Technical Note TN-001

Power Factor: Definition and Application

Power Factor is defined as the ratio of real power to apparent power. Power factor is related to the phase angle between voltage and current when there is a clear linear relationship. But it can still be defined when there is no apparent phase relationship between voltage and current, or when both voltage and current take on arbitrary values.

Power factor is a simple way to describe how much of the current contributes to real power in the load. A power factor of one (*unity or 1.00*) 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 such as heater elements have a power factor of unity, the current through them is directly proportional to the voltage applied to them. Capacitive and inductive (motor) loads have a power factor of zero and the current through them is defined in a more complicated way.

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*.

The reason it is important to have a power factor as close as possible to unity is that once the power is delivered to the load, we don't want any of it to be reflected back to the source. It took current to get it to the load and it will take current to carry it back to the source. Reflected power is undesirable for three reasons:

> Firstly, the transmission lines or power cord will generate heat according to the total current it carries, the real part plus the reflected part. This causes problems for the electric utilities and has prompted the passing of IEC 61000-3-2 and 61000-3-4, European regulations requiring all electrical equipment connected to a low voltage distribution system to minimize current harmonics and maximize power factor. In the United States a similar standard is now being formalized by the IEEE Standards

Committee, this draft has been assigned P1495/D1 for control purposes.

Secondly, the reflected power that isn't wasted in the resistance of the power cord may generate unnecessary heat in the source.

Finally, since the ac mains (dock power) 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.

Many engineers and technicians confuse a non-unity power factor with a simple misalignment of the voltage and current in a transmission line. While this misalignment, caused by capacitive or inductive elements in the load, is certainly a source of non-unity power factor, the whole story is not so simple. Any time the voltage and current in a transmission line are of opposite polarity, power is flowing from the load to the source, in the "wrong" direction. There are many possible causes for this to happen on a transient or repeating basis. In a power converter, whose job it is to provide power to a load of unspecified characteristics, a special circuit is required to insure that no power is ever transmitted back to the source.

POWER FACTOR CORRECTOR

A Power Factor Corrector (*PFC*) circuit is a switching power converter, usually a boost converter, that precisely controls its input current on an instantaneous basis, to match the waveshape of the input voltage. This 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 converters 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.

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.

Again, the goal is to derive the greatest amount of usable power from the least amount of input line current.

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