Harmonics White Paper

New Breakthrough In PWM Drives Technology Reduces Input Line Harmonics Without the Use of Filtering Devices

SIEMENS

Harmonic Distortion Damages Equipment and Creates a Host of Other Problems

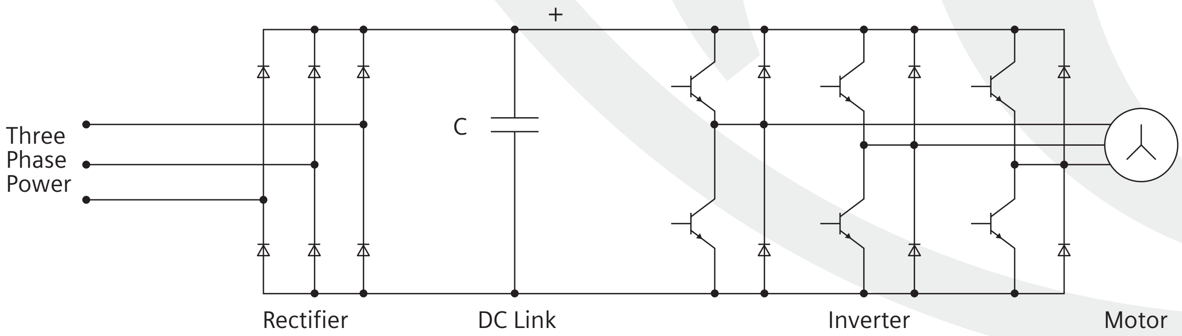
The use of PWM drives in HVAC systems has proven both efficient and cost effective. However, the generation of harmonic currents on the AC line can lead to problems and increased installation cost. Building design specifications often require compliance with IEEE 519 standards which limit the amount of harmonic current and voltage distortion allowed on the power system. In many cases this requires the use of some method to reduce the harmonic currents produced by standard PWM drives. Conventional methods of harmonic current reduction from PWM drives require extra hardware, space, and cost. A new PWM drive from Siemens Building Technologies, specifically designed for HVAC, provides a method for reducing the line harmonic currents without the need for additional components.

How Conventional PWM Drives Work

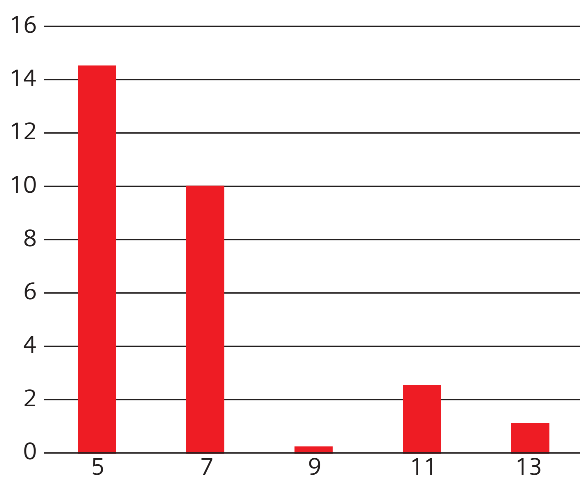
To understand harmonics one must first understand how a conventional PWM drive works and its power flow. Conventional PWM drives consist of a 6 pulse diode rectifier, dc link capacitor, IGBT inverter, and a processor based controller. The diode rectifier is used to convert AC line voltage to a constant 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 to constant torque loads that require high dynamic performance such as fast acting speed or position controlled applications. This type of drive 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 PWM Drive Single Line Diagram



Current Harmonic Spectrum Up to the 13th Fundamental

Harmonic results of a typical 6 pulse PWM drive.

Harmonic Considerations for HVAC Applications

Common Problems That Arise From Harmonics

Harmonics can create many problems in a facility. It 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 over-sizing transformers to accommodate a perceived or false load requirement that is reflected back onto the power line.

What Harmonics Looks Like On The Line Current

A characteristic of the 6 pulse diode rectifier is that the current drawn from the AC line is non-linear, 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 level and nearly constant 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, 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 PWM drive, harmonics current can be 120% to 130% Total Harmonic Distortion (THD). The current wave form diagram demonstrates the affects of harmonics on the waveform.

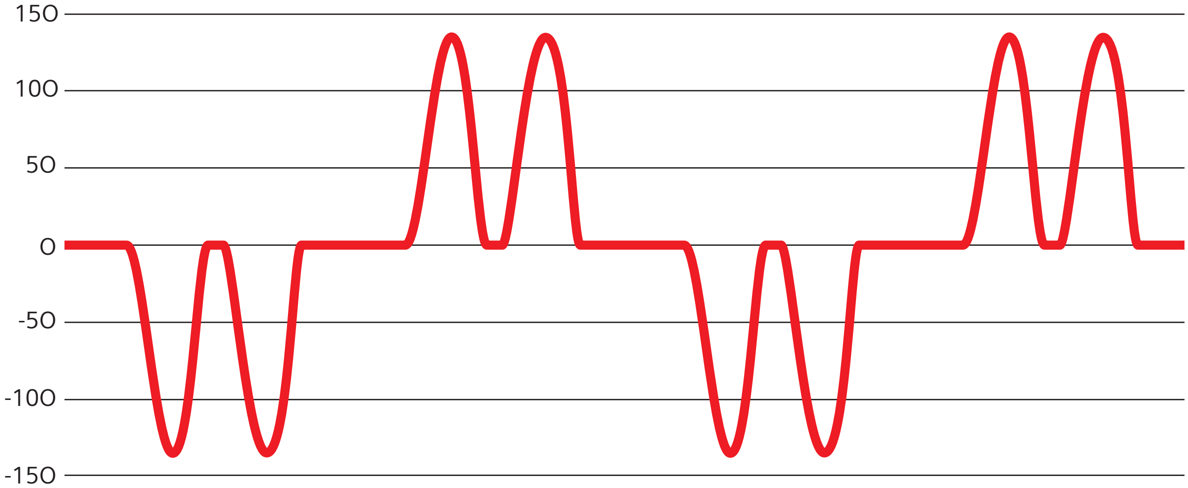
Harmonic Current Spectrum: The Fundamental Problem

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 six pulse bridge, have characteristic frequencies at $6n\pm1$ times the fundamental frequency where n is an integer. This means that if the fundamental frequency is 60 Hertz then the harmonics present are 5x60, 7x60, 11x60, 13x60 and so on. 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 5th and 7th harmonic currents are predominantly large with standard PWM drives.

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 provides 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 PWM drives is influenced by the recommended practices and in some cases corrective measures must be taken to comply with the guidelines. In the case of PWM drives this means higher cost because AC line reactors and or DC link chokes are often added to help reduce the amount of 5th and 7th harmonic currents.



Current Wave Form

When measured at the input terminal of a PWM 6 pulse drive, THD can be in excess of 150%.

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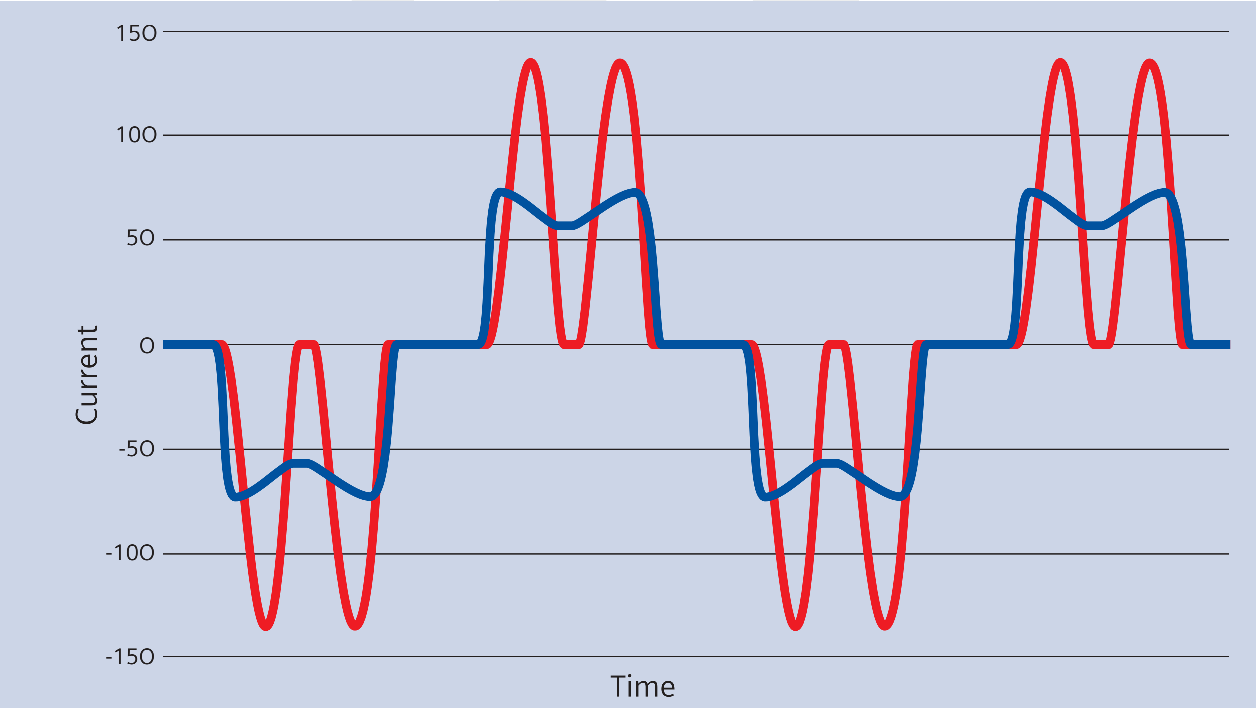
The SED2 PWM Drive Reduces Input Line Harmonic Currents Without Using Line Reactors Or DC Link Chokes

The HVAC Products Division of Siemens Building Technologies has recently introduced the SED2, a new family of variable frequency drives designed specifically for the HVAC market. Typical applications for this drive are fan and pumps with variable torque load characteristics. These drives have been designed for limited overload capabilities, do not allow operation of the motor above base speed, and provide a new method of reducing the input line harmonic currents without the addition of extra components.

Because an HVAC drive does not require high overload capability, the SED2 drive design has used this fact to allow operation with significantly reduced values of DC link capacitors, typically 2% of a conventional PWM drive. This means that the level of the DC link voltage of the SED2 is lower and has more ripple content than a conventional PWM drive 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 PWM drives but rather a quasi 120° conduction period per diode. The resulting SED2 line current is approximately equivalent to a standard PWM drive equipped with additional AC line reactors and a DC link choke. Rather than performing vector control calculations, the controller now performs powerful new control technologies to compensate for the effects of the lower level, high ripple, DC link voltage to assure smooth and quiet operation of the fan or pump motor.

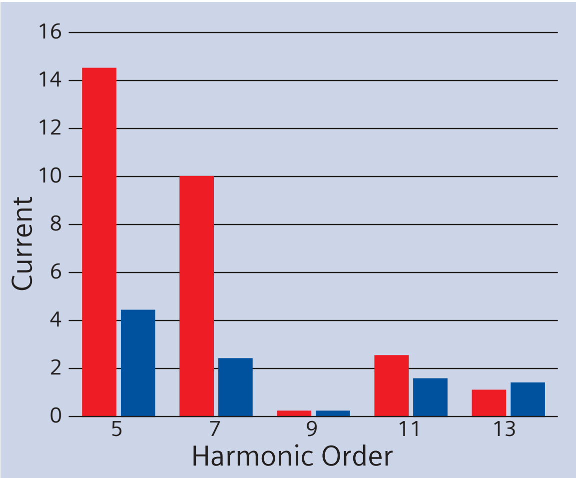
Conclusion:

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 conventional PWM drives equipped with additional line reactors and DC link chokes.



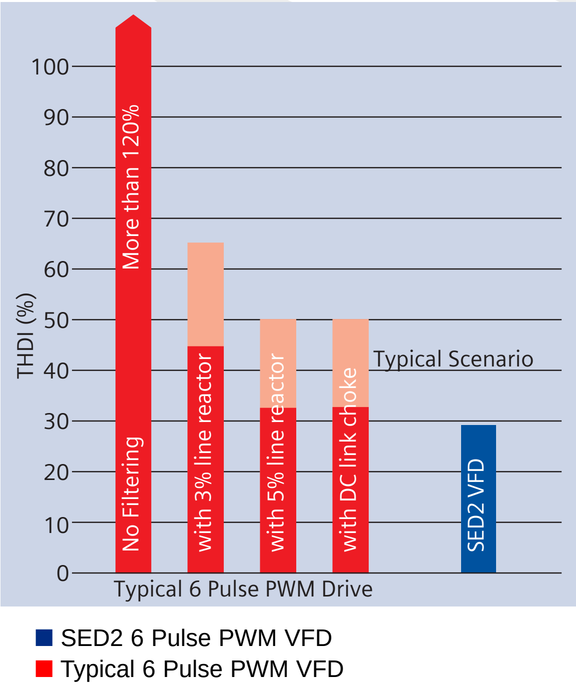
Current Wave Form Of Typical 6 Pulse Drive Vs. The SED2

At the input terminal of a PWM 6 Pulse Drive, THD can be in excess of 120% without any filtering (i.e., 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 PWM drive and the SED2 VFD, note how the SED2 demonstrates superior, lower harmonic results at the 5th and 7th fundamental.



Total Harmonic Distortion Reduction Comparison

In tests between a typical 6 pulse PWM drive with and without line reactors and DC link chokes versus the SED2 VFD, the Siemens Easy Drive demonstrates superior harmonic performance. In typical HVAC applications, the SED2 VFD can reduce harmonics by up to 25% more than other VFDs even with line reactors and DC link chokes.

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SED2

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