Power Electronics

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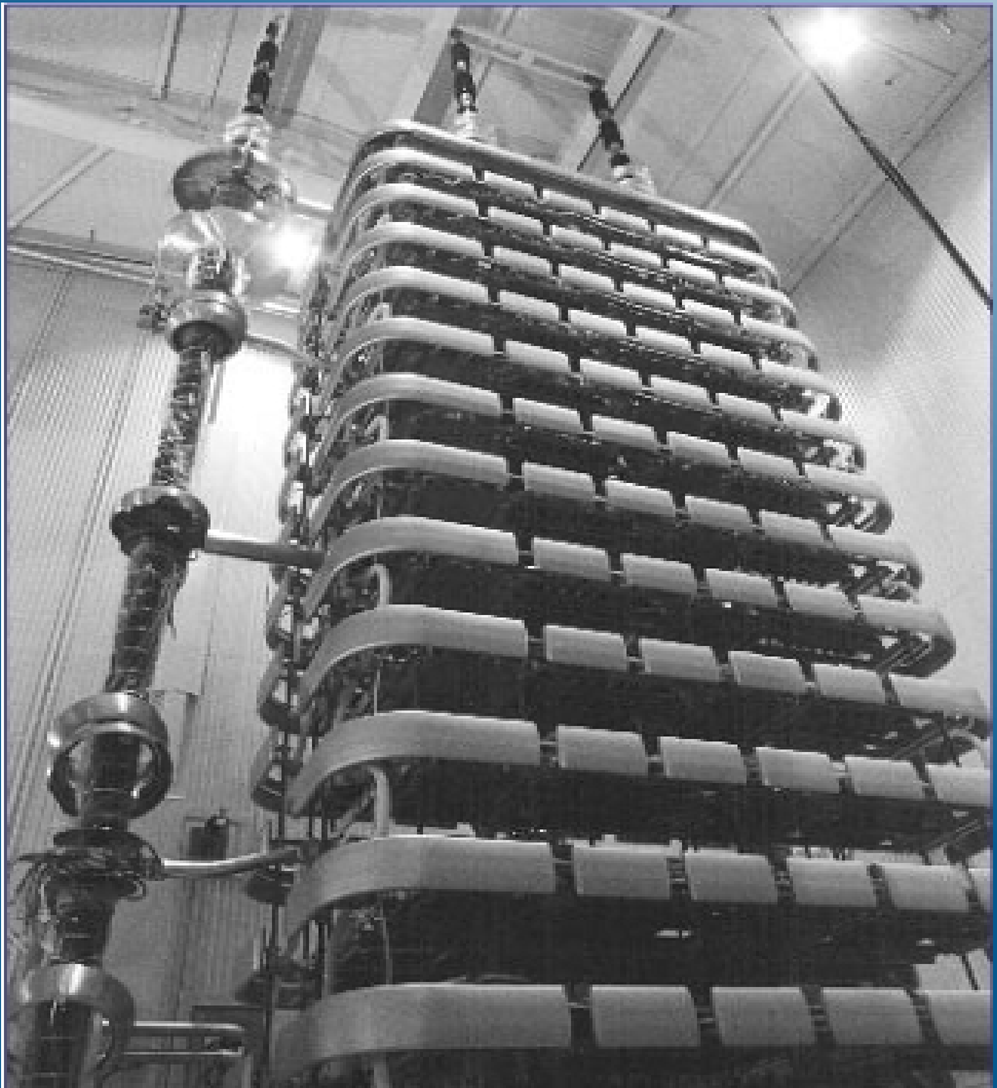

- HVDC thyristor valve tower 16.8 m tall in a hall at Baltic Cable AB in Sweden

Power Electronics

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Power Electronics

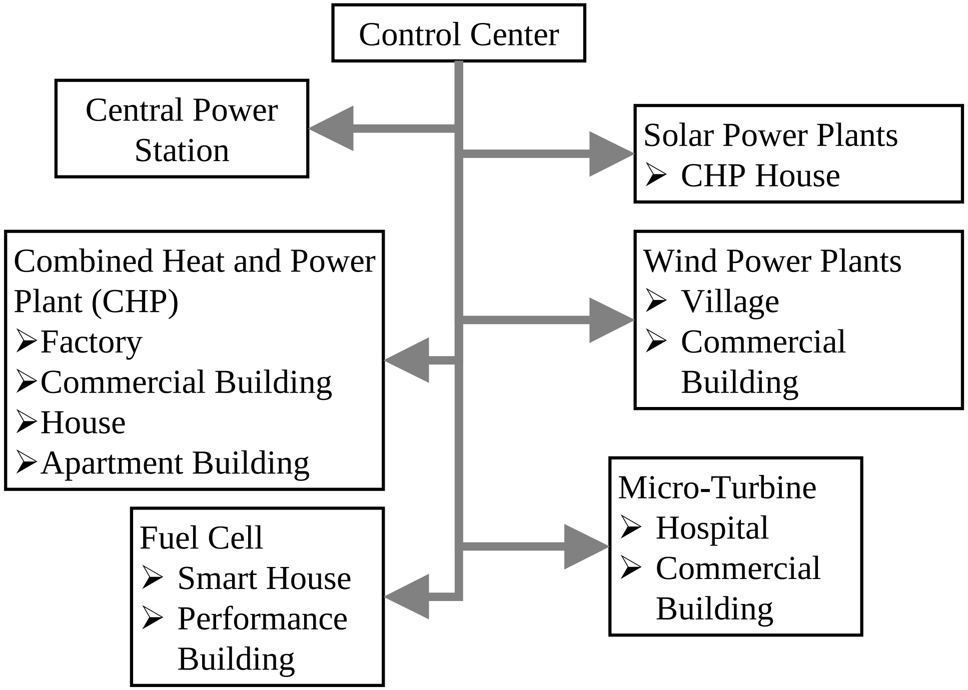
Power Electronics play a significant role in wind and photovoltaic (PV) power systems. In these types of systems power electronics is used to convert the electric power generated by wind turbine generators and PV cells to the form required by the electric grid operators and the associated regulatory Agencies responsible for the stability of the Grid.

As the technology for the power semiconductor devices and integrated circuit develops, the potential for applications of power electronics become wider. There are already many power semiconductor devices that are commercially available, however, the development in this direction is continuing.

Power Electronics

Increasing applications of Power Electronic Equipment in Power Systems

- Availability of high power semiconductor devices
- Decentralized renewable energy generation sources
- Increased power transfer with existing transmission system
- Effective control of power flow needed in a deregulated environment
- Norms for Power quality



Power Electronics

- **Utility stabilization applications**
  - High- voltage dc transmission(HVDC)
  - Flexible ac transmission(FACTS)
  - Static var compensation & harmonics
  - suppression: TCR, TSC, SVG, APF
  - Custom power & power quality control
  - Supplemental energy sources :
  - wind, photovoltaic, fuel cells
  - Energy storage systems

Power Electronics

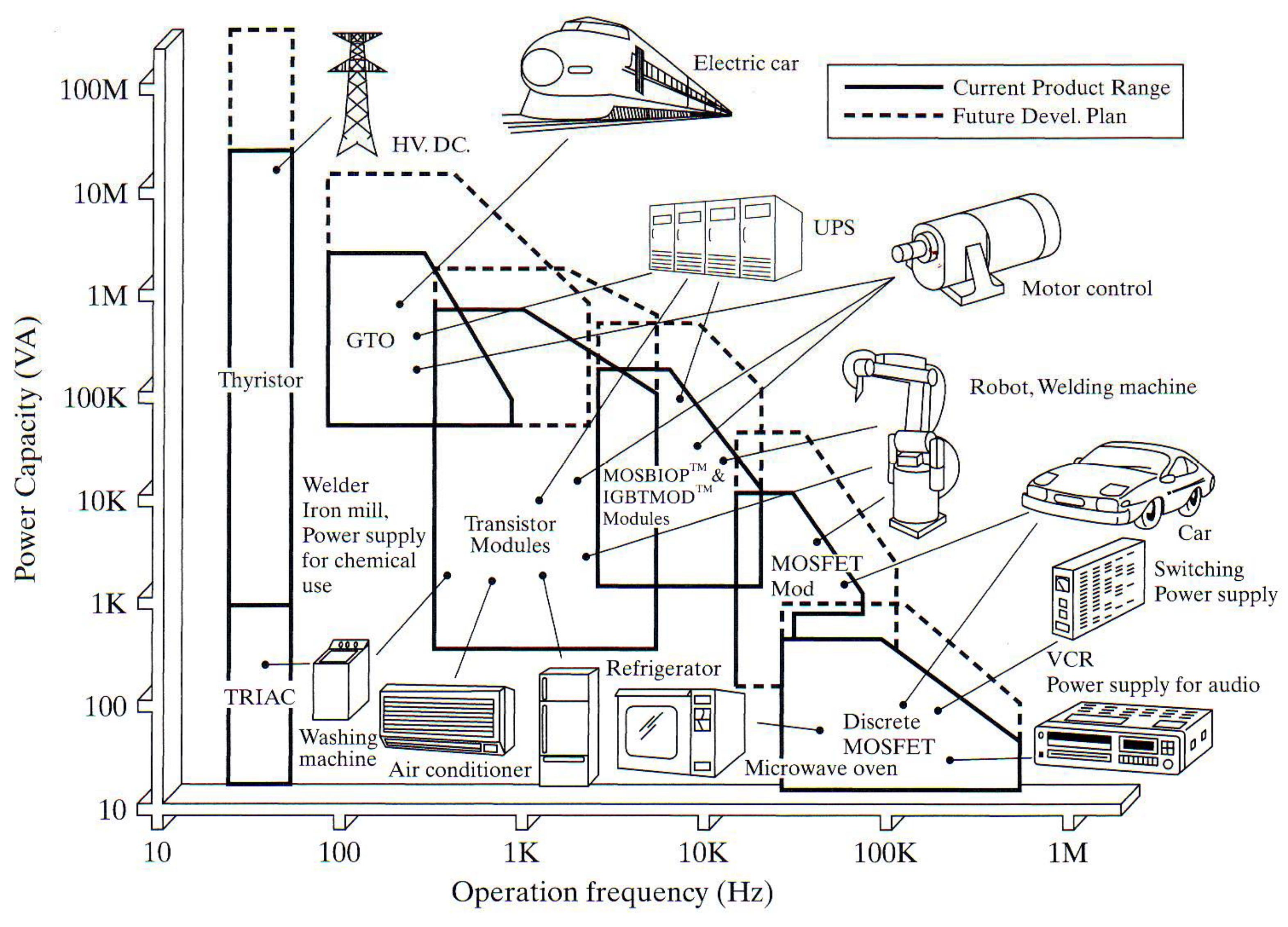
Power Electronics occupy a very important segment of the renewable energy space.

As the technology for the power semiconductor devices and integrated circuit develops, the potential for applications of power electronics become wider. There are already many power semiconductor devices that are commercially available, however, the development in this direction is continuing.

The power semiconductor devices or power electronic converter fall generally into six categories :

- ❖ AC to DC Converter (Controlled Rectifier)
- ❖ DC to DC Converter (DC Chopper)
- ❖ AC to AC Converter (AC voltage regulator)
- ❖ DC to AC Converter (Inverter)
- ❖ Static Switches

Power Electronics Applications



Power Electronics Applications

1. Uncontrolled turn on and off (Power Diode)
2. Controlled turn on uncontrolled turn off (Thyristors)
3. Controlled turn on and off characteristic (Power Transistor, BJT, MOSFET, GTO, IGBT)
4. Continuous gate signal requirement (BJT, MOSFET, IGBT)
5. Pulse gate requirement (SCR, GTO)
6. Bipolar voltage-withstanding capability (SCR, GTO)
7. Unipolar voltage-withstanding capability (BJT, MOSFET, GTO, IGBT)
8. Bidirectional current capability (TRIAC)
9. Undirectional current capability (SCR, GTO, BJT, MOSFET, IGBT)

STATIC CONVERTERS

Static converter is a power electronic converter that can convert electric power from one form to another.

The static power converters perform these function of power conversion.

The Power Electronic Converter can be classified into six types:

1. **Diode Rectifier**
2. **AC to DC Converter (Controlled Rectifier)**
3. **DC to DC Converter (DC Chopper)**
4. **AC to AC Converter (AC voltage regulator)**
5. **DC to AC Converter (Inverter)**
6. **Static Switches**

STATIC CONVERTERS

Diode Rectifiers. A diode rectifier circuit converts AC voltage into a fixed DC voltage. The input voltage to rectifier could be either single phase or three phase.

AC to DC Converters. An AC to DC converter circuit can convert AC voltage into a DC voltage. The DC output voltage can be controlled by varying the firing angle of the thyristors. The AC input voltage could be a single phase or three phase.

AC to AC Converters. This converters can convert from a fixed ac input voltage into variable AC output voltage. The output voltage is controlled by varying firing angle of TRIAC. These type converters are known as AC voltage regulator.

DC to DC Converters. These converters can converter a fixed DC input voltage into variable DC voltage or vice versa. The DC output voltage is controlled by varying of duty cycle.

Static Switch. Because the power devices can be operated as static switches or contactors, the supply to these switches could be either AC or DC and the switches are called as AC static switches or DC static switches.

STATIC CONVERTERS

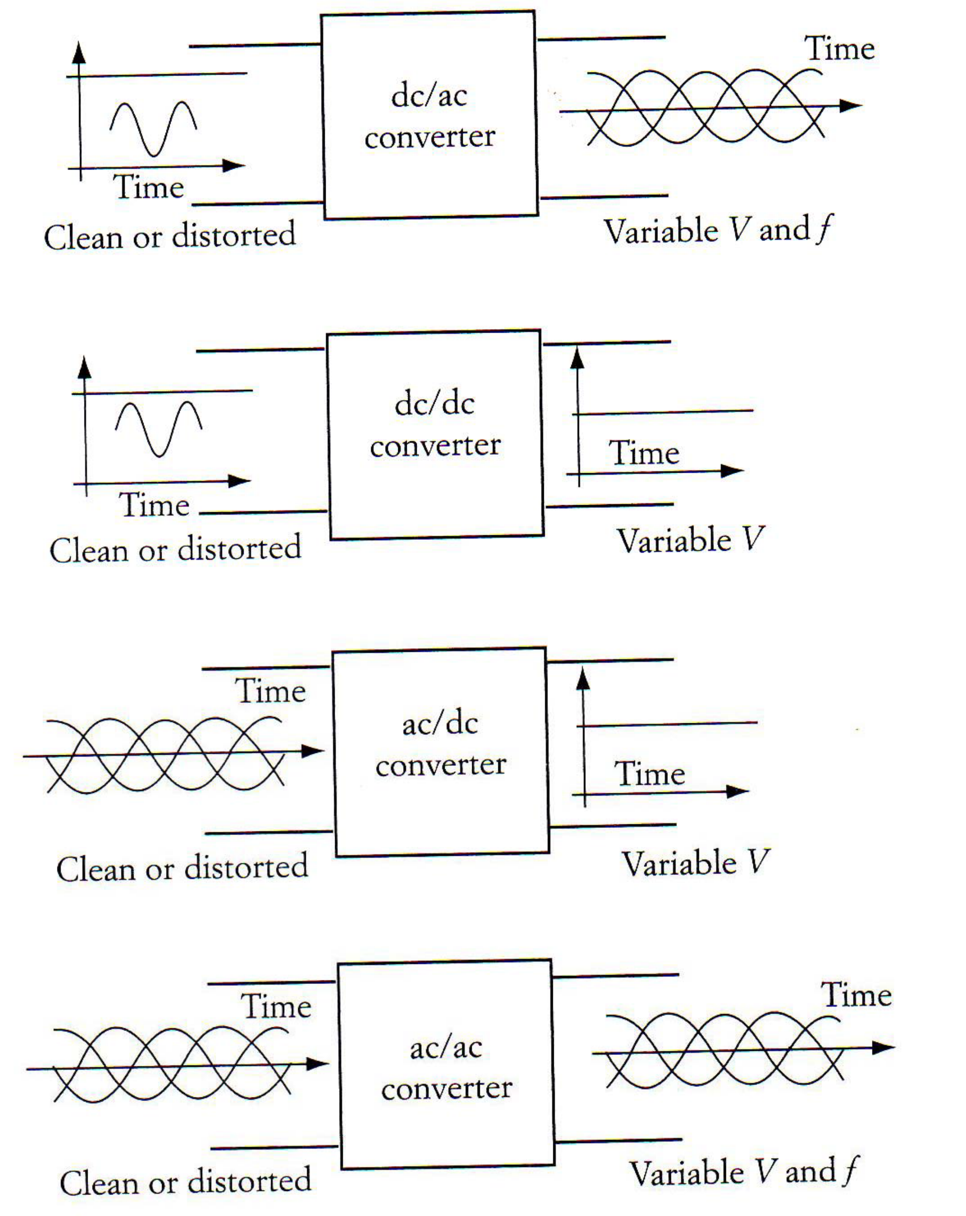


Table of Characteristic and Symbol of Power Electronic Devices

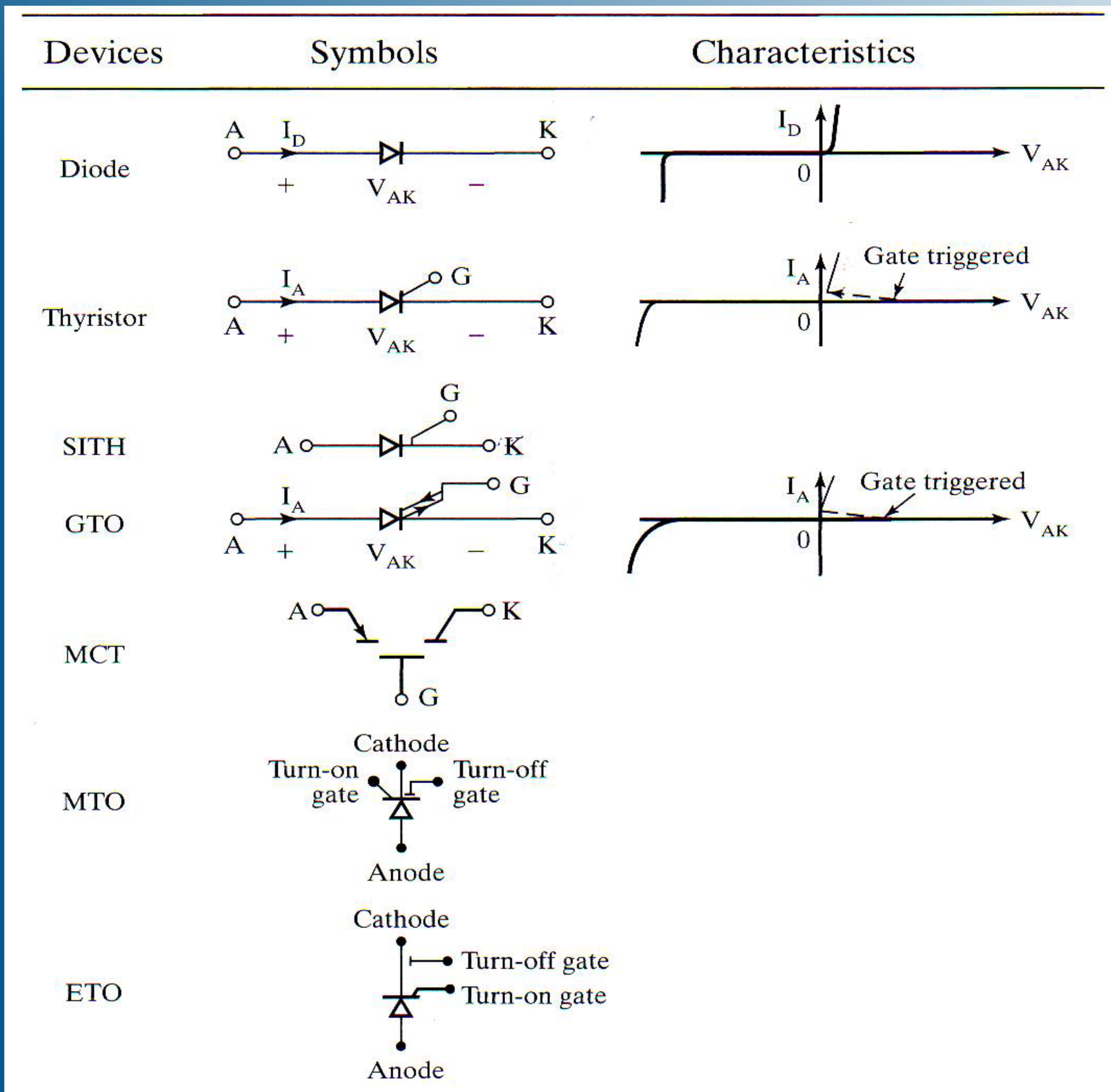
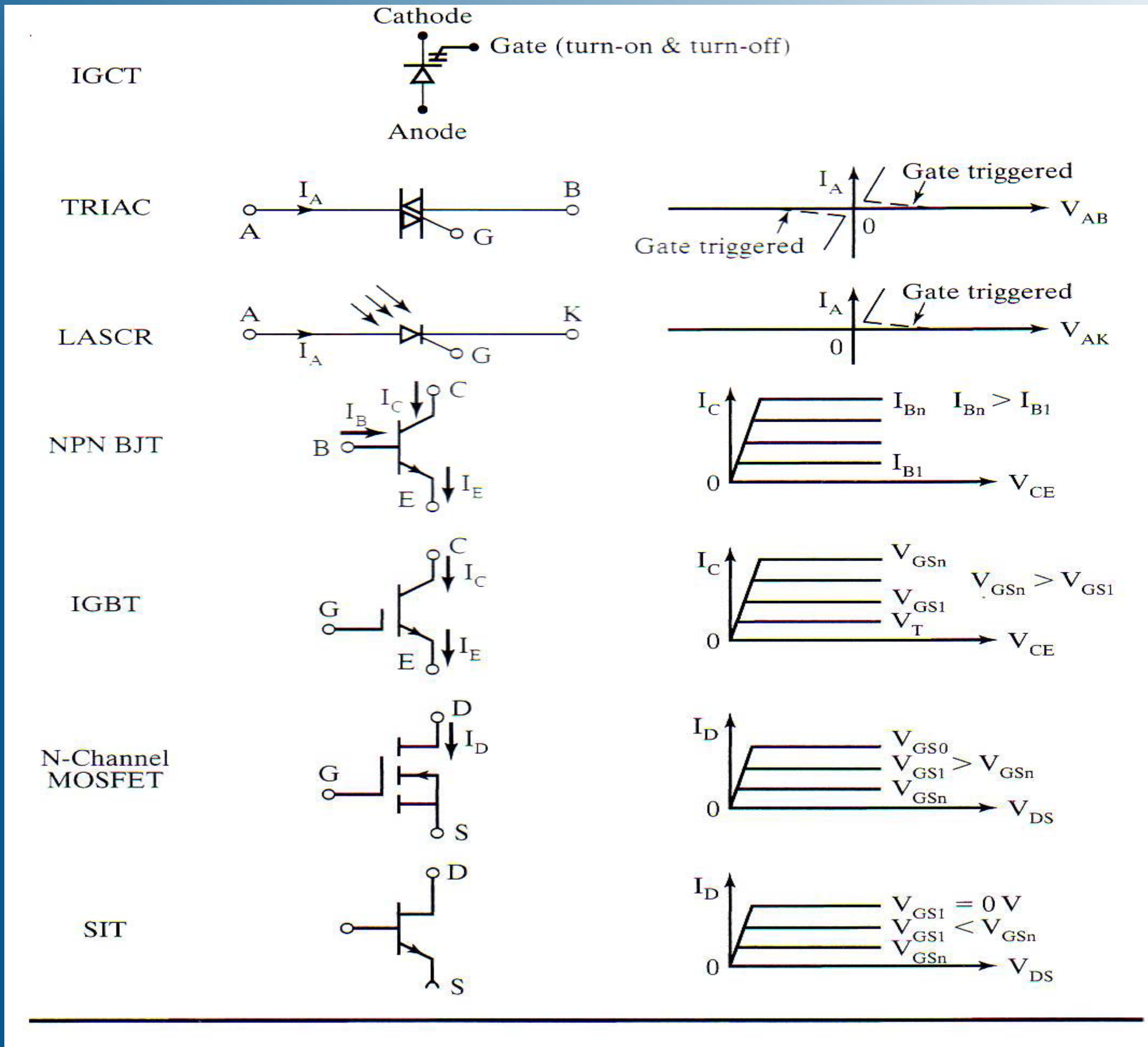
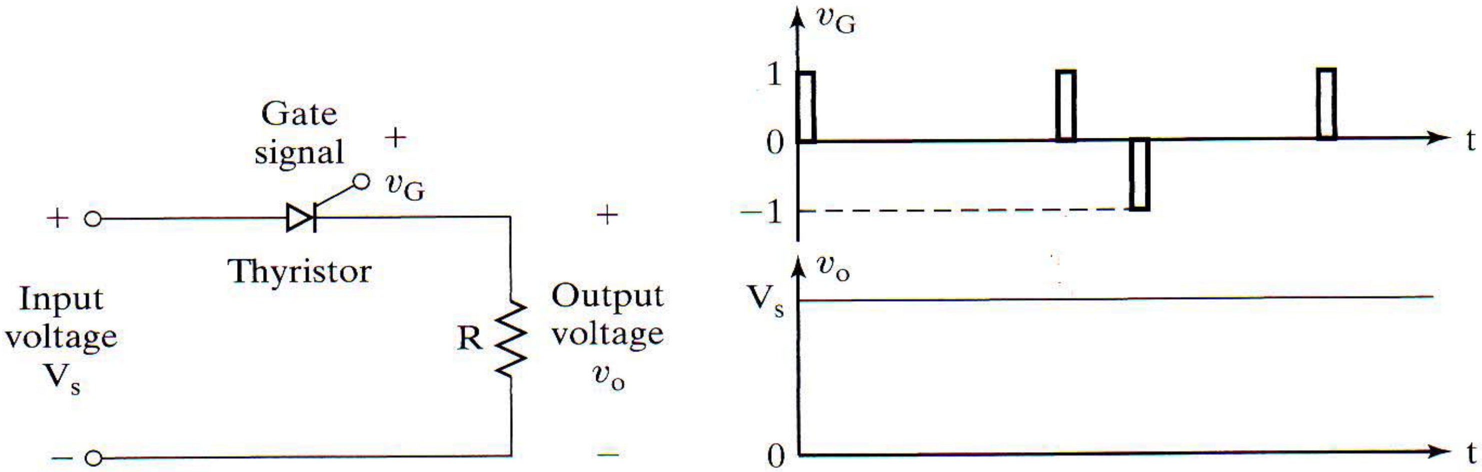


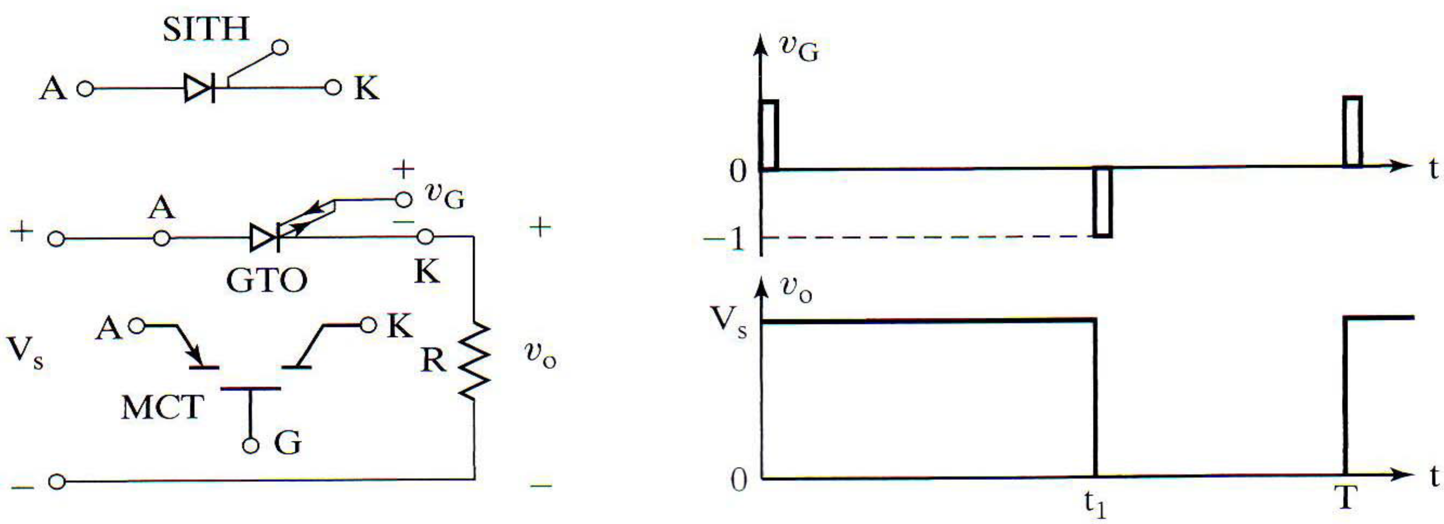
Table of Characteristic and Symbol of Power Electronic Devices



Control Characteristic of Power Electronic Devices



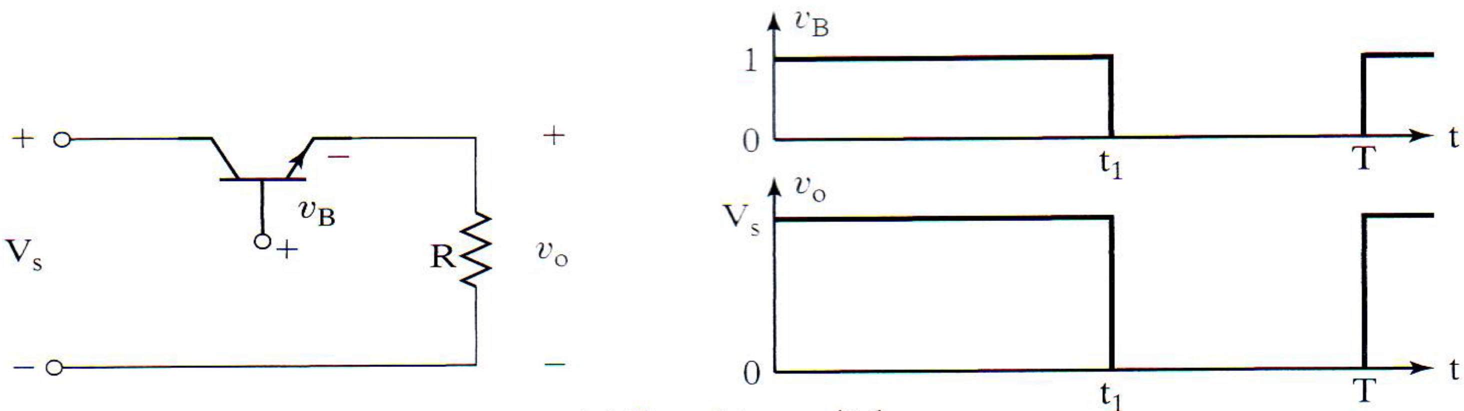
(a) Thyristor switch



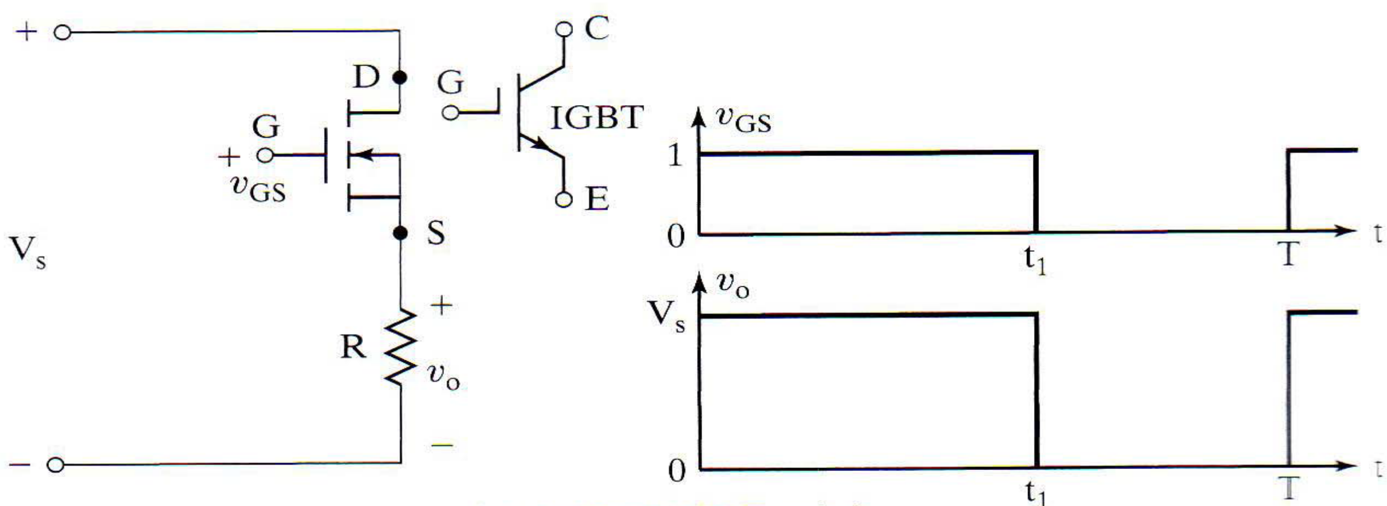
(b) GTO/MTO/ETO/IGCT/MCT/SITH switch (For MCT, the polarity of V_G is reversed as shown)

Control Characteristic of Power Electronic Devices

(b) GTO/MTO/ETO/IGCT/MCT/SITH switch (For MCT. the polarity of V_G is reversed as shown)



(c) Transistor switch



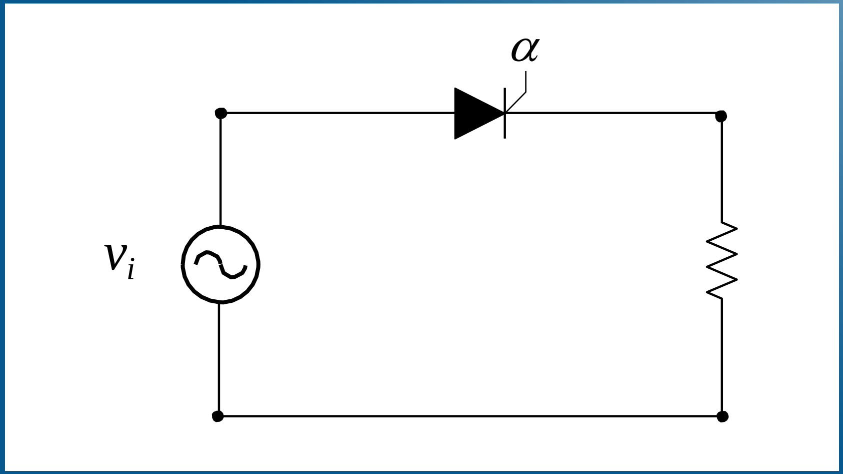
(d) MOSFET/IGBT switch

CONVERTERS

1. AC to DC Converters

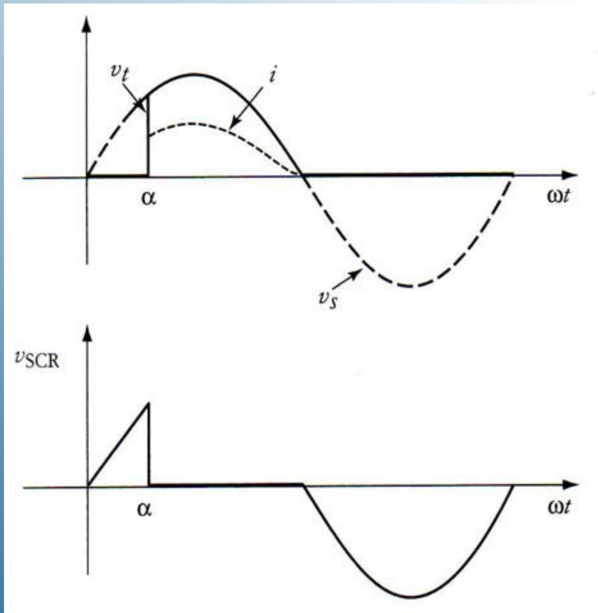
- **Single phase, half wave AC to DC converter**

Input voltage : $v_i = V_m \sin(\omega t)$

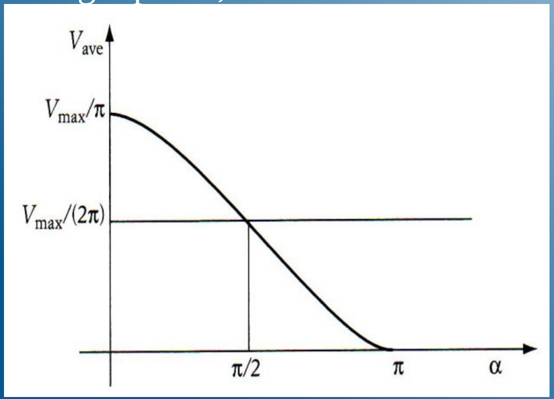


Output average voltage :

$$v_{o\,av} = v_{dcav} = \frac{V_m}{2\pi}(1 + \cos\alpha)$$



Waveform of single-phase, half wave AC to DC converter



CONVERTERS

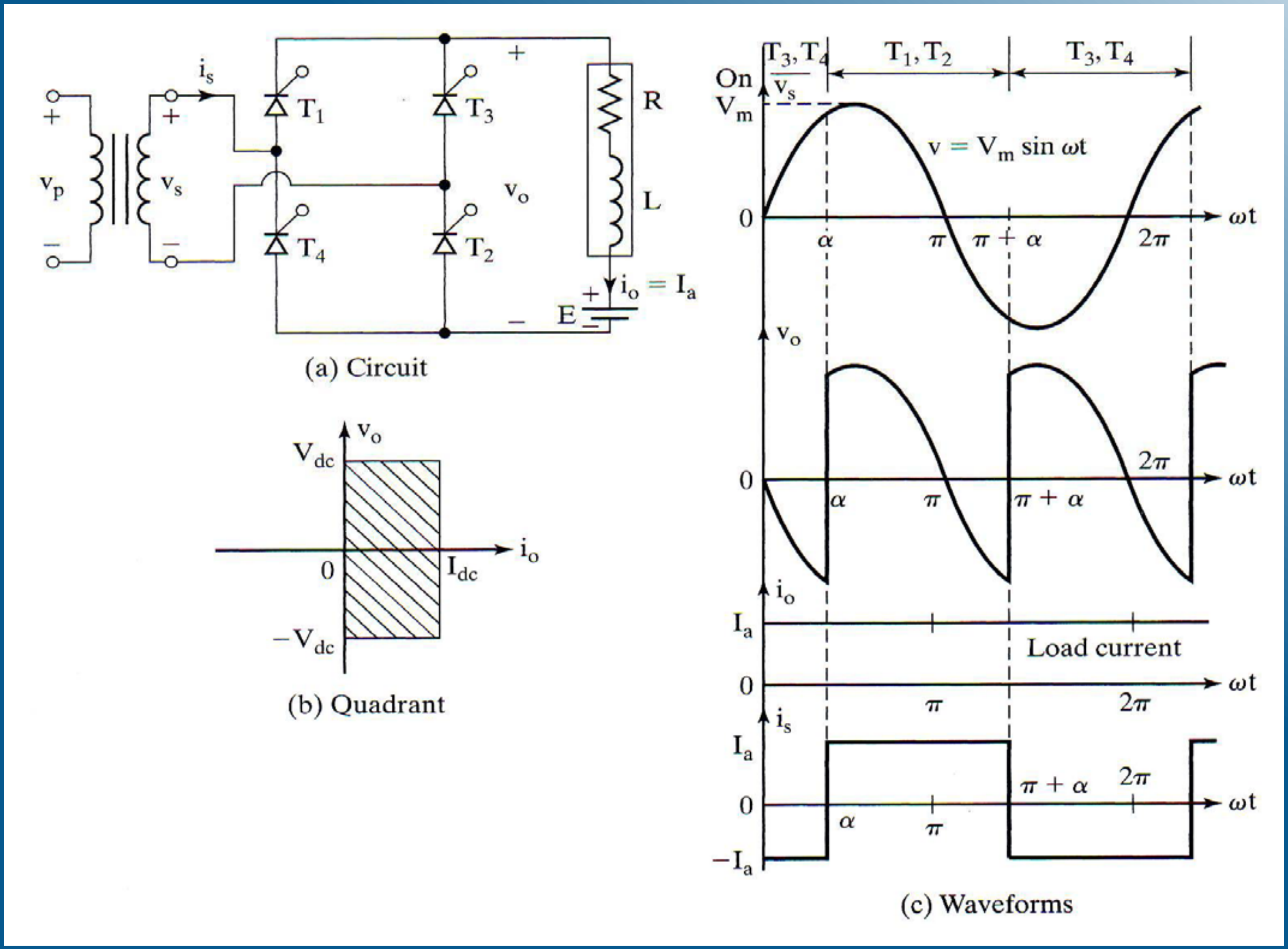
1. AC to DC Converters

- ❖ **Single phase, half wave AC to DC converter**

CONVERTERS

1. AC to DC Converters

- ❖ **Single phase, full wave AC to DC converter**



(a) Circuit

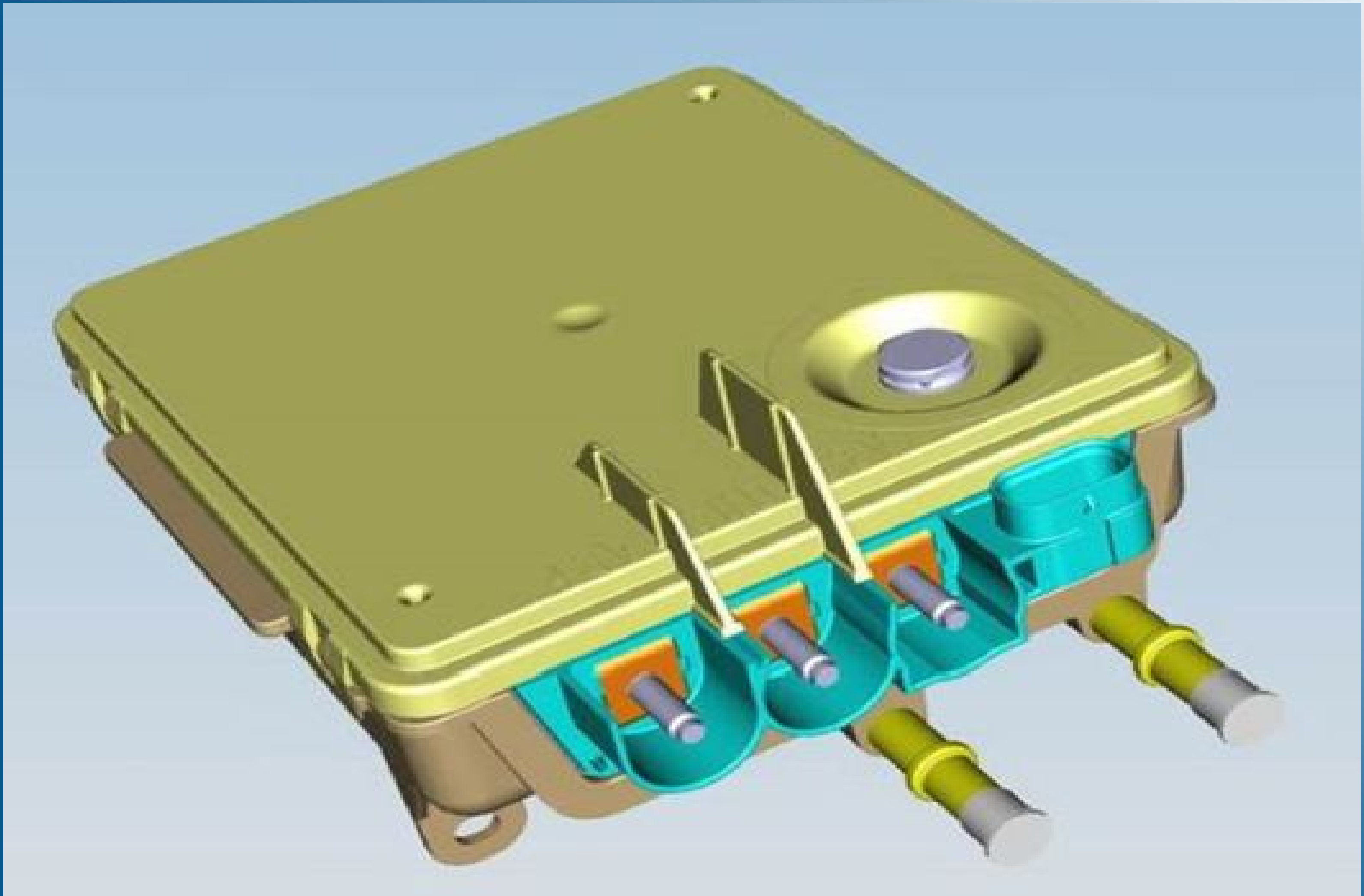
(b) Quadrant

(c) Waveforms

CONVERTERS

1. AC to DC Converters

❖ Single phase, full wave AC to DC converter



CONVERTERS

1. AC to DC Converters

- ❖ **Single phase, full wave AC to DC converter**

$$V_{dc} = \frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin \omega t \, d(\omega t) = \frac{2V_m}{2\pi}\left[-\cos \omega t\right]_{\alpha}^{\pi+\alpha}$$

$$= \frac{2V_m}{\pi}\cos\alpha$$

The rms value of the output voltage is given by

$$V_{rms} = \left[\frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} V_m^2 \sin^2 \omega t \, d(\omega t)\right]^{1/2} = \left[\frac{V_m^2}{2\pi}\int_{\alpha}^{\pi+\alpha}(1 - \cos 2\omega t)\, d(\omega t)\right]^{1/2} \quad (10.7)$$

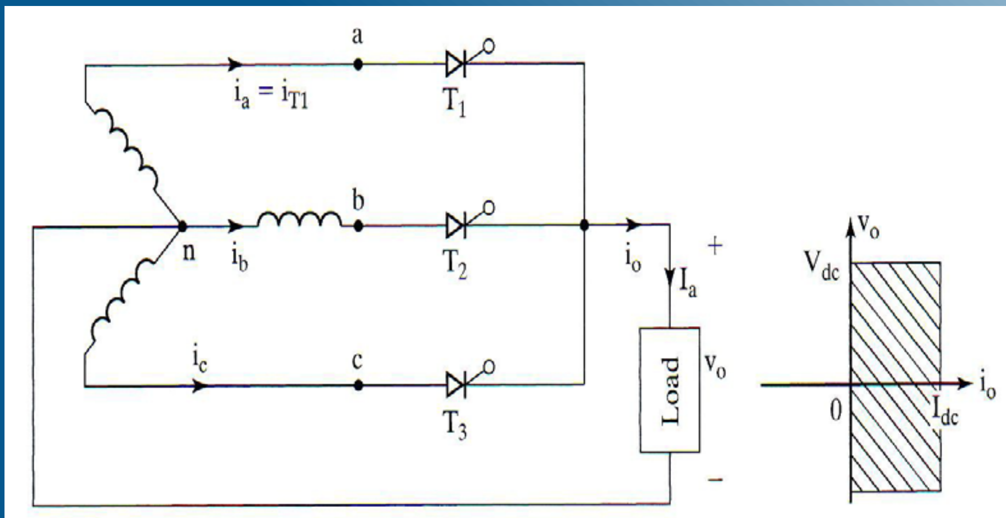
$$= \frac{V_m}{\sqrt{2}} = V_s$$

With a purely resistive load, thyristors T_1 and T_2 can conduct from α to π, and thyristors T_3 and T_4 can conduct from $\alpha + \pi$ to 2π.

CONVERTERS

1. AC to DC Converters

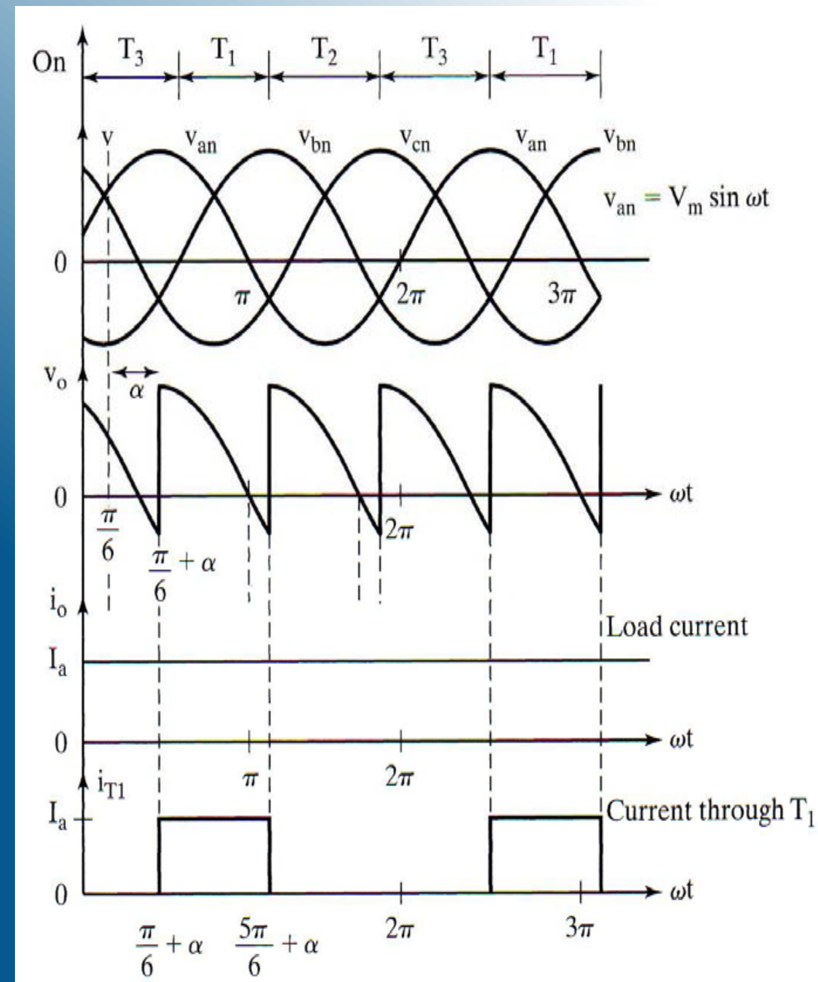
❖ Three phase, half wave AC to DC converter



(a) Circuit (b) Quadrant

If the phase voltage is : $\mathbf{v_{an} = V_m \sin\alpha}$ the average output voltage for a continuous load current is :

$$V_{dc} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m \sin \omega t \, d(\omega t) = \frac{3\sqrt{3}\,V_m}{2\pi}\cos\alpha$$



(c) For inductive load

CONVERTERS

1. AC to DC Converters

❖ **Three phase, half wave AC to DC converter**

The rms output voltage is found from

$$V_{rms} = \left[\frac{3}{2\pi}\left[\int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m^2 \sin^2\omega t \; d(\omega t)\right]\right]^{1/2}$$

$$= \sqrt{3} V_m \left(\frac{1}{6} + \frac{\sqrt{3}}{8\pi}\cos 2\alpha\right)^{1/2}$$

For a resistive load and $\alpha \geq \pi/6$:

$$V_{dc} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{\pi} V_m \sin \omega t \; d(\omega t) = \frac{3V_m}{2\pi}\left[1 + \cos\left(\frac{\pi}{6} + \alpha\right)\right]$$

$$V_n = \frac{V_{dc}}{V_{dm}} = \frac{1}{\sqrt{3}}\left[1 + \cos\left(\frac{\pi}{6} + \alpha\right)\right]$$

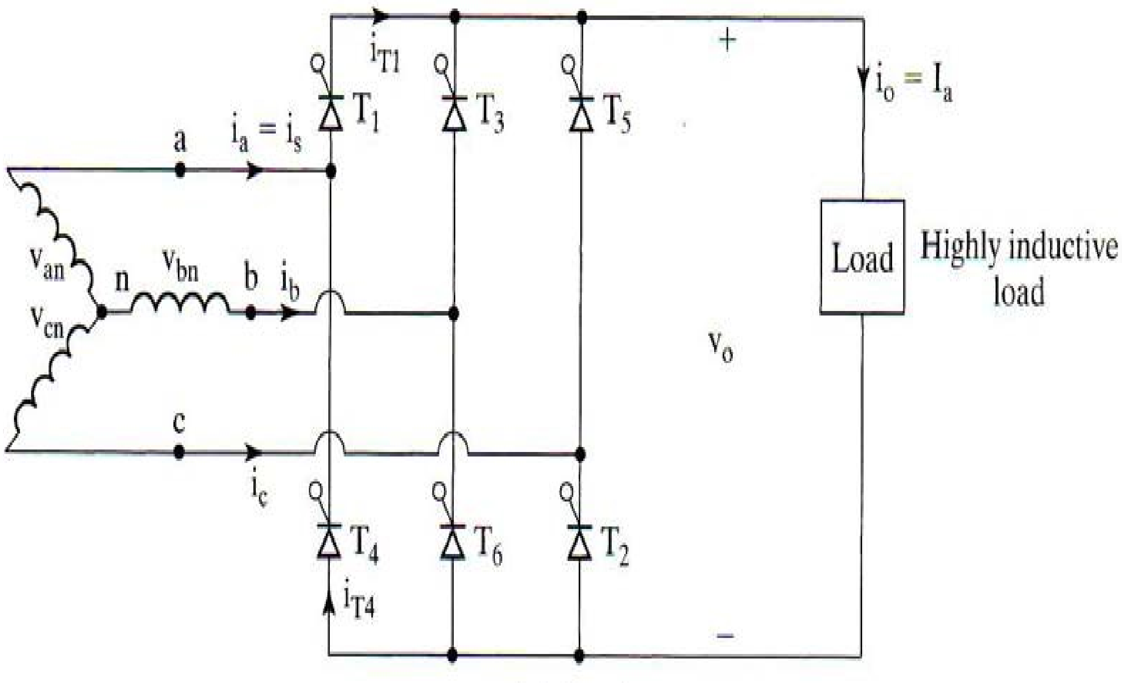
$$V_{rms} = \left[\frac{3}{2\pi}\int_{\pi/6+\alpha}^{\pi} V_m^2 \sin^2\omega t \; d(\omega t)\right]^{1/2}$$

$$= \sqrt{3}\, V_m\left[\frac{5}{24} - \frac{\alpha}{4\pi} + \frac{1}{8\pi}\sin\left(\frac{\pi}{3} + 2\alpha\right)\right]^{1/2}$$

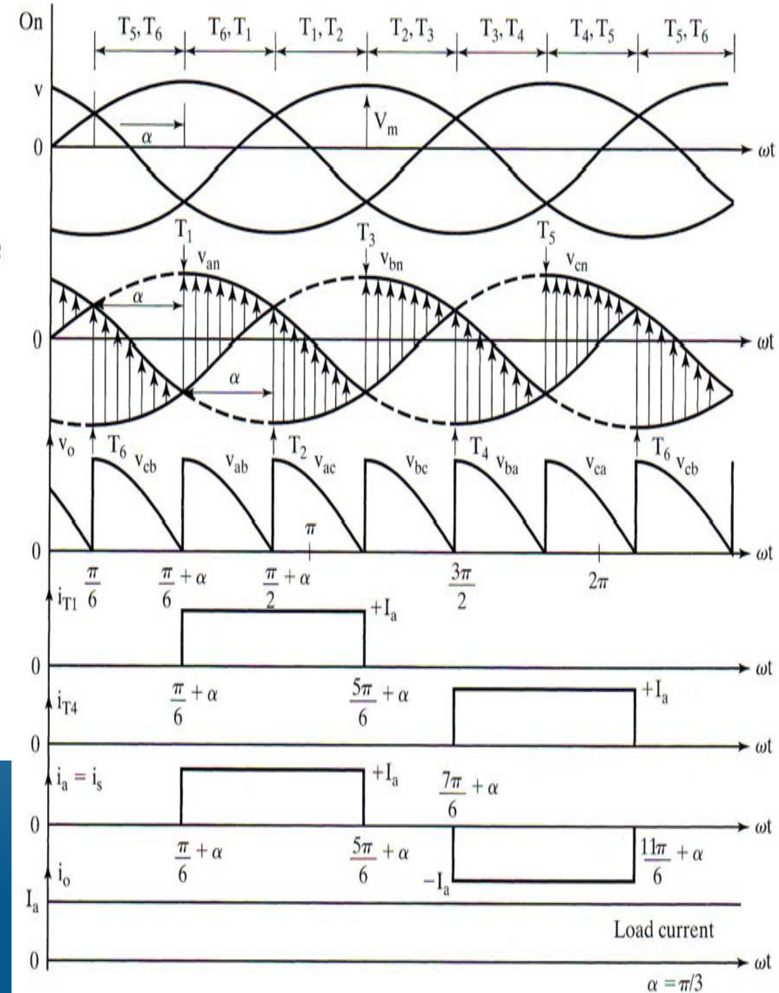
CONVERTERS

1. AC to DC Converters

❖ **Three phase, full wave AC to DC converter**



(a) Circuit



(b) Waveforms

CONVERTERS

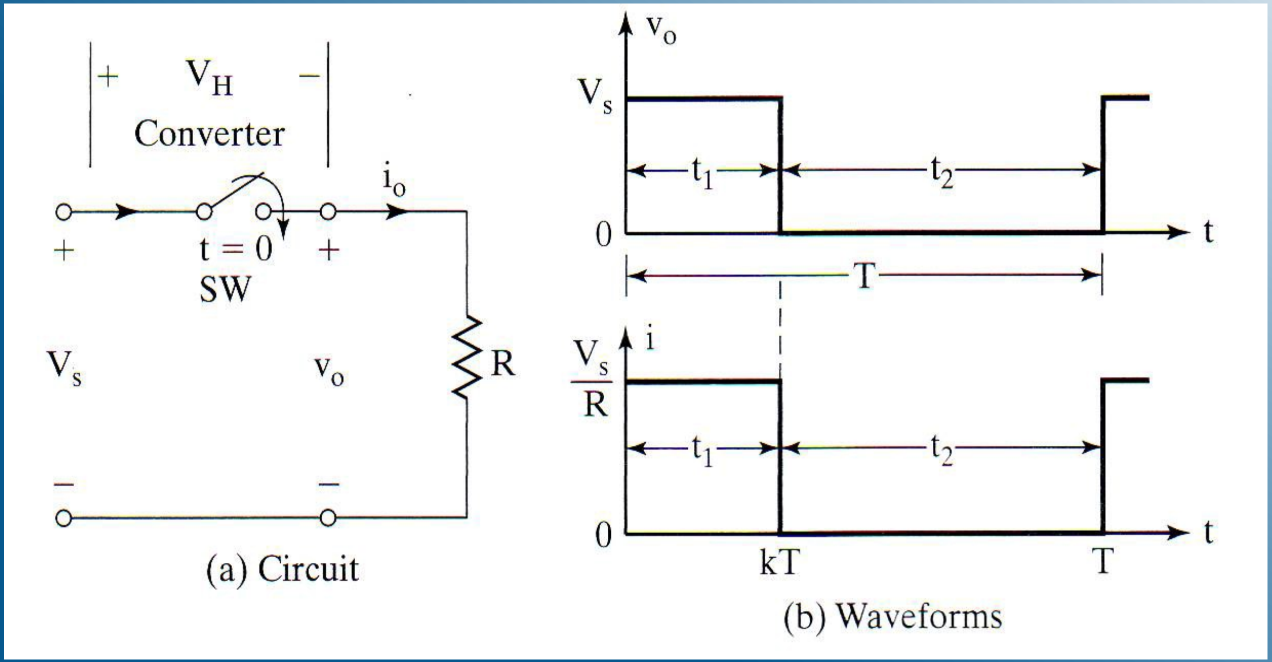
2. DC to DC Converters

- In many industrial application , DC-DC converter is required to convert a fixed-voltage DC source into a variable-voltage DC source. Like a transformer, DC-DC converter can be used to step down or step up a DC voltage source.
- Application :
  - Traction motor control in electric automobiles, trolley cars, marine hoists, forklift trucks, mine haulers, etc
- Advantages :
  - High Efficiency and fast dynamic response

CONVERTERS

2. DC to DC Converters

Principle Of Step-Down Operation



When the switch SW is closed for a time t_1, the input voltage V_s appears across the load $V_o = V_s$. If the switch remains off a time t_2, the voltage across the load is zero, $V_o = 0$.

The converter switch SW can be implemented by using Transistor, MOSFET, GTO, IGBT, BJT, etc.