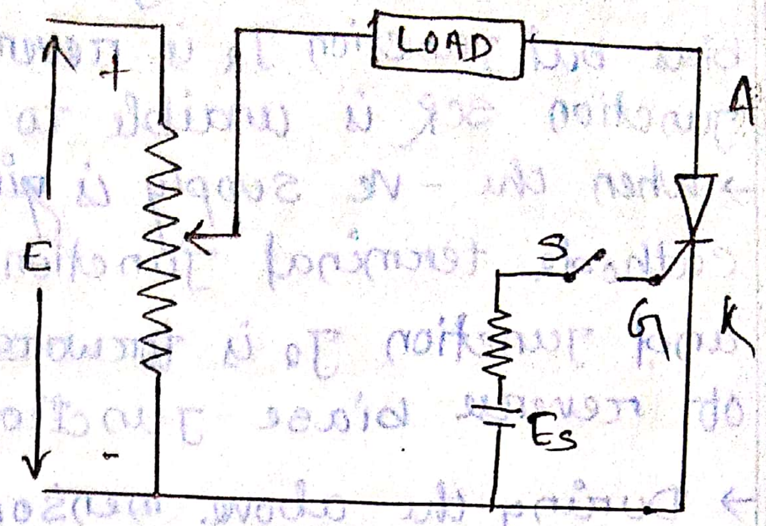
→ Outer "p" region is connected to anode outer "n" region is connect to cathod & inner "p" region connected to gate.

→ As SCR is maid up of silicon material & operates as a rectifier it is called as silicon control rectifier.

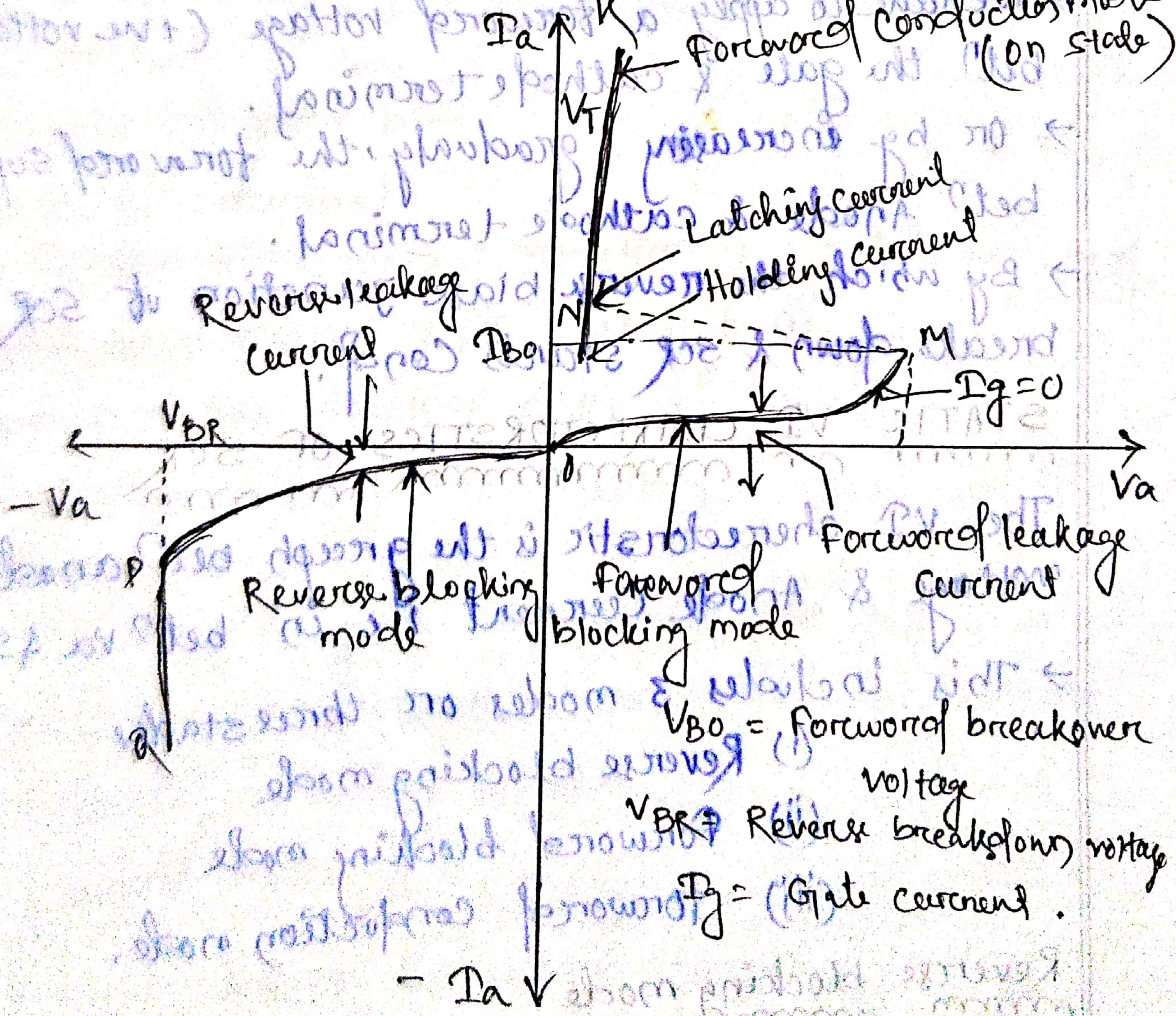
→ SCR is a unidirectional device that allows current to flow from anode to cathode.



(Physical const.)



(CKT diagram)



V_{BO} = Forword breakover voltage

V_{BR} = Reverse breakdown voltage

I_g = Gate current.

When forword supply is provided between the anode & cathode terminal the junction is J_1 & J_3 are forword bias but junction J_2 is reverse biase due to the reverse junction SCR is unaible to conduct.

→ When the -ve supply is given between anode & cathode terminal junction J_1 & J_3 are reverse bias and junction J_2 is forword biase due to the presence of reverse biase junction SCR can't conduct.

→ During the above mensoned period only a leakag current which is in terms of microamp (μA) & milliamp (mA) flows through the S.CR.

→ To make the SCR is conduction mode.

→ we have to apply a forword voltage (+ve voltage) betn the gate & cathode terminal.

→ Or by increasing gradualy, the forword supply betn Anode & cathode terminal.

→ By which the reverse biase junction of SCR breaks down & SCR starts cond.

STATIC VI CHARECTERSTICS OF SCR

The VI cherectoristic is the graph betn anode voltage & Anode current i.e in betn V_a & I_a

→ This includes 3 modes or three stades

(i) Reverse blocking mode

(ii) Forword blocking mode

(iii) forword conduction mode.

Reverse blocking mode

→ Here -ve supply is provided in betn anode & cathode terminal i.e anode is connected with -ve terminal of the supply & cathode is connected +ve terminal of the supply.

→ Due to which junction J_1 & J_3 are reverse biased & middle junction J_2 is forward biased.

→ Therefore SCR is unable to conduct.

→ if we will increase the "-ve" supply gradually at a perticular voltage reverse biase junction breaks down & a rapid current will flow instantly which will damage the device.

→ The voltage at which the reverse junction is breaks down is known as reverse breakdown voltage (V_{BR}).

Forword blocking mode

→ when anode is connected with "+ve" terminal & cathode is connected with -ve terminal of the supply forword biase is apply betn anode & cathode terminal.

→ At this time period junction J_1 & J_3 are forword bias & junction J_2 is reverse biase.

→ Due to the presence of reverse junction SCR unable to cond. only a leakage current will flow through it.

→ by providing a "+ve" supply also SCR is in blocking state. So this time period is known as forword blocking mode.

Forword conduction mode

→ when anode to cathode forword voltage is increased gradually by keeping the gate terminal open the reverse biase junction J_2 will have an avalanch break down.

→ The "+"ve voltage which reverse junction breaks is known as forword break over voltage (V_{BO})

→ as the junction breaks SCR starts conduction & current will gradually increase to its conduction point & voltage drops down to 1 to 2 volt this voltage is called as on-state voltage drop.

→ after this by increasing voltage current will increase up to its maximum limit & makes the SCR conduction. So this mode is known as forward conduction mode.

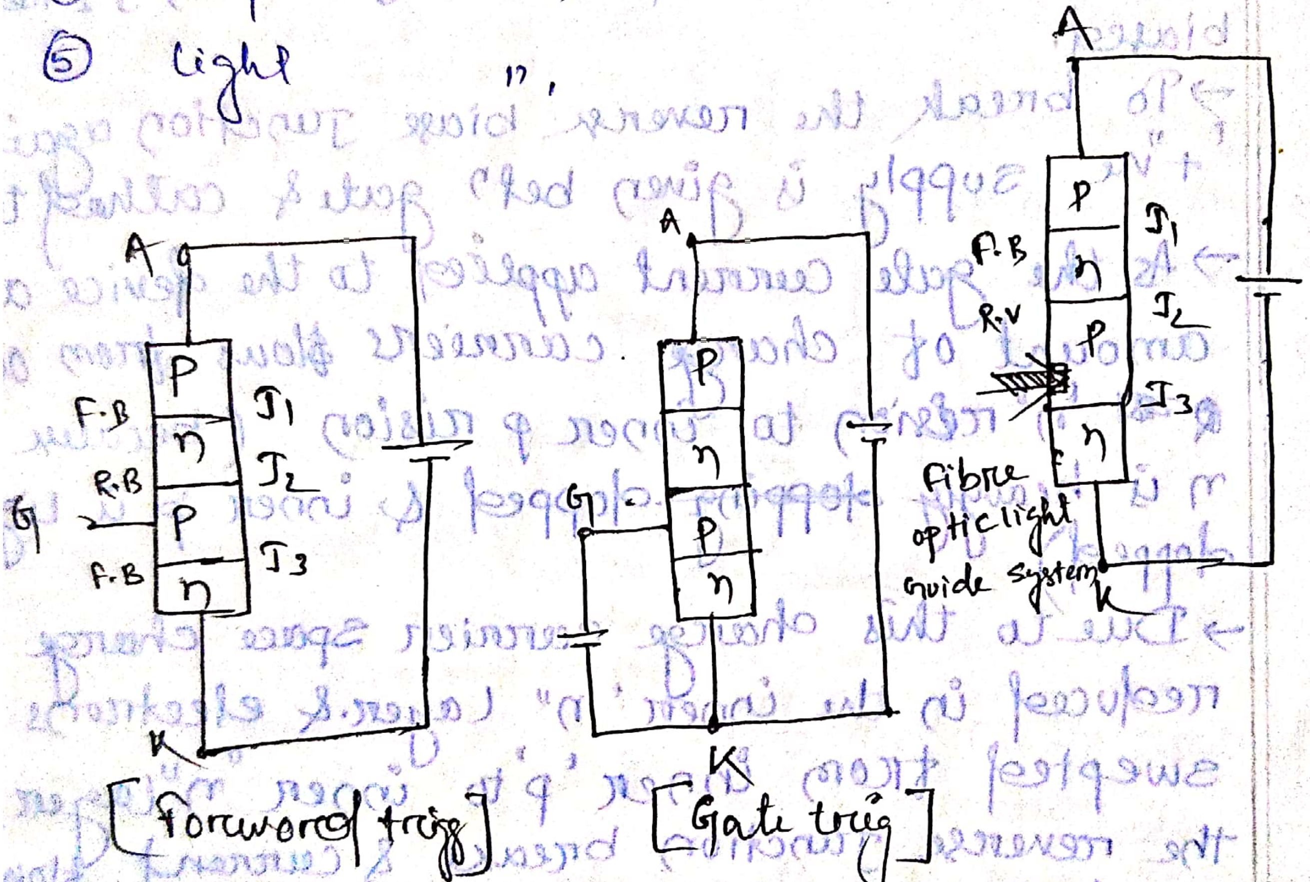
→ The minimum value of anode current (I_a) at which SCR starts conduction is known as laching current.

→ Ones the thyristor starts conduction gate loses its control at this time the thyristor can be turned off by holding current.

→ holding current is the current of minimum value of anode current bellow which SCR will turn off.

Turn On Methods of SCR

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



Forword voltage triggering

Heare a forword voltage is applied in betn anode & cathode terminal, by gradualy increasing this voltage the reverse junction "J_2" breaks down & SCR starts conduction.

note

The working principle is same as forword condn mode.

Gate triggering

This is a simple, reliable & efficient method of triggering.

→ at first a forward supply is provided betn anode & cathode terminal. due to which Junction J_1 & J_3 are forward biase & Junction J_2 reverse biased.

→ To break the reverse biase Junction again a +ve supply is given betn gate & cathode terminal.

→ As the gate current applied to the device a large amount of charge carriers flows from outer "n" region to inner p region. (because outer n is heavily ~~dopping~~ dopped & inner p is lightly dopped)

→ Due to this charge carrier space charge is reduced in the inner "n" layer & electrons swepted from inner 'p' to inner "n" layer, thus the reverse Junction breaks & current flows from anode to cathode.

→ $V_{BO} = 2 \times V_s$ (V_{BO} = breakover voltage)

→ Once SCR starts conduction gate loses its control & this terminal can be removed

→ the range of Gate current is lies 20 milli apm to 200 milli Amp.

note (i) Latching current is the minimum current at which thyristor starts conduction.

(ii) Holding current is the minimum current below which thyristor gets turn off.

$\frac{dv}{dt}$ triggering

With forword voltage accrose anode and cathode & gate terminal open. Junction J_1 J_3 forword biased junction J_2 reverse biased.

→ The reverse biase junction makes the thyristor behave like a capacitor

→ The charging current of capacitor $i_c = \frac{dq}{dt}$

$$= \frac{d}{dt}(C \cdot V_a) \quad \left[\text{where } C \text{ is the capacitance}, V_a = \text{Anode volt.}\right]$$

$$= \frac{dV_a}{dt} + V_a\frac{dc}{dt} \quad \left[\text{As capacitance is const}\right]$$

$$\boxed{i_c = \frac{C\, dV_a}{dt}}$$

Temperature triggering

During forword blocking mode most of the applied voltage appears accros reverse junction J_2.

→ This voltage associated with a leakage current, by increasing the supply voltage the leakage current increases. as ~~direct~~ current increases the temperature of the junction also increases.

→ At a perticular temperature, with in safe limit of temperature the revese junction breaks & SCR starts conduction.

Light triggering method

Heare the light is provided through fiber optic light guide system, this light is applicable to break the reverse junction & makes the SCR to conduct.

This triggering methode is used in light activated Silicon control rectifier (LASCR)

→ Application :- HVDC (High voltage d.c transmission system)

(ii) series parallel combination of SCR.

Swithing caracterstics of thyristor

→ It is otherwisely known as dynamic or transient carectoristics.

→ its divided in to two type (i) Turn on } Charcector stics. Turn of }

→ Thyristor leads to different voltage and current during turn on & turn off is known as swithing carectorstics.

Turn On charactorstics :—

→ The diff. voltages and current during turn on time is known as turn on charcectorstics.

→ The transition time from forword blocking mode to forword conduction ~~mode~~ mode i.e off state to on state is called as turn on time.

Turn on time = delay time + Rise time + Spread time

$T_{on} = T_d + T_r + T_p$ [total takes 1 to 4 μs)

Blocking state :—

Heare gate voltage (V_g) is maximum & anode voltage (V_a) as well, Gate current (I_g) gradualy increases from zero and anode current (I_a) is equals to leakage current (I_L), power loss is minimum.

delay time :-

Vg is maximum Va decreses to zero 0.9 Va. Ia increases to 0.1 Ia. Ig increses to 0.9 Ig. power loss also increases

Rise time (TR) :-

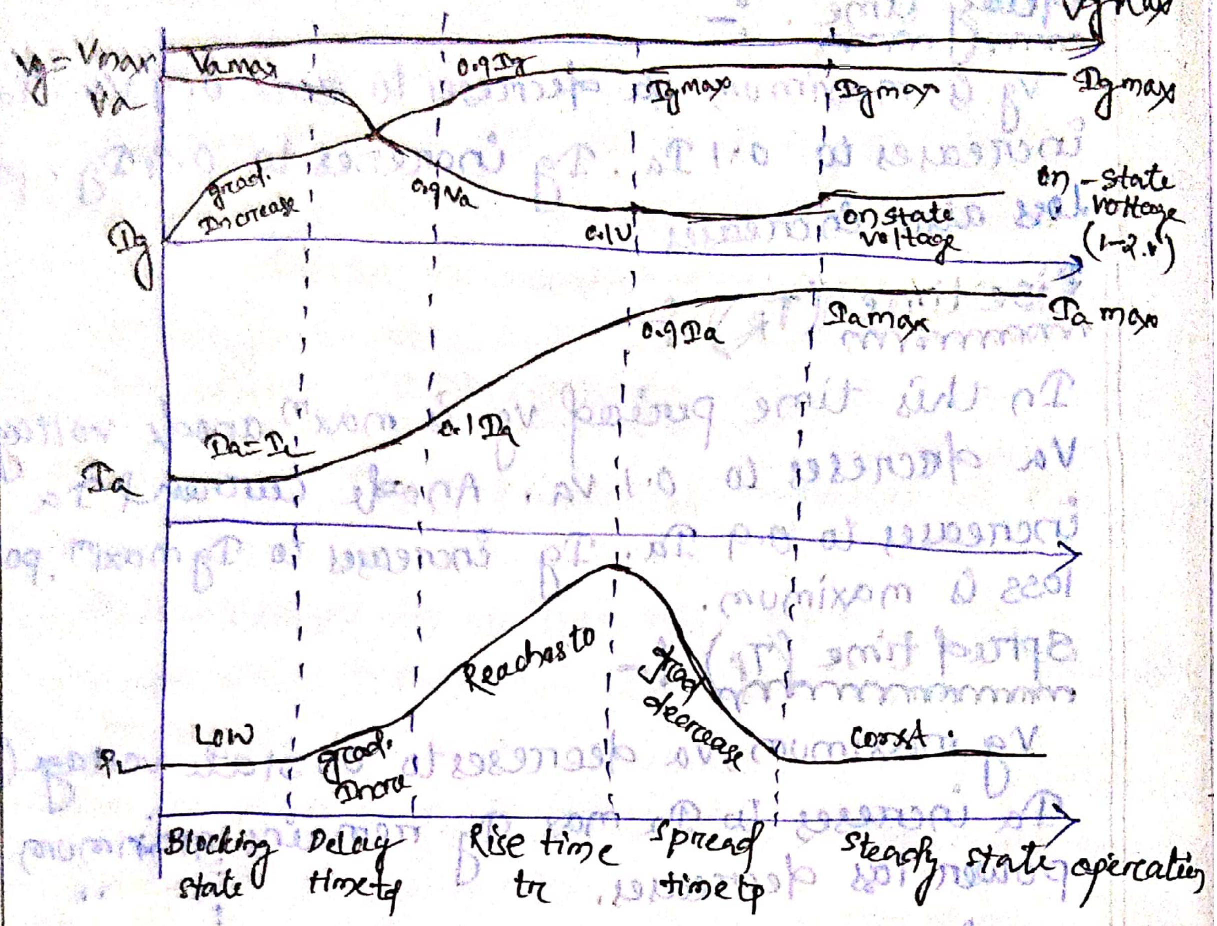
In this time period vg is max^m anode voltage Va decreses to 0.1 Va. Anode current Ia increases to 0.9 Ia. Ig increases to Ig maxi^m. power loss is maximum.

Spred time (Tp) :-

Vg maximum, va decreses to on state voltage (1 to 2 volt) Ia increses to Ia max Ig remains maximum. power loss decreases.

Stedy state :-

Vg = vgmax
va = Onstate voltage
Ia = Iamax
Ig = Ig max
power loss Cond.



[Turn - On - characteristics]

Blocking state

$V_g = V_{g\,max}$

$V_a = V_{a\,max}$

I_g = gradually increasing

I_a = leakage current

P_L = Less

Delay time

$V_g = V_{g\,max}$

$V_a = 0.9\, V_a$

$I_g = 0.9\, I_g$

$I_a = 0.1\, I_a$

P_L = increases

Rise time

$V_g = V_{g\,max}$

$V_a = 0.1\, V_a$

$I_g = I_{g\,max}$

$I_a = 0.9\, I_a$

P_L = increases

Spread time

$V_g = V_{g\,max}$

$I_g = I_{g\,max}$

V_a = On - state voltage

$I_a = I_{a\,max}$

P_L = decreases.

Steady state

$V_g = V_{g\,max}$

$I_g = I_{g\,max}$

V_a = On state voltage

$I_a = I_{a\,max}$

P_L = Const.

Turn off characteristics

The transition time from forward conduction state (on state) to forward blocking state (off state) is known as turn off time of SCR.

→ The turning off process is known as comutation process.

→ Turn off = Reverse recovery time + Gate recovery time

$$T_q = T_{rr} + T_{gr}$$

→ Slow turn off time is 50 to 100 micro second and fast turn off time is 3 to 50 micro second.

*Ones the thyristor is on gate losses its control, the SCR can be turn off by reducing the anode current Ia bellow holding current (IH)

→ If forward voltage is applied to the SCR at this moment (at Ia = 0) the device will not be able to block this forward voltage & again starts conduction.

→ To overcome this a reverse voltage is applied to the SCR

→ At this time period of some excess charge carrier are present in the 4 layers & 3 junct.

→ These charge carrier should be removed by apply a reverse voltage.

→ 60% of charge carriers from junction J1 & J3 are removed within time period t1 to t2.

→ Remaining 40% of the charge carriers from junction J1 & J3 removed by the time period t2 to t3.

→ Both these time periods are combined called as reverse recovery time (T_{rr})

→ To clear the junction J_2 reverse voltage is maintained, due to which recombination occurres & the junction clears out this time period is called as gate recovery time (T_{gr}) this is the instant from t_3 to t_4.

→ At instant t_4 junction J2 recovers & forword voltage can be applied.

→ ~~pr~~ Practically thyristor requireds some extra time to turn off. this is called as commutation (t_c)

→ for general turn off (t_c) must be greater then (t_q) ~~of~~

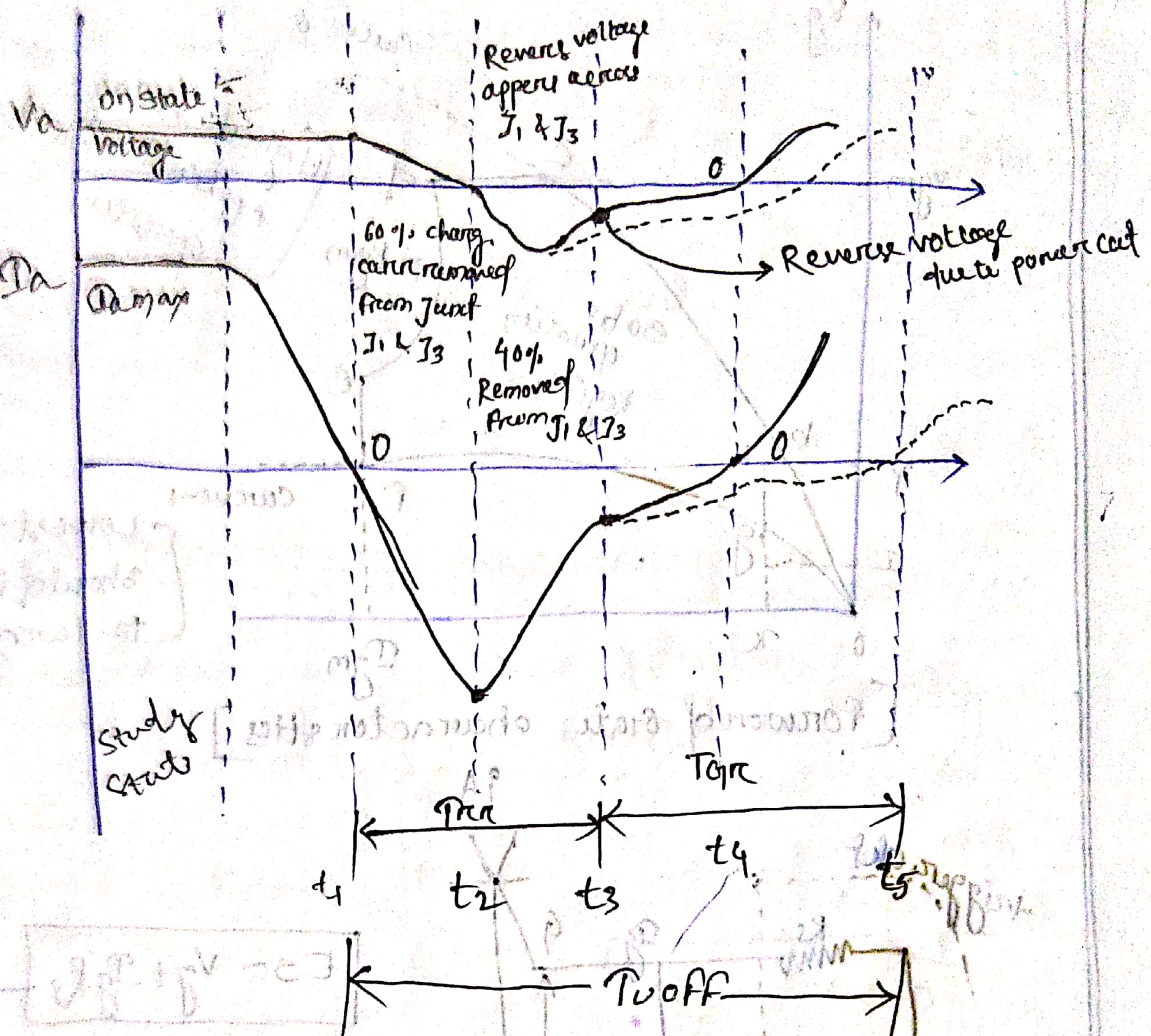
→ If ($T_q > T_c$) device will turn on at undesired instant. this process is called as commutation failure.

→ Turn off time is the time betn the instant anode current becoms zero & SCR regains its blocking capability

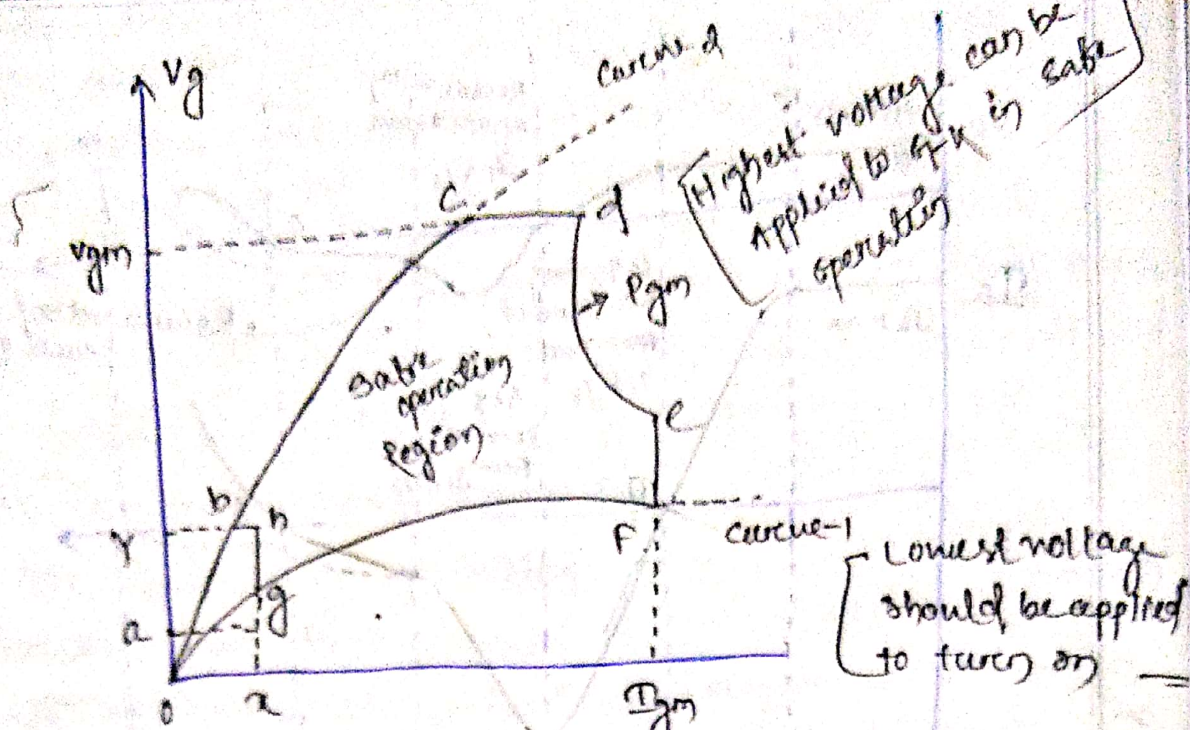
OR

→ It is the time in which all the charge carriers must be removed from 4 layer 3 junction

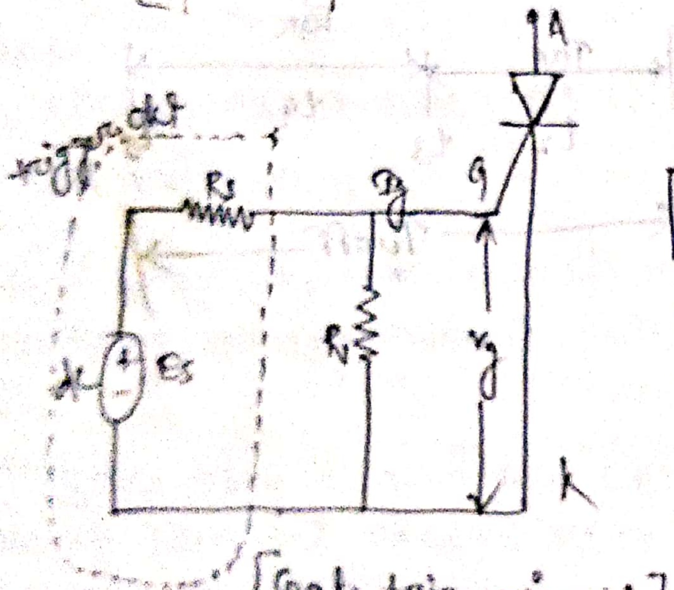
→ Commutation time t_c is the time between instant anode current becoms zero to reverse voltage reaches to zero.



Va
On state voltage
Reverse voltage appears across J1 & J3
0
Reverse voltage due to power cut
Ia
Iamax
60% charge carrier removed from Junct J1 & J3
40% Removed from J1 & J3
0
Steady state
Trr
Tgr
t1
t2
t3
t4
t5
Tq off



[forward Gate characteristics]



[Gate triggering ckt]

$$E_s = V_g + I_g R_s \quad (1)$$

E_s = Supply voltage

V_g = Gate to cathode voltage

I_g = Gate current

R_s = Source Resistance

R_1 = Provides Easy path for leakage current

By applying a gate triggering ckt the SCR can be operated only within its safe operating region.

→ If the SCR will operate beyond curve one or curve 2 or Pgm region the junction J3 will destroy and SCR will be damaged.

→ Equation 1 is written in terms of max^m gate volt.

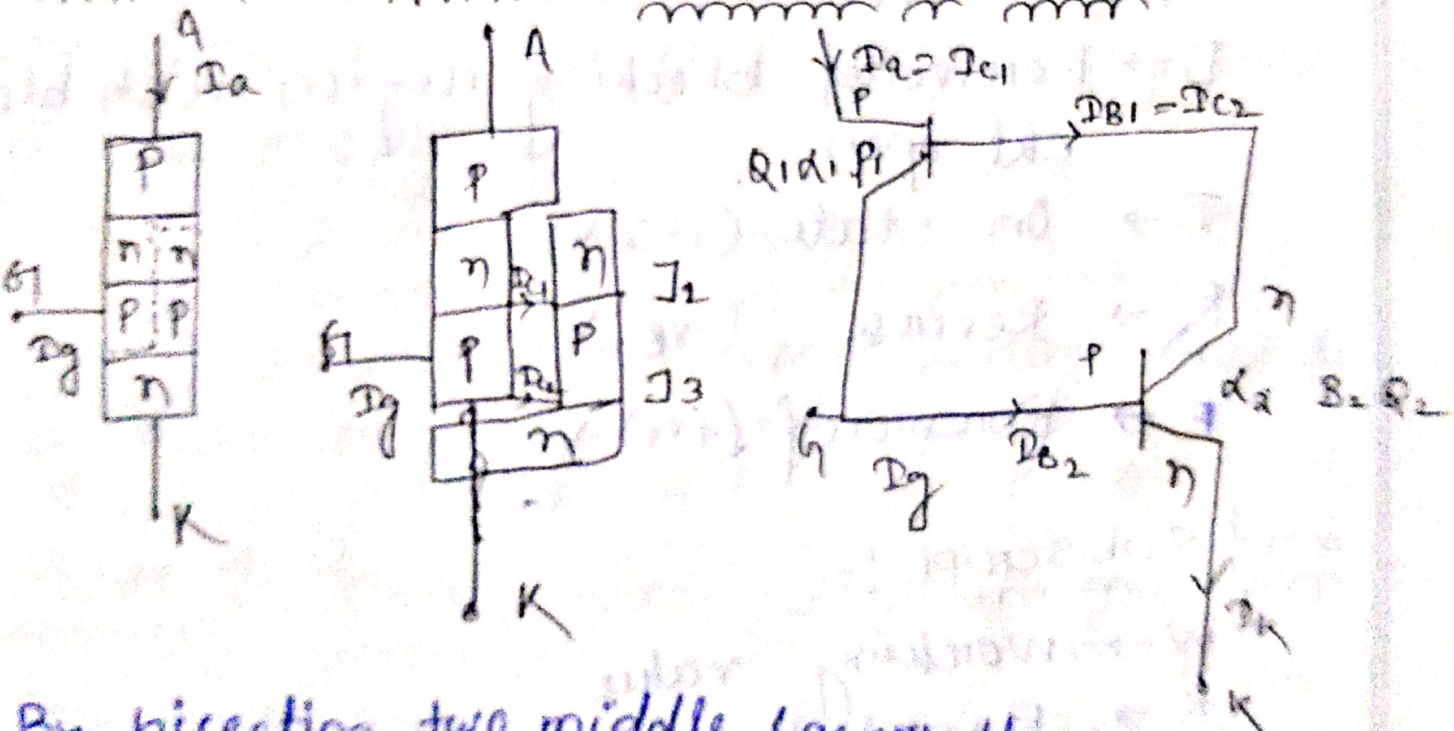
& maximum gate current, if we will right in terms of minimum gate current and minimum gate voltage than E_s is given by

$$E_s = \left(I_{gmn} + \frac{V_{gmn}}{R_1}\right) R_1 + V_{gmn} \quad (2)$$

I_{gmn} = minimum gate current

V_{gmn} = " " voltage

TWO TRANSISTOR ANALOGY OF S.C.R



By bisecting two middle layers the 4 layer pnpn SCR converted in to two transistors one is pnp & another is npn transistor this is known as two transistor analogy or model of thyristor as we know transistor have three terminal as collector base & emitter.

THYRISTOR RATING

Thyristor rating indicates voltage, current power & tempr limits whithin which thyristor can be used without any damaged.

The disadvantage of thyristor is it have low thermal time constant.

Subcription

1st Subcription

D → Forword blocking region with block ckt open

T → On state (1-2 V)

R → Reverse (-ve) V.

F → Forword (+ve) V

2nd Subscript :-

W → working value

R → Repetative value

S → Surge on non repetative value

T → Trigger

3rd Subscript

M → Maximum or peak value

Note

A → Anode

K → Kathode

G → Gate

VDWM :- peak working forword blocking voltage.
It is the maximum forword blocking voltage that a thyristor can with-stand during its working.

VDRM :- peak repetative forword blocking volt.
It is the peak transient voltage the transistor can withstand repetately in its forword blocking mode.

VDSM :- peak surge forword voltage
It is the max^n forword surge voltage that doesn't repeat.

VRWM :- peak working reverse voltage
It is the maximum reverse voltage that a ty thyristor can withstand repetately.

VRSM :- peak surge reverce voltage
It is the peak value of reverse surge voltage that will not repeat.

VRRM :- peak repetally reverse voltage
It is the peak reverse transient voltage that occurs repetally.

VT :- On state voltage drop
It is the voltage drop between anode and cathode with specific on state current.

Forword $\frac{dv}{dt}$ Ratting
The rate of rise of forword anode to cathode voltage.

Thyristor protection :

Thyristor should be operated with its specified rating of voltage & current for sometime

(i) $\frac{di}{dt}$ is very large during turn on

(ii) $\frac{dv}{dt}$ is very high, causes falls triggering

(iii) Spurious signal across gate and cathode turns on the SCR.

(iv) over voltage

(v) over current.

may lead to as normal operating condn which should be protected to prevent the device from damage.

→ protection generally following types

(i) $\frac{di}{dt}$ protection

(ii) $\frac{dv}{dt}$,,

(iii) over voltage protection

(iv) over current ,,

(v) gate protection

$\frac{di}{dt}$ protection

when thyristor is forward bias and turn on by a gate signal anode current being should flow across reverse junction.

→ Current spreads hole area of the junction very fast.

If the rate of size of anode current i.e $\frac{di}{dt}$ is large as compared to the spread velocity of carriers local hotspot will from near junction gradually this increses and very damage the device.

→ For limitting the hotspot a series inductor of very small value called $\frac{di}{dt}$ inductor is connected with anode ckt.

→ $\frac{di}{dt}$ should like 20-500 Amp/m.s.

$\frac{dv}{dt}$ protection :-

If the rate of rise of sudenly applied voltage accross thyristor is high the device gets turn on

→ this is called as a $\frac{dv}{dt}$ turn on which leads to falls triggering of SCR.

→ This can be avoided by using snubber ckt in parallel with the device.

$\frac{dv}{dt}$ should lie in the range 20-500 v/m sec.

Snubber ckt

Consist of series combination of resistance and capacitance in parallel with SCR.

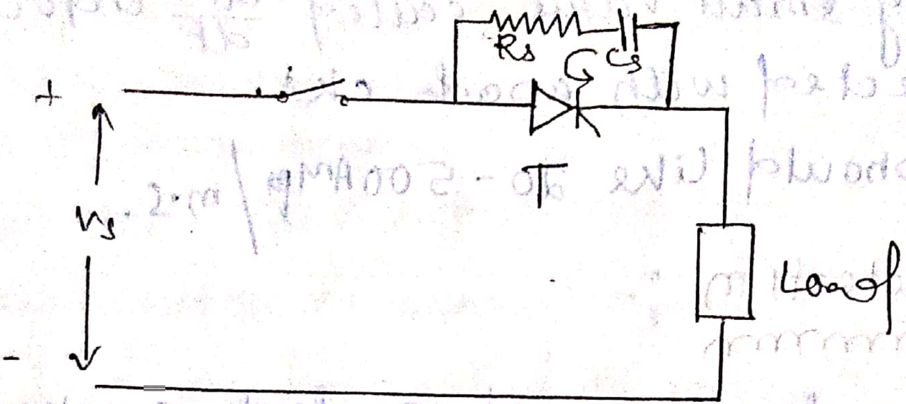
→ The capacitor prevents unwanted $\frac{dv}{dt}$ triggering of SCR resistance damp out rising ossilation and limits the current

→ When switch S is closed a shuden voltage appears behave like a short ckt and voltage.

across SCR is zero.

→ gradually with time voltage builds up slowly and $\frac{dv}{dt}$ is less.

→ SCR fired capacitor discharge through thyristor and $I = \frac{V_c}{R_s}$ at this time ~~resistance~~ resistor limits the current.



→ provids local path for internal over voltage

→ Thems over voltage ocilation.

→ limits $\frac{dv}{dt}$

Over voltage protection

Thyristor is sensitive to over voltage transient which leads to thyristor value the main cause of transient over voltage is falls turn on of SCR or permanent damage to device due to reverse breakdown.

→ over voltage is two type (i) Internal overload
(ii) External overload

→ Internal over voltage is caused by operation of thyristor large voltage generated in terms during Commutation of SCR.

→ The reverse recovery current rises to its pic value after if decrease with $\frac{di}{dt}$ a large amount of transient is produce.

→ This internal overvoltage may damage the SCR

→ External overvoltage is caused by (i) supply line

(ii) Load ckt (iv) Transformer

(iii) lightling (v) Interruption of current in the inductive ckt.

→ These leads to overvoltage and produce large fault current lastly damage the device.

Suparation of over voltage

The effect of over voltage can be minimised by useing RC ckt and non linier resister called voltage clamping device R.

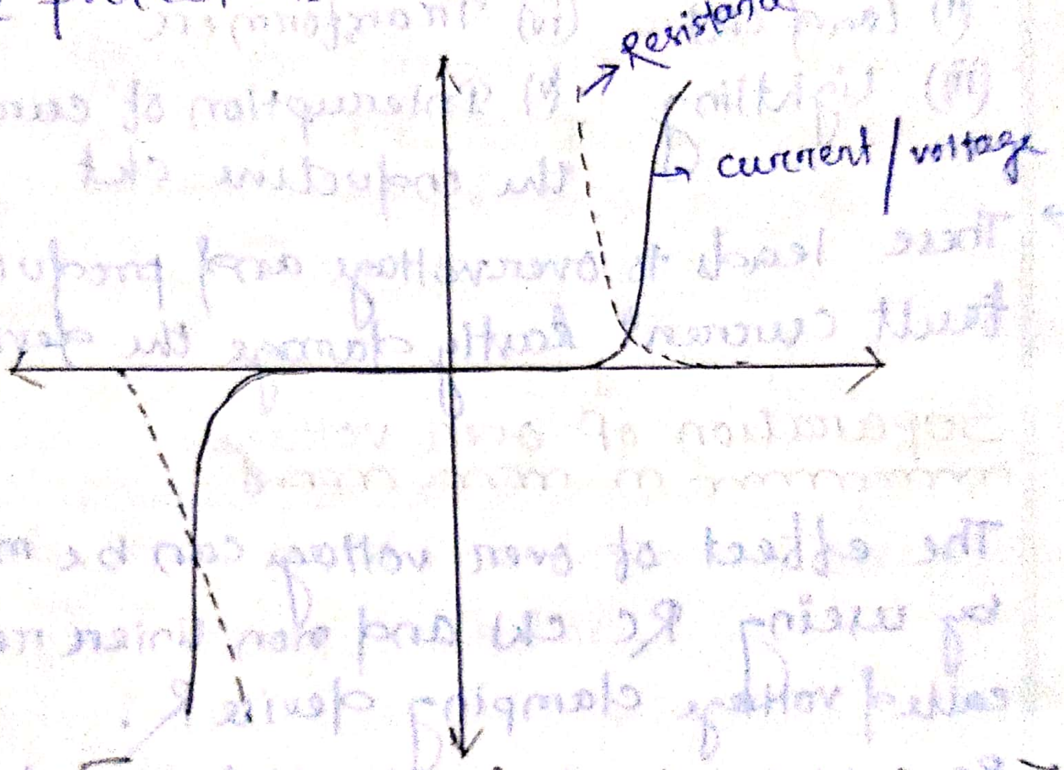
→ RC ckt is snumber ckt which provids local path for internal over voltage caused by reverse recovery current. The resistance thamsout the osilation produce in it.

→ A voltage camping device is a nonlinear resistor connected across SCR it has a falling resistance characteristics with increasing voltage.

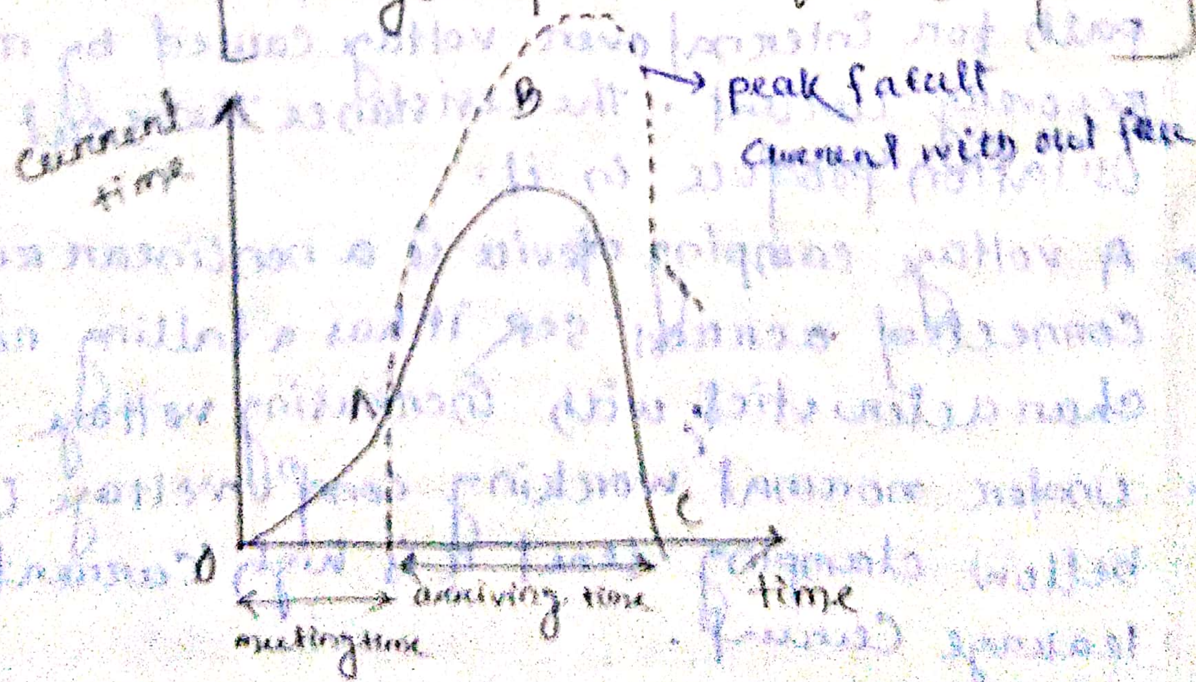
→ Under normal working cond voltage lies bellow clamping level R is high current leakage current.

→ When voltage surge appiers voltage is high resistance is low maximum current flows through SCR and encrease voltage drop in the source and line as a result voltage droups down and damping it successesfully after surge dicipeation it return breaks to normaly cond^n.

→ Selinium diods metal oxide variastore or avalance diode supration are used for over-voltage protection.



[voltage amp charc of V.C. device]



[FACLE]

Over current protection :-

Thyristors generally have a small time const. If thyristor is subjected to over current due to short ckt or faults. its junction temp increases after safe limit it will damage the device so we need to protect over current.

→ The protecting device for over current are
  (i) ckt breakers
  (ii) fuse
  (iii) FACLF [fast acting current limiting fuse]

→ The surge current can be protected by electronic crowbar protection.

→ In crowbar protection a current sencing resister measures converter current. If the value is greater than preset value a signal produce and shorts the converter over current.

Gate protection

A gate ckt should protect over voltage and over current

→ Over voltage leads to falls triggering

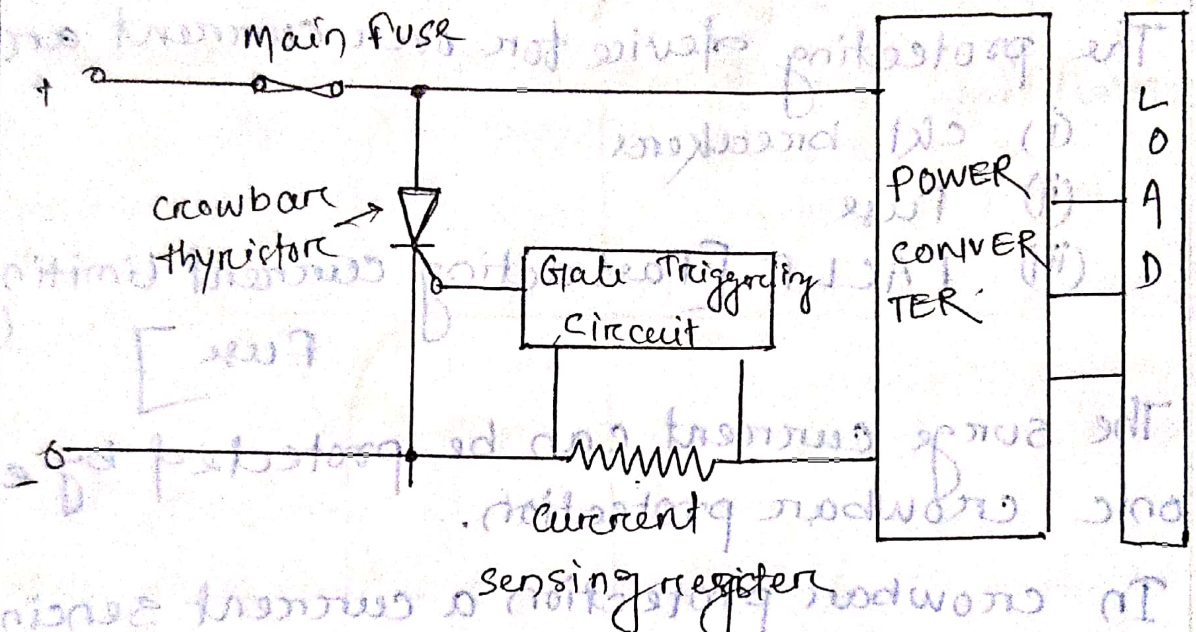
→ Over current encreases the junction temp.

→ Zinner diode is used parallely for voltage protection and a series resistance connected for current protection.

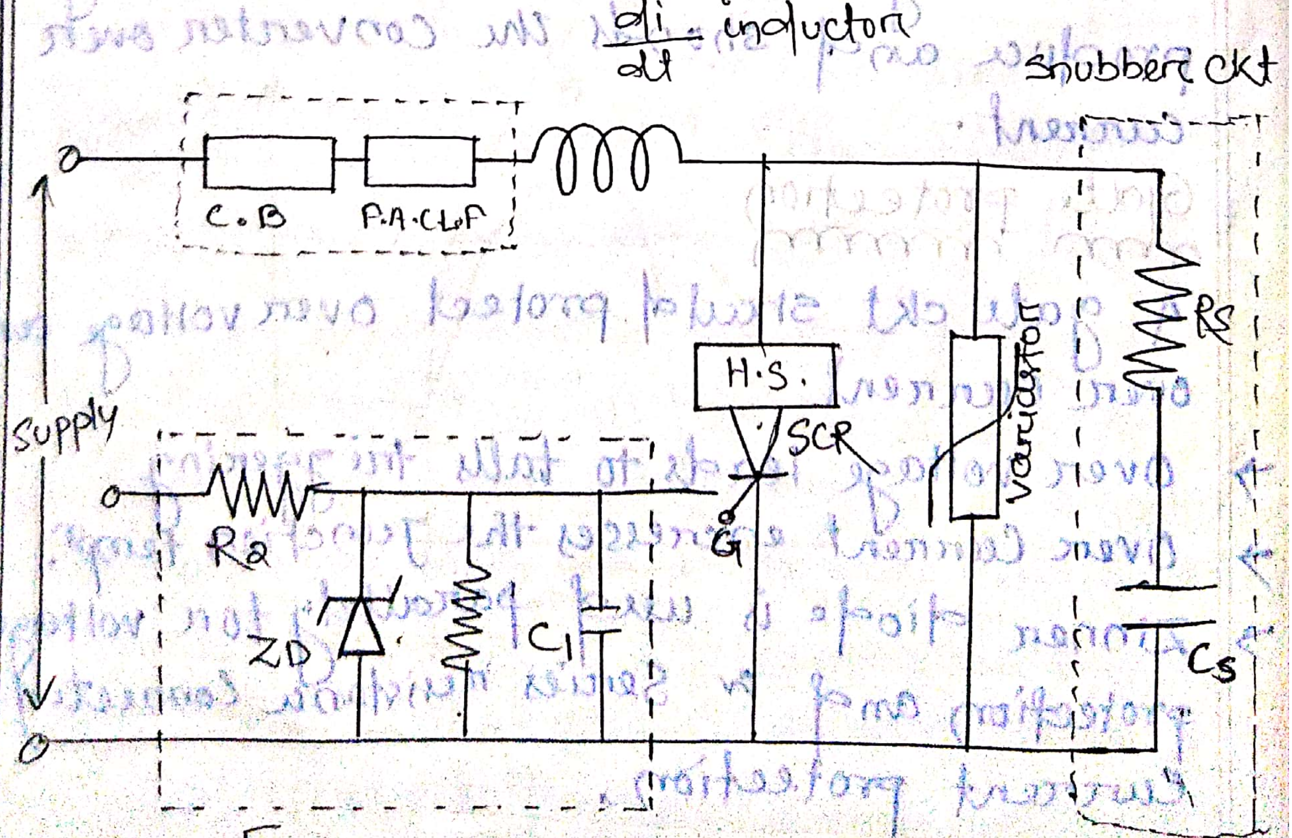
Scanned by CamScanner

→ The spurious or noise signal can be eliminated by using twisted gate lead of shielded cable.

→ capacitor and resister is connected to by pass the noise signal.



[Elemenataray electronic crowbar circuit]



[THYRDSTOR PROTECTION]