Electric Vehicles

Pratyush Chakraborty

Power Electronics

- Power electronics is the electronics applied to conversion and control of high electric power.
- Control the flow of energy from source to load
- How to use power effectively
- P=VI, change the V or I (magnitude, type) –like transformer but more versatile
- $P=\omega T$ where gear can change the torque to change rpm

Types of Devices

There are three type of semiconductor switches:

- Uncontrolled switch

On and Off state are controlled by power supply. Ex:Diode

- Semicontrolled switch

Controlled turn-on by a gate signal.

Ex: Silicon Controlled Rectifier or Thyristor

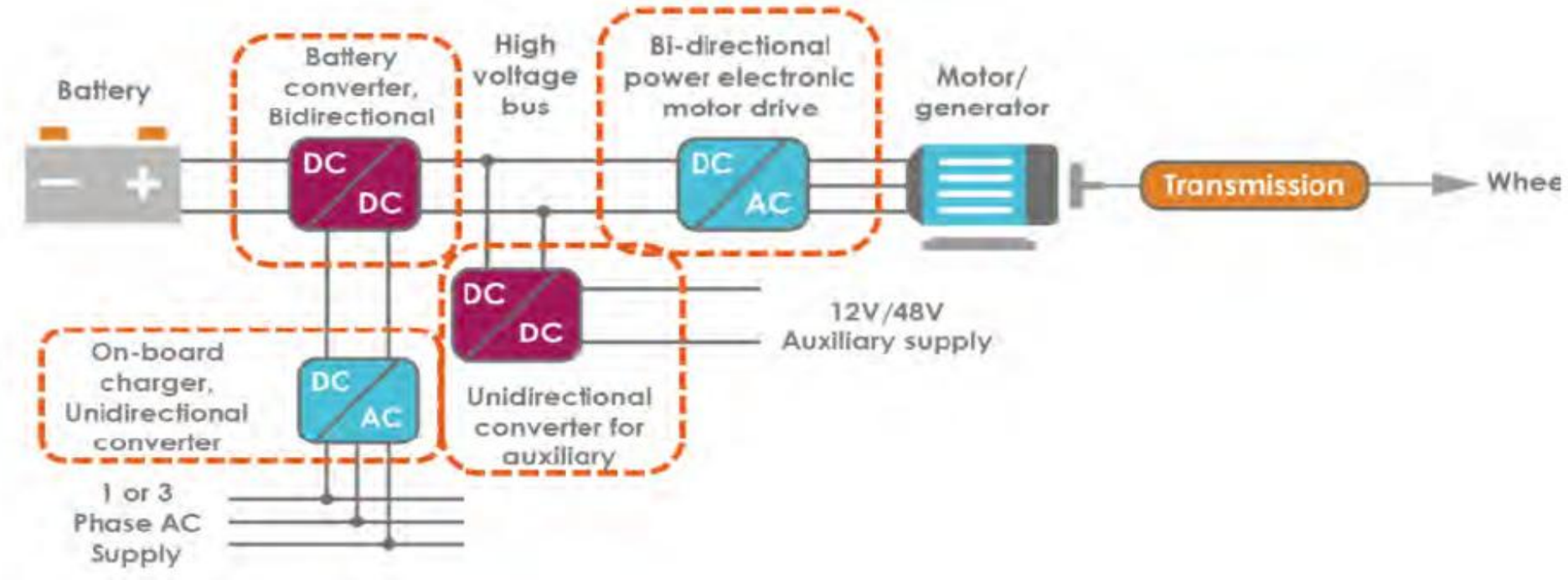
- Fully Controlled switch

Turned on and off by the application of control signals. Ex:BJT, MOSFET, IGBT

The power conversion systems can be classified according to the type of the input and output power:

- AC to DC (rectifier) –uncontrolled rectifiers, controlled rectifiers
- DC to AC (inverter)
- DC to DC (DC-to-DC converter)
- AC to AC (AC-to-AC converter) –AC voltage controllers, cycloconverters
- Static Switches

Power Converters in an EV



Materials

- Traditional materials
- **Silicon (Si):**
- The most established semiconductor for power devices, with a long history of use in diodes, transistors, and thyristors.
- **Germanium (Ge):**
- Was once common but is now rarely used in power electronics because of its unfavorable high-temperature properties.

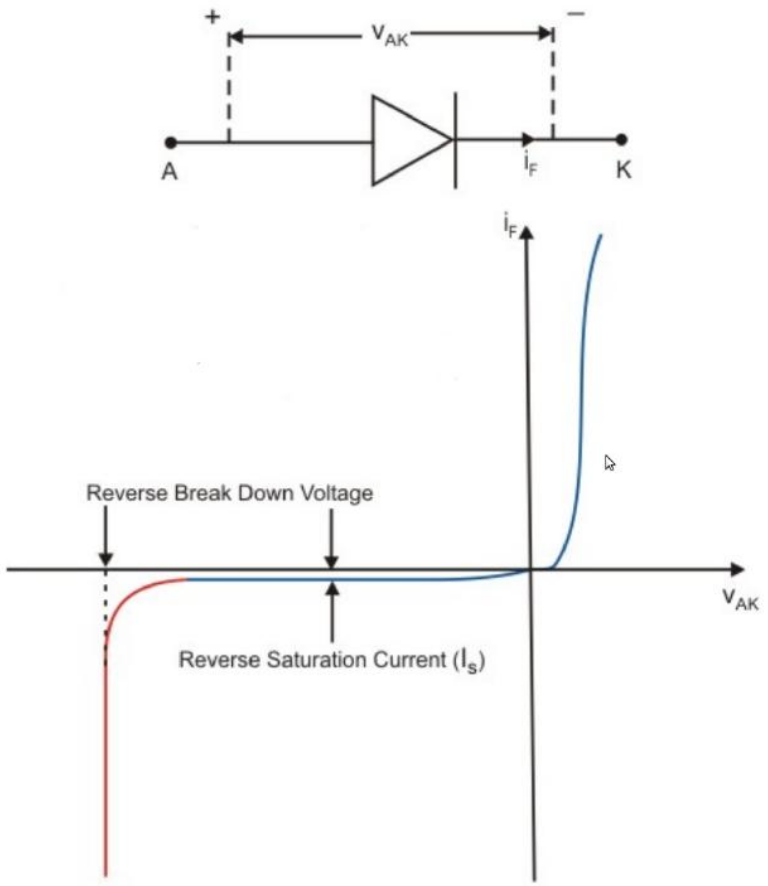
Modern, wide-bandgap (WBG) materials

- **Silicon Carbide (SiC):**
- A widely used and commercially available WBG material that offers advantages over silicon, including higher voltage handling and thermal stability.
- **Gallium Nitride (GaN):**
- Another key WBG material known for its higher bandgap energy and electron mobility compared to silicon, enabling faster switching speeds and higher efficiency.

Diode

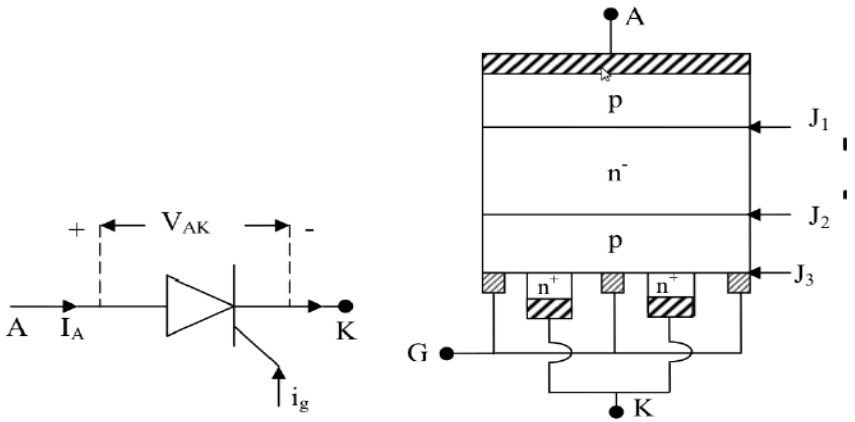
- Diode is forward biased when Anode voltage is higher than Cathode voltage (Vak > 0).
- Diode conducts in forward biased mode and the current is decided by the load connected.
- Signal Diode, Power Diodes
- The forward bias voltage is 0.7 V for normal/signal diodes and 1.5 V for power diodes.

Diode Characteristics

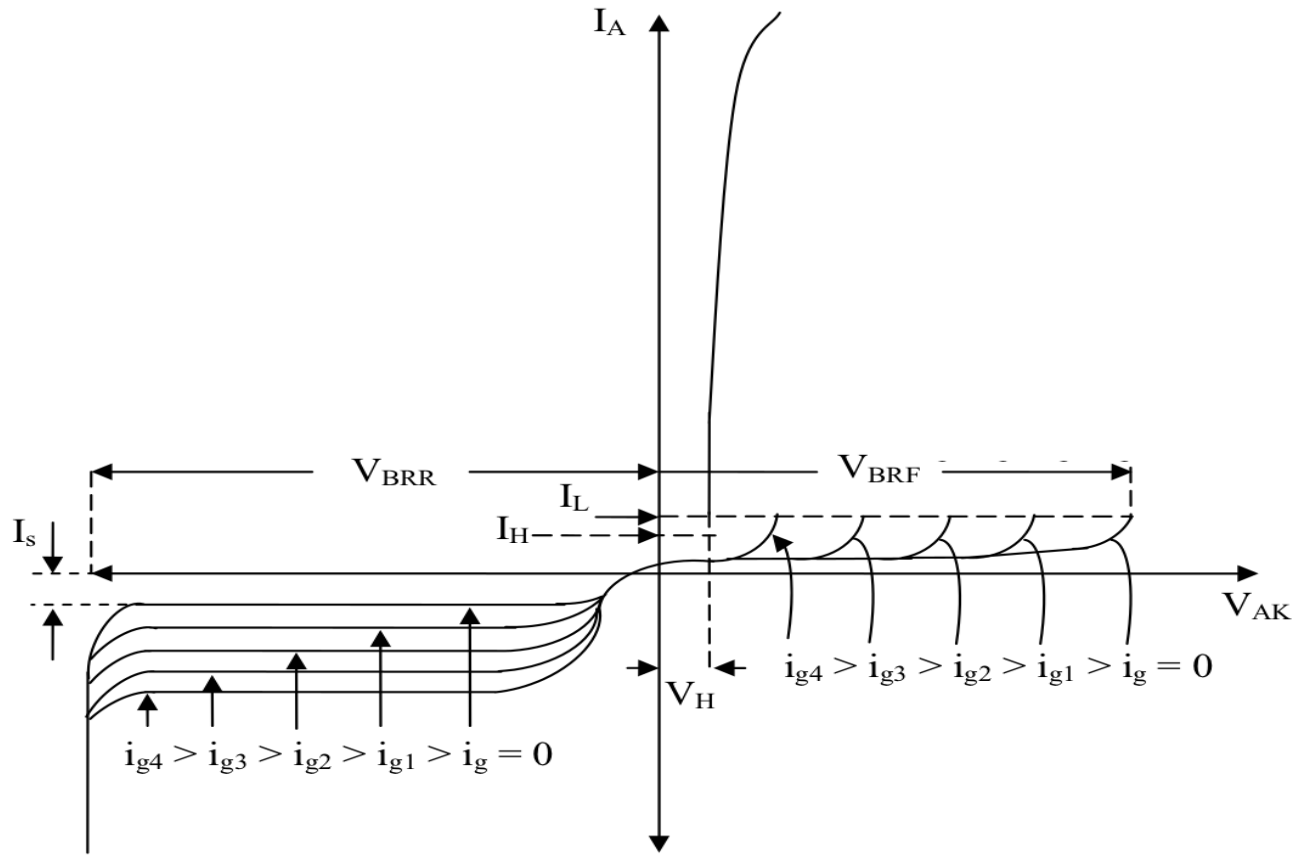


Thyristor-Silicon Controlled Rectifier

- It is a three terminal (anode, cathode, gate), four layer device (p-n-p-n). It has three junctions (j1,j2 and j3)
- When the device is forward biased and there is a leakage current in the device then it is said to be in forward blocking mode.
- When the voltage applied is higher than the forward breakover voltage (VBO) then the SCR conducts.

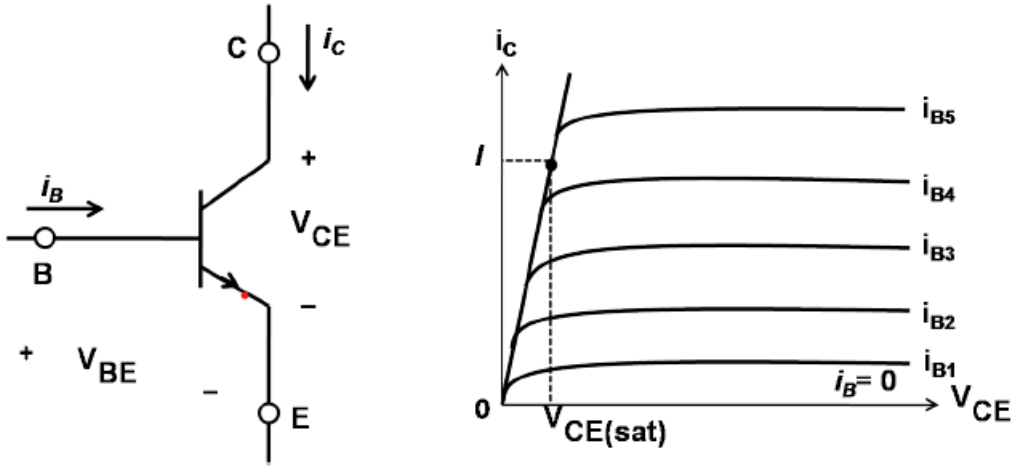


Thyristor-Silicon Controlled Rectifier



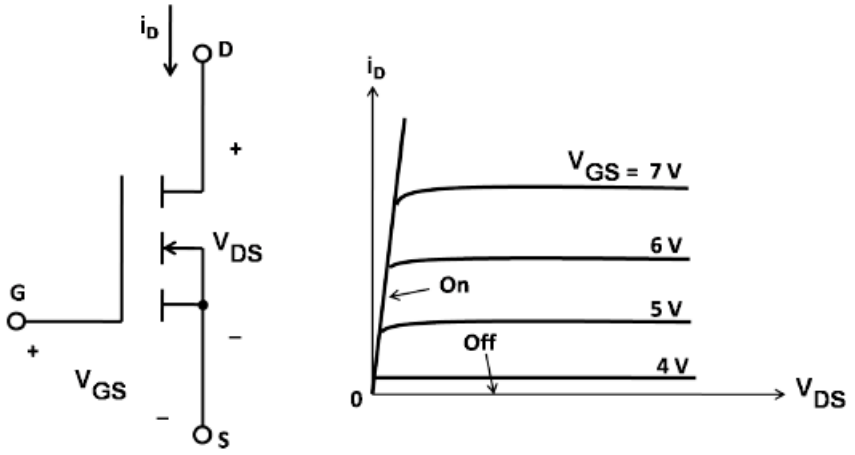
- A gate pulse (positive) will move the device from forward blocking to forward conducting mode.
- Higher the gate current, lower will be the voltage applied across the device. The gate current reduces the depletion layer around junction J2
- Once the device current is higher than the latch current(IL), the gate signal has no control over the device.
- The device will stop conducting when the current through the device is less than holding current (IH)

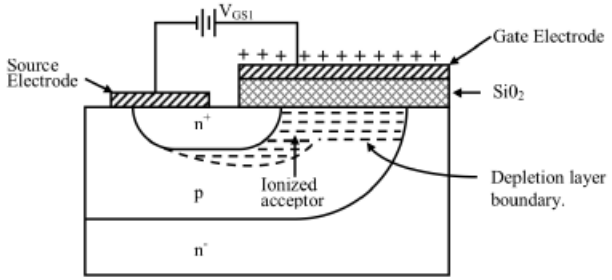
Bi-polar Junction Transistor (BJT)



BJT is a current controlled device.
Base current must be supplied continuously to keep them in on state.

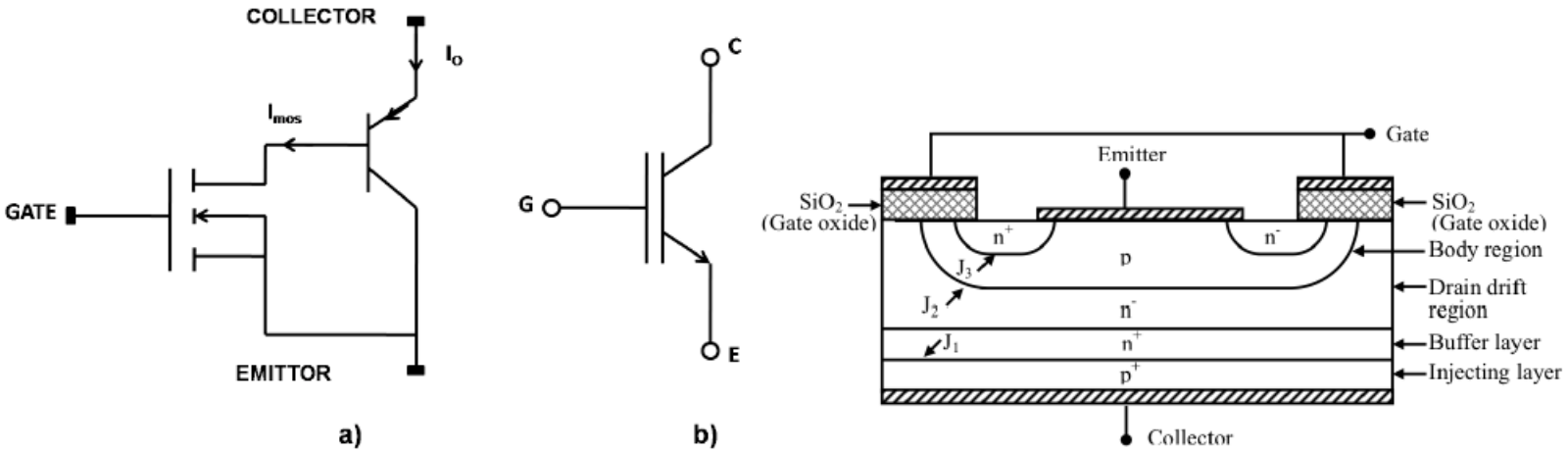
Metal Oxide Semi conductor Field Effect Transistor (MOSFET)





It is a voltage control device. It requires continuous application of a gate source voltage of appropriate magnitude in order to be in on state.

Insulated Gate Bipolar Transistor (IGBT)



It combines the property of MOSFET and BJT.

Device characteristic	Power BJT	Power MOSFET	IGBT
Voltage rating	High <1 kV	High <1 kV	Very high >1 kV
Current rating	High <500 A	Low <200 A	High >500 A
Input drive	Current ratio h_{FE} ~ 20–200	Voltage V_{GS} ~ 3–10 V	Voltage V_{GE} ~ 4–8 V
Input impedance	Low	High	High
Output impedance	Low	Medium	Low
Switching speed	Slow (µs)	Fast (ns)	Medium
Cost	Low	Medium	High