Series and Parallel operation of Thyristors.

- Need for series connection of SCRs

- When our requirement is of high voltage operation, and the available voltage rating of SCR is not sufficient, then we connect some SCRs in series.
- The SCRs connected in series share the voltage during the blocking state.

- Need for parallel connection of SCRs

- When our requirement is of high current operation and available current rating of SCR is not sufficient, then we connect SCRs in parallel.
- The SCRs connected in parallel share the current during conduction state.

- While connecting SCRs in series or in parallel, we need to ensure that
  - ↳ Ratings of connected SCRs are fully utilized.
  - ↳ Operation of the system is satisfactory.

- String Efficiency :-

- A number of SCRs connected in series or in parallel is known as "String".

- When SCRs are connected in a string, we determine the degree of utilization of each SCR, using a term known as string efficiency.

$$\text{String Efficiency} = \frac{\text{Actual Voltage rating of string}}{\text{Voltage rating of each SCR} \times \text{No. of SCR in string}}$$

↙ For series connected SCRs.

$$\text{String Efficiency} = \frac{\text{Actual current rating of string.}}{\text{Current rating of each SCR} \times \text{No. of SCR in string}}$$

↙ For parallel connected SCRs.

- For obtaining highest utilization of SCR rating, hence for obtaining highest possible string efficiency, the SCRs to be connected in series or parallel should have identical I-V characteristics.

- However, even the SCRs of same rating may not have identical I-V characteristics, due to differences in internal structure resulting from manufacturing process.

⇓

- So, string efficiency can never be equal to 1.

- However, unequal voltage or current sharing by the SCRs in a string can be minimized to a great extent, by using external equalizing circuits.

↓

(discussed in details later on).

Derating Factor (Measure of reliability of string).

- If all the SCRs connected in a string is utilizing its capacity nicely (say around 90%), then the string efficiency is good (around 90%).

⇓

However, the string may not be very much reliable. As each SCR is working close to their maximum rated capacity, any abnormal voltage or current may damage the SCR or string.

- Now, if we add one more SCR to the same string, then each SCR will utilize somewhat lower capacity due to addition of extra SCR.

⇓

The overall string efficiency will reduce, due to lower utilization of capacity.

⇓

However, the string will become more reliable. Now the SCRs are not working very close to their maximum rating, so they can withstand higher abnormal voltage and current.

- So, the use of extra SCRs in the string improve the reliability of the string, though at an increased cost.
- The measure of the reliability of a string is given by derating factor (DRF).

Derating Factor = 1 − String Efficiency

① Series operation of SCRs.

Ideal condition :-

↳ All the SCRs connected in series have same rating and identical characteristics. Due to identical characteristics, they share equal voltage.

Practical condition :-

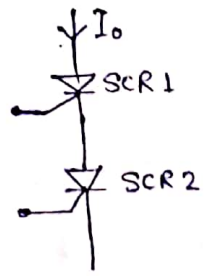
↳ However, practically the situation is different. Even when SCRs have same rating, their characteristics differ and hence voltage shared by each SCR is not equal.

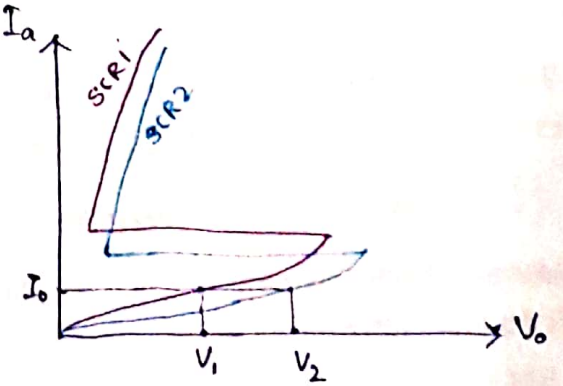
∵ Problem related to series connected SCRs ⇒ Unequal sharing of voltages.

- There are different reasons for this problem of unequal sharing of voltages.

Reason 1 :-

↳ Due to difference in forward blocking characteristics of series connected SCRs.





- Under forward blocking mode, same leakage current I_o flows through both SCRs, but the voltage blocked by them differs due to difference in characteristics.

Solution

↓

Use of static equalising circuit.

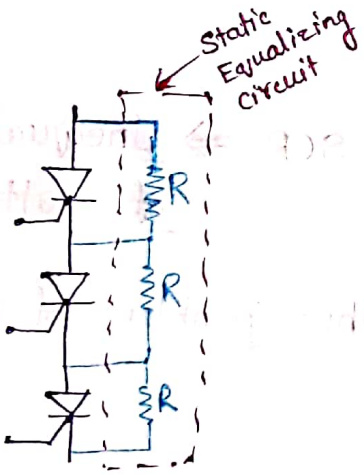
- So, the two SCRs take a total voltage of $V_1 + V_2$, instead of $2V_2$.

- This problem is overcome by static equalizing circuit, which consists of shunt resistance R, connected across each SCR.

- Magnitude of this shunt resistance is given by

$$R = \frac{n V_{bm} - V_s}{(n-1)\Delta I_b}$$

Here,



V_{bm} → Maximum permissible blocking voltage of each SCR.

V_s → String voltage.

ΔI_b → $I_{bmx} - I_{bm}$

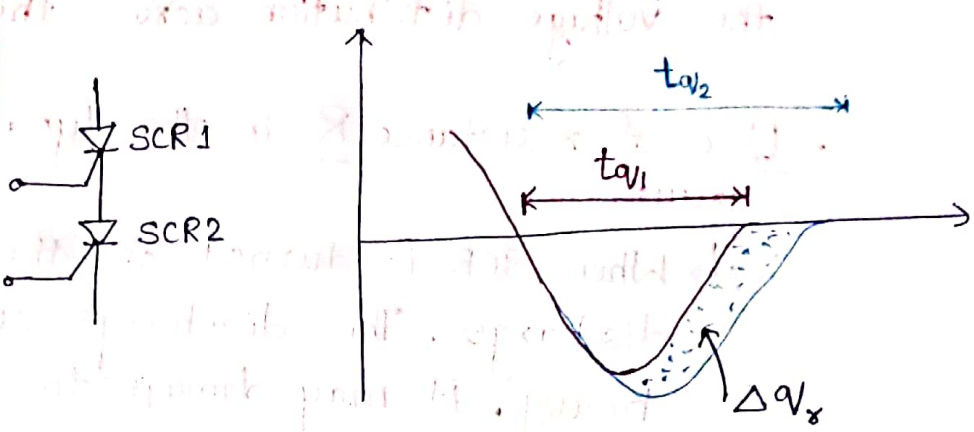
↓

Difference between maximum and minimum blocking current or leakage current.

n → No. of SCRs in a string.

Reason 2

↳ Due to difference in reverse recovery characteristics (Switching characteristics).



- Voltage unbalance may appear across SCRs connected in series, during turn-off process, due to difference in reverse recovery characteristics.

- If both the SCRs have same reverse recovery characteristics, then they turn off simultaneously. So, they will share the total voltage equally.

- But if SCR1 has shorter - reverse recovery time then it will turn-off first. SCR2 takes longer time to turn-off. So, all the supply voltage appears across SCR1 only.

- So, during turn-off process, different voltage may appear across the SCRs. This is overcome by use of dynamic equalizing circuit. It consists of a capacitor 'C' ~~connected across SCR~~. and a resistor in series with capacitor. The whole arrangement is connected across the SCR.

Solution

↓

Use of dynamic equalizing circuit.

- The difference in reverse recovery charge of both SCRs, ΔQ_R, induces a voltage in the capacitor, which ultimately tends to equalise the voltage distribution across the SCRs.

- Use of resistance 'R' in the dynamic equalizing circuit.
  - ↳ When SCR is turned on, the capacitor discharges. This discharge current is heavy. It may damage the SCR. So, to limit the discharge current of capacitor, resistance is used in the dynamic equalizing circuit.

- Use of 'Diode' in the dynamic equalizing circuit.
  - Due to presence of resistance in the dynamic equalising circuit, the charging time of capacitor may increase. This will reduce the effectiveness of capacitor in equalizing the voltage.
  - So, a diode is used to bypass the resistor during charging time of capacitor.

- Value of capacitor, to be used in dynamic equalizing circuit is found using.

$$C = \frac{(n-1)\Delta Q_R}{n V_{bm} - V_s}$$

ΔQ_R → diff. in stored charge

V_{bm} → Maximum permissible blocking voltage of each SCR.

n → No. of SCR in string.

V_s → Source voltage

So, 'Equalizing Circuits for Series connected SCRs. is as shown below.