Seven-nine weeks

Thyristor protection

To obtain satisfaction and reliable operation of thyristor it is necessary to provide protection against the all circumstance that will disturb the operation of the thyristor. The protection will be for:

1- Thermal protection
2- Gate protection
3- Anode- Cathode protection

Thermal Protection

Power losses in semiconductor device appear in the form of heat. The accumulation of heat energy increase the temperature of internal structure of device. There are two main thermal effect of thyristor:

1- Junction temperature:- the ability of thyristor to block the applied voltage with specific temperature limits. If the limit exceeded the thyristor will be ON even not a suitable gate voltage applied
2- Transient temperature impedance:- the resistance between the thyristor junction and cooling surface, the large thyristor has low thermal resistance. The high temperature may be detrimental of the physical structure of the thyristor, with small size and light weight power electronics the removal of the heat and control of internal temperature is very important. The maximum temperature of the junction can withstand called $T_{jMax.}$ Typical semiconductor package are designed for T_{jMax} of 125^{o} C

Cooling and mounting of thyristor

Power dissipation in electrical components raises the internal temperature and affects performance and reliability. The temperature difference between the junction and ambient can be written as:

$$T_j - T_A = P_{av}(\theta_{js} + \theta_{ts} + \theta_{As})$$

$$\Theta_{12} = \frac{T_1 - T_2}{P_{av}}$$

$$\Theta = (\theta_{cs} + \theta_{js} + \theta_{As})$$

T_j: the junction temperature

T_A : the ambient temperature

θ_{js}: thermal resistance of junction

θ_{cs}: thermal resistance of case heat sink

θ_{As}: thermal resistance of ambient

Thyrsitor Mounting

The internal power losses in a thyristor causes high thermal stress which give rise to mechanical forces. Thyristor must be braced to withstand such mechanical forces. The thyristor mounting must be designed to transfer the heat flow from the junction, depending on the low or high power rating of thyristor there are five mounting:

1- Lead mounting

   For low current rating the lead mounting can be used, and no additional cooling or heat sink required.

2- Stud mounting

   It is widely used due to flexibility and roughness, the stud at the anode and mounting by stud and nut. If the electrical connection between anode and heat sink non desired a mica or rubber washer used between them. This mounting is used with small and medium rating

3- Bolt – down mounting

   The device has flanges or tabs which usually contain one or more holes. Bolts are placed through these holes n order to attach the device to heat sink. This mounting is used n medium and small rating. This is also called as flat pack mounting.

4- Press – fit mounting

   This type designed for the insertion into appropriate hole in heat sink. It is used in high volume applications, the cost of this type less than for the stud type. It is employed for large rating

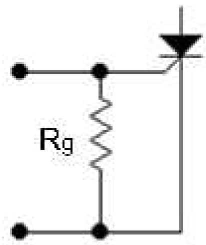
5- Press – pak mounting

   This is called also (disc) or (hockey puck) because of its shape. The thyristor placed between two heat sink, the space between two heat sink fill either with air. Water or oil cooled. It is used for very high current rating.

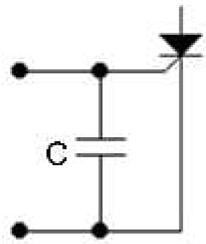
Gate Protection Circuits

The output of the gate firing circuit shown previously is normally connected between the gate and cathode but this not directly. So, must be used a protection circuit between the firing circuit and gate – cathode terminals

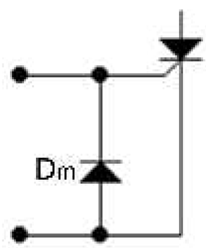
A **resistor** use which increase the dv/dt capability and increase the holding and latching current.
reduce the turn-off



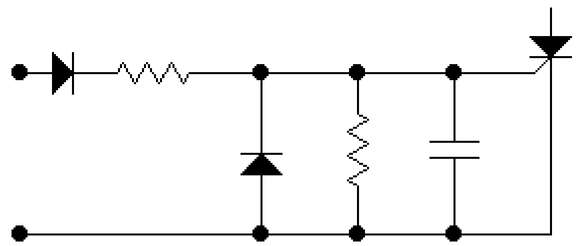
capacitor used, which remove high frequency noise component, increase dv/dt capability and increase the gate delay time. As in figure below



At shown in figure down diode use, which protect the gate from negative voltage.



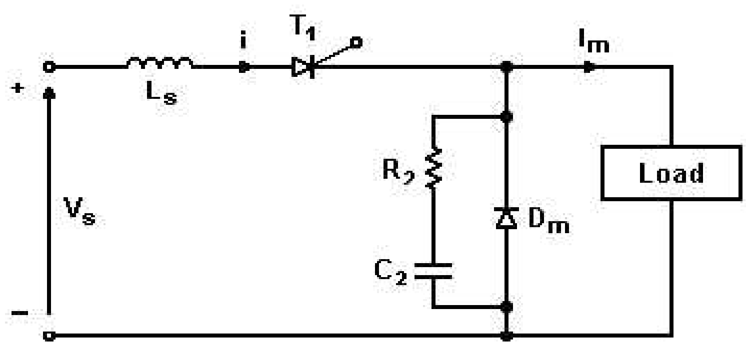
This circuit improve the dv/dt capability, reduce the turn-off time. Since D1 allows only a positive pulse and R1 kill any transient oscillation and limit the gate current.



Anode- Cathode protection circuit

1-di/dt protection

As the thyristors have restricted overcurrent capacity. A minimum time is required to spread the current conduction throughout the junction. If the rate of rise of anode current is very high compared to spreading velocity at turn on, then this could lead to localized (hot- spot) heating and the device may fail as a result of excessive heating. In practice thyristor could be protect from di/dt by using the circuit below



D$_m$ will conduct when the thyristor T1 is off, if the thyristor is fired D_m still conduct, so di/dt limited only by stray inductance of the circuit. In order reduce the high di/dt by a series inductor L added to the circuit as shown. The forward di/dt is given as:

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

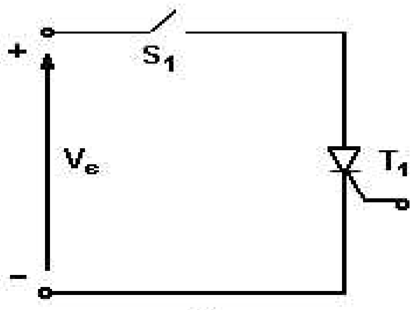
L$_s$, total inductance include stray and series inductance connected.

2-dv/dt protection

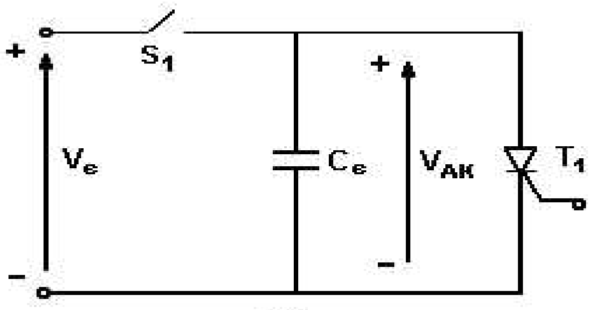
A high dv/dt may cause damage to a thyrsitor. In most power electronic circuits, protection is necessary against the effect of rise of voltage (dv/dt) across the device. If the S1 in figure (a) is closed at t=0, a voltage will be applied across SCR may be high enough to turn on the thyristor. The dv/dt can be limited by connected capacitor Cs across the thyristor as shown in figure (b)

$$V_C = \frac{1}{C}\int i\,dt$$

$$\frac{dV_C}{dt} = \frac{i(t)}{C}$$

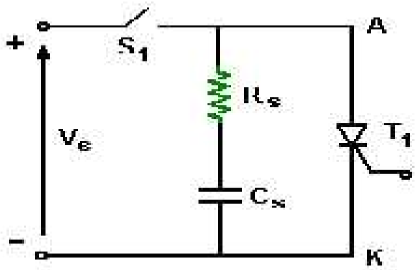


(a)

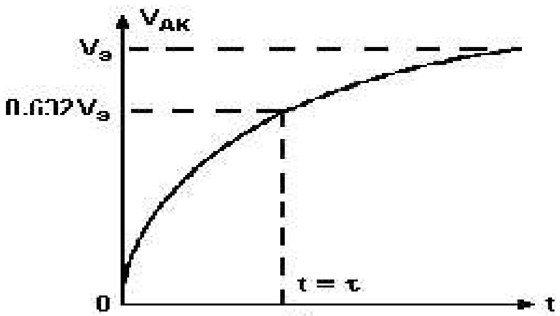


(b)

The rate of rise voltage is limited by the value of capacitor used. In order to limit the discharge current when the thyristor is turn off a resistor Rs is inserted in series with capacitor as shown (c). This is resistor capacitor arrangement is known snubber circuit



(c)



(d)

For figure (c) when S1 is closed at time t=0, the voltage across the capacitor is given be

$$V_C = V_S(1 - \exp(\frac{-t}{R_S\,C_S}))$$

This charge capacitor voltage is seen by the thyristor anode and cathode terminal $V_{AK,}$ this is depicted by the waveform of figure(d). The rate of rise of voltage across the SCR can be represented by

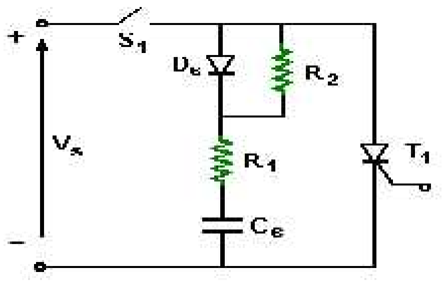
$$\frac{dV}{dt} = \frac{0.632 V_S}{R_S\, C_S} = \frac{0.632 V_S}{2}$$

The snubber circuit basically consists of a series connected resistor and capacitor placed in shunt with a SCR

The value of Rs could get for discharge current I_D by $R_S = \frac{V_S}{I_{TD}}$

It sometimes necessary to use on resistor for dv/dt and another for limiting the discharge current of the snubber capacitor. This arrangement is shown in figure (e). In this circuit, R_s and C_s are used for dv/dt protection, while R1+R2 is used for limiting the capacitor discharge current.

$$I_{TD} = \frac{V_S}{R_1 + R_2}$$



(e)

Snubber losses power given by

$$P_s = 0.5\, C_s V_S^2\, f_s$$

when switch S is closed, the capacitor behaves like a short circuit and SCR in the forward blocking state offers a very high resistance. In the figure, R_L is the load resistance and L the source inductance. The voltage equation is

$$V_S = (R_S + R_L)i + L\frac{di}{dt}$$

The solution of above equation is

$$i = I(1 - e^{\frac{-t}{2}})$$

$$I = \frac{V_S}{R_S + R_L} \quad , \quad 2 = \frac{L}{R_s + R_L}$$

Differentiating with respect to t

$$\frac{di}{dt} = Ie^{-t/\tau}.\frac{1}{\tau}. = \frac{V_s}{R+R_l}.\frac{R+R_l}{L}e^{t/\tau} = \frac{V_s}{L}e^{t/\tau}$$

The value of di/dt is maximum when t=0

$$(\frac{di}{dt})_{max} = \frac{V_s}{L}$$

$$L = \frac{V_s}{(di/dt)_{max}}$$

Now, voltage across the thyristor is given by

V=R. I $\qquad \frac{dv}{dt} = R.\frac{di}{dt}$

or

$$(\frac{dv}{dt})_{max} = R(\frac{di}{dt})_{max}$$

Sub the value of di/dt

$(\frac{dv}{dt})_{max} = R.\frac{V_s}{L}$ $\qquad$ or $\qquad$ $R = \frac{L}{V_s}.(\frac{dv}{dt})_{max}$

The parameters L,R_L, R and C should be so selected that the circuit becomes critically damped. Capacitor charge in minimum time for this condition. Therefore, from analytical we can write:

$\sqrt{(R_L + R)^2 - \frac{4L}{C}} = 0$ $\qquad$ or $\qquad$ $(R_L + R)^2 - \frac{4L}{C} = 0$

$$(R_L + R)^2 = \frac{4L}{C}$$

$$R_L + R = 2\sqrt{\frac{L}{C}}$$

Thyristor Isolation circuit

A common situation where a low-voltage, low current logic circuit controlling a high voltage, high current load. The logic cct is usually an IC is very often part of process control computer. The logic output V_0 will be either at 0 V or +5. When it is at 0V, the SCR is " off " and the load receives no power from the ac source. When V_o is +5V, the SCR is "on" and the 230V ac is switched to the load.

It is not desirable direct electrical between low power control and high power load, as done in this cct. One reasons is the possibility of the noise being coupled from the high current into logic circuit. The another reason is possibility of high voltage from load circuitry feeding back into the logic circuit as a result of component failure

Thus, it is often necessary to electrically isolate the low and high power. One mean for doing this is to use electro-mechanical relay. The logic cct drives the low current relay coil and the relay mechanically is as switch

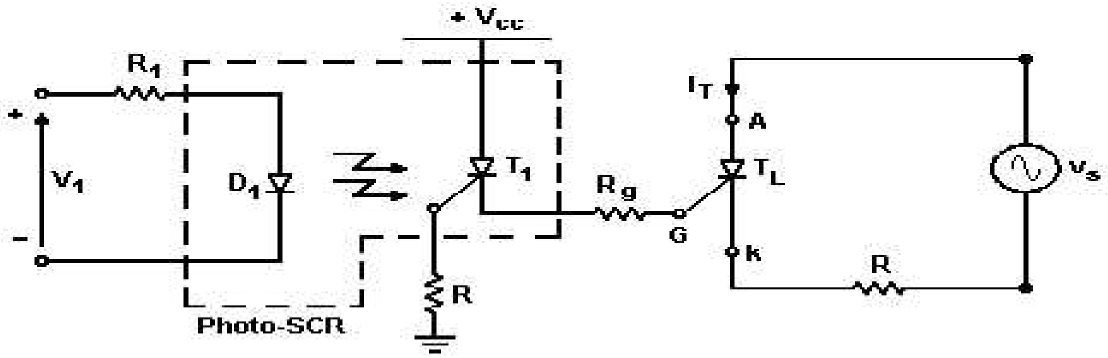
While relay widely used, they do have certain shortcoming including

1- They are fairly expensive
2- It is bulkier than solid state devices
3- Relays have shorter life than semiconductor
4- They create magnetic field and inductive "kick" which can be trouble some source of electrical noise
5- The contacts create sparking upon opening, this is highly undesirable in many industrial environments.

These disadvantage are largely overcome by devices called optical isolators or optoisolators, which use light energy to couple the control signal to the load. Optoisolators consists of a light source (infra-red emitter diode, IRED), a light sensitive device and a switching device. In most cases the light sensor and switching device are one and the same.

The IRED phototransistor combination can switch output of only 10mA, so can use photodarlington typical switch 500-100mA. It can used to increase the output current capacity but has disadvantage is that the photodartington has a switch less than speed phototransistor.

The output voltage from the logic circuit provides the relatively low current needed to activate the IRED, which turn controls the light device. When Vo is 0V, the IRED is nonconducting Vo is +5V, the IRED conducts and its radiant energy turn the device "on" switching the ac voltage across the load. The load receives ac power as long as Vo remains at +5V


+ Vcc
R1
+
V1
-
D1
T1
R
Photo-SCR
Rg
G
IT
A
TL
k
R
vs