ECE 325 – Electric Energy System Components
8- Fundamental Elements of Power Electronics

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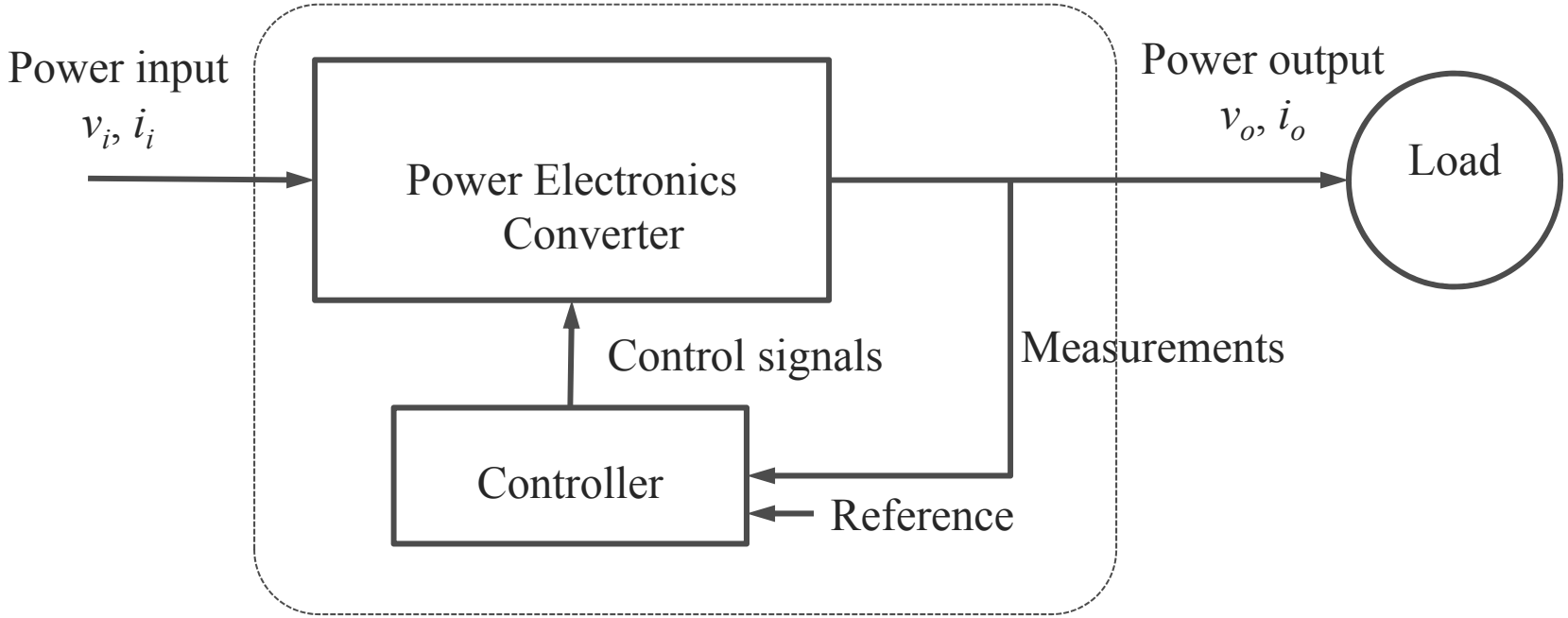
Content

(Selected materials from Chapter 21)

- Power semiconductor switches
  - Diodes, thyristors, etc.
- DC-to-DC switching converters
- DC-to-AC switching converters

Introduction

- A power electronics system is to process and control the flow of electric energy by supplying voltages and currents in a form that optimally suits the loads
- A typical power electronics (PE) system:



Applications of PE converters

- For DC voltage or current, a PE converter can regulate the magnitude at a desired level or adjust the magnitude to a desired level
- For AC voltage or current, a PE converter can adjust the magnitude and frequency and change the number of phases
- Applications:
  - Switched-mode (DC) power supplies
  - Uninterrupted power supplies (UPS)
  - Adjustable speed motor drives
  - High-voltage DC transmission (HVDC)
  - Battery-based utility energy storage
  - Electric vehicles (EVs) and hybrid electric vehicles (HEVs)
  - Renewable energy integration, e.g. solar PV and wind generation

Classification of PE converters

Four types of PE converters	Examples of application
DC-to-DC (boost up/step down):	Power supplies for electronic devices
DC-to-AC (inverter, to 1-phase or 3-phase AC)	The battery (discharging) and solar PV interfaces to the power grid
AC-to-DC (rectifier)	The battery (charging) interface to the power grid and power adapters for electronic devices
AC-to-AC	Variable-speed motor drive

- Two examples of variable-speed motor drives

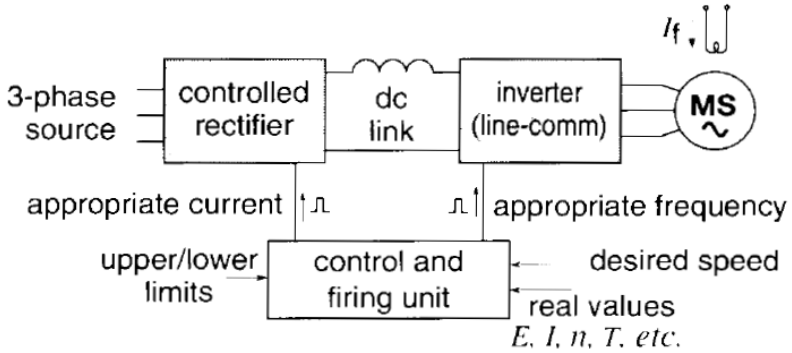


Figure 23.3
Variable-speed synchronous motor drive using a controlled rectifier and a line-commutated inverter fed from a dc link current source (see Section 23.2).

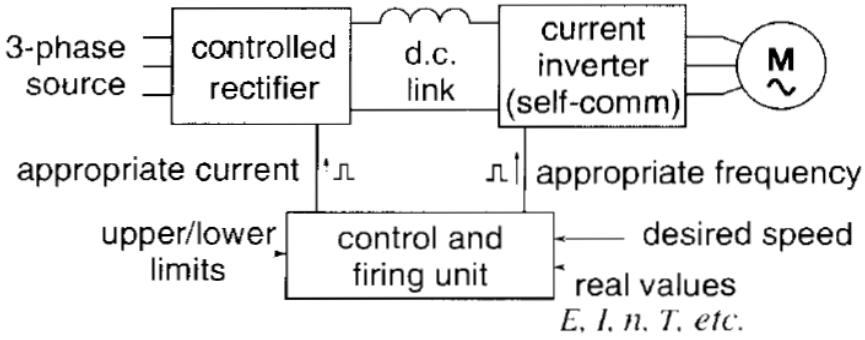


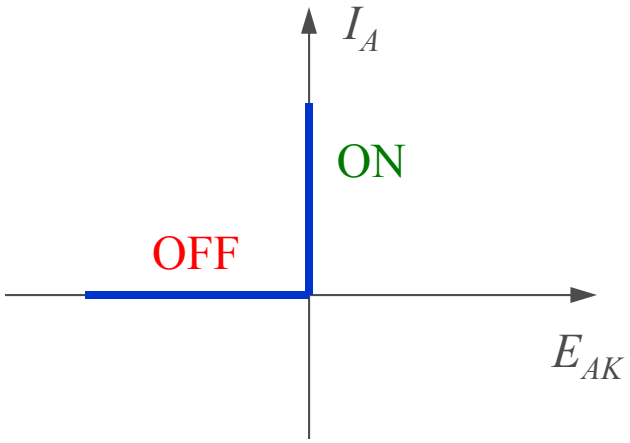
Figure 23.5
Variable-speed drive using a controlled rectifier and a self-commutated inverter fed from a dc link current source (see Section 23.9).

Power semiconductor switches

- Power semiconductor switches are the key functional components in a PE converter; other components are such as resistors, inductors and capacitors.
- Two states: ON (conducting) and OFF (open-circuit)
- Three types of power semiconductor devices in terms of the controllability
  - Diodes: their ON and OFF states are controlled by the polarity and magnitude of its voltage and the magnitude of its current.
  - Thyristors: they are turned **ON** by a **control signal** and turned OFF when its current goes to zero
  - Controllable switches: both **ON and OFF** states are controllable by **control signals**

Ideal Diode

- 2 terminals: A (anode) and K (cathode)
- It starts to conduct (ON) as long as the voltage E_{AK} becomes >0 (forward biased)
- When ON, it has zero voltage drop
- When E_{AK} becomes <0 (reverse biased), it turns OFF and has no leakage current
- Both ON and OFF switches are instantaneous



Ideal I-V characteristics

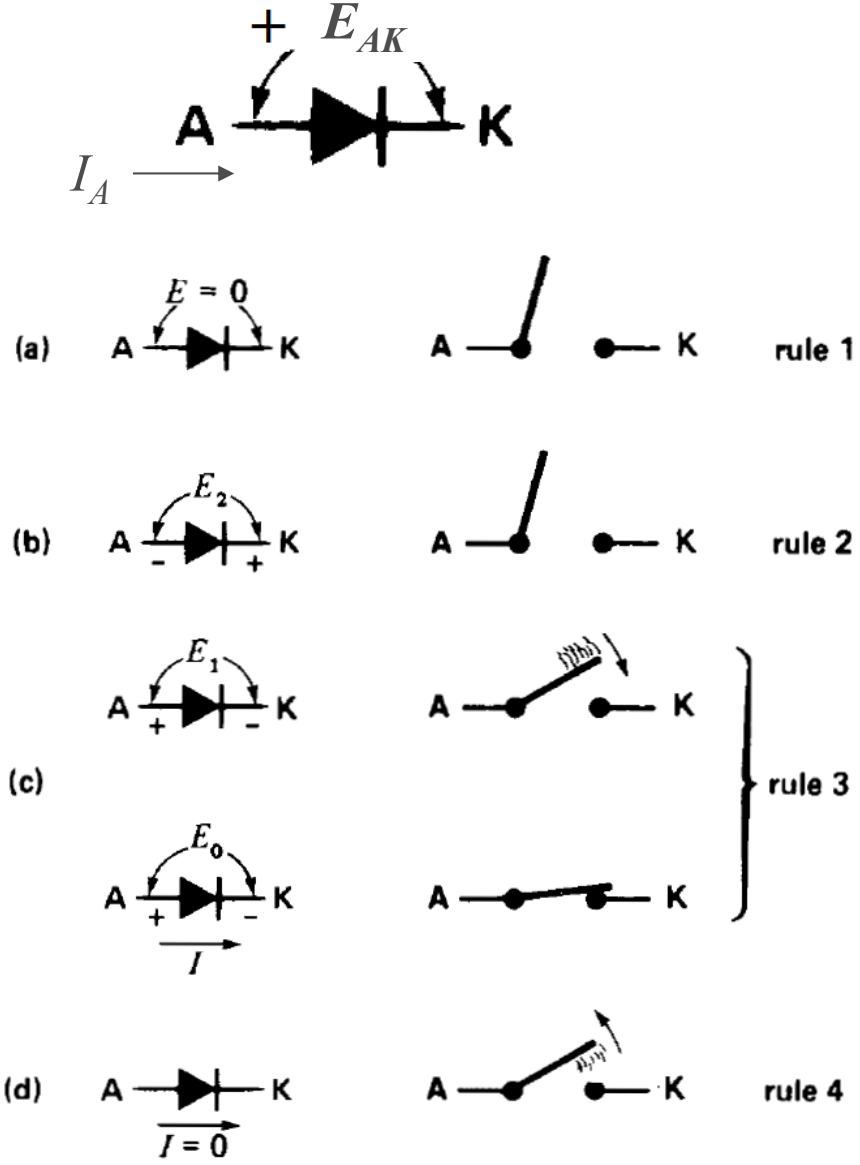
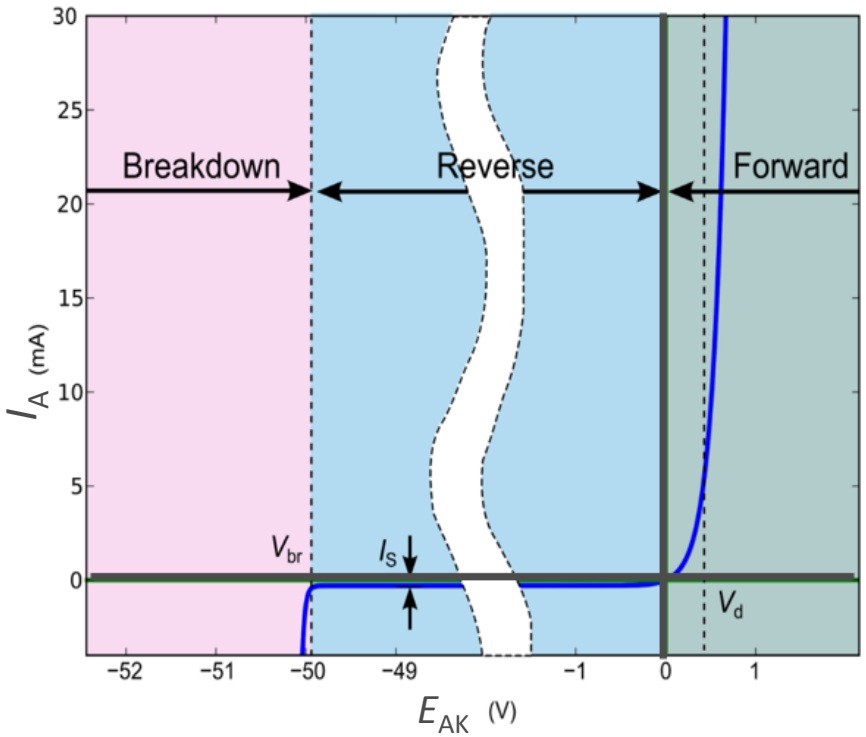


Figure 21.9
Basic rules governing diode behavior.

Practical Diodes



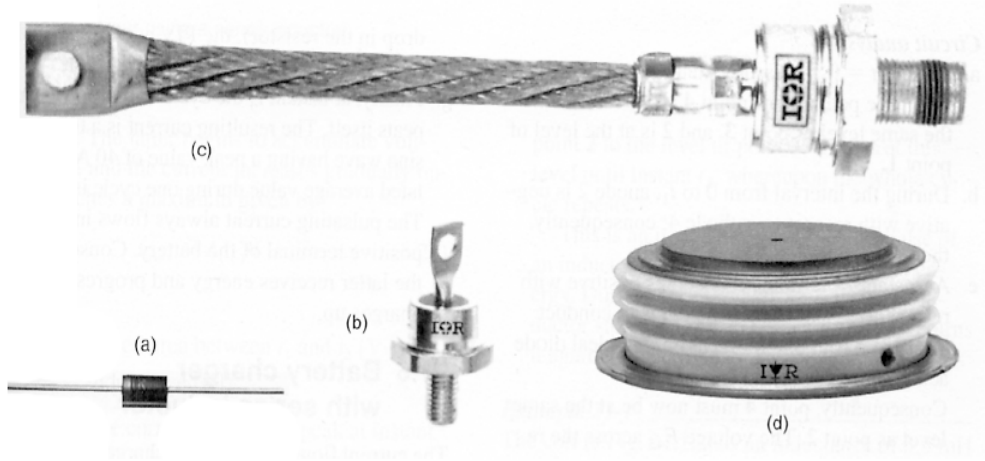


Figure 21.10
a. Average current: 4 A; PIV: 400 V; body length: 10 mm; diameter: 5.6 mm.
b. Average current: 15 A; PIV: 500 V; stud type; length less thread: 25 mm; diameter: 17 mm.
c. Average current: 500 A; PIV: 2000 V; length less thread: 244 mm; diameter: 40 mm.
d. Average current: 2600 A; PIV: 2500 V; Hockey Puk; distance between pole-faces: 35 mm; diameter: 98 mm.
(*Photos courtesy of International Rectifier*)

Real I-V Characteristics

- When a diode is forward biased with a voltage V_d about 0.7V or more is applied, it acts like a closed switch with a negligible voltage drop <1.5V.
- When a diode is reverse biased, it has a negligible current I_S flowing through
- At very large reverse bias, beyond its peak inverse voltage (V_{br}=50 to 4000V), the diode breaks down, begins to conduct in reverse and is usually damaged