1.4 Study of GTO

The Gate turn off thyristor (GTO) is a four layer PNPN power semiconductor switching device that can be turned on by a short pulse of gate current and can be turned off by a reverse gate pulse.

- This reverse gate current amplitude is dependent on the anode current to be turned off.
- There is no need for an external commutation circuit to turn it off. So inverter circuitsbuilt by this device are compact and low-cost.
- The device is turned on by a positive gate current and it is turned off by a negativegate cathode voltage.

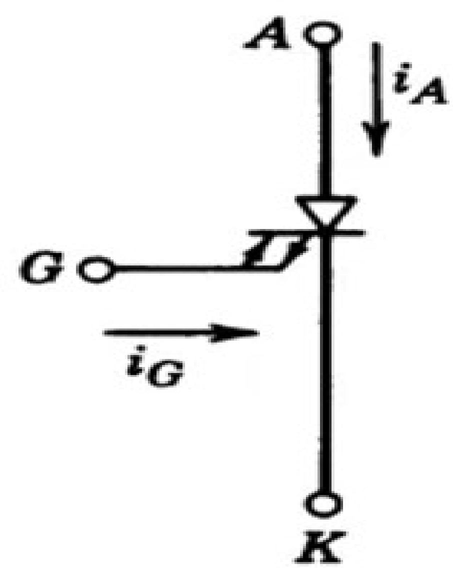

Fig 1.4.1 Symbol of GTO

[Source: "Power Electronics" by P.S.Bimbra, Khanna Publishers Page: 127]

The Symbol has three terminals namely Anode(A), Cathode(K) and Gate(G). The two-way arrow convention on the gate lead distinguishes the GTO from the conventional thyristor.

CONSTRUCTION

Consider the below structure of GTO, which is almost similar to the thyristor. It is alsoa four layer, three junction P-N-P-N device like a standard thyristor. In this, the n+ layer at the cathode end is highly doped to obtain high emitter efficiency. This result the breakdown voltage of the junction J3 is low which is typically in the range of 20 to40 volts.The doping level of the p type gate is highly graded because the doping level should be low to maintain high emitter efficiency, whereas for having a good turn OFF properties, doping of this region should be high. In addition, gate and cathodes should be highly interdigited with various geometric forms to optimize the currentturn off capability.

The junction between the P+ anode and N base is called anode junction. A heavily doped P+ anode region is required to obtain the higher efficiency anode junction so that a good turn ON properties is achieved. However, the turn OFF capabilities are affected with such GTOs. This problem can be solved by introducing heavily doped N+ layers at regular intervals in P+ anode layer as shown in figure. So this N+ layer makes a direct contact with N layer at junction J1. This cause the electrons to travel from base N region directly to anode metal contact without causing hole injection from P+ anode. This is called as a anode shorted GTO structure.Due to these anode shorts, the reverse blocking capacity of the GTO is reduced to thereverse breakdown voltage of junction j3 and hence speeds up the turn OFF mechanism.

However, with a large number of anode shorts, the efficiency of the anode junction reduces and hence the turn ON performance of the GTO degrades. Therefore, careful considerations have to be taken about the density of these anode shorts for a good turn ON and OFF performance.

PRINCIPLE OF OPERATION

The turn ON operation of GTO is similar to a conventional thyristor. When the anode terminal is made positive with respect to cathode by applying a positive gate current, the hole current injection from gate forward bias the cathode p-base junction.

This results in the emission of electrons from the cathode towards the anode terminal. This induces the hole injection from the anode terminal into the base region. This injection of holes and electrons continuous till the GTO comes into the conduction state.

In case of thyristor, the conduction starts initially by turning ON the area of cathode adjacent to the gate terminal. And thus, by plasma spreading the remaining area comes into the conduction.

Unlike a thyristor, GTO consists of narrow cathode elements which are heavily inter digitated with gate terminal, thereby initial turned ON area is very large and plasma spreading is small. Hence the GTO comes into the conduction state very quickly.

TWO TRANSISTOR MODEL OF GTO OPERATION

The aspects of the Gate turnoff thyristor, GTO are very similar to that of the ordinary thyristor. In GTO, one PNP and one NPN transistor being connected in a regenerative configuration whereby once turned on the system maintains itself in this state.

When a potential is applied across the gate turn-off thyristor between the anode and cathode, no current will flow because neither device is turned on. Current would only flow if the voltage exceeded the breakdown voltage and current would flow as a result of avalanche action, but this mode would not suggested for normal operation. In this non-conducting state the gate turn-off thyristor is said to be in its forward blocking mode.

To turn the device on it is necessary to inject current into gate circuit of the device. When this is done, it turns on TR2 in the Fig. This pulls the collector of this transistor down towards the emitter voltage and in turn this turns on the other transistor TR1.

The fact that TR1 is now switched on ensures current flows into the base of TR2, and thus this feedback process ensures that once the gate turn-off thyristor like any other thyristor is turned on it remains on.The key capability of the gate turn-off thyristor is its ability to be turned off by the use of the gate electrode on the device.

The device turn off is achieved by applying a negative bias to the gate with respect to the cathode. This extracts current from the base region of TR2. The resulting voltage drop in the base starts to reverse bias the junction and thereby stopping the current flow in this transistor TR2.Which stops the injection into the base region of TR1 and this prevents current flow in this transistor.

When the overall current flow stops and the depletion layers around the junctions grow- the gate turn-off thyristor enters its forward blocking state again.

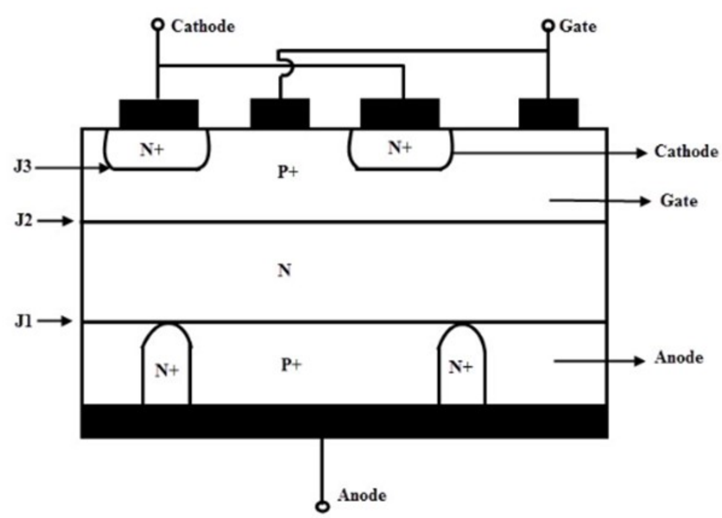

Fig. 1.4.2. Basic structure of GTO

[Source: "Power Electronics" by P.S.Bimbra, Khanna Publishers Page: 127]

Static VI characteristics of GTO

The static I-V characteristics of a GTO is identical with that of a conventional thyristor.If gate current is not able to turn on the GTO,it behaves like a high-voltage, low gain transistor with considerable anode current. This leads to a noticeable power loss under such conditions. In the reverse mode, reverse-voltage blocking capability of GTO is low, typically 20 to 30V, because of (i) anode shorts and (ii) large doping densities on both sides of reverse blocking junction J3

GATE TURN-ON:

The turn-on process in n GTO is similar to that of a conventional thyristor. Gate turn-on time for GTO is made up of delay time, rise time and spread time like a CT. Further, turn- on time in a GTO can be decreased by increasing its forward gate current as in a thyristor. In Fig. 1.15 (b), a steep-fronted gate pulse is applied to tum-on GTO. Gate drive can be removed once anode current exceeds latching current. However, some manufacturers advise that even after GTO is on, a continuous gate current, called back porch current should be applied during the entire on-period of GTO. The aim of this recommendation is to avoid any possibility of unwanted turn-off of the GTO.

GATE TURN-OFF:

The turn-off characteristics of a GTO are different from those of an SCR. Before the initiation of turn-off process, a GTO carries a steady current Ia. Fig. 15(b). This figure shows a typical dynamic turn-off characteristic for a GTO. The total turn-off 'time tq is subdivided into three different periods; namely the storage period (ts), the fall period (tf) and the tail period (tt).

In other words,

$$t_q = t_s + t_f + t_t$$

Initiation of turn-off process starts as soon as negative gate current begins to flow after t= 0 at instant A. The rate of rise of this gate current depends upon the gate circuit inductance L and the gate voltage applied. During the storage period, anode current Ia and anode voltage (equal to on-state voltage drop) remain constant. Termination of the storage period is indicated by a fall in If and rise in Va . During ts excess charges, i.e. holes, in p base are removed by negative gate current and the centre junction comes out of saturation. In other words, during storage time the negative gate current rises to a particular value and prepares the GTO for turning-off (or commutation) by flushing outthe stored carriers. After ts anode current begins to fall rapidly and anode voltage starts rising The anode current falls to a certain value and then abruptly changes its rate of fall. This interval during which anode current falls rapidly is the fall time tf Fig. 1.15 (b) and is of the order of 1second. The fall period tf is measured from the instant gate current is maximum negative to the instant anode current falls to its tail current.

At the time t = ts + tf there is a spike in voltage due to abrupt change in anode current. After tf anode current ia and anode voltage Va keep moving towards their turn-off valuesfor a time called tail time tt . After tf anode current reaches zero value and Va undergoes a transient overshoot due to the presence of Rs, Cs and then stabilizes to its off-state value equal to the source voltage applied to the anode circuit. Here Rs and Cs are the snubber circuit parameters. The turn-off process is complete when tail current reaches zero. The over shoot voltage and tail current can be decreased by increasing the size of Cs, but a compromise with snubber loss must be made. The duration off, depends upon the device characteristics.

APPLICATION OF GTO:

- GTOs are used in motor drives, static VAR compensators (SVCs)

and AC/DC power supplies with high power ratings.

DISADVANTAGES OF GTO

Compared to a conventional SCR, the GTO has the following disadvantages:

1. Magnitude of latching, holding currents is more. The latching current of the GTO is
   several times more as compared to conventional thyristors of the same rating.
2. On state voltage drop and the associated loss is more.
3. Due to multi cathode structure of GTO, triggering gate current is higher than thatrequired for normal SCR.
4. Gate drive circuit losses are more. Its reverse voltage blocking capability is less thanthe forward voltage blocking capability.

ADVANTAGES OF GTO OVER BJT

Compared to BJT the GTO has the following advantages:

1. High blocking voltage capabilities
2. High over current capabilities
3. exhibits low gate currents
4. fast and efficient turn off
5. Better static and dynamic dv/dt capabilities