## Power Factor Correction

Power Factor (PF) is defined as the ratio of real power to apparent power. In a typical AC power supply application where both the voltage and current are sinusoidal, the PF is given by the cosine of the phase angle between the input current and the input voltage and is a measure of how much of the current contributes to real power in the load. A power factor of unity indicates that 100% of the current is contributing to power in the load while a power factor of zero indicates that none of the current contributes to power in the load. Purely resistive loads have a power factor of unity; the current through them is directly proportional to the applied voltage.

The current in an ac line can be thought of as consisting of two components: real and imaginary. The real part results in power absorbed by the load while the imaginary part is power being reflected back into the source, such as is the case when current and voltage are of opposite polarity and their product, power, is negative.

It is important to have a power factor as close as possible to unity so that none of the delivered power is reflected back to the source. Reflected power is undesirable for three reasons:

1. The transmission lines or power cord will generate heat according to the total current being carried, the real part plus the reflected part. This causes problems for the electric utilities and has prompted various regulations requiring all electrical equipment connected to a low voltage distribution system to minimize current harmonics and maximize power factor.
2. The reflected power not wasted in the resistance of the power cord may generate unnecessary heat in the source (the local step–down transformer), contributing to premature failure and constituting a fire hazard.
3. Since the ac mains are limited to a finite current by their circuit breakers, it is desirable to get the most power possible from the given current available. This can only happen when the power factor is close to or equal to unity.

The typical AC input rectification circuit is a diode bridge followed by a large input filter capacitor. During the time that the bridge diodes conduct, the AC line is driving an electrolytic capacitor, a nearly reactive load. This circuit will only draw current from the input lines when the input's voltage exceeds the voltage of the filter capacitor. This leads to very high currents near the peaks of the input AC voltage waveform as seen in Figure 33.

Since the conduction periods of the rectifiers are small, the peak value of the current can be 3–5 times the average input current needed by the equipment. A circuit breaker only senses average current, so it will not trip when the peak current becomes unsafe, as found in many office areas. This can present a fire hazard. In three–phase distribution systems, these current peaks sum onto the neutral line, not meant to carry this kind of current, which again presents a fire hazard.

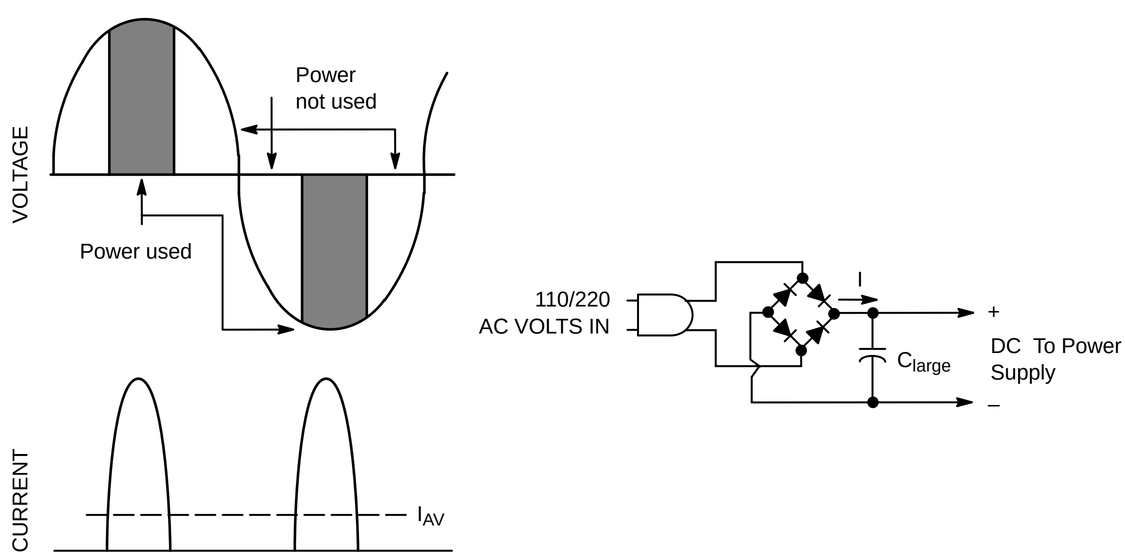


**Figure 33. The Waveforms of a Capacitive Input Filter**

A Power Factor Correction (PFC) circuit is a switching power converter, essentially a boost converter with a very wide input range, that precisely controls its input current on an instantaneous basis to match the waveshape and phase of the input voltage. This represents a zero degrees or 100 percent power factor and mimics a purely resistive load. The amplitude of the input current waveform is varied over longer time frames to maintain a constant voltage at the converter's output filter capacitor. This mimics a resistor which slowly changes value to absorb the correct amount of power to meet the demand of the load. Short term energy excesses and deficits caused by sudden changes in the load are supplemented by a ”bulk energy storage capacitor”, the boost converter's output filter device. The PFC input filter capacitor is reduced to a few microfarads, thus placing a half–wave haversine waveshape into the PFC converter.

The PFC boost converter can operate down to about 30 V before there is insufficient voltage to draw any more significant power from its input. The converter then can begin again when the input haversine reaches 30 V on the next half–wave haversine. This greatly increases the conduction angle of the input rectifiers. The drop–out region of the PFC converter is then filtered (smoothed) by the input EMI filter.

A PFC circuit not only ensures that no power is reflected back to the source, it also eliminates the high current pulses associated with conventional rectifier–filter input circuits. Because heat lost in the transmission line and adjacent circuits is proportional to the square of the current in the line, short strong current pulses generate more heat than a purely resistive load of the same power. The active power factor correction circuit is placed just following the AC rectifier bridge. An example can be seen in Figure 34.

Depending upon how much power is drawn by the unit, there is a choice of three different common control modes. All of the schematics for the power sections are the same, but the value of the PFC inductor and the control method are different. For input currents of less than 150 watts, a *discontinuous–mode* control scheme is typically used, in which the PFC core is completely emptied prior to the next power switch conduction cycle. For powers between 150 and 250 watts, the *critical conduction mode* is recommended. This is a method of control where the control IC senses just when the PFC core is emptied of its energy and the next power switch conduction cycle is immediately begun; this eliminates any dead time exhibited in the discontinuous–mode of control. For an input power greater than 250 watts, the *continuous–mode* of control is recommended. Here the peak currents can be lowered by the use of a larger inductor, but a troublesome reverse recovery characteristic of the output rectifier is encountered, which can add an additional 20–40 percent in losses to the PFC circuit.

Many countries cooperate in the coordination of their power factor requirements. The most appropriate document is IEC61000–3–2, which encompasses the performance of generalized electronic products. There are more detailed specifications for particular products made for special markets.

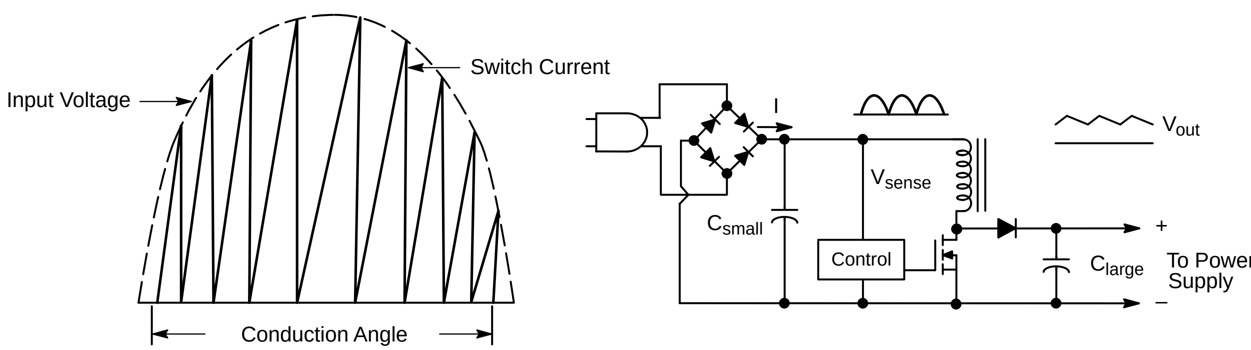


**Figure 34. Power Factor Correction Circuit**

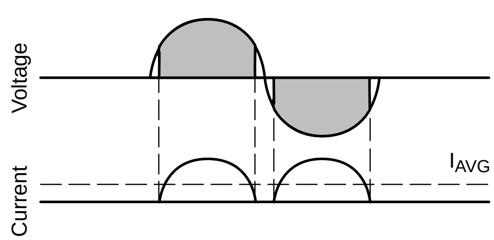


**Figure 35. Waveform of Corrected Input**