

# Simple, Reliable EN-Compliant Power System

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The recent amendment to EN61000-3-2 has restated the harmonic current limits required for compliance as applied to most professional and industrial equipment that consumes less than 1000 W.

In many cases, the limits of Amendment 14 can be met without using active power factor correction (PFC). Alternatives, such as passive harmonic attenuation, are an attractive substitute, given the inherent cost, reliability and noise advantages of passive solutions.

One approach is to address the requirement with a conventional front end and a passive harmonic filter (Fig. 1). The system consists of a passive harmonic current attenuation module, labeled harmonic filter, and an autoranging ac-dc front-end module, labeled FARM3. Combined with EMI filter holdup components, the system provides full compliance to EN harmonic current, EMI and transient immunity standards.

In general, it's immaterial whether the harmonic filter is on the ac or dc side of the rectifier. However, in the interest of minimizing power losses, there's an advantage to inserting the filter after the rectifier. Typically, with a conventional front end, required to operate over the entire universal input voltage range of 85 Vac to 264 Vac, the rectifier bridge incorporates a feature known as doubling or strapping. In this case, the doubler is engaged

automatically over the input voltage range of 90 Vac to 132 Vac, and disengaged in the range above 180 Vac to reduce the range of dc voltage on the bus by a factor of two.

The holdup capacitors collect and store energy at the peaks of the line voltage. Energy stored in the capacitors is continuously delivered to the downstream load. Holdup capacitor values to satisfy ripple and holdup requirements are also unaffected by the location of the filter and are determined by the equation:

$$C = 2P\Delta t / (V_1^2 - V_2^2),$$

where P is operating power, Δt is the discharge interval, V<sub>1</sub> is the capacitor voltage at the beginning of Δt, and V<sub>2</sub> is the capacitor voltage at the end of Δt.

Fig. 2 is a functional diagram of an autoranging rectifier. The dc bus voltage in the low range (90 Vac to 132 Vac) is  $2\sqrt{2}V_{rms}$ , or approximately two times the peak voltage of the ac line. In the upper range, the bus voltage is  $\sqrt{2}V_{rms}$ . The result is that the dc output bus is approximately 320 Vdc at either 115Vac or 230 Vac, thus reducing the required operating range of the downstream converters, which in turn affords a power density and efficiency advantage.

In the bridge mode or high range, where the switch labeled "strap" is open, the series capacitors may be treated as a single capacitor of half the individual value. In the doubler mode (switch closed), the capacitors are each charged indi-

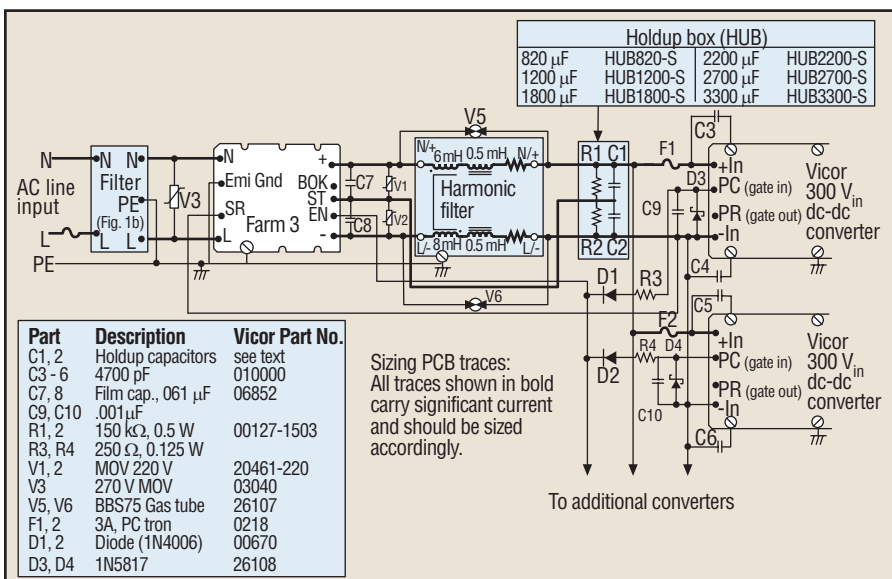


Fig. 1. Component power front-end system for EN compliance.

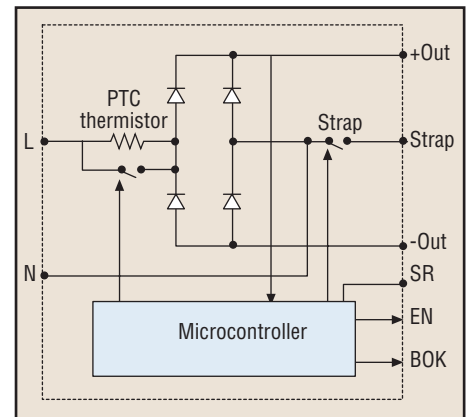


Fig. 2. An autoranging rectifier.

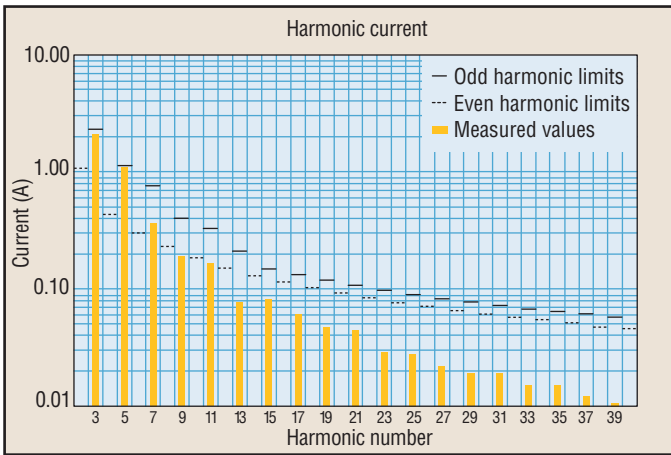


Fig. 3. Measured harmonic current versus EN61000-3-2 limits.

vidually on alternate half-line cycles.

The harmonic filter module includes two mutually coupled inductors in series with each side of the applied voltage. The slope of the power derating and dissipation curves is reduced by a factor of two in the post rectifier application when operating in the low range or doubler mode. This is because only one of the two coupled inductors is conducting load current during any half cycle, whereas both would be conducting each half cycle when employed on the ac line in front of the rectifier bridge.

When the ac front end of the power-conversion system is in the doubling mode, there's an advantage to having the harmonic filter on the dc side of the rectifier, because power dissipated, or loss in the filter, is reduced by a factor of two in the low range. Thus, the incentive to use the harmonic attenuator on the dc side of the bridge. Basically, it has a positive impact on the amount of power derating as the line voltage is decreased.

actual harmonic current data relative to the imposed limits at full rated power using the hardware solution described. Conducted emissions standards, such as EN55011 and EN55022, set quasi-peak and average limits on the spectral contents of conducted noise reflected from the input of power systems back to the source. To comply, conducted noise must fall below specified limits.

Today, most switching power supplies operate at a frequency between 100 kHz and 1 MHz. Usually, the dominant peaks in the conducted noise spectrum reflected back to the power line correspond to the fundamental switching frequency and its harmonics. Typical filters, such as the one included in the FARM3 rectifier of Fig. 1, attenuate the amount of reflected noise and use both common and mode differential filtering. Common-mode noise is, by definition, the noise component that is common to both power lines, and is equal in both phase and magnitude

In this case, the harmonic filter is specified to have a maximum power rating of 600 W, (i.e., at both 115 Vac and 230 Vac), whereas on the ac side of the bridge, given requirements for worldwide operation, the power would have to be derated to 300 W at 115 V.

Fig. 3 illustrates

on each of the input lines. The "protective" earth connection provides a return path. The differential component, on the other hand, is equal and opposite in phase in each leg of the line.

The Transient Surge Immunity requirements defined in EN61000-4-5, Level 3, specify that the power-conversion systems equipment must withstand a 1000-V pulse superimposed on the mains. The pulse rise time is 1.2 μs with a tail that is 50 μs. Riding on top of the line voltage, this surge can occur at any phase angle with either polarity. The equipment must be able to withstand this event without failure to comply with this standard. The standard requires that the applied transient voltage be set to 1000-V line-to-neutral and 2000-V line- or neutral-to-earth (or chassis) during the test.

The simplest way to satisfy this transient surge requirement is with a metal oxide varistor included up front (Fig. 1), which clamps the applied voltage to a safe and non-catastrophic level. The transient suppressor goes into conduction at the specified threshold and dissipates some of the energy associated with the transient event. Ultimately, the system should be designed so the bulk of the energy is absorbed in the holdup capacitors. Largely, the energy associated with the transient is conducted through the rectifier front end and is delivered to the bus capacitors.

A power-conversion system is generally required to withstand transient and surge events. This means all of the components employed must have ratings consistent with those requirements. Thus, it's important to address this requirement at the component selection and circuit-design level.

Parts of this article were previously published in "Passiv geht's auch, Elektronik," John Harding, May 2004, and "Standards Change for EN Compliance, EPD," John Harding, May 2003.

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