PQTN BRIEF
Power Quality Testing Network
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Harmonic Filter for Personal Computers: Passive, Parallel-Connected Series Resonant

Background

Large numbers of personal computers or similar electronic loads operating on a common branch circuit can distort the source voltage waveshape. The power supplies used in most personal computers (PCs) generate high levels of harmonic current. This is typically a diode rectifier with a smoothing capacitor. In 3-phase power systems, PCs may overload the branch circuit wiring when third harmonic current contributions from each phase add up in the neutral conductor.

Objective

One way to reduce the distortion caused by PCs is to add a passive harmonic filter. The objective was to evaluate the performance of a connected passive filter designed for this purpose. The effects of the filter on harmonic current distortion and its reactive power demand on the power system were also evaluated.

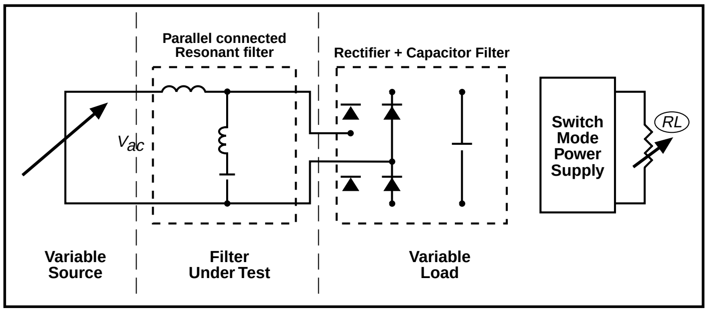

Figure 1. Block Diagram of Test Setup

Units Tested

The commercially-available passive filter was designed to reduce third harmonic current levels for one to three standard PCs when powered through the filter. The filter was rated by the manufacturer at 6 A, 120 V, single-phase, 60 Hz. It was packaged in a 5.9 x 5.9 x 4.7-inch (2340 cc) metal enclosure and weighed 7.75 pounds (3.52 kg). In addition, a plug and receptacle built into the filter unit facilitated user connection. A standard computer power supply driving a variable resistor was used to conduct the tests. Figure 1 illustrates the test configuration. The source voltage was provided by a special utility system simulator, which permits variation in voltage level, frequency, and harmonic content. The harmonic filter was installed between the variable utility and the power supply load.

Test Results

Load I_{thd}

The harmonic filter significantly improved the total harmonic distortion of the line current (I_{thd}) by reducing the third harmonic. Figure 2 illustrates harmonic distortion in the current and voltage waveforms for both the filtered and unfiltered cases at 200 W. The filter reduced harmonic distortion at all load levels. At 1 A loading, the filter reduced I_{thd} from 135% to 24% of the fundamental current. The degree of improvement was slightly less dramatic at higher load levels; I_{thd} was reduced from 112% to 32% at 4 A.

Figure 3 shows the filter's frequency response from both the load and power source sides. From the load side, the filter is tuned to carry the third harmonic (180 Hz) current required by the PC. In effect, the third harmonic is trapped between the filter and the PC load. From

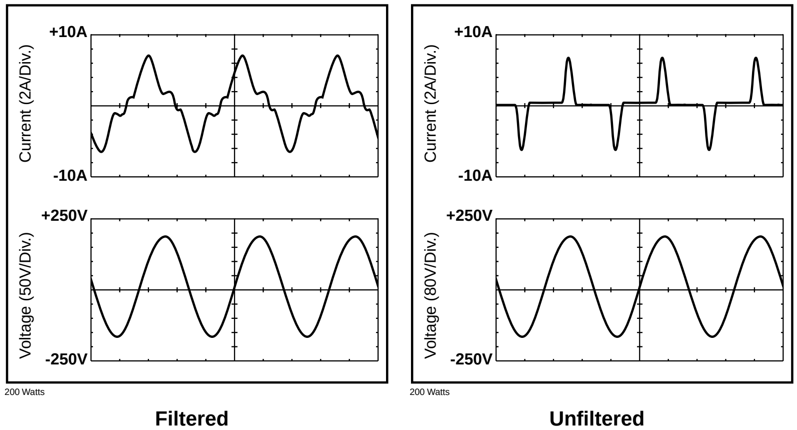

Figure 2. Waveforms

the source side, the filter is detuned to a nonharmonic frequency (150 Hz) to prevent it from being overloaded by harmonics in the supply voltage (V_{thd}). Above 5% supply voltage distortion, the filter must be derated because of an increase in the reactive current attributed to the distortion. (The current increased from 3.8 A at 5% to 5.3 A at 16% V_{thd}.)

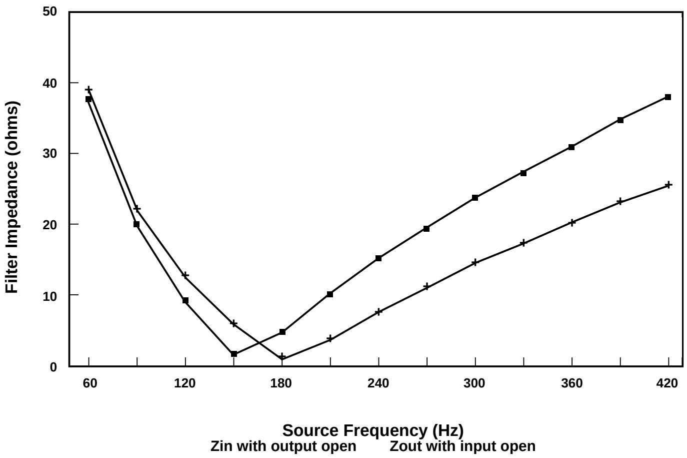

Figure 3. Waveforms

Zin: The filter impedance measured from the input side filter (with output side open). Zout: The filter impedance measured from the output side filter (with input side open).

TUTORIAL: "Reactive Power Demand" in Nonsinusoidal Power Systems

"Reactive Power" is a measure of the rate at which energy oscillates in a power system with no net gain or loss. It includes the out-of-phase (or quadrature) current components with respect to voltage at all frequencies. Although by definition reactive power is neither gained nor lost, its oscillation or transfer in the power system will contribute to system losses resulting from line losses, I^2R. The transfer of reactive power will also affect voltage regulation resulting from line voltage drop, $I(R+j\omega L)$.

To reduce these effects, power engineers apply the concept of "reactive power compensation." For power systems with sinusoidal voltages and currents, compensation is achieved by simply adding reactive components, i.e., capacitors and inductors that correct the system power factor by supplying the needed fundamental leading or lagging current. The passive filter evaluated for this PQTN Brief is capacitive at the fundamental frequency and supplies reactive power to the system. Because the filter contribution is greater than required by the PC load, it is said to "overcompensate" the branch circuit.

In power systems with nonsinusoidal currents, e.g., feeding PC loads, a passive filter can compensate the fundamental and prominent harmonic frequency, but other frequency components will remain as a residual reactive power demand. An active filter is required to completely compensate for the fundamental, harmonic, and residual reactive power demands in a nonlinear system.

REFERENCE

Alexander E. Emanuel, IEEE Transactions on Power Delivery, Vol. 5, No. 3, July 1990.

REACTIVE POWER DEMAND

The shunt-connected filter changed the character of the reactive power demand in the test circuit. (See tutorial on reactive power demand.) For the unfiltered PC load, the reactive power demand is primarily related to the harmonic distortion components rather than to the fundamental component of the load current with $I_{fund} = .95\ I_{load}$. Although the true power factor of the PC under test was 0.6 (238 W/396 VA), the PC load circuit appears to exhibit a displacement power factor of unity if only the fundamental load current is considered. The addition of the passive filter compensates for most of the nonfundamental reactive power demand and reduces the distortion component of the load current. However, this current is higher (4 A), than necessary to power the PC (2 A), because the shunt branch of the filter draws large amounts of leading fundamental current. That is, the filter shunt branch generates reactive power and, consequently, the filter-PC combination exhibits a leading power factor (0.6).

SUMMARY

The parallel-connected resonant filter effectively reduced the current harmonic distortion of a PC load and trapped the load-generated third harmonic, while providing capacitive reactive power compensation beyond what is required by the PC. With a 200 W load, the filter operated without problems from 87% to 106% V_{rms} and from 1% to 16% V_{thd}. The computer power supply functioned normally throughout the tests.

SIGNIFICANCE

Given the growing number of PCs, harmonic distortion generated by typical rectifier power supplies is expected to increase, thereby increasing the need for filtering. Tuned harmonic filters can help reduce current distortion and compensate for reactive power demand. The price of this type of filter may range from \$100 to \$200. Ultimately, a more efficient and cost-effective solution may involve redesigning the switch-mode power supply to reduce harmonic distortion.

ACKNOWLEDGMENTS

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