POWER ELECTRONICS
Introduction

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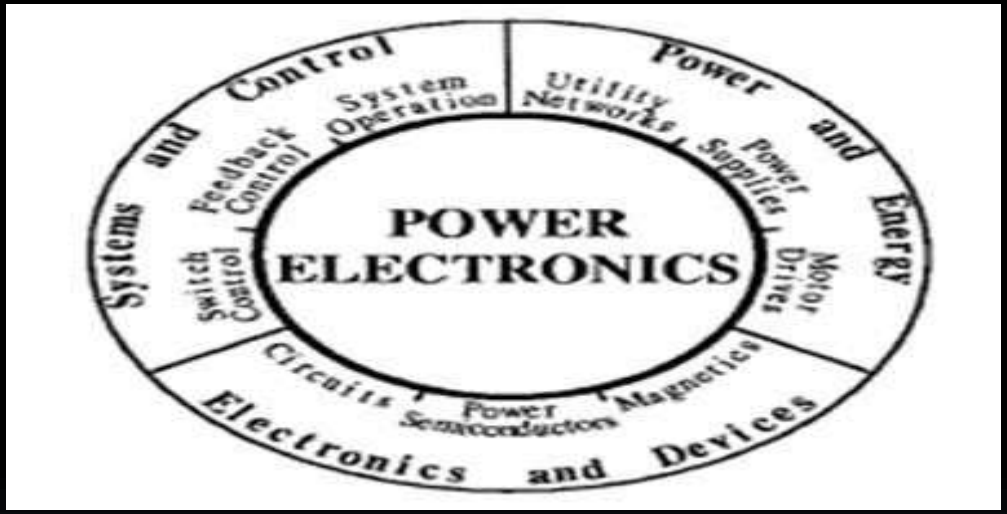
Definition:

Power Electronics is the subject concerning the application of principles of electronics at high rated power levels and not signal levels.



It is the technology of conversion, control and conditioning of electric power into a desired electrical output. It is the conglomeration of control system, electronics and power systems.

Rapid Growth

Rapid growth of Power Electronics is due to:

– Advances in power (semiconductor) switches

–Advances in microelectronics (DSP, VLSI, microprocessor/microcontroller)

– New ideas in control algorithms

– Demand for new applications

Comparison: PE & Signal Processing

- In Power Electronics —

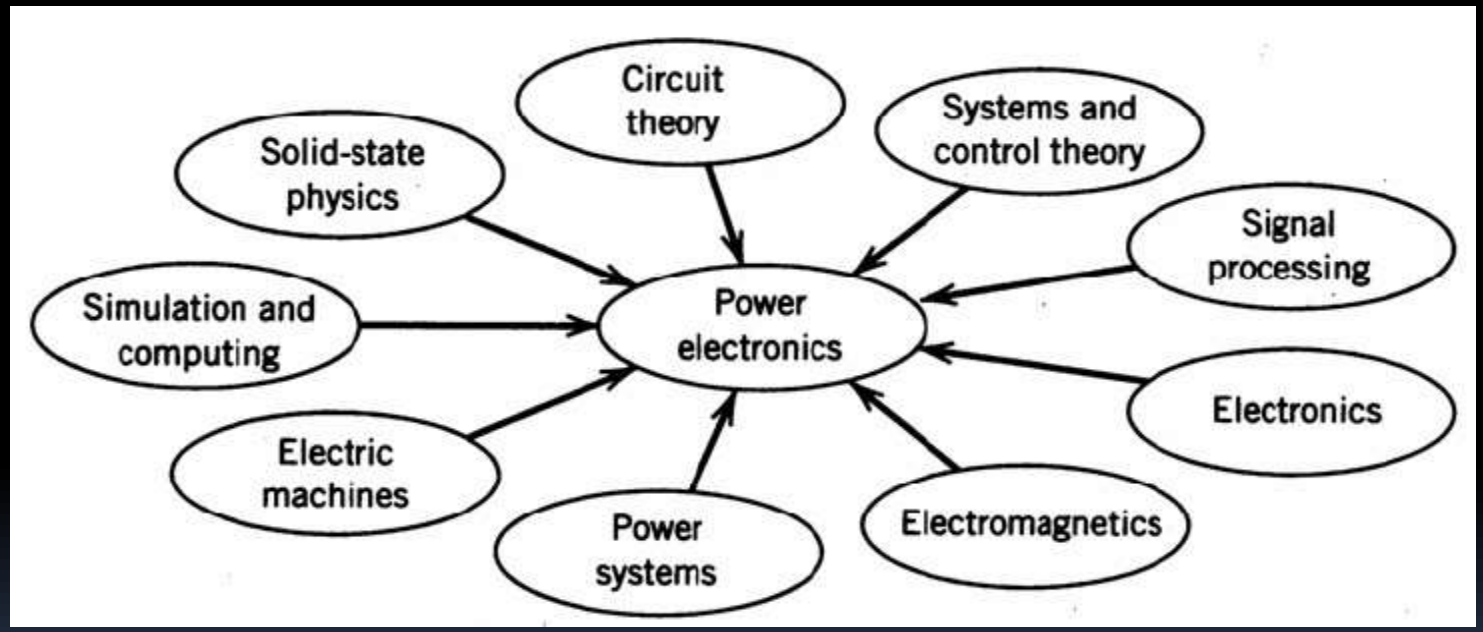
1. The focus is on power conversion at the highest possible efficiency using very small control signals.
2. Semiconductor devices work as switches.
3. Power handled may range from a few watts to several mega-watts.

- In Signal Processing —

1. Semiconductor devices generally work as controlled sources in the linear region of their characteristics.
2. The focus is on information processing with minimum loss of information.
3. Power handled will be of the order of few milli-watts or few watts.

Interdisciplinary Nature of Power Electronics

- **Range of power scale :**



milliwatts(mW) ⇨ megawatts(MW) ⇨ gigawatts(GW)

Contributing Areas

- **Electronics –**

Deals with solid – state devices and signal processing circuits.

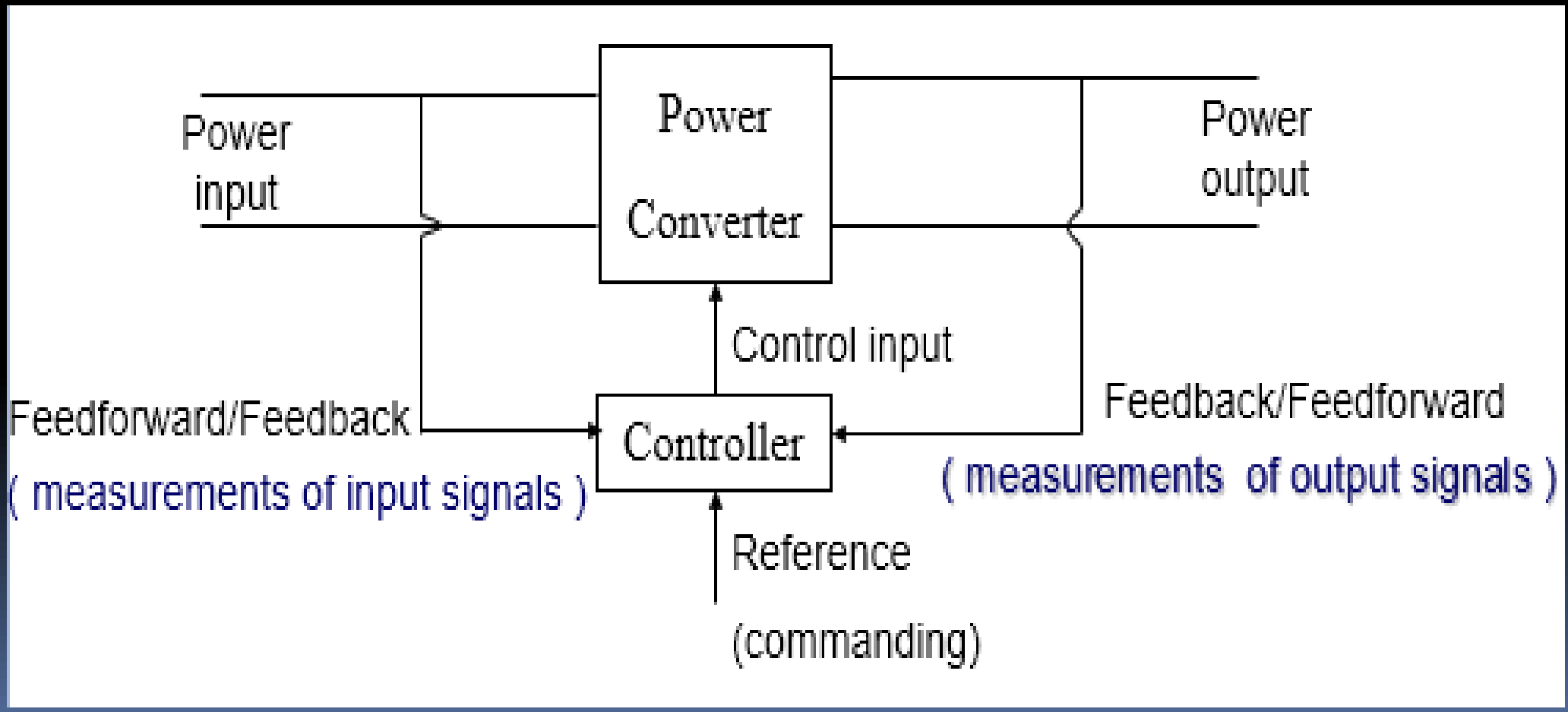
- **Power System –**

Deals with static and rotating power equipment.

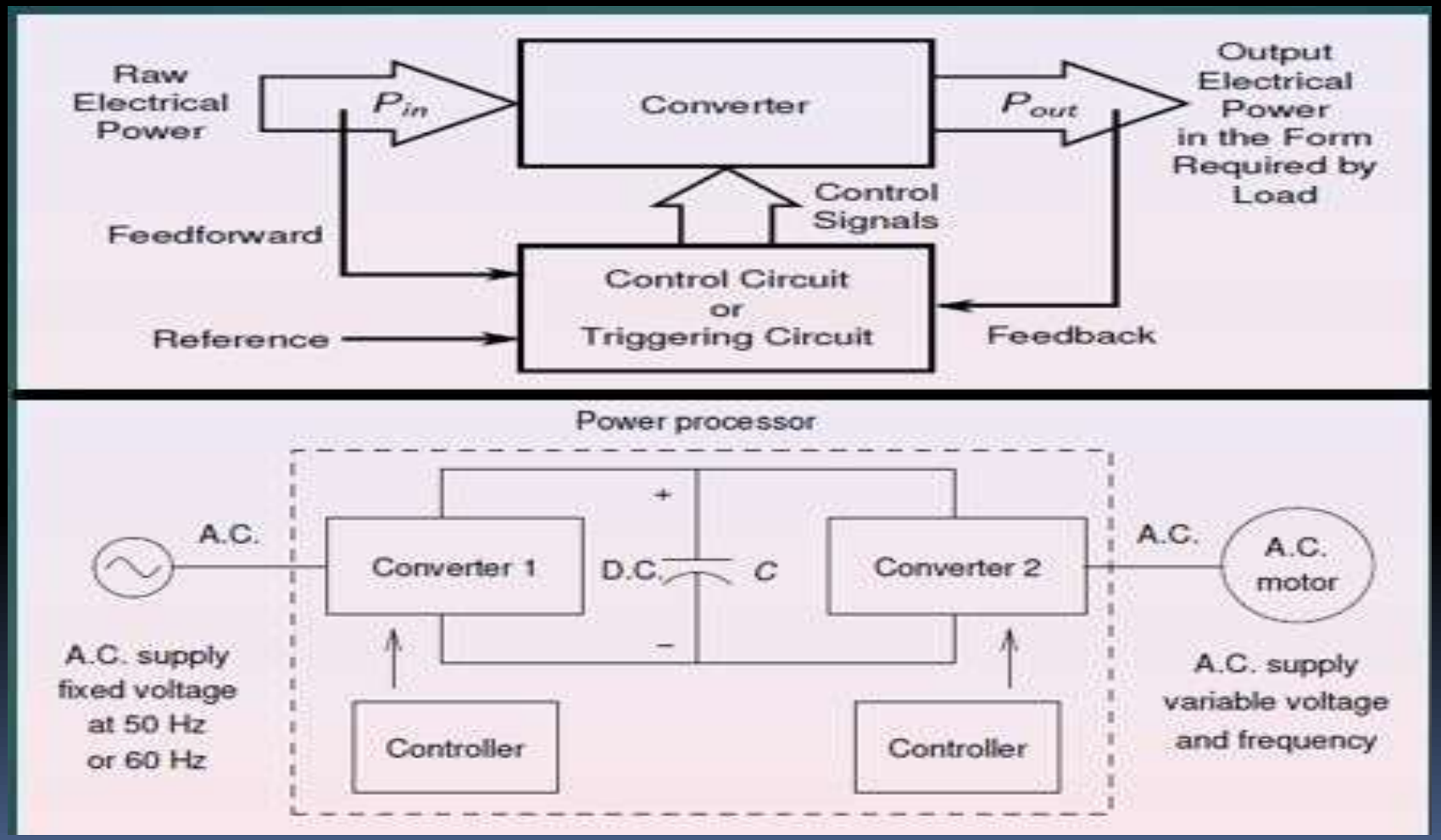
- **Control System –**

Deals with steady state and dynamic characteristics of closed – loop system.

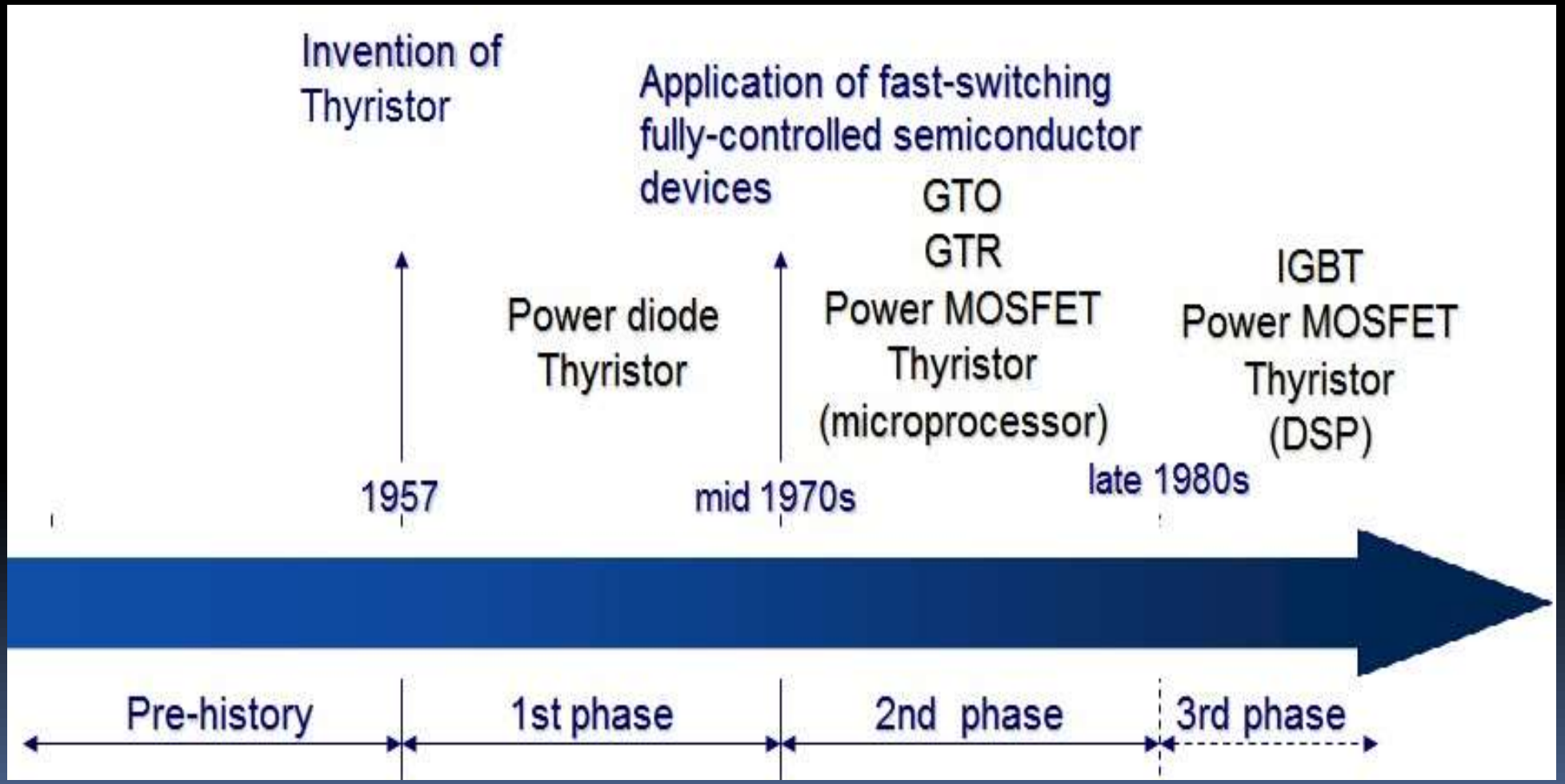
General Structure of Power Electronic System



Power Processor

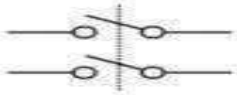
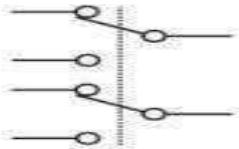
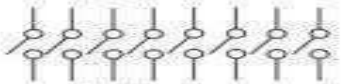


History of Power Electronic Devices

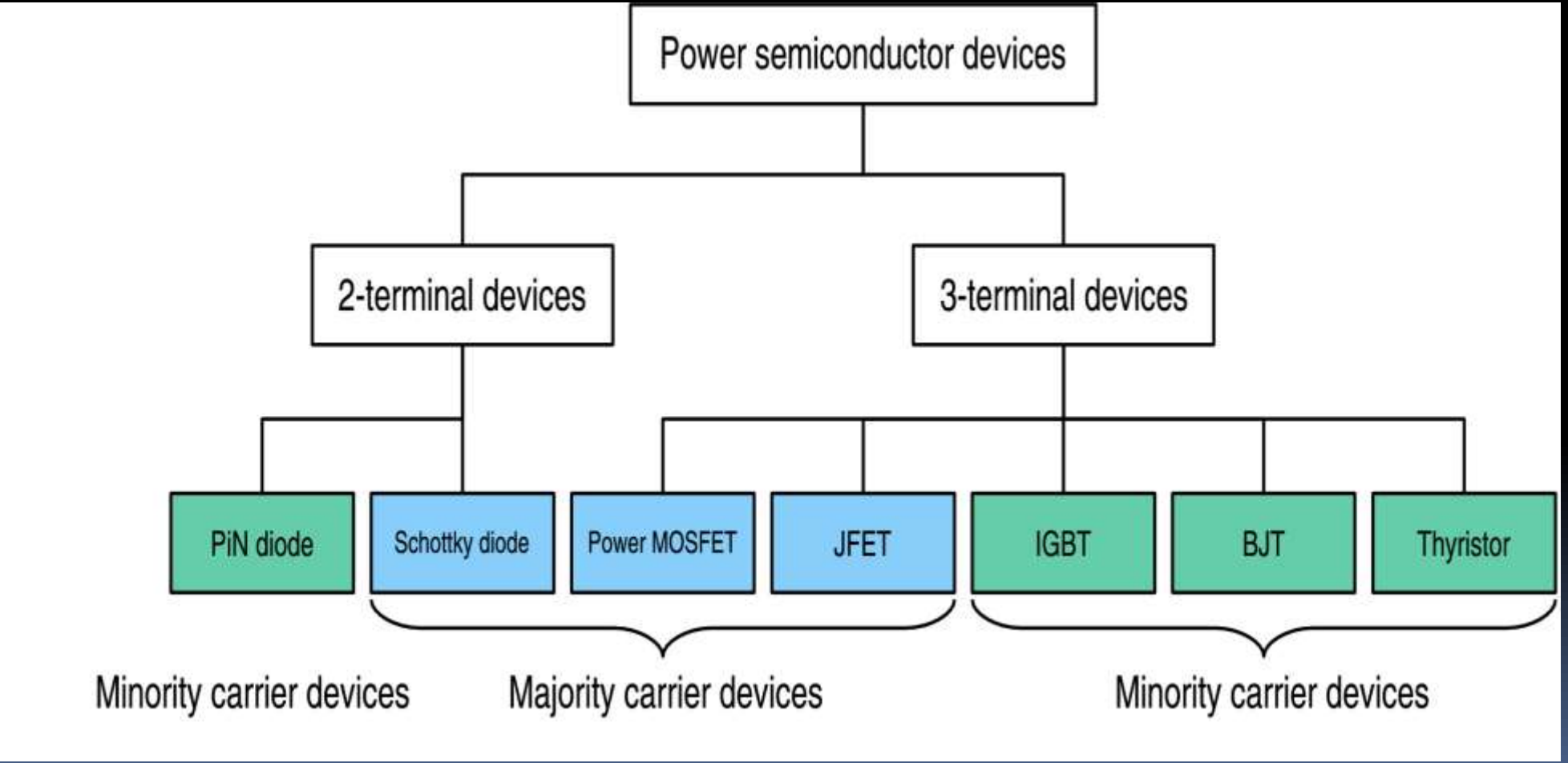


Different Types of Relay Switches

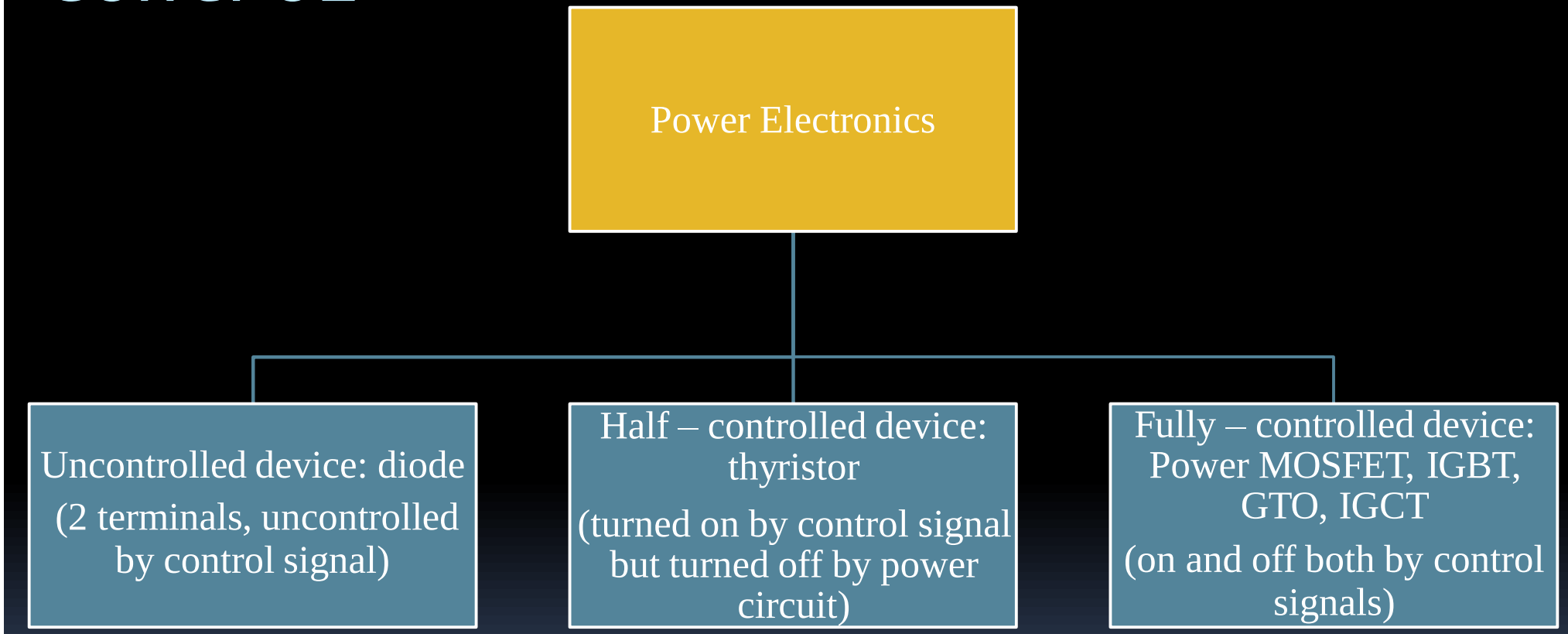
Switches:

Name	Symbol	Image
SPST (Single Pole, Single Throw)		
SPDT (Single pole, double throw)		
DPST (Double pole, single throw)		
DPDT (Double pole, double throw)		
DIP Switch		

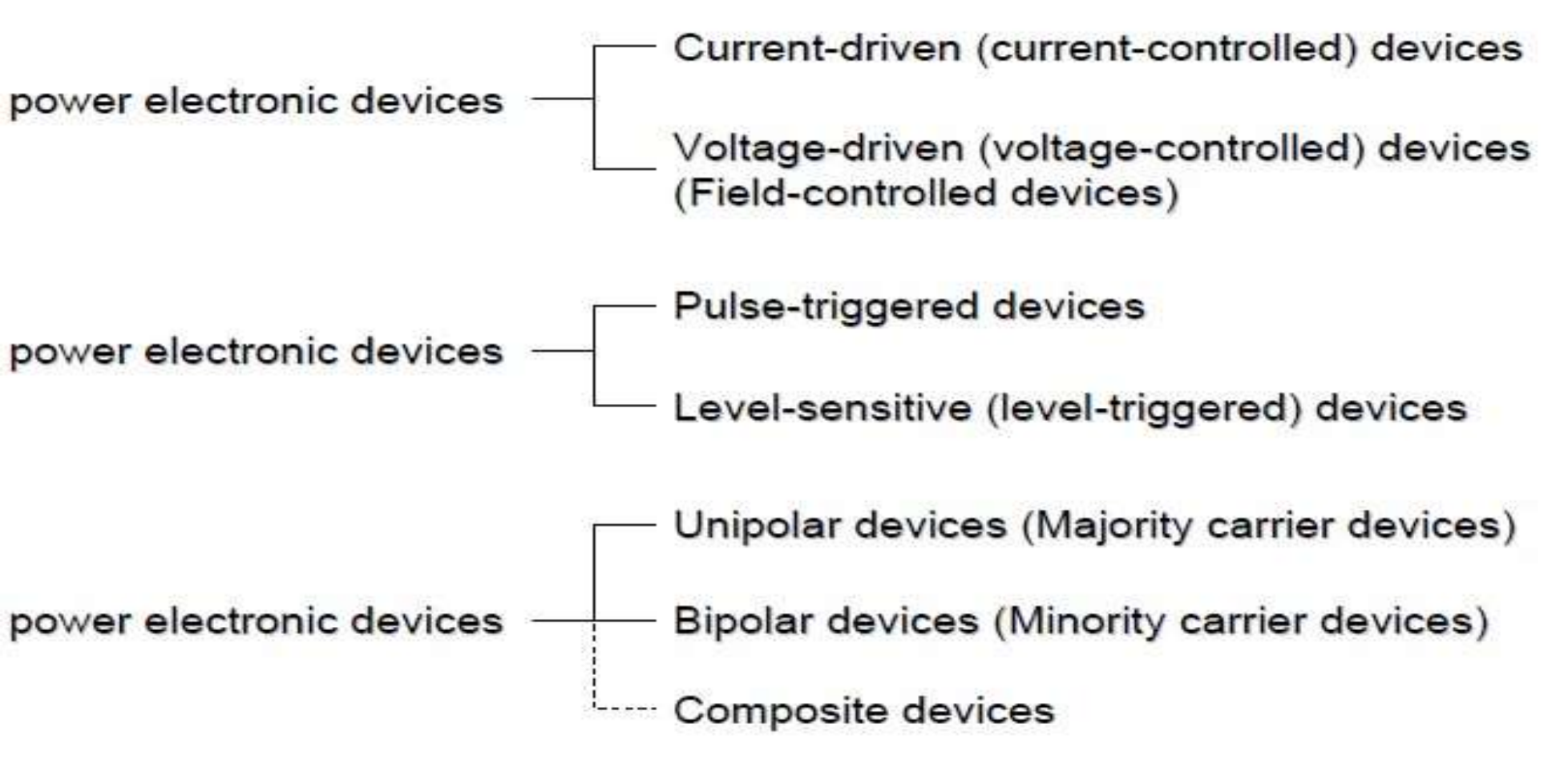
Classification of Power Electronic Devices



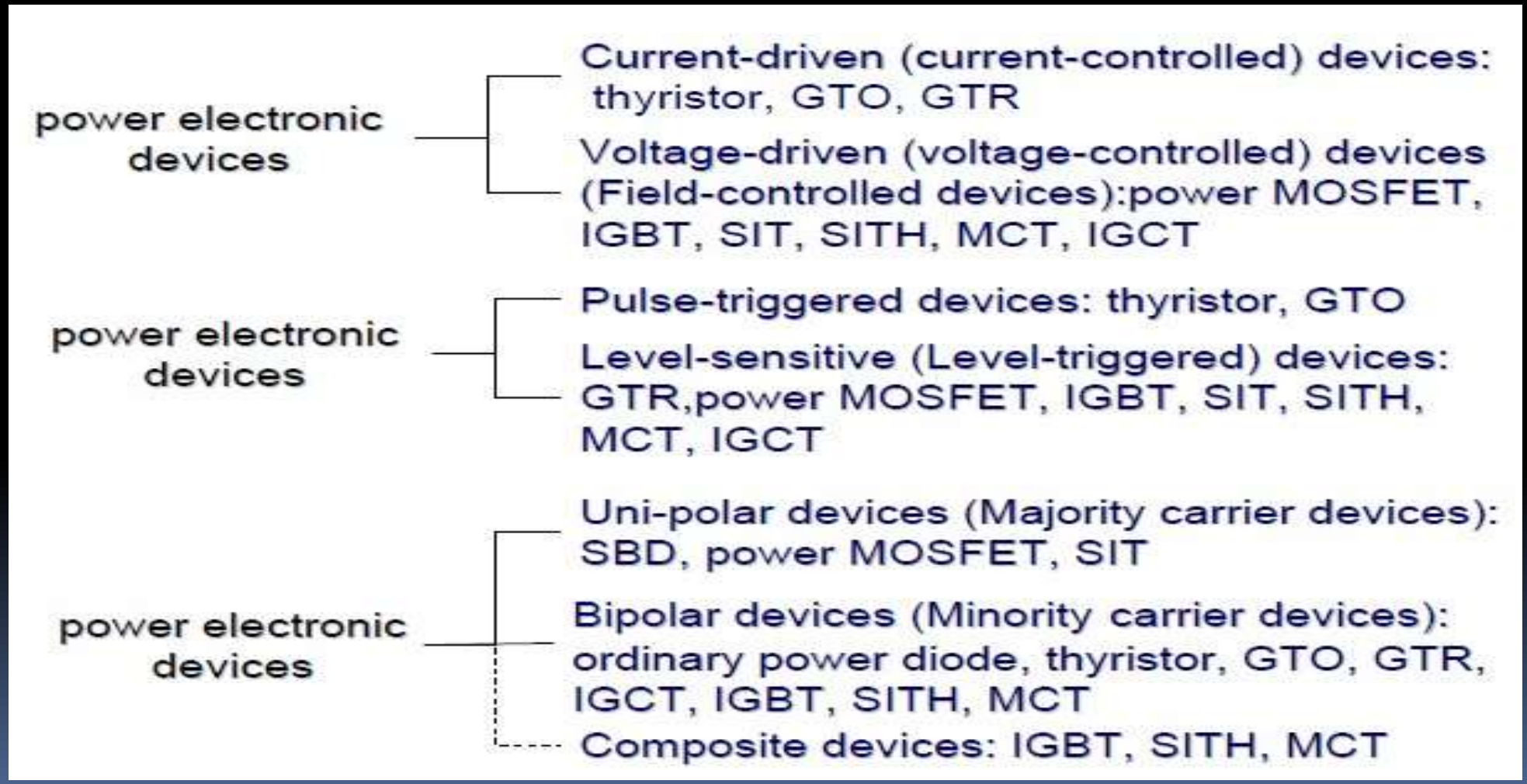
Classification by Control



Other Category Classification



Devices under Categories



Power Semiconductor Switches

- Power Diodes
  1. P – N Junction Diode
  2. Fast Recovery Diode
  3. Schottky Diode
- Power Transistor
  1. Bipolar Junction Transistor (BJT)
  2. Metal Oxide Semiconductor Field Effect Transistor (MOSFET)
  3. Insulated Gate Biased Transistor (IGBT)
  4. Unijunction Transistor (UJT)
  5. Static Induction Transistor (SIT)
  6. MOS – controlled Thyristor (MCT)

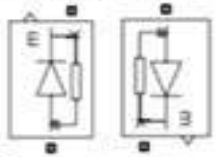
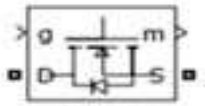
Thyristors Varieties

1. Phase Controlled Thyristors (SCR)
2. Bidirectional Phase Controlled Thyristors (BCT)
3. Fast Switching Thyristors (SCR)
4. Light Activated (LASCR)
5. Bidirectional Diode Thyristors (DIAC)
6. Bidirectional Triode Thyristors (TRIAC)
7. Silicon Unilateral Switch (SUS)
8. Silicon Controlled Switch (SCS)
9. Light Activated SCS (LASCS)
10. Programmable Unijunction Transistor (PUT)
11. Reverse Conducting Thyristor (RCT)

Thyristors Varieties

12. Gate Turn – Off Thyristor (GTO)
13. Gate Assisted Turn – Off Thyristor (GATT)
14. FET – controlled Thyristor (FET - CTH)
15. Silicon Bilateral Switch (SBS)
16. MOS Controlled Thyristor (MCT)
17. Static Induction Thyristor (SITH)
18. MOS Turn – off Thyristor (MTO)
19. Emitter Turn – Off Thyristor (ETO)
20. Integrated Gate – Communicated Thyristor (IGCT)
21. Gate assisted Turn – Off Thyristor (GAT)
22. Asymmetrical Thyristor (ASCR)

Symbol Representation

Type	Schematic Symbol	SimPower Device	Commutation	Characteristics	Typ. Application
SCR		 Thyristor	Line	Pass current in one direction, active control	Simple power control circuits, overcurrent protection circuits (crowbar)
DIAC		 Opposing Diodes	Line	Pass current in both directions, A/C waveforms, passive control (forward voltage)	Light dimmer, symmetrical firing of TRIACs
GTO		 Gto	Forced	High power applications, active control, extended switch-off time (tail-time)	HVDC Systems, applications with low switching frequencies
Diode		 Diode	Line	Pass current in one direction, passive control (forward voltage)	Rectifier, protection circuitry (free-wheel)
IGBT		 IGBT	Forced	Fast switching, medium or high power applications	Electric Heater, audio amplifier
MOSFET		 Mosfet	Forced	Low power capablities	Signal amplifier, electronic switching

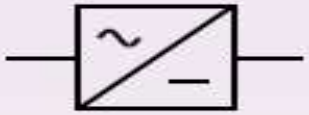
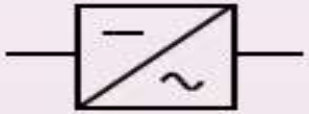
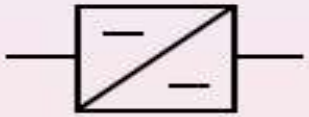
Power Electronic Switching Devices

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)

Power Electronics Converters

Power output / Power input	DC	AC
AC	AC to DC converter (Rectifier)	AC to AC converter (Fixed frequency : AC controller Variable frequency: Cycloconverter or frequency converter)
DC	DC to DC converter (Chopper)	DC to AC converter (Inverter)

Types of Converters

Converter Type	Input	Output	Symbol
Rectifier	A.C. at constant voltage and frequency	D.C. at variable voltage	
Inverter	D.C. at constant voltage	A.C. at desired voltage and frequency	
Chopper	D.C. at constant voltage	D.C. at desired voltage	
Cycloconverter	A.C. at constant voltage and frequency	A.C. at desired voltage and frequency	
A.C. Voltage Controller	A.C. at constant voltage and frequency	A.C. at desired voltage and input frequency	 ACVC

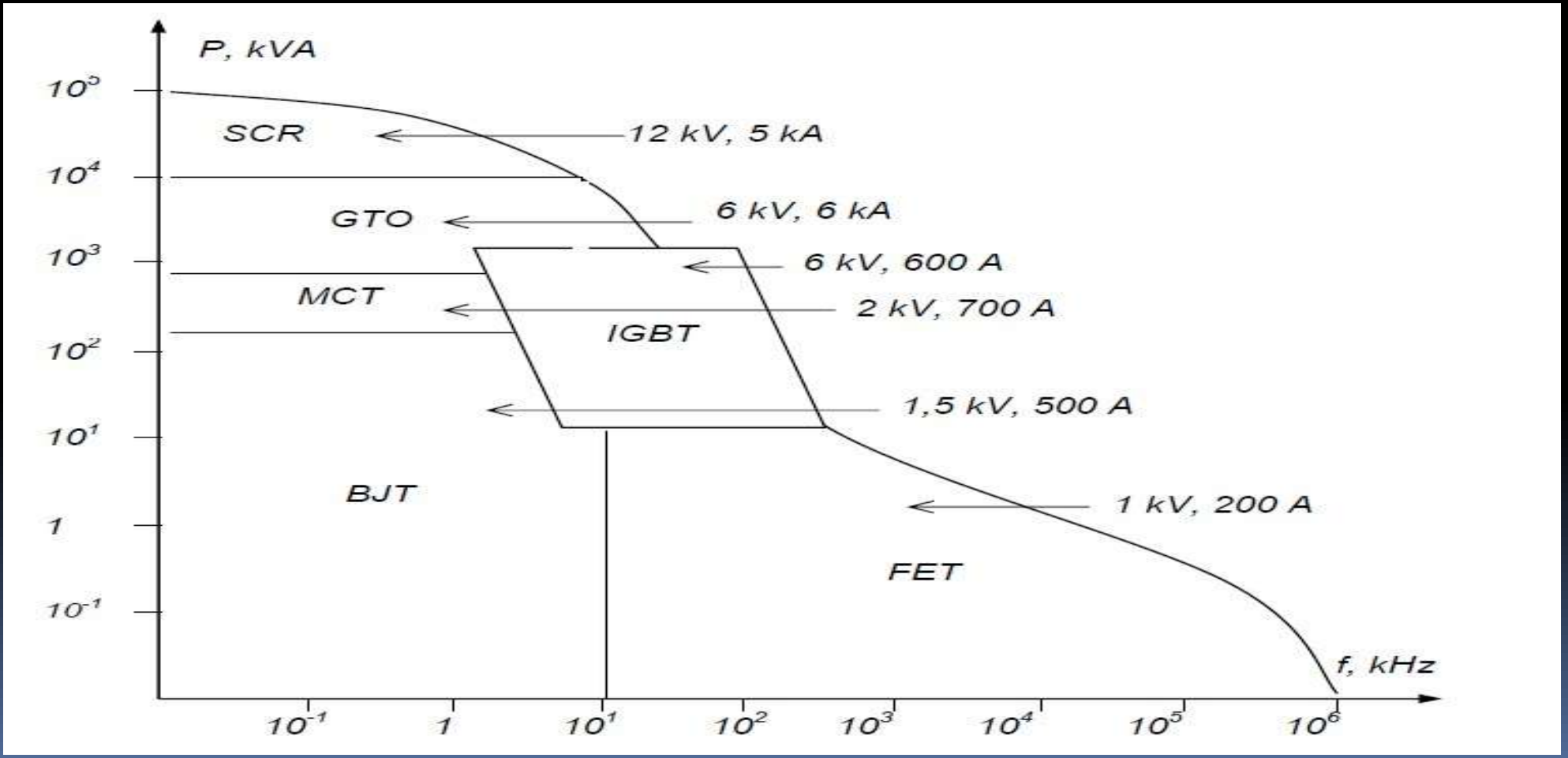
Power Electronic Converters

Circuit type	Essential features
Voltage regulators	Regulate a DC supply to a fixed voltage output
Power amplifiers	Large-signal amplification of voltages and currents
Switches	Electronic switches (e.g., transistor switches)
Diode rectifier	Converts fixed AC voltage (single- or multiphase) to fixed DC voltage
AC-DC converter (controlled rectifier)	Converts fixed AC voltage (single- or multiphase) to variable DC voltage
AC-AC converter (AC voltage controller)	Converts fixed AC voltage to variable AC voltage (single- or multiphase)
DC-DC converter (chopper)	Converts fixed DC voltage to variable DC voltage
DC-AC converter (inverter)	Converts fixed DC voltage to variable AC voltage (single- or multiphase)

Scope of Power Electronics

Power Level (Watts)	*System*
0.1-10	• Battery-operated equipment • Flashes/strobes
10-100	• Satellite power systems • Typical offline flyback supply
100 – 1kW	• Computer power supply • Blender
1 – 10 kW	• Hot tub
10 – 100 kW	• Electric car • Eddy current braking
100 kW –1 MW	• Bus • micro-SMES
1 MW – 10 MW	• SMES
10 MW – 100 MW	• Magnetic aircraft launch • Big locomotives
100 MW – 1 GW	• Power plant
> 1 GW	• Sandy Pond substation (2.2 GW)

Power and Frequency Rating of Power Devices



Characteristics of Ideal Switch

- Turns On – Off in zero time.
- ON state, Zero voltage drop, High current.
- OFF state, Zero current flow. Withstand high voltage.
- Zero power dissipation.
- Little power for controlling.
- High reliability.
- Small size and weight.
- No maintenance.

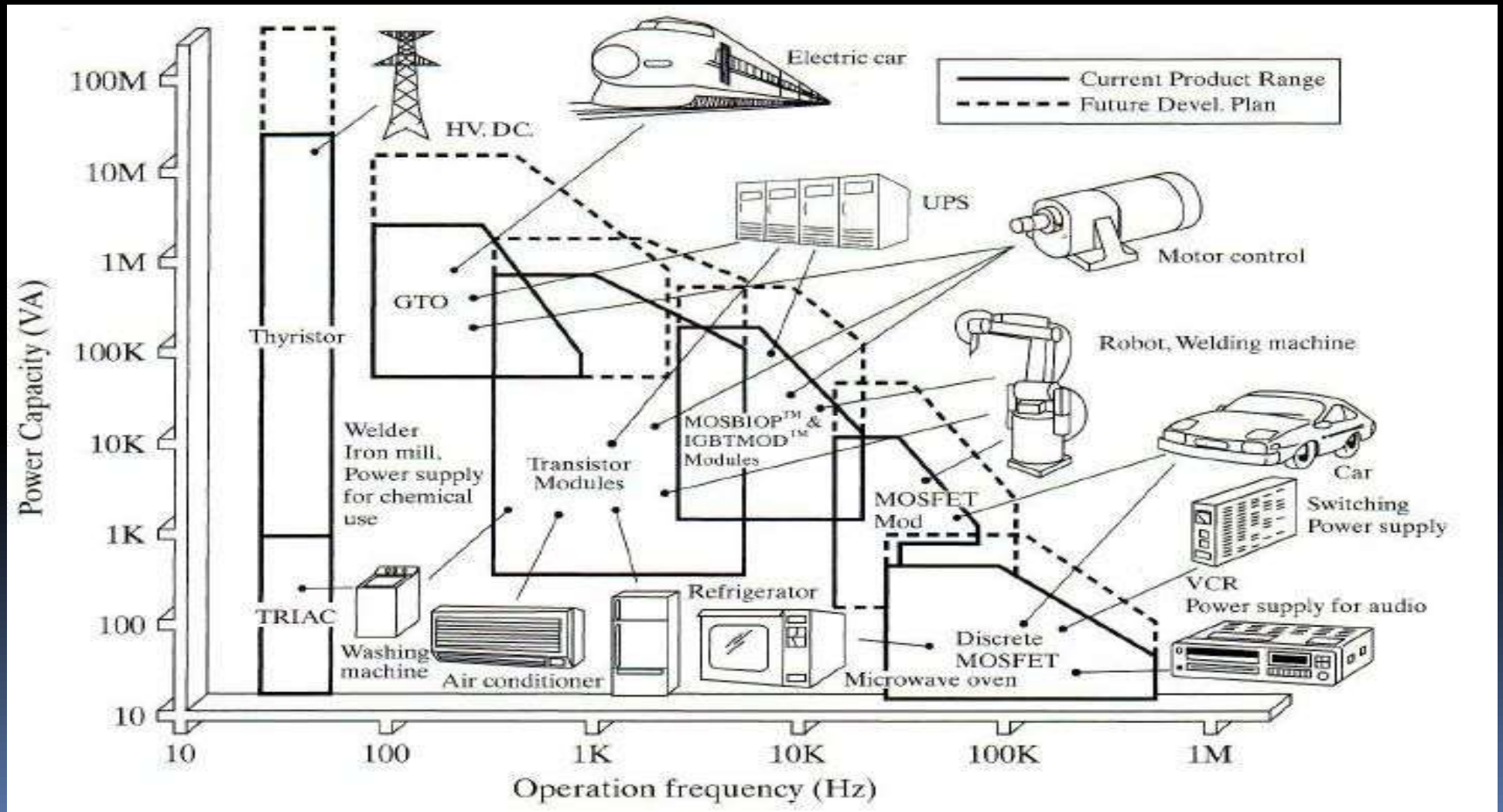
Advantages of Power Electronic Converters

- High efficiency
- High reliability
- Long life and less maintenance
- Fast dynamic response
- Small size and less weight & cost.

Drawbacks of Power Electronics

- Harmonics generating tendency
- Power regeneration is difficult
- Low overload capacity.
- AC – DC & AC – AC converters operate at low i/p power factors.

Power Electronics Applications



Applications:

- Industrial
- Transportation
- Utility systems
- Power supplies for all kinds of electronic equipment
- Residential and home appliances
- Space technology
- Other applications

Sector wise Applications:

- Industrial applications

1. Motor drives
2. Electrolysis
3. Electroplating
4. Induction heating

- Transportation applications

1. Trains & locomotives
2. Subways
3. Trolley buses
4. Magnetic levitation
5. Electric vehicles
6. Automotive electronics

Sector wise Applications:

- Utility systems

1. High-voltage dc transmission(HVDC)
2. Flexible ac transmission(FACTS)
3. Static VAR (**volt-ampere reactive**) compensation & harmonics suppression: TCR, TSC, SVG, APF
4. Custom power & power quality control

- Power supplies for all kinds of electronic equipment

1. Telecommunications
2. Computers
3. Office equipment
4. Electronic instruments

Sector wise Applications:

- Residential and home appliances

1. Lighting
2. Heating
3. Air conditioning
4. Refrigeration & freezers
5. Cooking
6. Cleaning

- Space Technology

1. Spaceship power systems
2. Satellite power systems
3. Space vehicle power systems

Sector wise Applications:

- Other Applications

1. Nuclear reactor control
2. Power systems for particle accelerators
3. Environmental engineering

Major Issues of Concern in Power Electronics

- How to meet the requirement of the load or gain better control of the load?
- How to improve the efficiency

--for reliable operation of power semiconductor devices?

--for energy saving?

- How to realize power conversion with less volume, less weight, and less cost?
- How to reduce negative influence to other equipment in the electric power system and to the electromagnetic environment?

Major topics for the devices

- Appearance, structure, and symbol
- Physics of operation
- Characteristics
    1. Static characteristics
    2. Switching characteristics
- Specification
- Special issues
- Devices of the same family

Review Questions: Assignment

1. Define Power Electronics (PE)?
2. What are the subjects that contribute to PE?
3. Sketch the general structure of PE System.
4. Classify PE.
5. What are the different types of Power diodes, power transistors and thyristors?
6. Provide the symbolic representation of the following:

   SCR, DIAC, TRIAC, GTO, IGBT, MOSFET.
7. What are the different categories in which PE devices can be segregated?
8. What are the different types of PE converters?
9. Narrate the characteristics of an Ideal switch.
10. Mark the advantages and limitations of PE.
11. Mention the sector – wise applications of PE.
12. What are the major concern areas of PE?

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