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Power Factor Correction in Audio Applications

Table of Contents

white paper

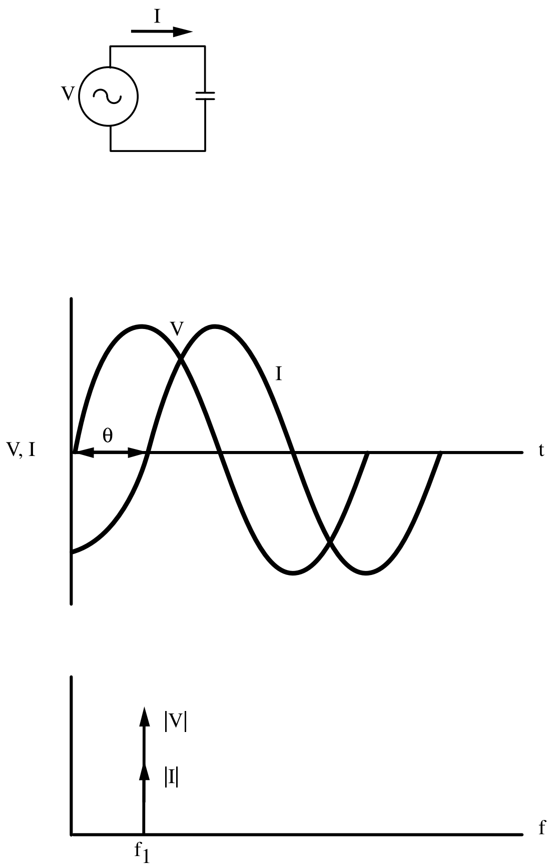

Fig. 1

Power Factor is related to the current drawn from the AC line by a load. In this paper power factor is discussed for linear and nonlinear loads.

Power Factor for a linear load as shown in Fig. 1a is defined as:

pf = VA cos θ

where pf = power factor

V = RMS of AC line voltage

A = RMS of AC line current I

θ = phase angle

This case involves resistive, inductive or capacitive loads, whose impedance can be characterized as a simple magnitude and phase angle. This would be the case for an AC motor or an incandescent lamp, for example. It is included for background purposes, but most presently available electronic equipment is nonlinear from the standpoint of the AC line.

We see that the frequency of the AC line current is the same as the frequency of the AC line voltage, but the phase angle may vary. the harmonic content is shown in Fig. 1b

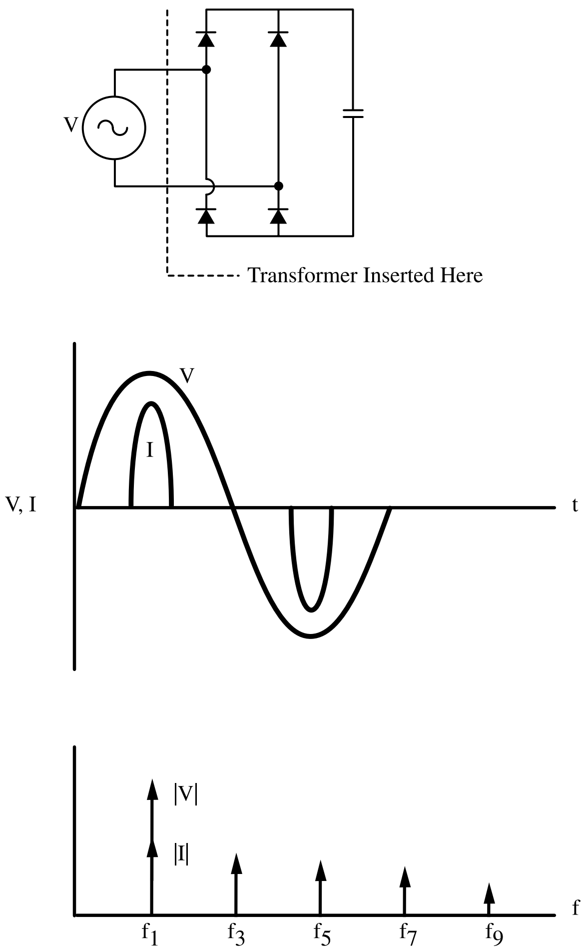

Fig. 2

Power Factor for nonlinear loads as shown in Fig. 2a is defined as:

pf = W / VA

where pf = power factor

W = true power draw

V = RMS of AC line voltage

A = RMS of AC line current I

This case involves a nonlinear element such as a rectifier. The two most common cases are shown in Fig. 2a, these are a rectifier/capacitor as used in a switchmode power supply, and a transformer/rectifier/capacitor as used in a line frequency power supply. In these circuits the diodes can only conduct when the AC line voltage is greater than the capacitor voltage, which leads to large current spikes at the peak of the AC waveform. In this case the harmonic content of the AC current will contain harmonics of the AC line voltage, usually up to several kHz. The harmonic content is shown in Fig. 2c.

The importance of the power factor of nonlinear loads becomes apparent when dealing with a three phase system. Historically, most office buildings were constructed before electronic fluorescent lamp ballasts and personal computers were the norm. Instead, linear loads such as incandescent bulbs were used. A safety problem occurred that resulted from the increased use of nonlinear loads with poor power factor, that is, high AC line harmonic content. This was due to the fact that in a Wye configured three phase AC system all harmonics from all three phases must flow in the ground conductor. With poor power factor, the sum of all these harmonics can exceed the load current on any one leg, so a heavily loaded system may have an overcurrent on the ground conductor, which of course cannot be protected with a circuit breaker or fuse. This caused some building fires, and subsequently the EU adopted standards to limit the harmonic content of the line current on products as a requirement of the CE label. This caused manufacturers of equipment such as shown in Fig. 2a to redesign.

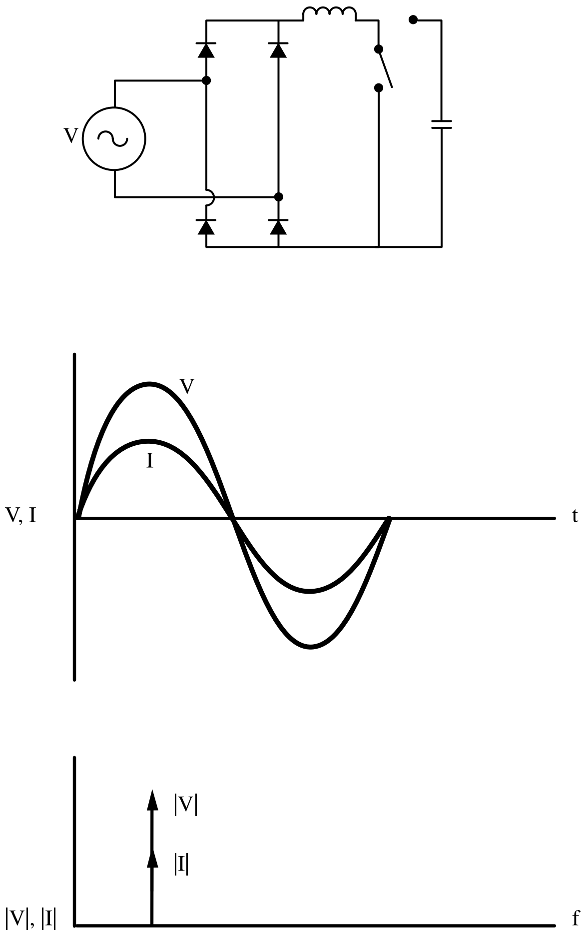

Fig. 3

A typical way of improving power factor is shown in Fig. 3a. In this popular scheme, a separate switching power converter is used to shape the AC line current draw into a sinewave. Since the converter operates only with a positive input voltage, it is placed after the rectifier and must shape incoming current into a rectified sinewave. The current shaping is done by closing a loop around the inductor current, then closing a second loop around the output capacitor voltage. In this manner, a switching power supply can present an almost purely resistive load to the AC line; harmonic content is shown in Fig. 3c. We can see that the peak current has dropped dramatically, as has the harmonic content.

The effects of poor power factor on system performance are mostly evident when the current draw is high. For an audio system this usually means the power amplifiers. If the amplifiers cause a high harmonic content to be present on the AC line, other equipment on the AC line may be affected. The presence of high frequency harmonics can cause audible artifacts in the system by working their way back into sensitive signal processing gear that shares the same AC line.

A conventional electronic light dimmer also produces a current with a high harmonic content; these devices are commonly encountered and are frequently a source of system level noise, often leading to separation of branch circuits and in some cases additional line isolation transformers to minimize the problem. Imagine if these dimmers were installed in a rack full of sensitive audio gear with no way to separate the AC lines! This is effectively what happens when a power amplifier with poor power factor is used in a rack, although to a lesser degree.

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