THYRISTOR

Abstract—Thyristor is common name given to the family of devices. It is very important member of power ele. Devices. It has large application now a day. This report gives introduction and explains characteristics of thyristor devices. It also contain basic introduction of power electronics. It contains basic information about power electronics devices like IGBT and Power MOSFET. At last it includes future applications of thyristor devices in different fields.

1. INTRODUCTION TO POWER ELE.

Power electronics is the study of electronic circuits for the control and conversion of electrical energy. The technology is a critical part of our energy infrastructure, and is a key driver for a wide range of uses of electricity. It is becoming increasingly important as an essential tool for efficient, convenient energy conversion, and management. For power electronics design,

` We consider only those circuits and devices that, in principle, introduce no loss and achieve near-perfect reliability. The two key characteristics of high efficiency and high reliability are implemented with switching circuits, supplemented with energy storage. .

This is driving tremendous expansion of their application. Personal computers, for example, would be unwieldy and inefficient without power electronic dc supplies. Portable communication devices and laptop computers would be impractical. High-performance lighting systems, motor controls, and a wide range of industrial controls depend on power electronics. Strong growth is occurring in automotive applications, in dc power supplies for communication systems, in portable devices, and in high-end converters for advanced microprocessors. In the near future, power electronics will be the enabler for alternative and renewable energy resources. During the next generation, we will reach a time when almost all electrical energy is processed through power electronics somewhere in the path from generation to end use.

1. HISTORY OF POWER ELE.



1. INTRODUCTION OF THYRISTOR

Thyristors are usually three-terminal devices that have four layers of alternating *p*-type and *n*-type material (i.e. three *p*–*n* junctions) comprising its main power handling section. In contrast to the linear relation which exists between load and control currents in a transistor, the thyristor is bistable. The control terminal of the thyristor, called the gate (*G*) electrode, may be connected to an integrated and complex structure as a part of the device. The other two terminals, called the anode (*A*) and cathode (*K*), handle the large applied potentials (often of both polarities) and conduct the major current through the thyristor.

The anode and cathode terminals are connected in series with the load to which power is to be controlled. Thyristors are used to approximate ideal closed (no voltage drop between anode and cathode) or open (no anode current flow) switches for control of power flow in a circuit. This differs from low-level digital switching circuits that are designed to deliver two distinct small voltage levels while conducting small currents (ideally zero). Thyristor circuits must have the capability of delivering large currents and be able to withstand large externally applied voltages. All thyristor types are controllable in switching from a forward-blocking state (positive potential applied to the anode with respect to the cathode, with correspondingly little anode current flow into a forward-conduction state (large forward anode current flowing, with a small anode–cathode potential drop). Most thyristors have the characteristic that after switching from a forward-blocking state into the forward-conduction state, the gate signal can be removed and the thyristor will remain in its forward-conduction mode.

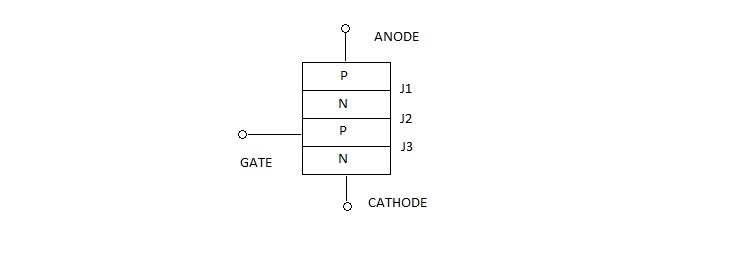
Almost all power semiconductor devices are made from silicon (Si). Research and development continues in developing other types of devices in silicon carbide (SiC), gallium nitride (GaN), and related material systems. However, the physical description and general behavior of thyristors is unimportant to the semiconductor material system used, though the discussion and any numbers cited in the chapter will be associated with Si devices.

1. BASIC STRUCTURE & OPERATION

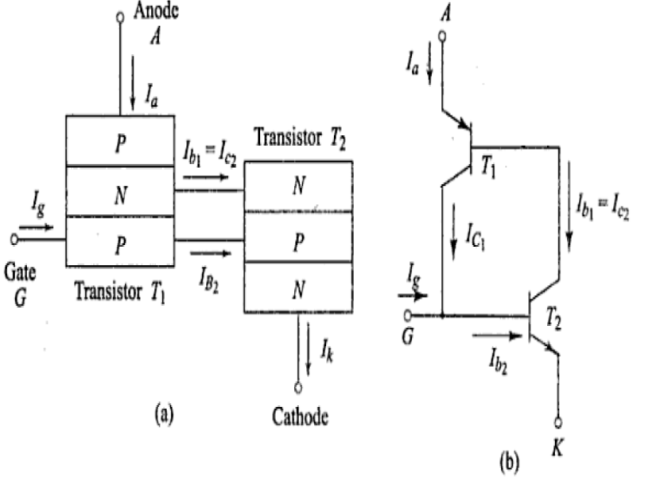
A high-resistivity region, *n*-base, is present in all thyristors. It is this region, the *n*-base and associated junction, J2 of Fig. 1, which must support the large applied forward voltages that occur when the switch is in its off- or forward-blocking state (non-conducting). The *n*-base is typically doped with impurity phosphorous atoms at a concentration of 1013 to 1014 cm−3.

Operation of thyristors is as follows. When a positive voltage is applied to the anode (with respect to cathode), the thyristor is in its forward-blocking state. The center junction, J2 is reverse biased. In this operating mode the gate current is held to zero (open circuit). In practice, the gate electrode is biased to a small negative voltage (with respect to the cathode) to reverse bias the GK-junction J3 and prevent charge-carriers from being injected into the *p*-base. In this condition only thermally generated leakage current flows through the device and can often be approximated as zero in value (the actual value of the leakage current is typically many orders of magnitude lower than the conducted current in the on-state). As long as the forward applied voltage does not exceed the value necessary to cause excessive carrier multiplication in the depletion region around J2 (avalanche breakdown), the thyristor remains in an off-state (forward-blocking). If the applied voltage exceeds the maximum forward-blocking voltage of the thyristor, it will switch to its on-state. However, this mode of turn-on causes non-uniformity in the current flow, is generally destructive, and should be avoided.

When a positive gate current is injected into the device, J3 becomes forward biased and electrons are injected from the *n*-emitter into the *p*-base. Some of these electrons diffuse across the *p*-base and get collected in the *n*-base. This collected charge causes a change in the bias condition of J1. The change in bias of J1 causes holes to be injected from the *p*-emitter into the *n*-base. These holes diffuse across the *n*-base and are collected in the *p*-base. The addition of these collected holes in the *p*-base acts the same as gate current. The entire process is regenerative and will cause the increase in charge carriers until J2 also becomes forward biased and the thyristor is latched in its on-state (forward-conduction).



1. TWO TRANSISTOR MODEL

****

Figure

Figure

This switching behavior can also be explained in terms of the two-transistor analog shown in Fig.2. The two transistors are regenerative coupled so that if the sum of their forward current gains (*α*’s) exceeds unity, each drives the other into saturation. The center junction J2 is reverse biased under forward applied voltage (positive, *vAK* ). The associated electric field in the depletion region around the junction can result in significant carrier multiplication, denoted as a multiplying factor *M* on the current components, *Ico* and *iG*

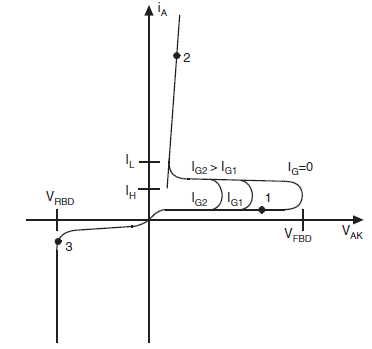
In the forward-blocking state, the leakage current *Ico* is small, both *α*’s are small, and their sum is less than unity. Gate current increases the current in both transistors, increasing their *α*’s. Collector current in the *npn* transistor acts as base current for the *pnp*, and analogously, the collector current of the *pnp* acts as base current driving the *npn* transistor. When the sum of the two *α*’s equals unity, the thyristor switches to its on-state (latches). This condition can also be reached, without any gate current, by increasing the forward applied voltage so that carrier multiplication (M *>>* 1) at J2 increases the internal leakage current, thus increasing the two *α*’s Another way to cause a thyristor to switch from forward blocking to forward-conduction exists.

Under a forward applied voltage, J2 is reverse biased while the other two junctions are forward-biased in the blocking mode. The reverse-biased junction of J2 is the dominant capacitance of the three and determines the displacement current that flows.

If the rate of increase in the applied *vAK* (*dvAK* /*dt*) is sufficient, it will cause a significant displacement current through the J2 capacitance. This displacement current can initiate switching similar to an externally applied gate current. This dynamic phenomenon is inherent in all thyristors and causes there to be a limit (*dv/dt*) to the time rate of applied *vAK* that can be placed on the device to avoid uncontrolled switching. Alterations to the basic thyristor structure can be produced that increase the *dv/dt* limit.

1. STATIC CHARACTERISTICS

A plot of the anode current (*iA*) as a function of anode–cathode voltage (*vAK* ) is shown in Fig.3 The forward-blocking mode is shown as the low-current portion of the graph (solid curve around operating point “1”). With zero gate current and positive *vAK* , the forward characteristic in the off- or blocking-state is determined by the center junction J2, which is reverse biased. At operating point “1” very little current flows (*Ico* only) through the device. However, if the applied voltage exceeds the forward-blocking voltage, the thyristor switches to its onor conducting-state (shown as operating point “2”) because of carrier multiplication (*M* in Eq. (6.1)). The effect of gate current is to lower the blocking voltage at which switching takes place. The thyristor moves rapidly along the negatively-sloped portion of the curve until it reaches a stable operating point determined by the external circuit (point “2”). The portion of the graph indicating forward-conduction shows the large values of *iA* that may be conducted at relatively low values of *vAK* , similar to a power diode.

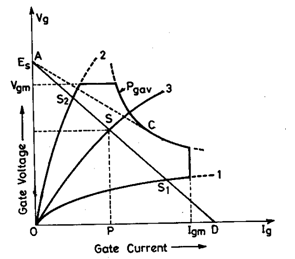


Figure

As the thyristor moves from forward-blocking to forward conduction, the external circuit must allow sufficient anode current to flow to keep the device latched. The minimum anode current that will cause the device to remain in forward conduction as it switches from forward-blocking is called the latching current *IL*. If the thyristor is already in forward conduction and the anode current is reduced, the device can move its operating mode from forward-conduction back to forward-blocking. The minimum value of anode current necessary to keep the device in forward-conduction after it has been operating at a high anode current value is called the holding current *IH*. The holding current value is lower than the latching current value as indicated in Fig.3

The reverse thyristor characteristic, quadrant III of Fig 3., is determined by the outer two junctions (J1 and J3), which are reverse biased in this operating mode (applied *vAK* is negative). Symmetric thyristors are designed so that J1 will reach reverse breakdown due to carrier multiplication at an applied reverse potential near the forward breakdown value. The forward- and reverse-blocking junctions are usually fabricated at the same time with a very long diffusion process (10–50 h) at high temperatures (*>*1200◦C). This process produces symmetric blocking properties. Wafer edge termination processing causes the forward-blocking capability to be reduced to about 90% of the reverse-blocking capability. Edge termination is discussed below. Asymmetric devices are made to optimize forward-conduction and turnoff properties, and as such reach reverse breakdown at a lower voltage than that applied in the forward direction. This is accomplished by designing the asymmetric thyristor with a much thinner *n*-base than is used in symmetric structures. The thin *n*-base leads to improved properties such as lower forward drop and shorter switching times.

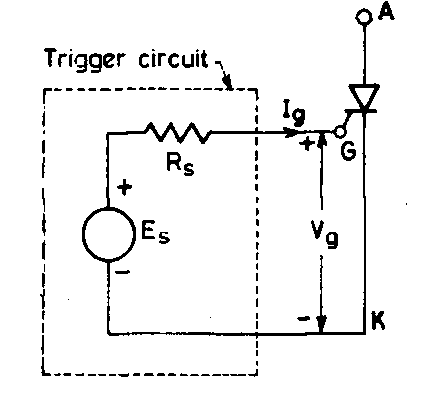
1. GATE CHARACTERISTICS

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Figure

The forward gate characteristics of a thyristor are shown in Fig 4. in the form of a graph between gate voltage and gate current. Here positive gate to cathode voltage Vg and positive gate to cathode current Ig represent dc values. As gate-cathode circuit of a thyristor is a p-n junction, gate characteristics of the device are similar to that of a diode. For a particular type of SCRs, Vg-Ig characteristic has a spread between two curves 1 and 2 as shown in Fig. 4 This spread, or scatter, of gate characteristics is due to difference in the low doping levels of p and n layers. The gate trigger circuitry must be suitably designed to take care of this unavoidable scatter of characteristics. In Fig. 4 curve 1 represents the lowest voltage values that must be applied to turn-on the SCR. Curve 2 gives the highest possible voltage values that can be safely applied to gate circuit.

Each thyristor has maximum limits as Vgm for gate voltage and Igm for gate current. There is also rated (average) gate power dissipation Pgav specified for each SCR. These limits should not be exceeded in order to avoid permanent damage of junction J3. There are also minimum limits for Vg and Ig for reliable turn-on, these are represented by oy and ox and respectively . As stated before, if Vgm , Igm and Pgav are exceeded, the thyristor can be destroyed.

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Figure

**N**on-triggering gate voltage is also prescribed by the manufacturers of SCRs. This is indicated by oa in Fig. 5 If firing circuit generates positive gate signal prior to the desired instant of triggering the SCR, it should be ensured that this unwanted signal is less than the non-triggering gate voltage oa. At the same time, all spurious or noise signals should be less than the voltage oa.

The design of the firing circuit can be carried out with the help of Figs.

ES = Vg + IgRS

1. TURN ON METHODS OF THYRISTORS

With anode positive with respect to cathode, a thyristor can be turned on by any one of the following techniques :

1. Forward voltage triggering
2. gate triggering
3. dv/dt triggering
4. Temperature triggering
5. Light triggering
6. ***Forward Voltage Triggering***

When anode to cathode forward voltage is increased with gate circuit open, the reverse biased junction J2 will break. This is known as avalanche breakdown and the voltage at which avalanche occurs is called forward break over voltage VB0. At this voltage, thyristor changes from off-state (high voltage with low leakage current) to on-state characterized by low voltage across thyristor with large forward current. As other junctions J1, J3 are already forward biased, breakdown of junction J2 allows free movement of carriers across three junctions and as a result, large forward anode-current flows.

1. ***Gate Triggering***:

Turning on of thyristors by gate triggering is simple, reliable and efficient, it is therefore the most usual method of firing the forward biased SCRs. This means that thyristor will remain in forward blocking state with normal working voltage across anode and cathode and with gate open. However, when turn-on of a thyristor is required, a positive gate voltage between gate and cathode is applied. With gate current thus established, charges are injected into the inner p layer and voltage at which forward break over occurs is reduced.

1. *dv/dt  Triggering*

If forward voltage is applied to A to K J1,J3 forward bias and J2 is reverse bias.J2 acts as capacitor As charges exists at the junction if voltage is suddenly applied charging current will flow turning device to ON.

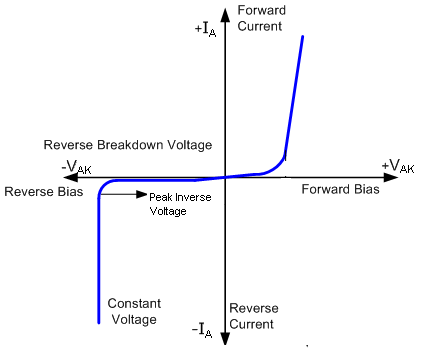
1. ***Temperature Triggering***

During forward blocking, most of the applied voltage appears across reverse biased junction J2. This voltage across junction J2 associated with leakage current may raise the temperature of this junction. With increase in temperature, leakage current through junction J2 further increases. This cumulative process may turn on the SCR at some high temperature.

1. ***Light Triggering***

For light-triggered SCRs, a recess (or niche) is made in the inner p-layer. When this recess is irradiated, free charge carriers (holes and electrons) are generated just like when gate signal is applied between gate and cathode. The pulse of light of appropriate wavelength is guided by optical fibers for irradiation. If the intensity of this light thrown on the recess exceeds a certain value, forward biased SCR is turned on. Such a thyristor is known as light-activated SCR (LASCR).

1. TYPES OF POWER ELECTRONICS DEVICES
2. POWER DIODE
3. DIAC
4. TRIAC
5. POWER MOSFET
6. IGBT
7. *Power Diode*

Among all the static switching devices used in power electronics (PE), the power diode is perhaps the simplest. It is a two terminal device, and terminal A is known as the anode whereas terminal K is known as the cathode. If terminal A experiences a higher potential compared to terminal K, the device is said to be forward biased and a current called forward current (*IF* ) will flow through the device . ****

Figure

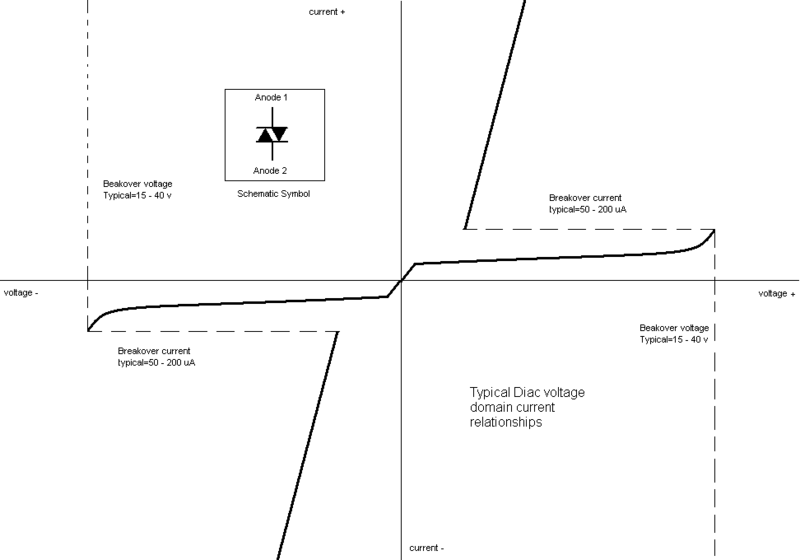
This causes a small voltage drop across the device (*<*1 V), which in ideal condition is usually ignored. On the contrary, when a diode is reverse biased, it does not conduct and a practical diode do experience a small current flowing in the reverse direction called the leakage current

In the forward direction, a potential barrier associated with the distribution of charges in the vicinity of the junction, together with other effects, leads to a voltage drop. In the figure 6 , the forward characteristic is expressed as a threshold voltage *Vo* and a linear incremental or slope resistance, *r* . The reverse characteristic remains the same over the range of possible leakage currents irrespective of voltage within the normal working range.

1. *DIAC*

The **DIAC**, or 'diode for alternating current', is a trigger diode that conducts current only after its breakdown voltage has been reached momentarily. When this occurs, diode enters the region of negative dynamic resistance, leading to a decrease in the voltage drop across the diode and, usually, a sharp increase in current through the diode. The diode remains "in conduction" until the current through it drops below a value characteristic for the device, called the holding current. Below this value, the diode switches back to its high-resistance (non-conducting) state.

This behavior is bidirectional, meaning typically the same for both directions of current. Most DIACs have a three-layer structure with breakdown voltage around 30 V. In this way, their behavior is somewhat similar to (but much more precisely controlled and taking place at lower voltages than) a neon lamp. DIACs have no gate electrode, unlike some other thyristors that they are commonly used to trigger, such as TRIACs. Some TRIACs contain a built-in DIAC in series with the TRIAC's "gate" terminal for this purpose.

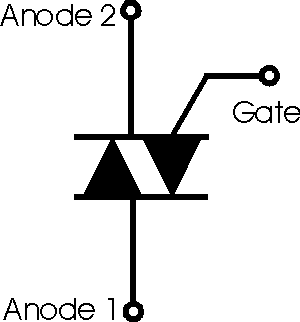
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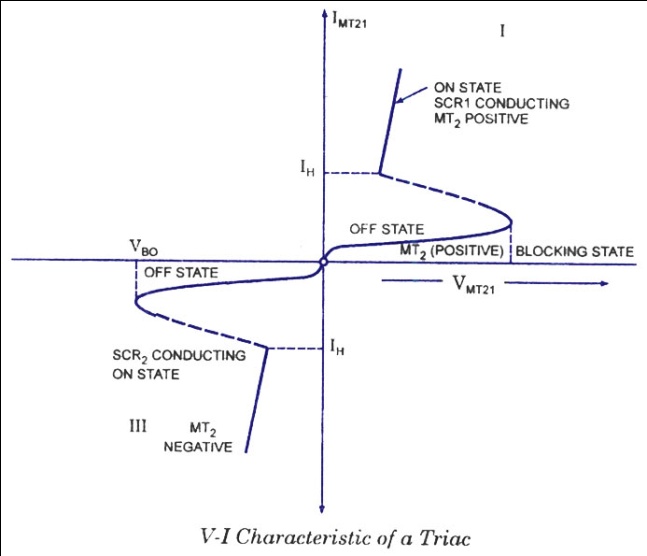
Figure

DIACs are also called *symmetrical trigger diodes* due to the symmetry of their characteristic curve. Because DIACs are bidirectional devices, their terminals are not labeled as *anode* and *cathode* but as A1 and A2 or MT1 ("Main Terminal") and MT2.

1. *TRIAC*

Triacs are widely used in AC power control applications. They are able to switch high voltages and high levels of current, and over both parts of an AC waveform. This makes triac circuits ideal for use in a variety of applications where power switching is needed. One particular use of triac circuits is in light dimmers for domestic lighting, and they are also used in many other power control situations including motor control.

The triac is a development of the thyristor. While the thyristor can only control current over one half of the cycle, the triac controls it over two halves of an AC waveform. As such the triac can be considered as a pair of parallel but opposite thyristors with the two gates connected together and the anode of one device connected to the cathode of the other, etc..

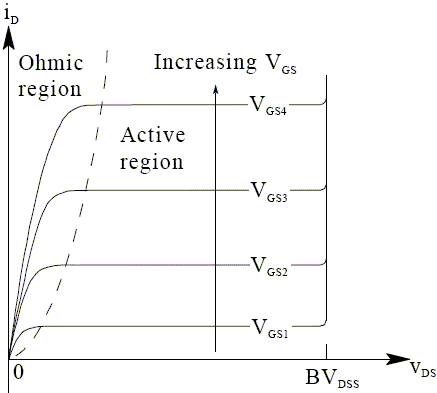
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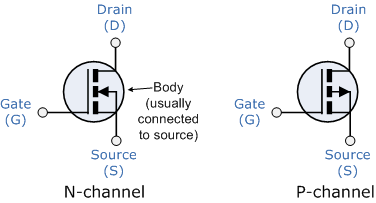
Figure

1. *POWER MOSFET*

One of the main contributions that led to the growth of the power electronics field has been the unprecedented advancement in the semiconductor technology, especially with respect to switching speed and power handling capabilities. The area of power electronics started by the introduction of the silicon controlled rectifier (SCR) in 1958. Since then, the field has grown in parallel with the growth of the power semiconductor device technology. In fact, the history of power electronics is very much connected to the development of switching devices and it emerged as a separate discipline when high power bipolar junction transistors (BJTs) and MOSFETs devices where introduced in the 1960s and 1970s .

In the 1980s, the development of power semiconductor devices took an important turn when new process technology was developed that allowed the integration of MOS and BJT technologies on the same chip. Thus far, two devices using this new technology have been introduced: integrated gate bipolar transistor (IGBT) and MOS controlled thyristor (MCT). Many of the IC processing methods and equipment have been adopted for the development of power devices. Power semiconductor devices represent the “heart” of modern power electronics, with two major desirable characteristics of power semiconductor devices that guided their development are the *switching speed* and *power handling capabilities.*

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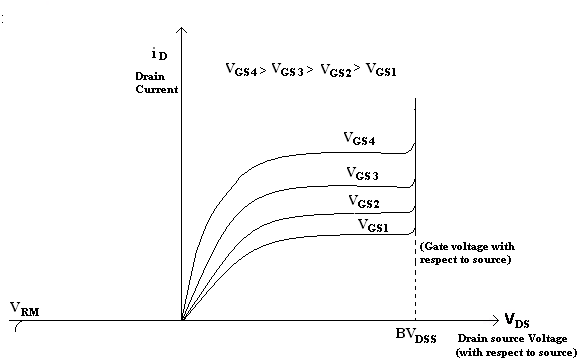
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Figure

1. *IGBT*

The **insulated gate bipolar transistor** or **IGBT** is a three-terminal power semiconductor device, noted for high efficiency and fast switching. It switches electric power in many modern appliances: electric cars, trains, variable speed refrigerators, air-conditioners and even stereo systems with switching amplifiers. Since it is designed to rapidly turn on and off, amplifiers that use it often synthesize complex waveforms with pulse width modulation and low-pass filters.

The IGBT combines the simple gate-drive characteristics of the MOSFETs with the high-current and low–saturation-voltage capability of bipolar transistors by combining an isolated gate FET for the control input, and a bipolar power transistor as a switch, in a single device

 The first-generation devices of the 1980s and early 1990s were relatively slow in switching, and prone to failure through such modes as latch up and secondary breakdown. Second-generation devices were much improved, and the current third-generation ones are even better, with speed rivaling MOSFETs, and excellent ruggedness and tolerance of overloads.

Figure

Their high pulse ratings, and low prices on the surplus market, also make them attractive to the high-voltage hobbyist for controlling large amounts of power to drive devices such as solid state Tesla coils and coil guns.

1. CURRENT & FUTURE APPLICATIONS

The most important application of thyristors is for line frequency phase-controlled rectifiers. This family includes several topologies, of which one of the most important is

used to construct HVDC transmission systems. The use of thyristors instead of diodes allows the average output voltage to be controlled by appropriate gating of the thyristors. If the gate signals to the thyristors were continuously applied, the thyristors in would behave as diodes. If no gate currents are supplied they behave as open circuits. Gate current can be applied any time (phase delay) after the forward voltage becomes positive. Using this phase control feature, it is possible to produce an average dc output voltage less than the average output voltage obtained from an uncontrolled diode rectifier.

1. *In power converter circuits*
2. *Phase controlled Rectifiers (AC to DC)*

Dc motor drive , Battery charger circuit

1. *Choppers (fixed DC to var. DC)*

Subway Cars , Battery driven vehicles

1. *Inverters ( DC to AC)*

UPS , Space power supply

1. *Cycloconverters (AC to AC)(one freq. to another)*

AC drives like multi MW ac motor drive

1. *AC voltage Controllers (AC regulators)*

Lighting control , Speed control of fans & pumps

1. *Industrial application*
2. *Motor drives*
3. *Electrolysis*
4. *Electroplating*
5. *Induction heating*
6. *Welding*
7. *Arc furnaces and ovens*
8. *Lighting*
9. *Application in space technology*
10. *Spaceship power systems*
11. *Satellite power systems*
12. *Space vehicle power systems*
13. *Other Applications*
14. *Nuclear reactor control*
15. *Power systems for particle accelerators*
16. CONCLUSION

From this it can be concluded that Power electronics is the study of electronic circuits for the control and conversion of electrical energy. The technology is a critical part of our energy infrastructure, and is a key driver for a wide range of uses of electricity. It is becoming increasingly important as an essential tool for efficient, convenient energy conversion, and management. For power electronics design, we consider only those circuits and devices that, in principle, introduce no loss and achieve near-perfect reliability. The two key characteristics of high efficiency and high reliability are implemented with switching circuits, supplemented with energy storage. Switching circuits can be organized as switch matrices. This facilitates their analysis and design.

Acknowledgment

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