

Active PFC for Electronic Power Supplies

The proliferation of electronic loads on power distribution systems has led to inefficient and unsafe conditions due to the typically poor power factor of electronic power conversion equipment. Waveform distortion and the overheating of transformers and neutral conductors in three-phase systems are just a few of the effects.

Consequently, economic and safety concerns—along with new regulations designed to maintain the integrity of power distribution systems—have created an acute interest in power factor correction (PFC) strategies.

When choosing a strategy for PFC, it is essential to recognize that the poor power factor occurring in electronic power conversion equipment is entirely different from the traditional poor power factor seen with inductive motor loads, and requires a different corrective approach.

Two Sources of Poor PF

In its simplest form, poor power factor caused by reactive linear circuit elements results as the current either leads or lags the voltage, depending on whether the load looks capacitive or inductive (Figure 1a). This type of

poor power factor is easily corrected by adding a reactive component of opposite sign in parallel with load to cancel the reactive term (Figure 1b).

On the other hand, less than acceptable power factor typically associated with electronic power conversion equipment is caused by nonlinear circuit elements. In most off-line power supplies, the AC-DC front end consists of a bridge rectifier followed by a large filter capacitor (Figure 2b). With this circuit, current is drawn from the line only when the peak voltage on the line exceeds the voltage on the filter capacitor (Figure 2a). Since the rate of rise and fall of the current is greater than that of the line voltage, and the current flows discontinuously, a series of predominantly odd harmonics is generated—third, fifth, seventh, etc. (Figure 2c). It is these harmonics that

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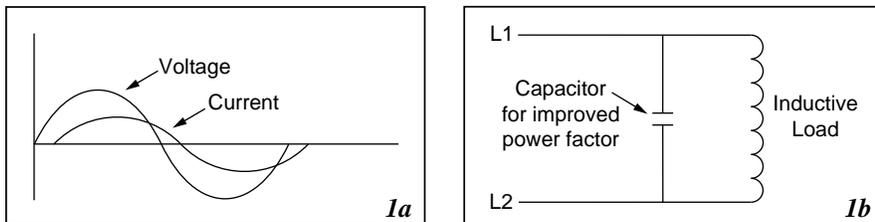


Figure 1—Traditional poor power factor—the current either leads or lags the voltage.

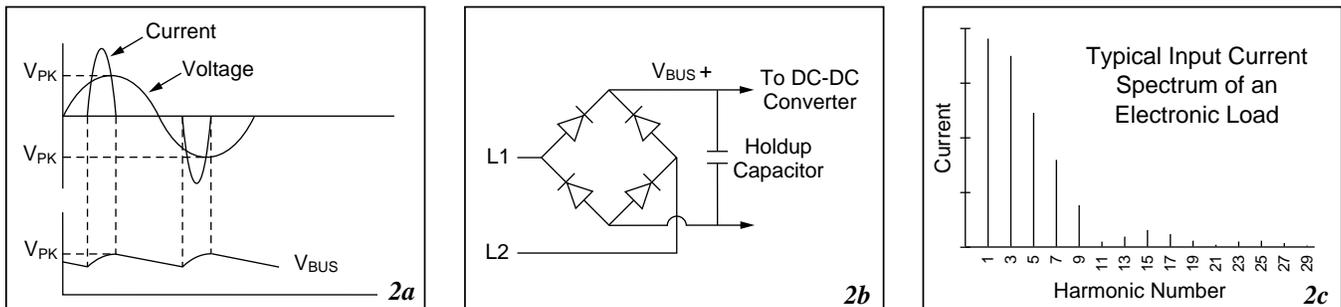


Figure 2—Entirely different from the traditional type, the poor power factor occurring in electronic loads generates odd harmonics.

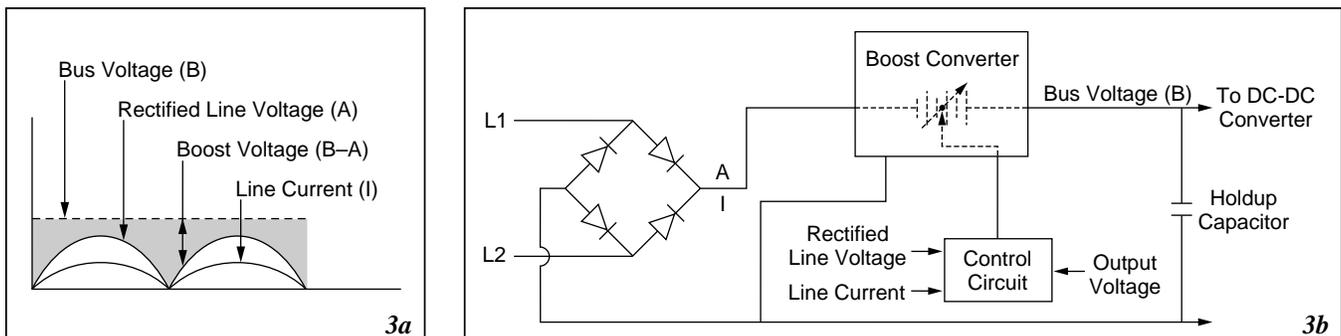


Figure 3—Correcting the poor power factor associated with electronic power supplies requires an active approach in which a control circuit adjusts a boost voltage to maintain a sinusoidal input current.

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cause the problems with the power distribution system.

The power factor of the system shown in Figure 2 can be improved slightly by either adding series inductance with the line or decreasing the value of the holdup capacitor, which will lengthen the conduction angle. However, both of these solutions severely limit the amount of power that can be drawn from the line.

The Active Approach to PFC

It is generally accepted that the most effective way to correct the poor power factor of electronic power supplies is to take an active approach.

In the operation of an active power factor correction circuit (Figure 3b), the incoming line voltage passes through a bridge rectifier, which produces a full wave rectified output (Figure 3a-A). Since the peak value of the line is less than the bus voltage, no current will flow into the holdup capacitor unless the line voltage is boosted above the voltage present on the holdup capacitor. This allows the control circuit to adjust the boost voltage (3a-B-A) to maintain a sinusoidal input current.

To maintain a sinusoidal input current, the control circuit uses the input voltage waveform as a template. The control circuit measures the input current, compares it to the input voltage waveform, and adjusts the boost voltage to produce an input current waveform of the same shape (3a-I). At the same time, the control circuit monitors the bus voltage and adjusts the boost voltage to maintain a coarsely regulated DC output (3a-B). Since the primary function of the control circuit is to maintain a sinusoidal input current, the DC bus voltage is allowed to vary slightly.

It is important to remember that a well designed power factor correction circuit will faithfully replicate distortion present in the incoming line voltage, so it is essential to use a low distortion voltage source when evaluating power factor correcting circuits.

Figure 3b illustrates the approach to power factor correction taken with the Vicor VI-HAM Harmonic Attenuator Module, a component-level AC front end that, when used with VI-26x or VI-J6x DC-DC converters, provides a universal input, near-unity power factor, off-line switching power supply that meets IEC 555.

The use of an active power factor correcting circuit results in few discontinuities in the input current and consequently low distortion and harmonic content of the input current being drawn from the line. For assistance in designing a component power solution with power factor correction, call Vicor's application engineering department.