State-of-the-Art Power Factor Correction: An Industry Perspective

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On 1 January 2001, the IEC 61000-3-2 regulation became effective. Since then, mitigating current harmonics has been essential to ensure that electronic equipment connected to single-phase power distribution lines conforms to electromagnetic compatibility directives. Today, high-quality rectification, commonly known as power factor correction (PFC), is a well-established technique widely adopted by the industry for powering various devices from the ac line. The topic has been studied by academia and industry since the mid-1980s; thus, an enormous amount of research has been published and countless solutions have been proposed since then. However, only a few of those solutions have encountered wide industrial usage. So, it is not the authors' intention to provide a comprehensive review, but to take stock of the most used PFC techniques from an industry perspective. This paper will review the power factor theory with non-sinusoidal currents, the practical and regulatory aspects of using PFC, and the most common industry solutions for power factor correction in equipment operated from the single-phase, public, low-voltage supply system, with a special focus on boost PFC pre-regulators, their control methods, design procedures, and issues.

harmonic currents | harmonic distortion | power factor | IEC 61000-3-2

In the past, the electric power distribution line was mainly loaded with linear loads, i.e., circuits including only resistors, capacitors, and inductors, which have a sinusoidal response to the sinusoidal line voltage. Depending on their inductance or capacitance, these loads may change the relative timing (phase) between voltage and current, but not the sinusoidal shape of the current.

In this scenario, power factor correction (PFC) was concerned with bringing the sinusoidal current absorbed by the load in phase with the line voltage.

The proliferation of electronic equipment powered by switch-mode power supplies (SMPSs) in household and commercial environments has completely changed the scenario. The switch-mode technology, though enabling a much more efficient use of electrical energy, has a significant negative impact on the quality of the distributed ac power, to the point that this has become a critical concern. To ensure an acceptable ac power quality, worldwide regulatory commissions implemented regulations for electrical and electronic products in the context of electromagnetic compatibility (EMC) directives [1][2][3][4]. This fueled the wide usage of PFC that we observe today.

In the end, there are at least three fundamental reasons why PFC is so widely used:

- There are benefits for the electric utility. PFC improves efficiency in energy transportation, transmission, and distribution; the size of cables (especially the neutral cable in three-phase systems) and power transformers can be reduced [5][6][7][8]; a “clean” current, i.e., with low harmonic content, prevents network-protection devices from malfunctioning [9];

- There are benefits for equipment users. A cleaner ac power reduces the risks of product failure or improper operation due to overstressed components connected to the ac input of the SMPS. Also, wall sockets are rated for the maximum current they can carry, and since less current is required for a given power, they can handle more power with their rated current;

- Power supply and equipment manufacturers must sell their products. To be marketable, the equipment must comply with several EMC regulations and one of them is the IEC 61000-3-2 [3] that sets limits on low-frequency harmonic currents injected into the public supply system. The use of PFC ensures compliance with this regulation. It is worth reminding that PFC entails additional costs, only partly compensated by savings due to the overall system optimization. Without this regulation that makes it practically mandatory, PFC usage would likely be limited to niche applications.

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