An increasing number of loads are non-linear, introducing harmonics into the power grid and thus significantly impairing the power quality. EPCOS PQSine™ is an active harmonic filter that effectively reduces the unwanted harmonics.

Linear loads have become a rarity in industrial plants, office buildings, data centers or even private households. Non-linear loads, by contrast, have become increasingly common: frequency converters in drive systems, the large numbers of switch-mode power supplies used in IT and communications equipment, and also more and more in household electronics. Even lighting technology employs mainly non-linear power supplies (Figure 1).

Figure 1:
Supply voltage and load current of non-linear loads:
As a result of the non-linear loads, the current does not follow the sinusoidal voltage, resulting in unwanted harmonics.

The non-linear current draw results in harmonics that cause distortion in the sinusoidal voltage, which in turn can cause interference for other loads. Harmonics are integer multiples of the basic frequency, i.e. of the line frequency of 50 Hz or 60 Hz. The harmonics have varying amplitudes and can extend into the upper kHz range. Harmonic pollution has a series of negative effects on power quality, including:

- problems for other loads due to the poor grid power quality;
- additional current load on the neutral conductor, as the harmonic currents contained of the 3rd, 9th, 15th, and 21st order etc. are accumulative and lead to inadmissibly high currents;
- phase-asymmetry (specifically when operating single-phase switch-mode power supplies) which additionally promotes the generation of harmonics.

In addition, harmonics transmitted via data or power lines can severely impair the function of sensitive devices or even destroy them. Typical examples include process controllers in factories or servers in data centers, where data corrupted by harmonics can cause enormous consequential damage.

Attempts are often made to eliminate harmonics directly at the load using passive components. This however necessitates a well-tuned resonant circuit for every harmonic frequency comprising capacitors and inductors. Such a solution, however, is only practicable if there is a limited spectrum of harmonics.
Active harmonic filters compensate harmonics

With the EPCOS PQSine series, TDK now offers an elegant and full automatic solution for many of the problems caused by harmonics and phase shifts. PQSine is connected to the grid in parallel with the load that is causing the harmonics. The heart of the new active harmonic filters is a controller based on a 32-bit digital signal processor (DSP) with a sampling rate of 48 kHz. With a response time of just 21 µs, PQSine offers class-leading performance. Its new selective drive control (SDC) algorithm is faster than conventional algorithms based on fast Fourier transform (FFT) analysis. Using the data determined in real time, PQSine feeds a compensation current into the grid, which cancels the non-linearity of the load current (Figure 2).

![Diagram of PQSine active harmonic filter](image)

**Figure 2:**
Functional principle of EPCOS PQSine: Harmonics and phase shifts are effectively reduced.

The PQSine series is designed for 3-phase grids with or without neutral conductors with voltages of between 200 V AC and 480 V AC at 50/60 Hz. PQSine enables harmonics of up to the 50th order (2500 Hz/3000 Hz) to be detected and filtered. The new filters can be cascaded in 60 A steps up to a maximum compensation current of 600 A in a single filter system.
High flexibility due to modular structure

The modular structure of PQSine offers enormous benefits. The 60 A modules can swiftly be replaced. In addition, a standard control cabinet with 180 A filter performance can quickly be expanded with one or two 60 A modules, for example, to a total output of up to 300 A (5 modules). To do this the modules are simply inserted into the cabinet with a busbar that is fundamentally designed for currents up to 300 A (Figure 3). Contacting requires neither screwing nor drilling, as both the power connections and control cables feature plug-in connectors.

Figure 3:
Flexible installation options:
The basic 60-A module (left) can be installed in wall-mounted cabinets (middle) or in floor cabinets (right): The cascadable modules enable systems with a maximum compensation current of 600 A in a single filter system.
Unlike conventional power factor correction, which can only compensate inductive loads, PQSine is also able to compensate capacitive reactive power components. In addition to their outstanding filtering capabilities, PQSine active harmonic filters also ensure balancing of the loads to all three phases. Moreover, neutral conductor currents are also compensated when using 4-wire devices. Optimum reliability is ensured by means of a series of self-monitoring systems. The most important of these are: overload protection, shutdown on overtemperature, protection against overvoltage or undervoltage and fan monitoring. A choice of 7" and 12.1" TFT color touchscreens is available for user-friendly input and reading of the data. PQSine offers a number of standard interfaces for control, programming, or diagnostics purposes: Ethercat 100 Mbit/s, USB, Active Sensor Bus and Display Bus.

**Figure 4:**
The three-level output topology of PQSine (left) produces a better approximation of the output current to a sinusoidal waveform (right). In addition, it reduces losses.

**Low loss output topology**

Many active filters employ two-level IGBT bridges at the output, in other words, an output topology that is comparable with that of 6-pulse frequency converters. PQSine, on the other hand, employs a three-level topology with a total of 12 IGBTs (4 IGBTs per phase conductor). This achieves a considerably better approximation to a sinusoidal wave of the output signal than is possible with two-stage systems (Figure 4). Switching losses are also considerably reduced because each IGBT only has to switch half of the operating voltage in the three-level topology.

**Key data for EPCOS PQSine active harmonic filters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. / max. input voltage [V AC]</td>
<td>180 to 528 (3P3W PQSine)</td>
</tr>
<tr>
<td></td>
<td>180 to 460 (3P4W PQSine)</td>
</tr>
<tr>
<td>Rated frequency [Hz]</td>
<td>50/60 Hz</td>
</tr>
<tr>
<td>Compensation current [A]</td>
<td>60 per module</td>
</tr>
<tr>
<td>Modularity</td>
<td>Cascadable up to 600 A</td>
</tr>
<tr>
<td>Response time [µs]</td>
<td>21</td>
</tr>
</tbody>
</table>