Thyristor

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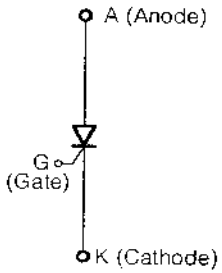
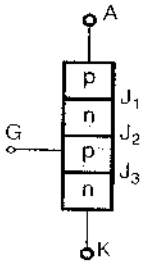
Thyristor is a four layer, 3 junction, 3 terminal semicontrolled p-n-p-n semiconductor switching device.

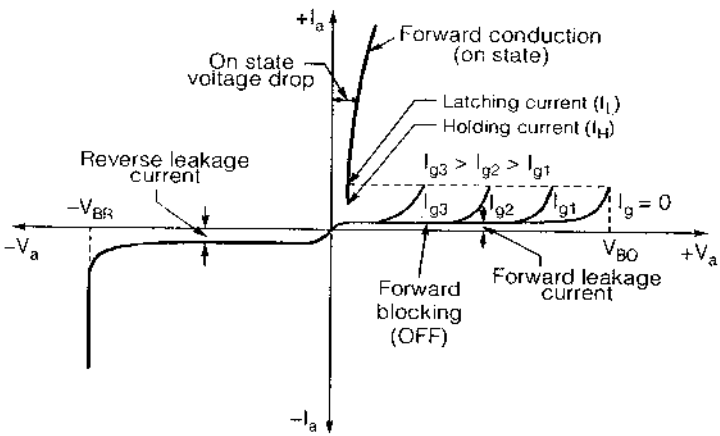


(Circuit Symbol)



(Schematic diagram)

Static V-I Characteristics of Thyristor



where, V_{BO} = Forward breakover voltage

V_{BR} = Reverse breakover voltage

I_g = Gate current

Thyristor Operates in Three-Region

1. **Forward blocking mode:**

Device is in OFF state. Anode is positive, cathode is negative and $V_a < V_{BO}$

$I_g = 0$

Junction: $J_1 \rightarrow$ Forward bias

$J_2 \rightarrow$ Reverse bias

$J_3 \rightarrow$ Forward bias

Only forward leakage current flow.

2. Forward conduction mode:

Device is in ON state. Anode is positive, cathcde is negative and $V_a > V_{BC}$

$I_g = 0$

Junction: $J_1 \rightarrow$ Forward bias

$J_2 \rightarrow$ Breakdown occur

$J_3 \rightarrow$ Forward bias

3. Reverse Blocking mode:

Device is in OFF state. Anode is negative, cathode is positive.

$I_g = 0$

Junction: $J_1 \rightarrow$ Reverse bias

$J_2 \rightarrow$ Forward bias

$J_3 \rightarrow$ Reverse bias

❑ Latching Current (I_L)

It is the minimum anode current to be attained above which the device continues to be in the ON state even after removal of the gate current.

❑ Holding Current (I_H)

It is the minimum anode current to be attained below which the device comes into the OFF state after applying a reverse voltage across it untill it regains its blocking capability.

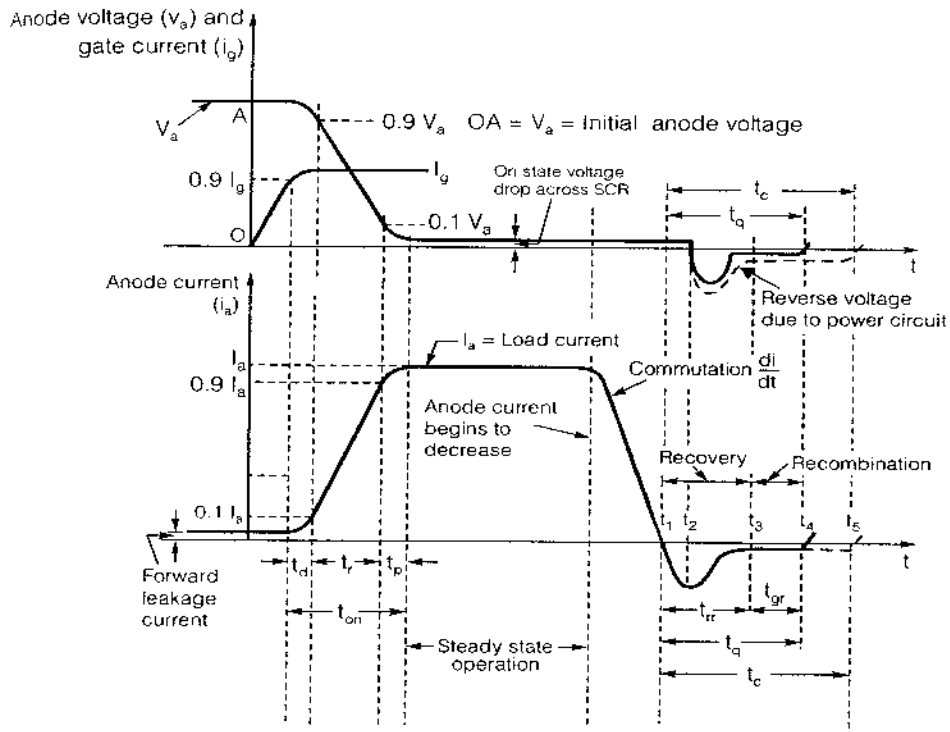
❑ Procedure to Turn-off the SCR

Bring down the anode current below holding current. After that apply a reverse voltage across it till excess carrier are removed and it regains its blocking capability.

Remember:

- By increasing the magnitude of Gate signal the breakdown voltage reduces.
- Latching current is related to turn-on process and holding current is related to turn-off process.
- $I_L > I_H$ or $I_L \approx IH$.
- The Gate signal needs to provide untill, the anode current is just above the latching value, so that it continuous to be in ON state even after removing gate signal.
- Gate looses the control after SCR is turn-on, thats why it is called partially controlled device.
- By increasing the value of load inductance the minimum pulse width required to turn-on the SCR is also increase.
- By increasing the value of resistance connected in series with inductive load, the minimum gate current width require is constant.
- By adding a resistance in parallel with load resistance the minimum pulse width is changed.

Switching Characteristics of Thyristor



Turn-on Characteristics	Turn-off Characteristics
Delay time (t_d) = 0.9 I_g to 0.1 I_a	$t_q = t_{off} = t_{rr} + t_{gr}$
Rise time (t_r) = 0.1 I_a to 0.9 I_a	t_q = Device turn-off time
Spread time (t_p) = 0.9 I_a to I_a	t_{rr} = Reverse recovery time
	t_{gr} = Gate recovery time
	t_c = Circuit turn-off time

Remember:

For successful commutation, $t_c > t_q$

Triggering Methods of SCR

(i) Forward voltage triggering.
(ii) Gate triggering
(iii) dv/dt triggering
(iv) Temperature triggering
(v) Light triggering

Remember:

- Light triggering thyristors are used in HVDC transmission system.
- The size of pulse transformer and average gate power dissipation can b reduced by using high frequency gating.

String Efficiency

It is measure of utilisation of SCRs rating to its full capacity.

$$\text{String efficiency} = \frac{\text{Total string voltage/current rating}}{\text{n (individual voltage/current rating of one SCR)}}$$

where, n = Number of SCRs connected in series/parallel.

$$\text{Derating factor} = 1 - \text{String efficiency}$$

Series Connection of SCR

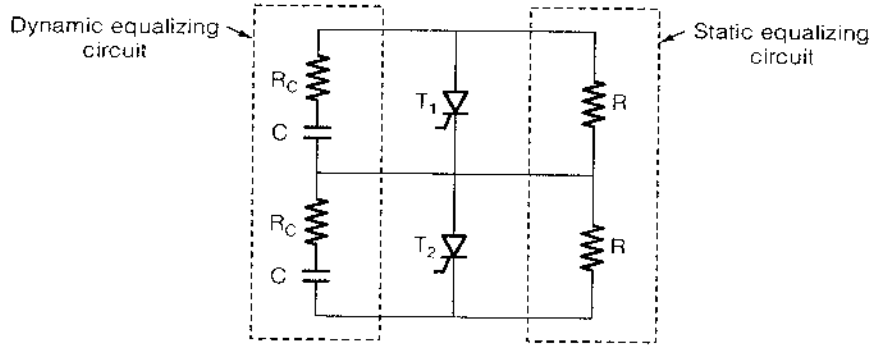
When the available voltage rating of SCR is not sufficient then we ha to connect some of the SCR in series so that they share the appli voltage during the off-state.

roblem Related to Series Connected SCR

nequal Sharing of Voltage:

g) Due to difference in forward blocking characteristics of series connected SCR. To overcome this problem, we use "static equalizing circuit".

g) Due to difference in the reverse recovery characteristic. To over come this problem, we use "dynamic equilising circuit".



$$R = \frac{nV_{bm} - V_s}{(n-1)\,\Delta I_b} \qquad C = \frac{(n-1)\,\Delta Q_R}{nV_{bm} - V_s}$$

V_{bm} = Maximum permissible blocking voltage
ΔI_b = $I_{b(max)} - I_{b(min)}$
= Difference between maximum and minimum leakage current
n = Number of SCR connected in series
V_s = Total string voltage
ΔQ_R = Difference in recovery charge

arallel Connection of SCR

When available current rating of the SCR is not sufficient then we have to connect some of the SCRs in parallel.

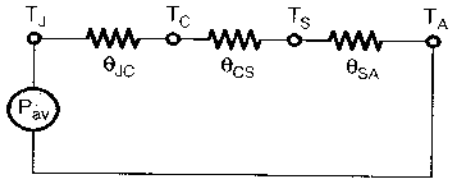
roblem Related to Parallel Connected SCR

nequal sharing of current:

) Due to difference in conduction characteristics of both SCR connected in parallel. To over come this problem connect current equilsing circuit.

) Due to temperature difference and to over come this problem we put all SCR in a common symmetrical heat sink.

Thermal Resistance



where, P_{av} = Average rate of heat generated

T_J = Junction temperature

T_C = Case temperature

T_S = Sink temperature

T_A = Ambient temperature

θ_{JC} = Thermal resistance between junction and case

θ_{CS} = Thermal resistance between case and sink

θ_{SA} = Thermal resistance between sink and ambient

$$P_{av} = \frac{T_J - T_C}{\theta_{JC}} = \frac{T_C - T_S}{\theta_{CS}} = \frac{T_S - T_A}{\theta_{SA}} = \frac{T_J - T_A}{\theta_{JA}}$$

$$\theta_{JA} = \theta_{JC} + \theta_{CS} + \theta_{SA}$$

Protection of Thyristor

(i) **Over current protection:** Fuse or circuit breaker connected in series with SCR to limit over-current.

(ii) **Over voltage protection:** Varistor are connected across SCR.

(iii) **High dv/dt protection:** Snubber circuit is provided across SCR.

(iv) **High di/dt protection:** Connect a inductor in series with SCR.

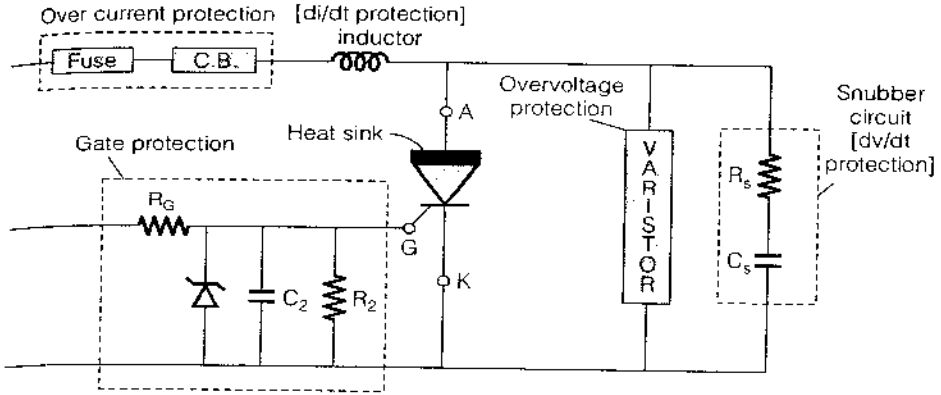
(v) **Thermal protection:** Provide heat sink in SCR.

Gate Protection

(i) **Over current protection:** Connect a resistance in series with Gate.

(ii) **Over voltage protection:** Zener diode is connected across the gate and cathode junction.

(iii) **Protection against noise:** Connect a capacitor and a resistor across gate and cathode.

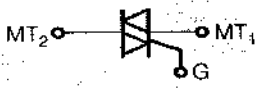
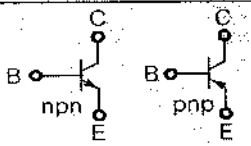
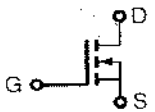
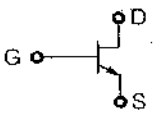
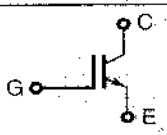


Circuit for protection of SCR

Remember:

- Gate current magnitudes are of the order of 20 to 200 mA.
- Triac is combination of antiparallel connection of two SCR.
- Diac is antiparallel connection of two SCR when $I_g = 0$.

Device	Circuit symbol	Voltage/current ratings
Diode	A K	5000 V 5000 A
Thyristors		
(a) SCR	A K G	7000 V 5000 A
(b) LASCR	A K G	6000 V 3000 A
(c) ASCR/RCT	A K G	2500 V 400 A
(d) GTO	A K G or A K G	5000 V 3000 A
(e) SITH	A K	2500 V 500 A

(f) MCT		1200 V 40 A
(g) Triac		1200 V 1000 A
Transistors		
(a) BJT		1400 V 400 A
(b) MOSFET (n-channel)		1000 V 50 A
(c) SIT		1200 V 300 A
(d) IGBT		1200 V 500 A

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