CHAPTER 1

Introduction

1.1 POWER ELECTRONICS

Power electronics circuits convert electric power from one form to another using electronic devices. Power electronics circuits function by using semiconductor devices as switches, thereby controlling or modifying a voltage or current. Applications of power electronics range from high-power conversion equipment such as dc power transmission to everyday appliances, such as cordless screwdrivers, power supplies for computers, cell phone chargers, and hybrid automobiles. Power electronics includes applications in which circuits process milliwatts or megawatts. Typical applications of power electronics include conversion of ac to dc, conversion of dc to ac, conversion of an unregulated dc voltage to a regulated dc voltage, and conversion of an ac power source from one amplitude and frequency to another amplitude and frequency.

The design of power conversion equipment includes many disciplines from electrical engineering. Power electronics includes applications of circuit theory, control theory, electronics, electromagnetics, microprocessors (for control), and heat transfer. Advances in semiconductor switching capability combined with the desire to improve the efficiency and performance of electrical devices have made power electronics an important and fast-growing area in electrical engineering.

1.2 CONVERTER CLASSIFICATION

The objective of a power electronics circuit is to match the voltage and current requirements of the load to those of the source. Power electronics circuits convert one type or level of a voltage or current waveform to another and are hence called *converters*. Converters serve as an interface between the source and load (Fig. 1-1).

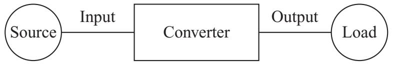

Figure 1-1 A source and load interfaced by a power electronics converter.

Converters are classified by the relationship between input and output:

ac input/dc output

The ac-dc converter produces a dc output from an ac input. Average power is transferred from an ac source to a dc load. The ac-dc converter is specifically classified as a *rectifier*. For example, an ac-dc converter enables integrated circuits to operate from a 60-Hz ac line voltage by converting the ac signal to a dc signal of the appropriate voltage.

dc input/ac output

The dc-ac converter is specifically classified as an *inverter*. In the inverter, average power flows from the dc side to the ac side. Examples of inverter applications include producing a 120-V rms 60-Hz voltage from a 12-V battery and interfacing an alternative energy source such as an array of solar cells to an electric utility.

dc input/dc output

The dc-dc converter is useful when a load requires a specified (often regulated) dc voltage or current but the source is at a different or unregulated dc value. For example, 5 V may be obtained from a 12-V source via a dc-dc converter.

ac input/ac output

The ac-ac converter may be used to change the level and/or frequency of an ac signal. Examples include a common light-dimmer circuit and speed control of an induction motor.

Some converter circuits can operate in different modes, depending on circuit and control parameters. For example, some rectifier circuits can be operated as inverters by modifying the control on the semiconductor devices. In such cases, it is the direction of average power flow that determines the converter classification. In Fig. 1-2, if the battery is charged from the ac power source, the converter is classified as a rectifier. If the operating parameters of the converter are changed and the battery acts as a source supplying power to the ac system, the converter is then classified as an inverter.

Power conversion can be a multistep process involving more than one type of converter. For example, an ac-dc-ac conversion can be used to modify an ac source by first converting it to direct current and then converting the dc signal to an ac signal that has an amplitude and frequency different from those of the original ac source, as illustrated in Fig. 1-3.

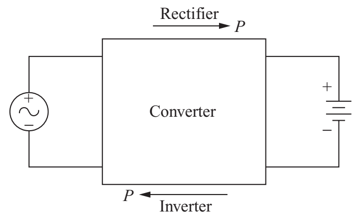

Figure 1-2 A converter can operate as a rectifier or an inverter, depending on the direction of average power *P*.

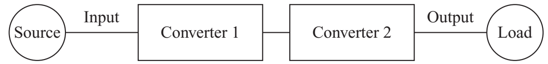

Figure 1-3 Two converters are used in a multistep process.

1.3 POWER ELECTRONICS CONCEPTS

To illustrate some concepts in power electronics, consider the design problem of creating a 3-V dc voltage level from a 9-V battery. The purpose is to supply 3 V to a load resistance. One simple solution is to use a voltage divider, as shown in Fig. 1-4. For a load resistor R_L, inserting a series resistance of $2R_L$ results in 3 V across R_L. A problem with this solution is that the power absorbed by the $2R_L$ resistor is twice as much as delivered to the load and is lost as heat, making the circuit only 33.3 percent efficient. Another problem is that if the value of the load resistance changes, the output voltage will change unless the $2R_L$ resistance changes proportionally. A solution to that problem could be to use a transistor in place of the $2R_L$ resistance. The transistor would be controlled such that the voltage across it is maintained at 6 V, thus regulating the output at 3 V. However, the same low-efficiency problem is encountered with this solution.

To arrive at a more desirable design solution, consider the circuit in Fig. 1-5*a*. In that circuit, a switch is opened and closed periodically. The switch is a short circuit when it is closed and an open circuit when it is open, making the voltage

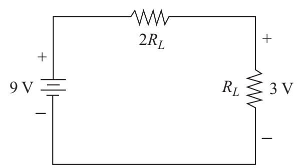

Figure 1-4 A simple voltage divider for creating 3 V from a 9-V source.