To obtain low ac line current THD, the passive techniques described in the previous chapter rely on low-frequency transformers and/or reactive elements. The large size and weight of these elements are objectionable in many applications. This chapter covers active techniques that employ converters having switching frequencies much greater than the ac line frequency. The reactive elements and transformers of these converters are small, because their sizes depend on the converter switching frequency rather than the ac line frequency.

Instead of making do with conventional diode rectifier circuits, and dealing after-the-fact with the resulting low-frequency harmonics, let us consider now how to build a rectifier that behaves as ideally as possible, without generation of line current harmonics. In this chapter, the properties of the ideal rectifier are explored, and a model is described. The ideal rectifier presents an effective resistive load to the ac power line; hence, if the supplied ac voltage is sinusoidal, then the current drawn by the rectifier is also sinusoidal and is in phase with the voltage. Converters that approximate the properties of the ideal rectifier are sometimes called power factor corrected, because their input power factor is essentially unity [1].

The boost converter, as well as a variety of other converters, can be controlled such that a near-ideal rectifier system is obtained. This is accomplished by control of a high-frequency switching converter, such that the ac line current waveform follows the applied ac line voltage. Both single-phase and three-phase rectifiers can be constructed using PWM techniques. A typical dc power supply system that is powered by the single-phase ac utility contains three major power-processing elements. First, a high-frequency converter with a wide-bandwidth input-current controller functions as a near-ideal rectifier. Second, an energy-storage capacitor smooths the pulsating power at the rectifier output, and a low-bandwidth controller causes the average input power to follow the power drawn by the load. Finally, a dc–dc converter provides a well-regulated dc voltage to the load. In this chapter, single-phase rectifier systems are discussed, expressions for rms currents are derived, and various converter approaches are compared.
The techniques developed in earlier chapters for modeling and analysis of dc-dc converters are extended in this chapter to treat the analysis, modeling, and control of low-harmonic rectifiers. The CCM models of Chapter 3 are used to compute the average losses and efficiency of CCM PWM converters operating as rectifiers. The results yield insight that is useful in power stage design. Several converter control schemes are known, including peak current programming, average current control, critical conduction mode control, and nonlinear carrier control. Ac modeling of the rectifier control system is also covered.

18.1 PROPERTIES OF THE IDEAL RECTIFIER

It is desired that the ideal single-phase rectifier present a resistive load to the ac system. The ac line current and voltage will then have the same waveshape and will be in phase. Unity power factor rectification is the result. Thus, the rectifier input current $i_{ac}(t)$ should be proportional to the applied input voltage $v_{ac}(t)$:

$$i_{ac}(t) = \frac{v_{ac}(t)}{R_e} \tag{18.1}$$

where $R_e$ is the constant of proportionality. An equivalent circuit for the ac port of an ideal rectifier is therefore an effective resistance $R_e$, as shown in Fig. 18.1(a). $R_e$ is also known as the emulated resistance. It should be noted that the presence of $R_e$ does not imply the generation of heat: the power apparently

![Fig. 18.1 Development of the ideal rectifier equivalent circuit model: (a) input port resistor emulation; (b) the value of the emulated resistance, and hence the power throughput, is controllable; (c) output port power source characteristic, and complete model.](image-url)