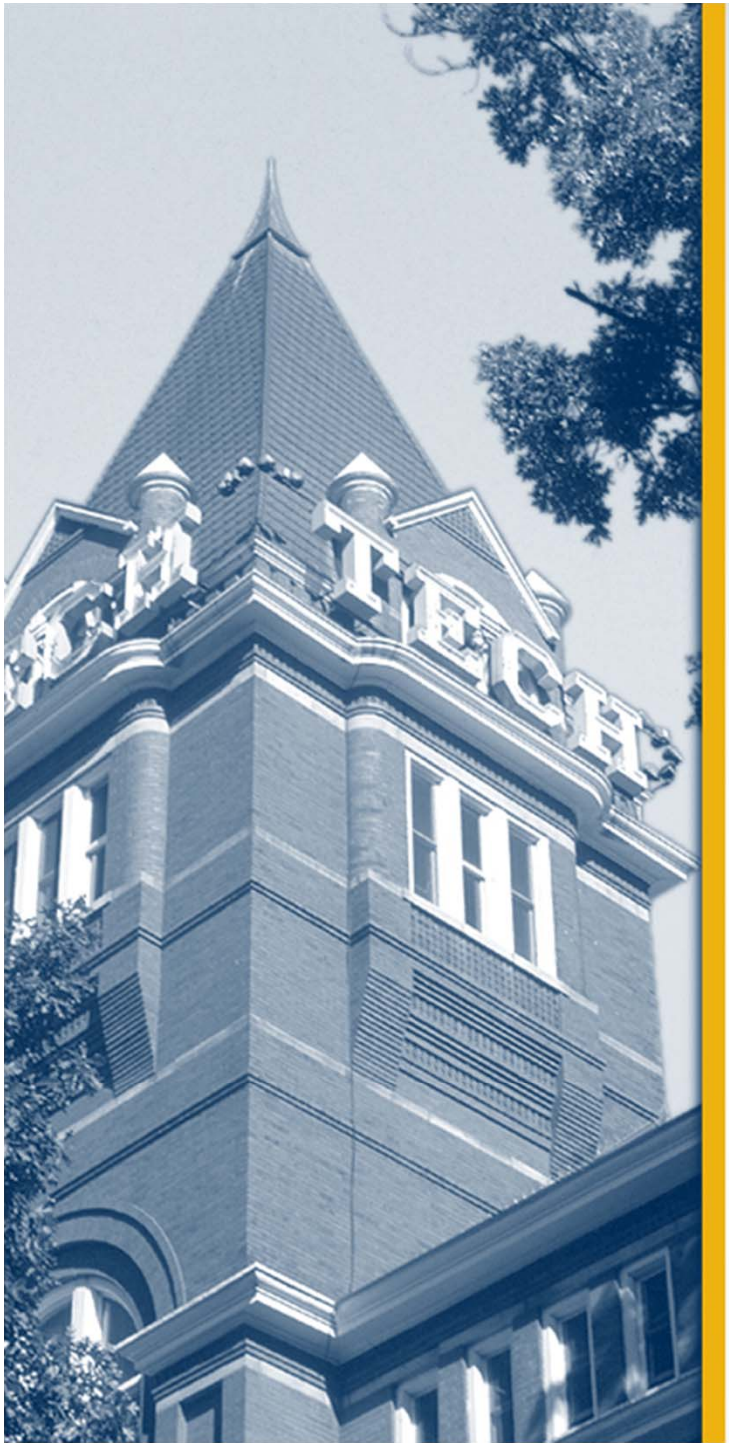

Thyristors

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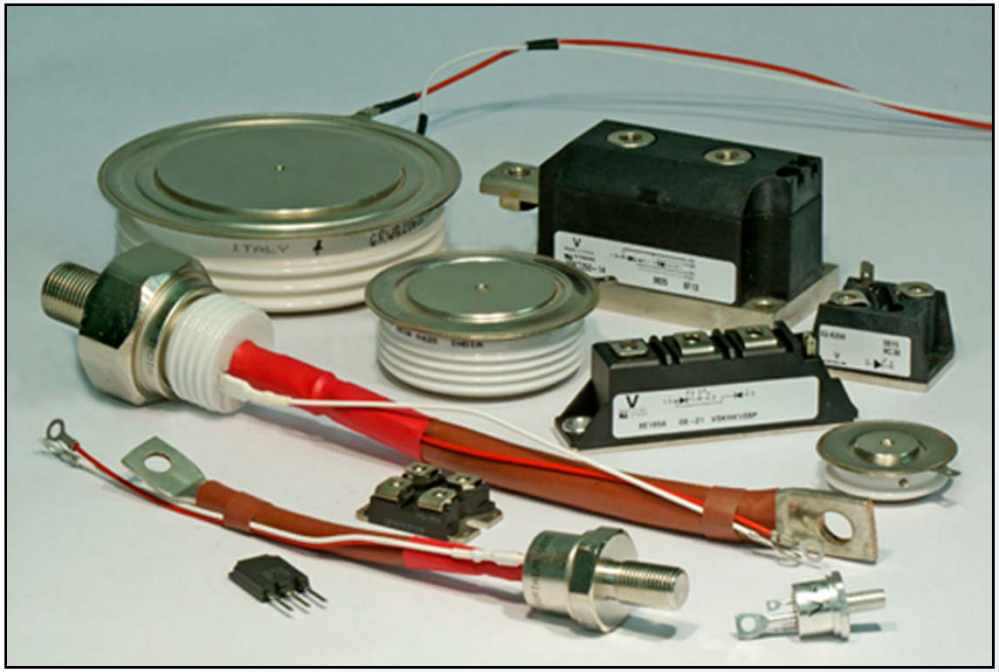
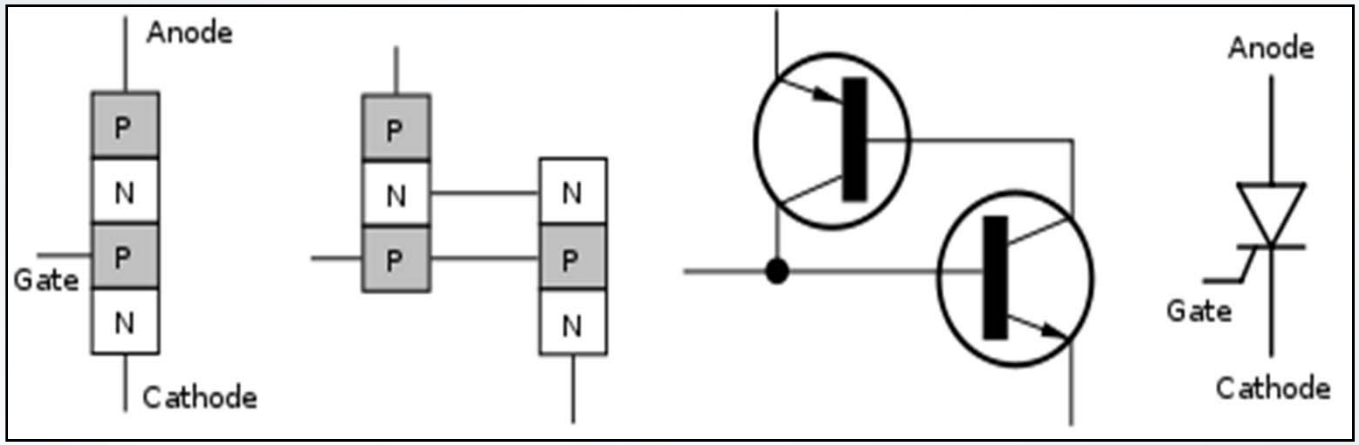
Objective

- Understanding of Thyristors in terms of:
  - Functionality
  - Applications
  - Key Design Tradeoffs



Background

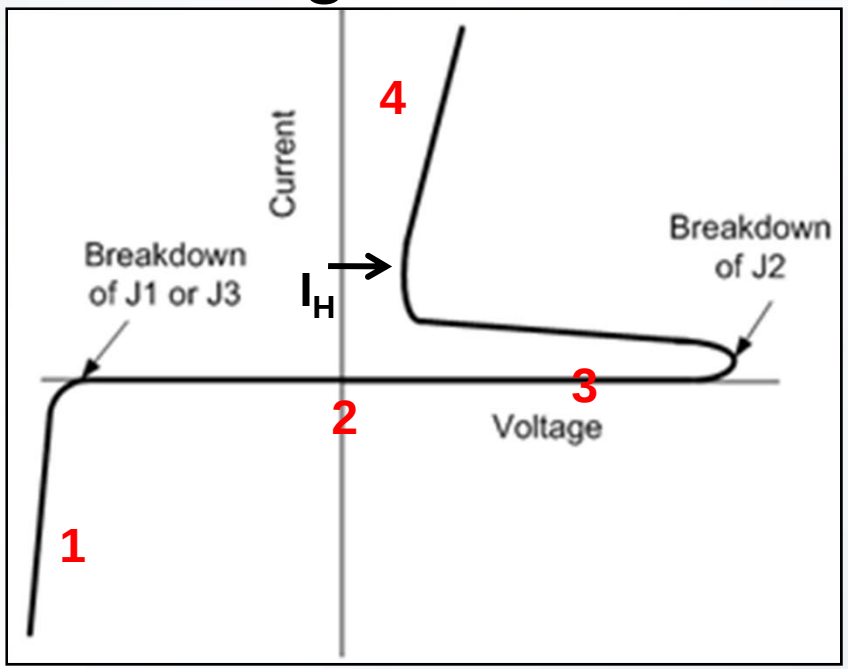
- Solid state, three terminal, semiconductor device with four layers of alternating N and P-type material or three PN junctions



- Mainly used in high-power switching applications

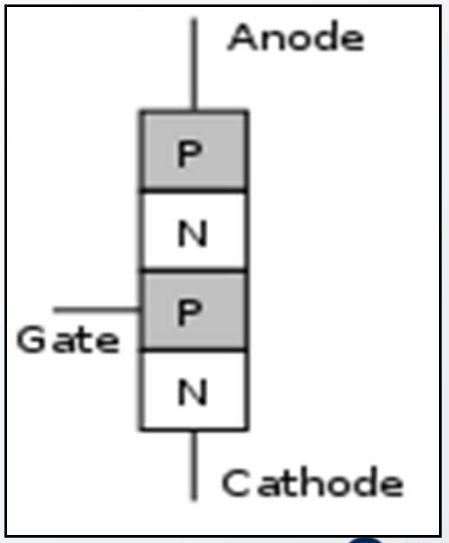
The I_A-V_{AK} Curve

- Forward bias breakdown voltage (V_{BF}) at J2
- Reverse bias breakdown voltage (V_{BR}) at J1 or J3
- States: 1.Reverse Blocking 2.Equilibrium 3.Forward Blocking 4.Forward Conducting



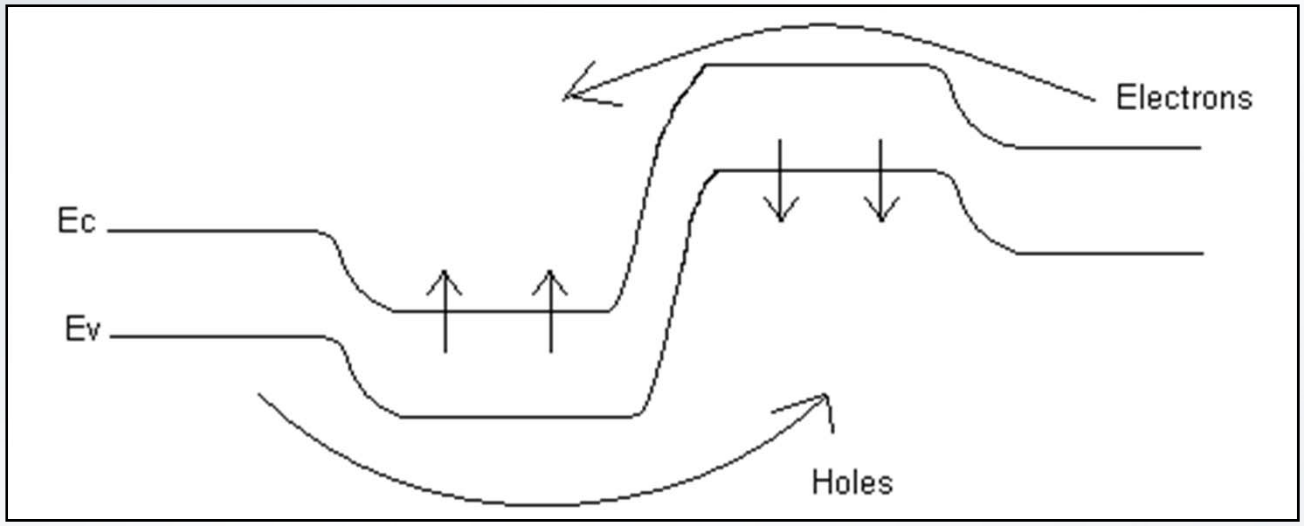
Forward Biased Thyristor

- Apply positive voltage at the gate causing breakdown
- Different V_G values can easily switch thyristor to "on state"
- $V_G > V_{BR}$, Avalanche Breakdown occurs causing conduction
- Device is latched, conduction continues until V_G removed or $I_A < I_H$



Energy Band Diagram(pnpn)

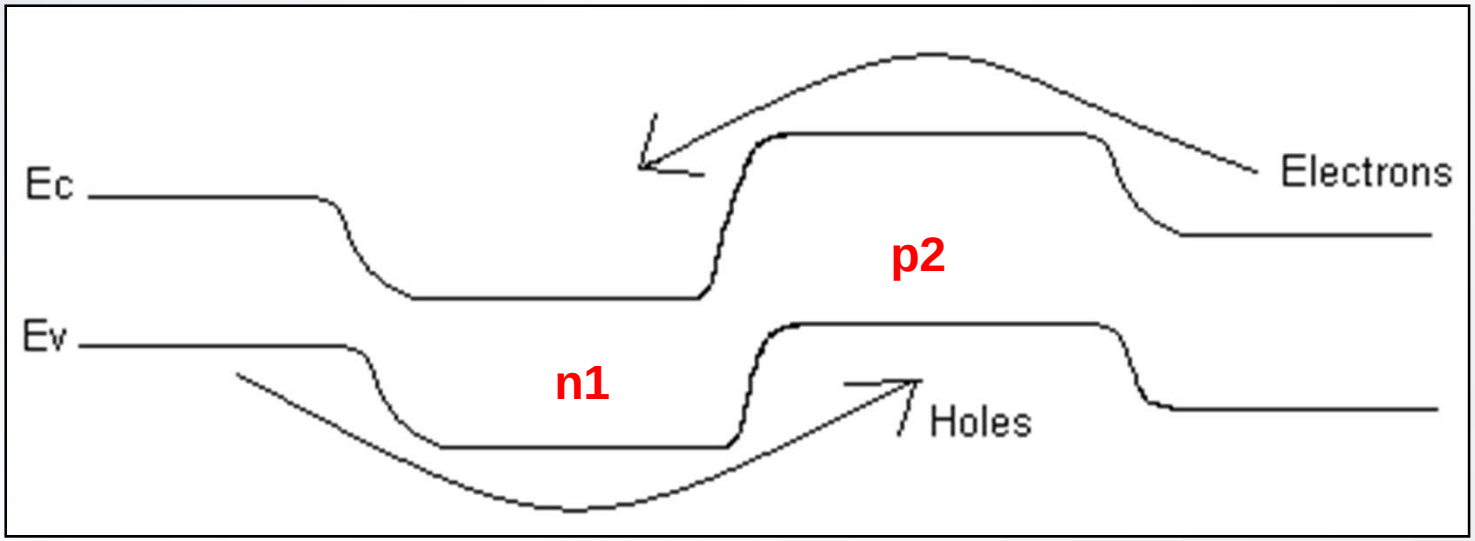
- Center junction is reversed biased while other two junctions in forward bias(forward bias)



- No recombination causing decreasing reverse bias(off-state)
- Small current flows through device

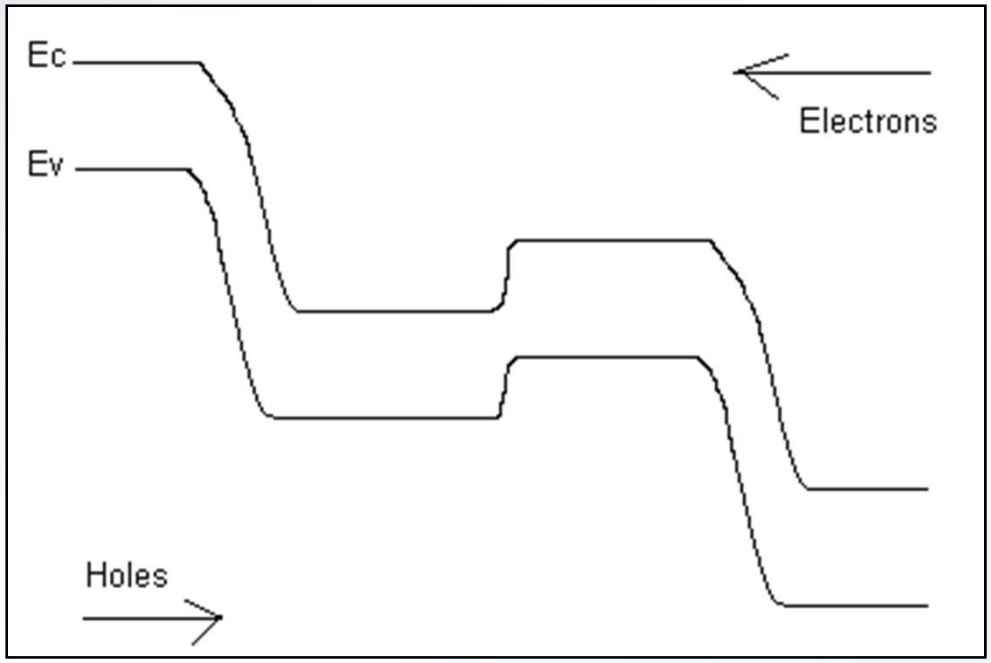
Accumulation(pnpn)

- Injected electrons accumulate in n1 region and injected holes accumulate in p2 region
- Low-Voltage, high current state



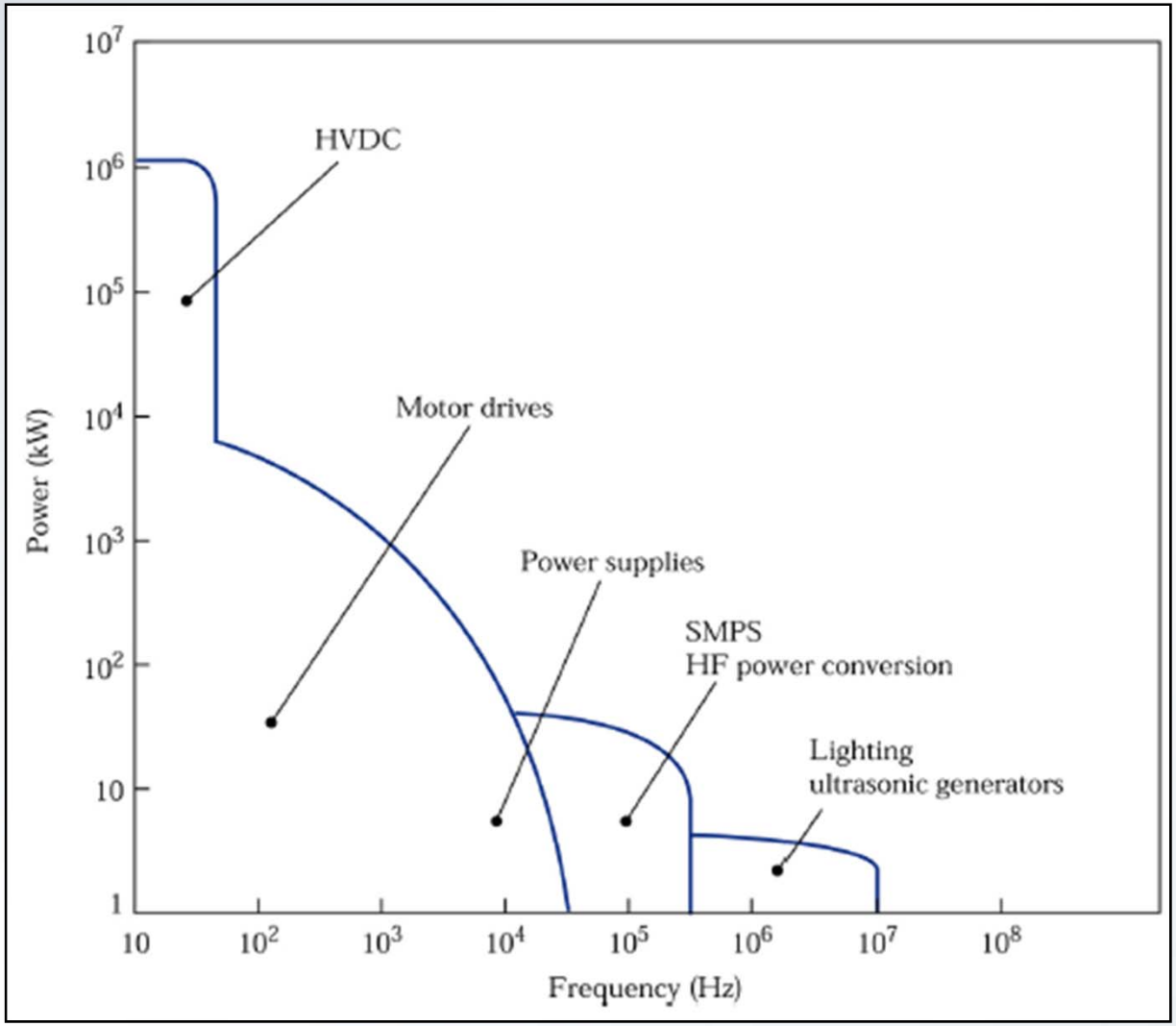
Energy Band Diagram(R-Bias)

- Center junction is forward biased while other two junctions in reverse bias(reverse bias)



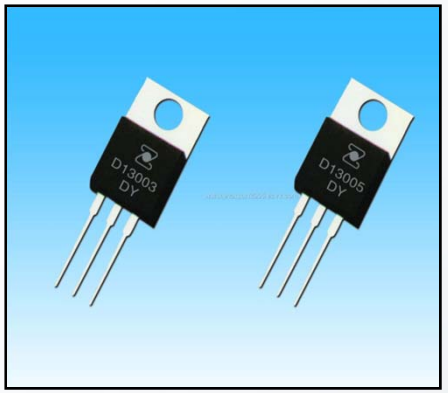
- No accumulation of charge in reverse bias

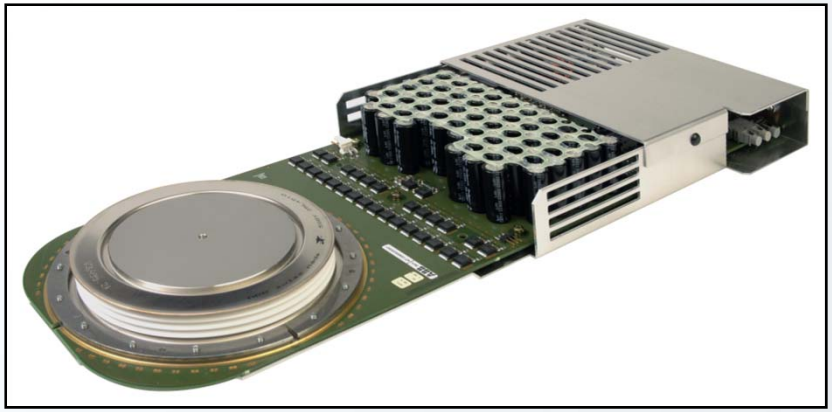
Applications



Types of Thyristors

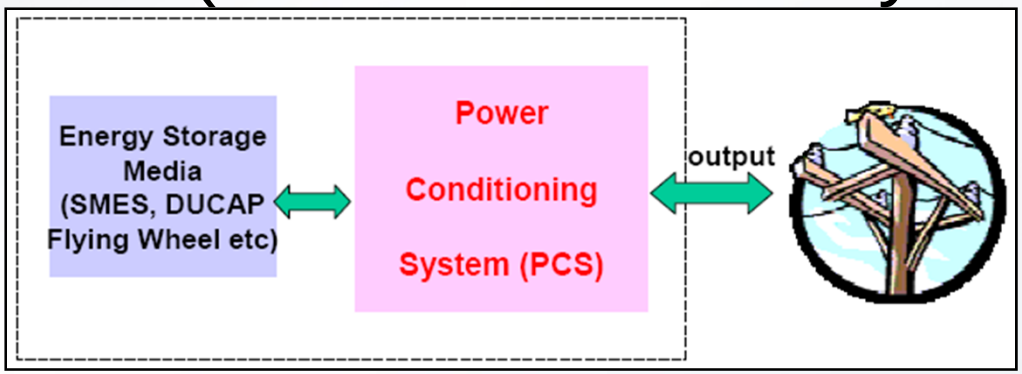
- SCR-Silicon controlled rectifier
- GTO-Gate turn-off
- IGCT-Integrated Gate Commutated
- RCT-Reverse Conducting
- LASCR-Light Activated SCR





Recent Development (ETOs)

- Emitter Turn-Off
- Low voltage MOSFETs in series with GTO
- Anode current provides turn-off energy
- Improvement of high power and high frequency used for PCS(Power Condition System)



- Low conduction loss

Drawbacks and Tradeoffs

- Only conducts in one direction
- TRIAC (5-layers) can conduct in both directions but requires snubber circuit to suppress voltage transients
- Not fully controllable and bad for high frequency applications due to large switching times
- TRIAC (5-layers) can conduct in both directions but requires snubber circuit to suppress voltage transients

Sources

- Anderson, Betty Lise, and Anderson, Richard L. Fundamentals of Semiconductor Devices, McGraw-Hill, 2005.
- ON Semiconductor, Thyristor Surge Protection Devices:

http://www.onsemi.com/PowerSolutions/content.do?id=16017

- Thyristors picture found on slide 2:

http://www.chtechnology.com/thyristors.html

- Thyristor pictures found on slide 3 and 5:

http://en.wikipedia.org/wiki/Thyristor

- Dr. Alex Q. Huang, Sandia Labs, ETO Thyristor:

http://www.sandia.gov/ess/docs/pr_conferences/2001/AlexHuang.pdf

- IGCT picture slide 10:

http://www.abb.com/cawp/seitp202/2aa5169bfbbbab85c125766c004d852b.aspx

Questions?