

Chapter 1 : Introduction to Power Electronics

1.1. Definition

Power electronics is an important subject of electrical engineering that deals with the control and conversion of electrical power using electronic equipment. From tiny consumer electronics to massive industrial systems and renewable energy sources, it covers a wide spectrum of technologies and applications. To appreciate power electronics' influence and importance in modern engineering, one must comprehend its concept and use.

Power electronics is the study, design, and implementation of electronic circuits used to convert and regulate the flow of electrical energy. Unlike traditional electronics, which primarily deals with the transmission and processing of information signals, power electronics focuses on high-power applications. These applications necessitate the conversion and control of electrical power to ensure the efficient, dependable, and safe operation of diverse equipment's and systems.

Power electronics combines concepts from electrical engineering and electronics, such as electrical circuit theory, semiconductor devices, and control systems. Power electronic circuits use power semiconductor devices like diodes, transistors, and thyristors to effectively transfer electrical power from one form to another, regulate voltage and current levels, and manage power supply to loads.

Power electronic systems are used in a variety of applications, such as:

- Power Generation
- Power Transmission
- Power Distribution
- Power Control

1.2. Types of Power Electronic Circuits

Power electronic circuits control the input and output power. There are several types of power converters based on the type of application. When we consider the power source, there are two main types of power sources, namely alternating current (AC) and direct current (DC). This forms four basic types of power electronics circuits shown in the figure below.

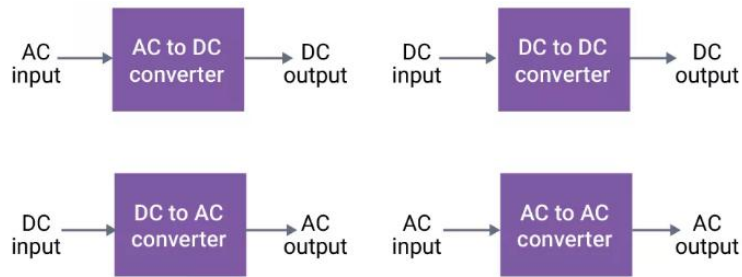


Figure 1: Basic types of power converters

➤ **AC/DC Converters (Rectifiers):**

- **Function** : Convert alternating current (AC) into direct current (DC).
- **Components**: Diodes, thyristors, and silicon-controlled rectifiers (SCRs) are commonly used to allow current to flow in a single direction.
- **Applications**: Utilized in battery chargers, electronic device power supply, and any other application needing a steady DC power source.

➤ **AC/AC Converters:**

- **Function**: Adjust the voltage, frequency, or phase of AC power.
- **Types**:
 - **Transformers**: Adjust the voltage of AC power.
 - **Cycloconverters**: AC power at one voltage and frequency can be directly converted to AC power at another voltage and frequency.
 - **Matrix Converters**: Offer flexible conversion without the need for DC stages in between.
- **Applications**: Utilized in frequency conversion, industrial power supplies, and motor speed control.

➤ **DC/DC Converters:**

- **Function**: Step up the voltage or step down the voltage to convert DC voltage levels to other DC voltage levels.
- **Types**:
 - **Buck Converters**: Reduce the output voltage by stepping down the input voltage.
 - **Boost Converters**: Increase the output voltage by stepping up the input voltage.

- **Buck-Boost Converters:** Provide an output voltage that is either more or less than the input voltage.
- **Applications:** Extensively utilized in power supplies, electric vehicles, and portable electronics devices.

➤ **DC/AC Converters (Inverters):**

- **Function:** Transform DC power into AC power.
- **Components:** To generate an AC output, use switching devices such as MOSFETs or IGBTs.
- **Applications:** UPS, grid-tied renewable energy systems, and electric motor drives are all applications that require this.

1.3. The Importance of Power Electronics

The drive towards more electrification has resulted in the need for more electric power. Apart from power generation, power processing plays a key role in efficient utilization of the available power. It is important that the raw power is converted to a form that is usable in different applications. Power electronics plays a pivotal role in providing power based on the desired specifications. The basic application which shows the significance of power electronics in our day-to-day life is the fan regulator. Before the advent of solid-state fan regulators, bulky and lossy resistive fan regulators were used. To control the fan speed, the AC mains voltage is passed through a resistor that is connected in series with the fan. So, when the fan is on, there is constant power dissipation in the series resistor. Research has come up with more innovative ways of controlling the fans or motors, in general, by controlling voltage and frequency. This is possible with the availability of power semiconductor devices.

In aerospace applications, especially in space applications, size, weight, and reliability are critical parameters. If power is handled at low frequencies, the transformers and other energy storage elements occupy a huge amount of space. With switching converters that work at high switching frequencies, the size of the energy storage elements is drastically reduced. The size of these components is inversely proportional to the switching frequency. So, devices with shorter switching times help to reduce the overall size and weight of systems.

State-of-the-art power electronic systems are capable of handling power from a few watts to several megawatts, enabling efficient and reliable interfaces between raw power and

regulated power. As a result, hydraulic and mechanical actuators are being replaced with electric motors that can be controlled precisely using power electronic interfaces.

1.4. The Benefits of Power Electronics

Electric power is scarce, and it is of prime importance to deliver the power to the loads with minimum losses. Advancements in power semiconductor research has resulted in more efficient chemistries such as silicon carbide and gallium nitride. The benefits of power electronics are:

1. High power density power supplies
2. Improved efficiency of up to 99% in power conversion
3. Noise-sensitive applications such as in medical devices are also transitioning to switching power supplies because of the efficiency and reliability
4. Power can be made available in the desired form and level as per specifications
5. Increased clean power generation using power electronic interfaces to connect the sources to grid
6. Wireless power transfer