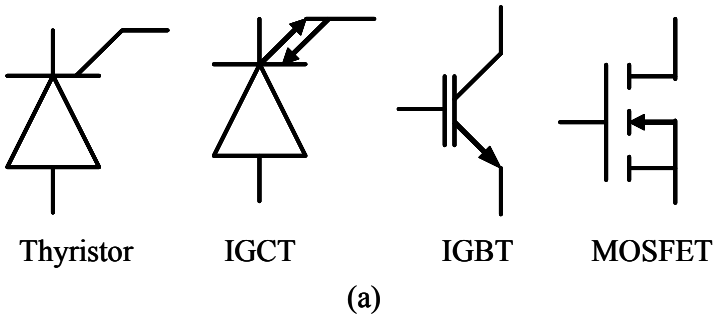
Chapter 15

UTILITY APPLICATIONS OF POWER ELECTRONICS

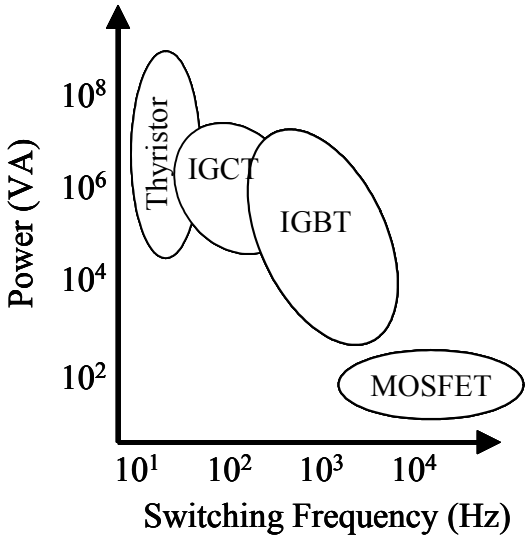
INTRODUCTION

- Distributed Generation (DG)
  - Renewable Resources (Wind, Photovoltaic, etc.)
  - Fuel Cells and Micro-Turbines
  - Storage - Batteries, Super-conducting Magnetic Storage, Flywheels
- Power Electronic Loads - Adjustable Speed Drives
- Power Quality Solutions
  - Dual Feeders
  - Uninterruptible Power Supplies
  - Dynamic Voltage Restorers
- Transmission and Distribution (T&D)
  - High Voltage DC (HVDC) and HVDC-Light
  - Flexible AC Transmission (FACTS)
    - Shunt Compensation
    - Series Compensation
    - Static Phase Angle Control and Unified Power Flow Controllers

POWER SEMICONDUCTOR DEVICES AND THEIR CAPABILITIES



(a)



(b)

Figure 15-1 Power semiconductor devices.

CATEGORIZING POWER ELECTRONIC SYSTEMS

Solid-State Switches

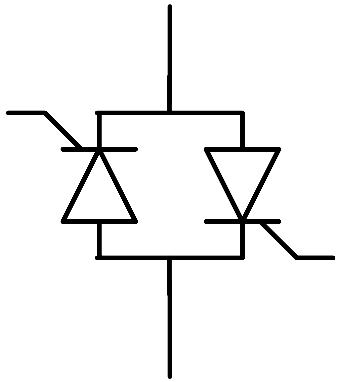


Figure 15-2 Back-to-back thyristors to act as a solid-state switch.

Converters as an Interface

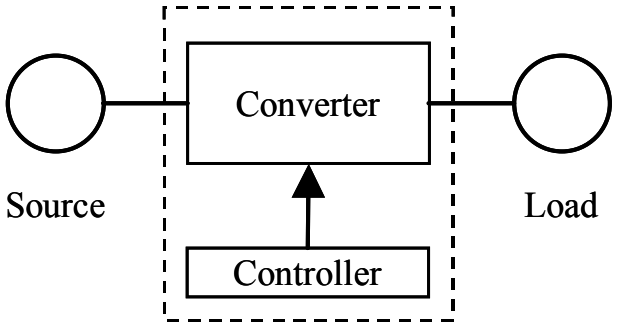


Figure 15-3 Power electronics interface.

Voltage-Link Systems

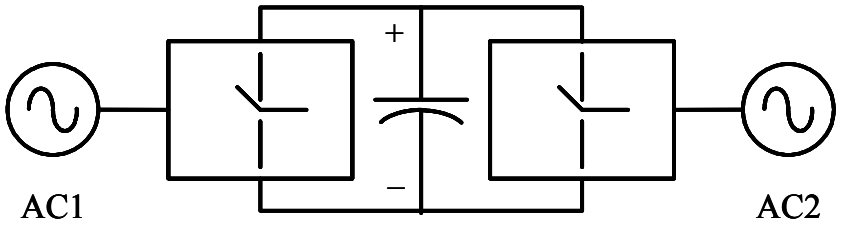


Fig. 15-4 Block diagram of the voltage-link systems.

Current-Link Systems

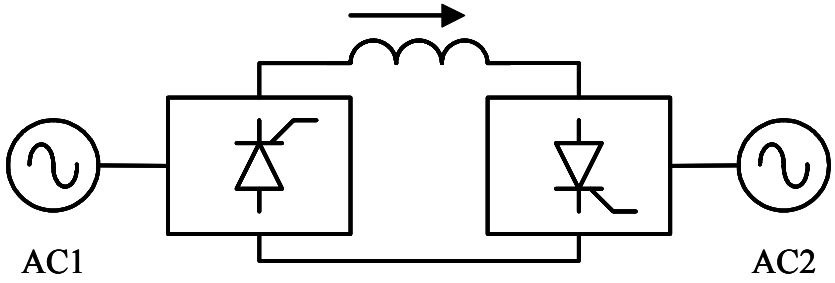


Figure 15-5 Block diagram of the current-link systems.

DISTRIBUTED GENERATION (DG) APPLICATIONS

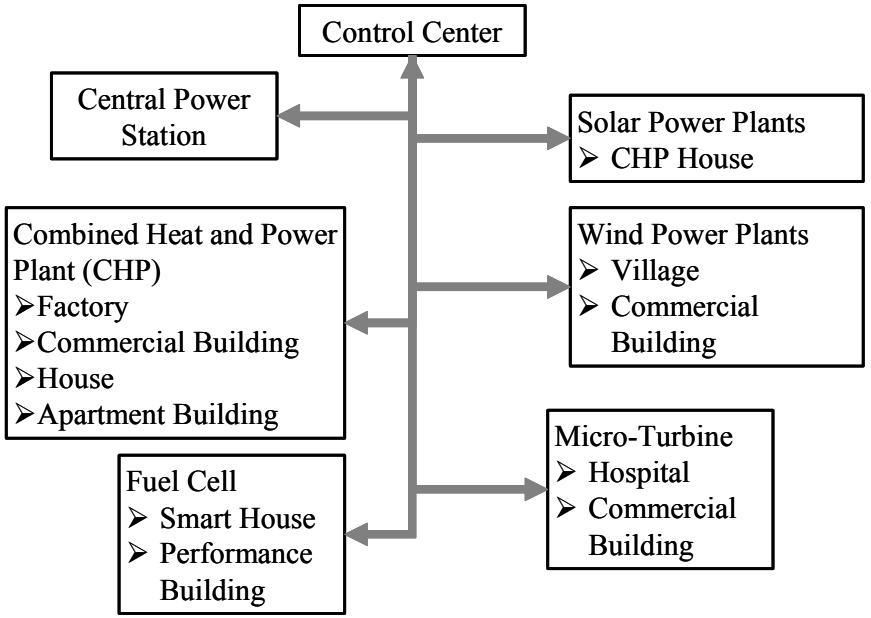


Figure 15-6 Distributed Generation (DG) systems.

Wind-Electric Systems

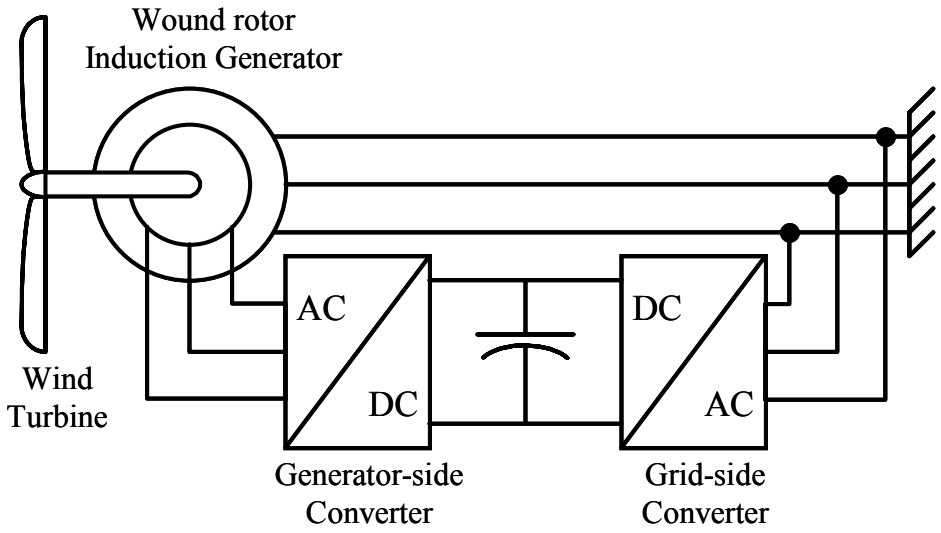


Figure 15-7 Doubly-fed induction generators for wind-electric systems.

Photovoltaic (PV) Systems

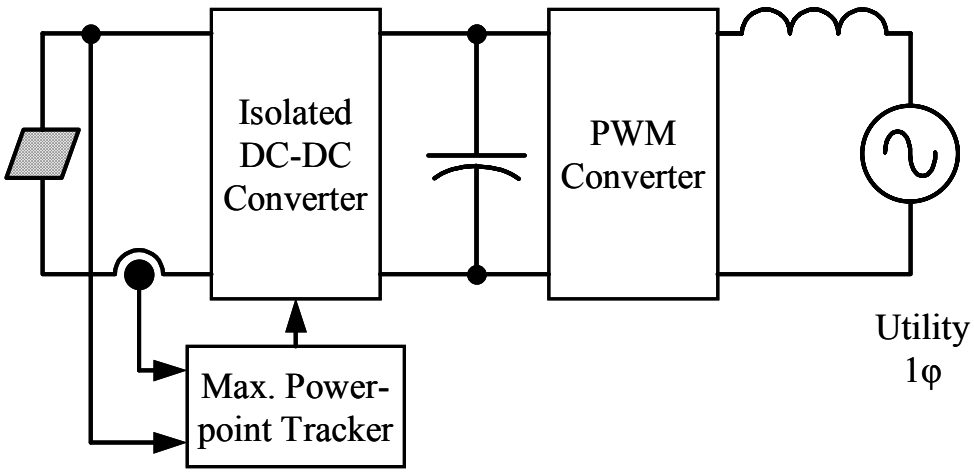


Figure 15-8 Photovoltaic systems.

Fuel Cell Systems

Energy Storage Systems

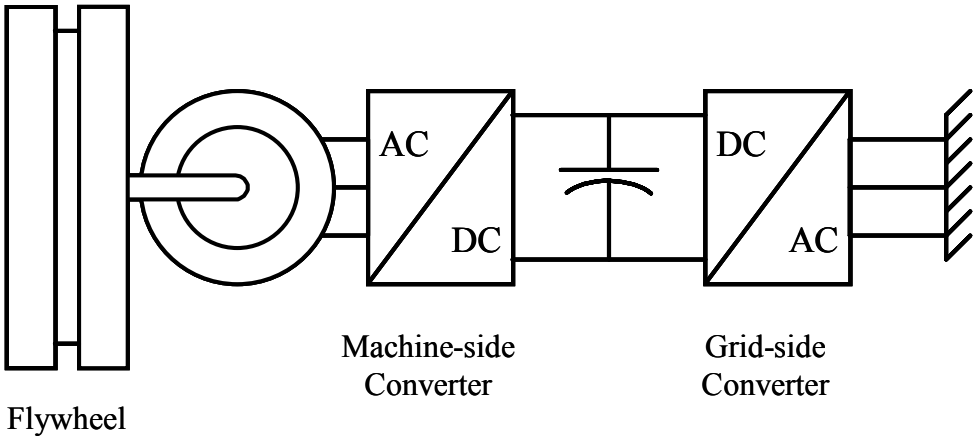


Figure 15-9 Flywheel storage system.

Micro-Turbines

POWER ELECTRONIC LOADS

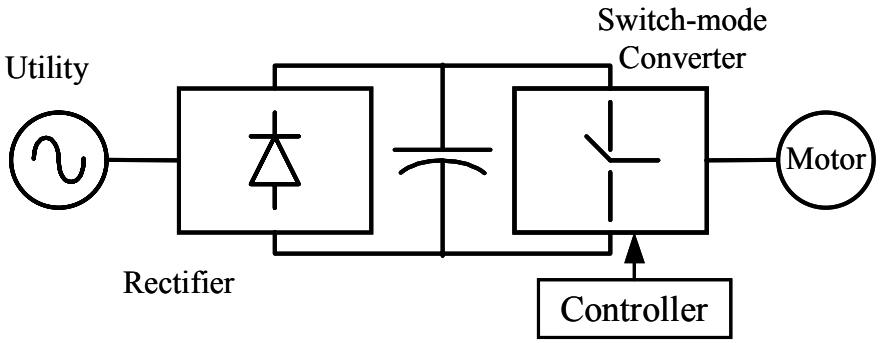


Figure 15-10 Adjustable-speed drive.

POWER QUALITY SOLUTIONS

Dual Feeders

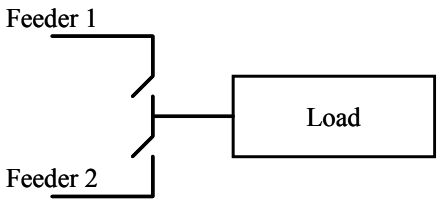


Figure 15-11 Dual-feeders.

Uninterruptible Power Supplies

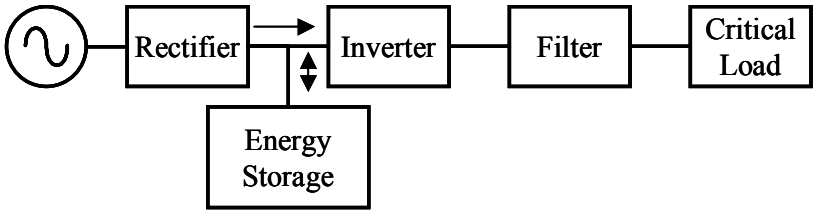


Figure 15-12 Uninterruptible power supplies.

Dynamic Voltage Restorers

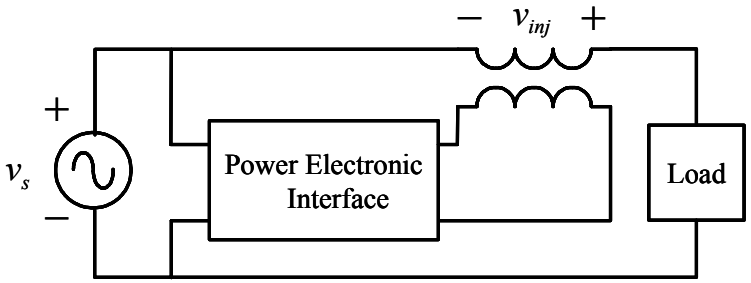


Figure 15-13 Dynamic voltage restorers.

TRANSMISSION AND DISTRIBUTION (T&D) APPLICATIONS

High Voltage DC (HVDC) Transmission

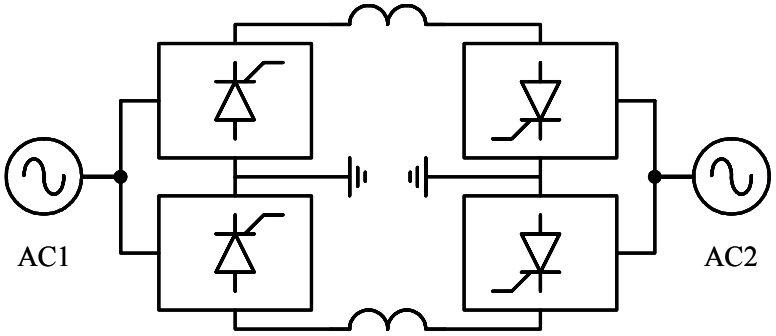


Figure 15-14 HVDC system block diagram (transformers are not shown).

Medium Voltage DC (MVDC)

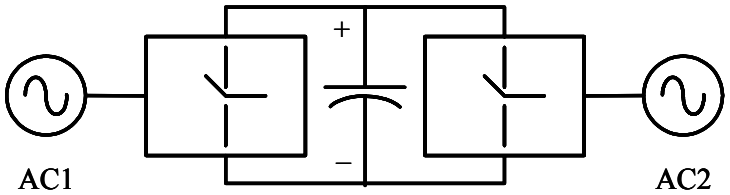


Figure 15-15 Block diagram for medium-voltage dc transmission systems.

Flexible AC Transmission Systems (FACTS)

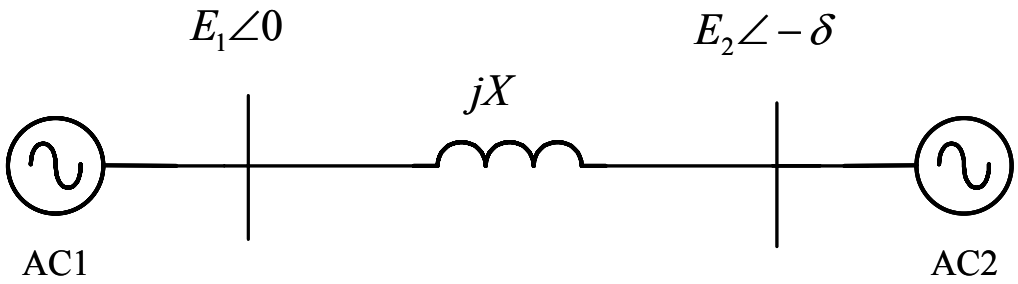


Figure 15-16 Power flow on a transmission line.

$$P = \frac{E_1 E_2}{X} \sin \delta$$

Shunt-Connected Devices to Control the Bus Voltage Magnitude

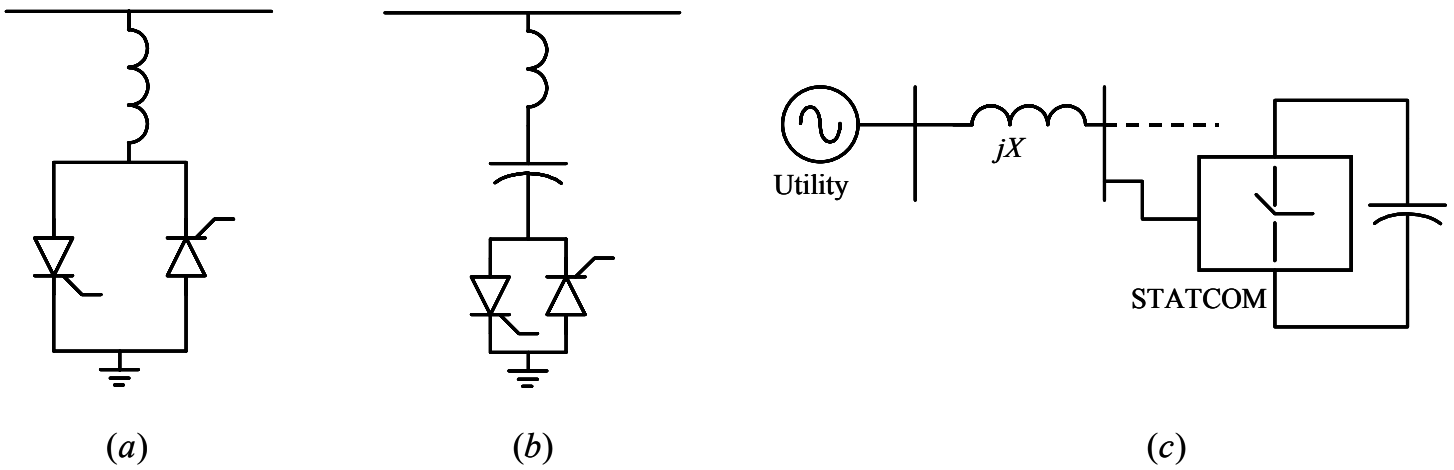


Figure 15-17 Shunt-connected devices for voltage control.

X

Series-Connected Devices to Control the Effective Series Reactance

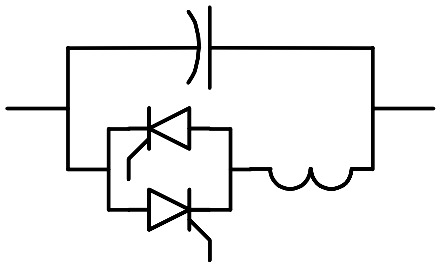
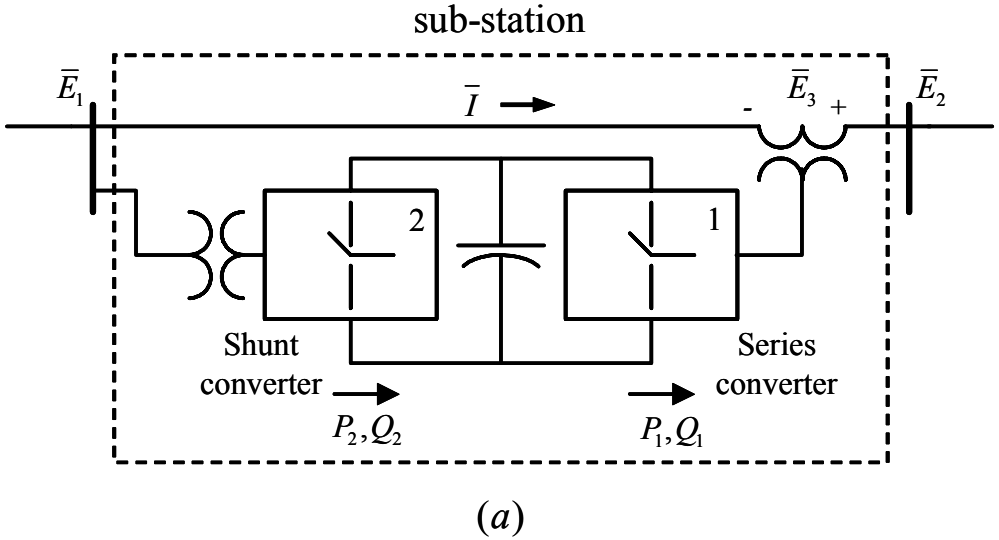


Figure 15-18 Thyristor-controlled series capacitor.

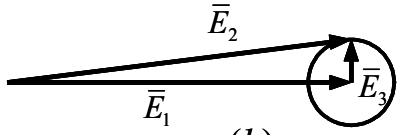
Unified Power Flow Controller (UPFC)

1. controlling the voltage magnitude E
2. changing the line reactance X, and/or
3. changing the power angle δ.



(*a*)

$$\bar{E}_1 + \bar{E}_3 = \bar{E}_2$$



(*b*)

Figure 15-19 UPFC.

$$P_1 = 3\,\mathrm{Re}(\bar{E}_3 \bar{I}^*) \qquad P_2 = P_1$$

$$Q_1 = 3\,\mathrm{Im}(\bar{E}_3 \bar{I}^*) \qquad Q_2 \neq Q_1$$