SIEMENS

HVAC Products

New variable speed drives technology reduces input line harmonics

Harmonic distortion damages equipment and creates a host of other problems

The use of variable speed drives (VSD) in HVAC systems has proven both efficient and cost-effective. However, the generation of harmonic currents on the AC line can lead to problems and increased installation cost.

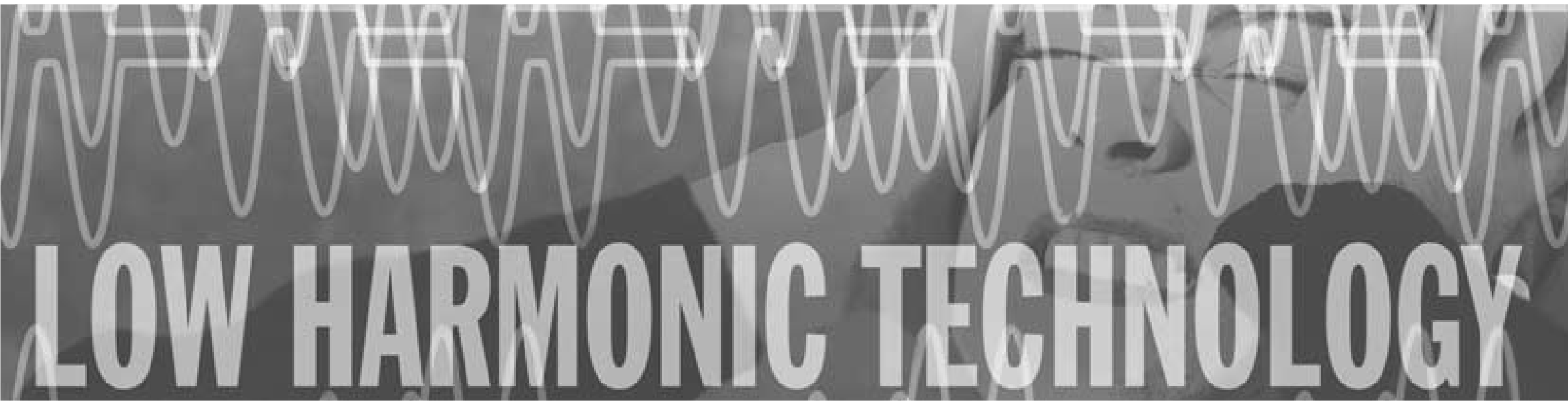
Building design specifications often require compliance with local installation guidelines and standards such as IEEE519.2 (USA), EA G5/4 (UK) and IEC [AS/NZ] 61000-3-6. The purpose of these guidelines / standards is to provide acceptable limits of harmonic current and voltage distortion allowed back into the public power system. In many cases, this requires the use of some method to reduce the harmonic currents produced by standard VSDs.

Conventional methods of harmonic current reduction from VSDs require extra hardware, space, and cost. A new type of VSD from Siemens Building Technologies – specifically designed for HVAC applications – provides a method for reducing the line harmonic currents without the need for additional components.

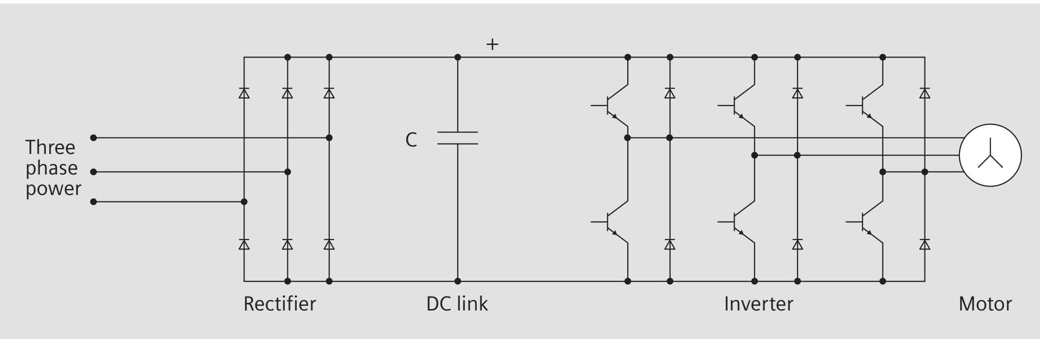
How conventional VSDs work

To understand harmonics, one must first understand how a conventional VSD works and how its power flows. Conventional VSDs consist of a 6-pulse diode rectifier, DC link capacitor, IGBT inverter, and a processor-based controller. The diode rectifier is used to convert AC line voltage to a constant fixed level DC voltage. The DC link capacitor acts as a filter to smooth the DC link voltage and help keep it constant.

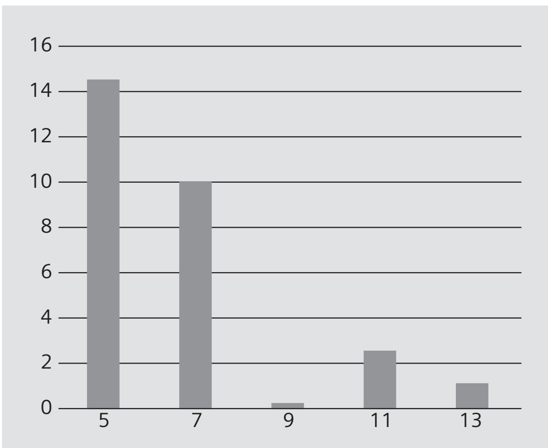
The inverter is used to convert the DC link voltage to a variable voltage, variable frequency 3-phase output for controlling the speed and torque of an induction motor and providing overload capabilities necessary for high dynamic motor performance. The controller is used to supervise the operation of the inverter as well as implement powerful vector control algorithms to obtain optimum dynamic performance from the induction motor. This type of drive is well suited for constant torque loads that require high dynamic performance, such as fast-acting speed- or position-controlled applications. This type of VSD is often used for HVAC applications even though the high performance and overload capabilities are not required.



What causes harmonic current problems?
When harmonic currents flow through the impedances of the power system, they cause corresponding voltage drops and introduce harmonics onto the voltage waveform. This causes the system voltage waveform to become distorted and since this voltage is distributed to other users on the power system, it causes harmonic currents to flow through otherwise linear loads. For example, if the system voltage has a 5th harmonic component and it is applied to an induction motor, then some 5th harmonic current will flow into the motor.



Power flow in a VSD single line diagram



Current harmonic spectrum up to the 13th fundamental
Harmonic results of a typical 6-pulse 3-phase rectifier

Harmonic considerations for HVAC applications

Common problems that arise from harmonics

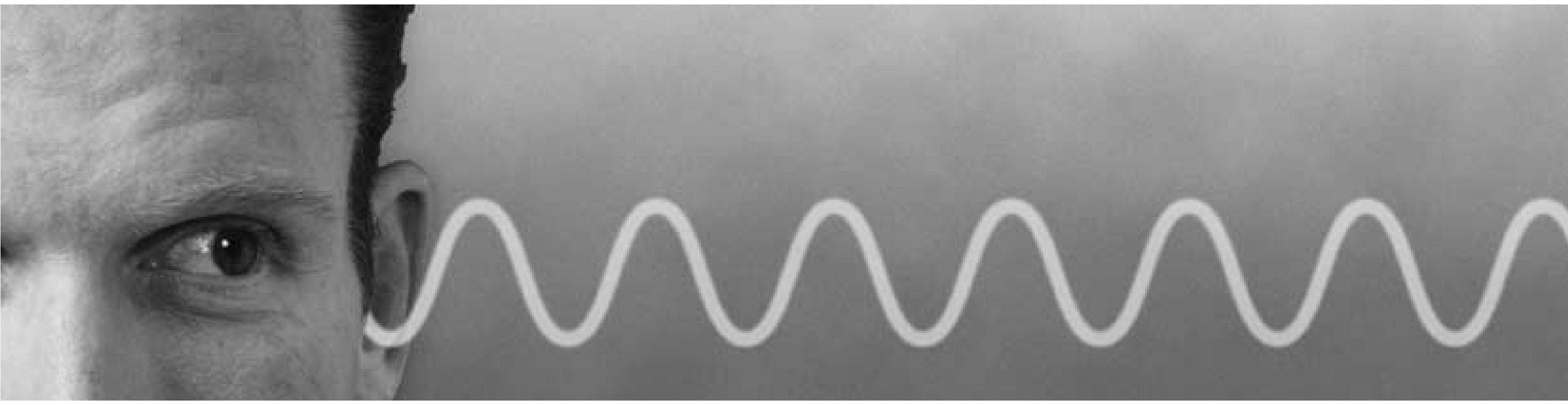
Harmonics can create many problems in a facility. They can cause additional motor heating as well as higher RMS currents through connected transformers and feeder equipment. Sensitive equipment such as instrumentation, computers and communications systems may fail to function correctly or get damaged. In severe cases of voltage distortion, in addition to equipment breakdowns or malfunctions, harmonics can add costs in oversizing transformers to accommodate a perceived or false load requirement that is reflected back onto the power line.

Impact of harmonics on the line current

A characteristic of the 6-pulse diode rectifier is that the current drawn from the AC line is nonlinear, meaning that the current waveform is not sinusoidal. This is caused because the rectifier diodes can only conduct current when the instantaneous input line voltage is greater than the DC link voltage. Since the DC link voltage is held at a high and nearly constant level by the action of the DC link capacitor, the diodes only conduct current near the peak of the input voltage waveform. This causes the line current to be narrow with high amplitude current pulses that charge the DC link capacitors on a periodic basis. The resulting AC line current drawn from the power system has a high amount of harmonic current. At the input terminal of a standard VSD, harmonics current can be 120 % to 130 % Total Harmonic Distortion (THD). The current waveform diagram demonstrates the affects of harmonics on the waveform.

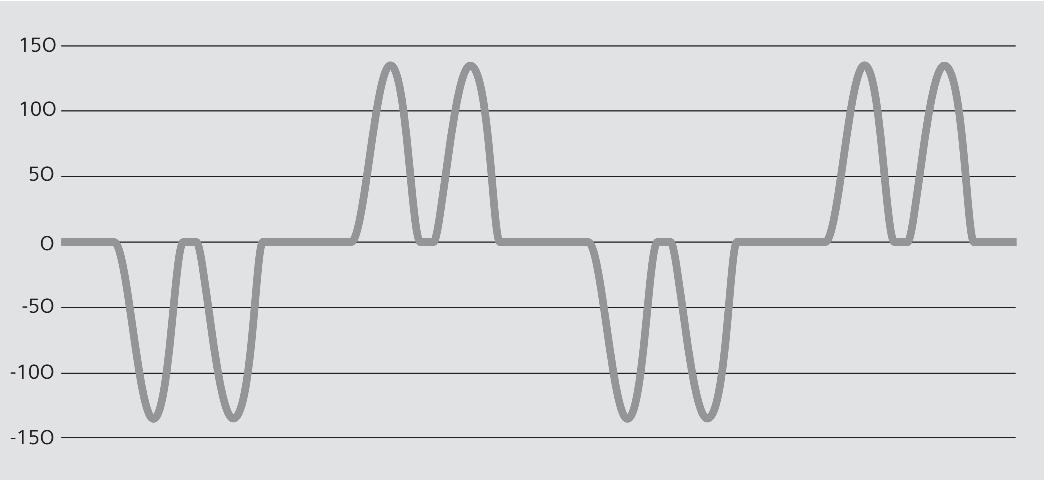
Harmonic current spectrum: The fundamental problem

All periodic waveforms can be represented by a set of sinusoidal waveforms consisting of the fundamental frequency plus various other harmonic frequencies. The AC line harmonic currents, with a 6-pulse bridge, have characteristic frequencies at $6n\pm1$ times the fundamental frequency where n is an integer. A 6-pulse VSD on a balanced supply will only generate odd order harmonics from the 5^{th} order upwards (5^{th}, 7^{th}, 11^{th}, 13^{th}, 17^{th}, etc). Even harmonics and triplen (multiples of 3^{rd}) will be canceled out. The amplitude of the harmonic currents depends on the impedance of the AC power system, the size of the DC link capacitor, and the load on the induction motor. The 5^{th} and 7^{th} harmonic currents are predominantly large with standard VSDs.



Typical methods used to reduce harmonics
The recommended practices of IEEE 519 provide guidelines for the design of electrical systems that contain both linear and nonlinear loads. It addresses the responsibility that users have not to degrade the voltage of the utility serving other users by requiring excessive amounts of nonlinear currents from the utility. It also addresses the responsibility of the utilities to provide users with close to a sine wave of voltage. The recommended practices provide guideline limits on the amount of harmonic current drawn from the utility at the point of common coupling as well as limits on the amount of voltage distortion the harmonic currents can produce.

The design of HVAC electrical systems using VSDs is influenced by the recommended practices, and in some cases, corrective measures must be taken to comply with the guidelines. In the case of VSDs, this means higher cost because AC line reactors or DC link chokes are often added to help reduce the amount of 5^{th} and 7^{th} harmonic currents.



Current waveform
When measured at the input terminal of a 6-pulse VSD, Total Harmonic Destortion can be in excess of 150 %.

The SED2 reduces input line harmonic currents without using line reactors or DC link chokes

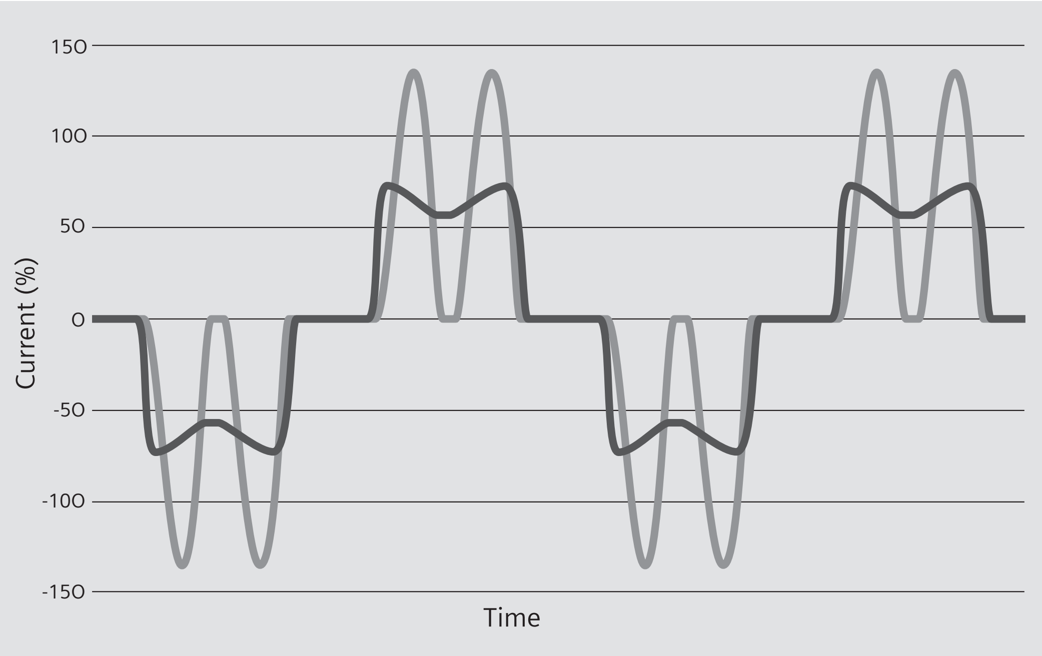
Siemens Building Technologies has recently introduced the SED2, a new family of VSDs designed specifically for the HVAC market. Typical applications for this drive are fan and pumps with variable torque load characteristics. The fact that these applications are low dynamic by nature means the overall topology of the SED2 now provides a new method of reducing the input line harmonic currents without the addition of extra components. It is known as LHT (Low Harmonic Technology).
Industrial VSDs are typically designed with a 160 % + overload characteristic whereas the SED2 only requires 110 % overload to satisfy the dynamics of a fan or pump. This fact allows operation with significantly reduced values of DC link capacitors – typically 2 % of a conventional VSD. This means that the level of the DC link voltage of the SED2 is lower and has more ripple content than a conventional VSD and this in turn results in a longer conduction period for the diodes in the rectifier section. The SED2 input line current no longer has the high amplitude narrow pulse of charging current seen with other VSDs but rather a quasi 120° conduction period per diode.
The resulting SED2 line current is approximately equivalent to a standard VSD equipped with additional AC line reactors or a DC link choke. Rather than performing vector control calculations, the controller now uses powerful new control technologies to compensate for the effects of the higher ripple DC link voltage to assure smooth and quiet operation of the fan or pump motor.

Conclusion

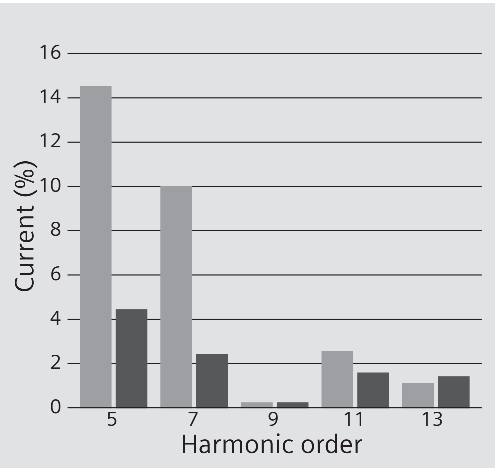
Test results have demonstrated the ability of the SED2 to significantly reduce the lower order harmonic currents drawn from the AC power system without the need for additional components.
Harmonic performance is equal or better than that of conventional VSDs equipped with additional AC line reactors or DC link chokes.

HarmonEE

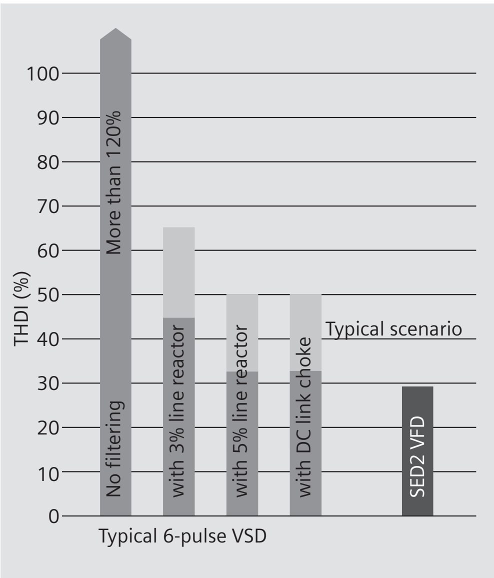
HarmonEE is a program specifically designed to calculate the harmonic currents, total harmonic current distortion and total harmonic voltage distortion. The data is then used to compare the results against various international guidelines and standards such as IEEE519.2 (USA), EA G5/4 (UK and Hong Kong) and IEC (AS/NZ) 61000-3-6 (used globally).
HarmonEE will also be able to show the difference of the LHT performance of the SED2 compared to a traditional VSD.



Current waveform of a typical 6-pulse VSD vs. the SED2
At the input terminal of a 6-pulse VSD, THD can be in excess of 120 % without any filtering (i.e. AC line reactors or DC link chokes). The SED2 produces only 29 % THD.



Current harmonic spectrum comparison up to the 13th fundamental
In tests between a conventional 6-pulse VSD and the SED2, note how the SED2 demonstrates superior, lower harmonic results at the 5th and 7th fundamental.



■ SED2 6-pulse VSD
■ Typical 6-pulse VSD

Total harmonic distortion reduction comparison
In tests between a typical 6-pulse VSD with and without AC line reactors and DC link chokes versus the SED2, the Siemens Easy Drive demonstrates superior harmonic performance. In typical HVAC applications, the SED2 can reduce harmonics by up to 25 % more than other VSDs even with AC line reactors or DC link chokes.

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