Reduced Harmonics Technology
in Altivar™ 212 Adjustable Speed Drives

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Introduction

This data bulletin provides an introduction to power line harmonics and describes the reduced harmonics technology (RHT) used in Altivar™ 212 adjustable speed drives for mitigating power line harmonics.

Power line harmonics and harmonic distortion are words found in almost every specification for adjustable speed drives. While harmonics is a term referred to regularly, there are few industry guidelines on this subject. An increasing number of electronic devices that generate power line harmonics are being installed and retrofitted into buildings. This includes devices that convert AC power to DC power and draw power intermittently. Personal computers, electrical control equipment, lighting ballasts, and adjustable speed drives are examples of these types of devices. This intermittent current draw, caused by the capacitors charging in these devices, can have high peak current values. Managing these high peak current values and managing the input current waveform are the keys to mitigating power line harmonics.

What are Harmonics?

Intermittent current draw can cause the building's power grid to carry power flowing at frequency multiples of the 60 Hz base frequency, in addition to the 60 Hz power supplying the building's electrical needs. Power flowing at frequency multiples other than 60 Hz, consisting of voltage and current components, is often called harmonic distortion. In other words, power line harmonics exist in the form of current and voltage waveforms that are present at frequencies other than base frequencies. This can be thought of as non-productive power that is flowing through the conductors along with the productive power that is supplying the building's electrical needs. This harmonic distortion is measured as the sum of various frequency components which are integer multiples of the 60 Hz base power line frequency. This total sum of the harmonic current distortion is often referred to as THDI.

Another way to understand harmonics is to consider two of your favorite musical instruments. When a saxophonist and blues guitarist hit the C note on their respective instruments, you hear the common base frequency. However, you also hear the various distinctive tones each instrument makes. These various audible tones are generated from various frequency components which are integer multiples of the base frequency, just as currents flow at multiples of the base power line frequency.

Why the Concern About Power Harmonics?

While various harmonic tones give the various musical instruments their character, power line harmonics are less desirable. The impact of intermittent current draw in electronic control equipment and personal computers is often only a minor concern as the power draw is small. However, devices that draw a significant amount of power, such as adjustable speed drives and lighting loads, can have a pronounced negative impact on the building's power grid. These impacts include transformer and

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conductor overheating, circuit breaker tripping, fuse opening, and interference with communication networks. Lack of awareness of power harmonics can lead to improperly sized power conductors and disruption of the operation of sensitive equipment. Other variables of an installation can reduce or intensify the actual level of harmonics. These variables include system impedance, line voltage imbalance, transformer size and loading, percent of transformer load that exhibits intermittent current draw, and the available short circuit current. Sites or installations where the AC drive load is a significant portion of the transformer load require the most design attention.

What Can Be Done About Power Line Harmonics?

Reducing the high peak current values and managing the input current waveform are the keys to harmonic mitigation. Various methods of harmonic mitigation are available today, such as adding AC line reactors or DC chokes, tuned harmonic trap filters, 12- and 18-pulse AC drive designs, and other active front-end devices that recreate an AC sine wave that virtually eliminates power harmonics. Each method offers cost–benefit trade-offs. A common mistake is to specify a solution that increases the installation and operating costs. The best solution is a trade-off between acceptable harmonic distortion and acceptable costs.

What Does the Altivar 212 Drive Offer?

The Altivar 212 adjustable speed drive, designed specifically for pump and fan applications, has a unique and effective approach to reducing harmonics called reduced harmonics technology (RHT). The Altivar 212 drive offers a unique, optimized power section and a powerful motor control method that significantly reduces harmonic currents. The Altivar 212 drive reduces harmonics by 60% or more without the use of additional harmonic reduction devices.

Design Principle of the Altivar 212 Drive

The key design principles contributing to the Altivar 212 drive's reduced harmonic technology are as follows:

1. The optimized power section
2. A powerful motor control processor combined with the design of the motor control algorithm

The power section is optimized by reducing the DC bus capacitance value to approximately 3%–5% of the capacitor value of an equivalent horsepower, standard AC drive. This modifies the input current waveform characteristics by significantly reducing current spikes typically observed during the capacitor charging cycle. Total current draw is reduced, lowering input current harmonics and input line current values. The second key design aspect of the Altivar 212 drive is the powerful motor control processor and the engineering of the motor control algorithm. As there is less DC bus capacitance, there is more DC ripple on the DC bus. The motor control processor and algorithm manage the ripple and produce a sinusoidal current waveform to the motor.

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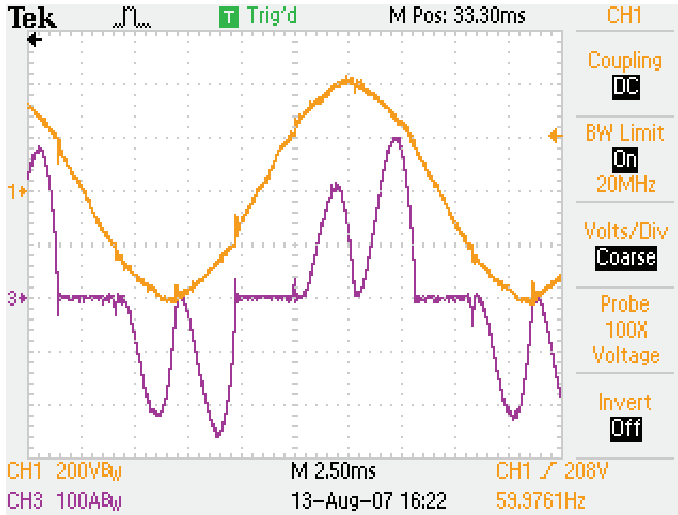
Typical 6-Pulse AC Drive Input Waveforms

Figure 1 shows typical input voltage and current waveforms of a 100 hp 6-pulse AC drive. The double-humped waveform shows the peak current reaching 300 A as the capacitors charge. Total harmonic current distortion (THDI) = 80% in this example.

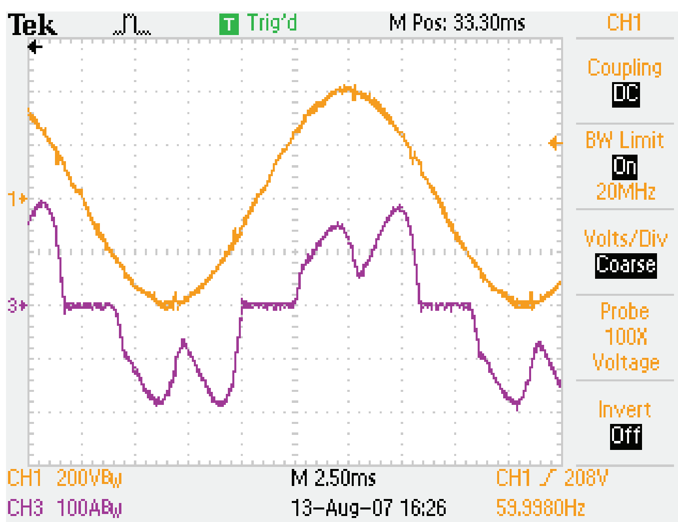
Figure 1: Typical 6-Pulse AC Drive Input Waveforms



Typical 6-Pulse AC Drive with Line Reactor Input Waveforms

Figure 2 shows typical input voltage and current waveforms of a 100 hp 6-pulse AC drive with a 3% input line reactor. The double-humped waveform shows the peak current reaching 190 A as the capacitors charge, but note that the peak currents are reduced in comparison to Figure 1. THDI = 38% in this example.

Figure 2: Typical 6-Pulse AC Drive with Line Reactor Input Waveforms



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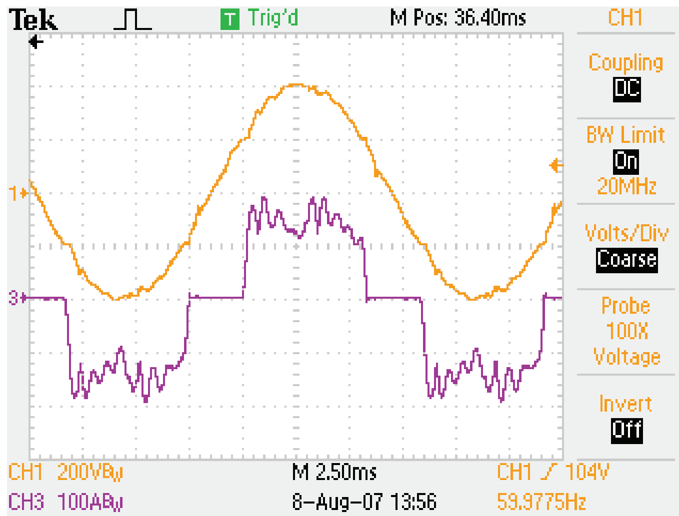
Altivar 212 AC Drive Input Waveforms

Figure 3 shows typical input voltage and current waveforms of a 100 hp Altivar 212 AC drive. Note the dramatic change in the shape of the input current waveform.The current peaks reach up to 190 A, similar to results with a line reactor. However, because of the reduced capacitance, the input current is a square-shaped waveform, eliminating the large double-humped waveform which generates large harmonic currents. This square current waveform produces less harmonic currents. The THDI is reduced to 33% in this example.

Figure 3: Typical Altivar 212 AC Drive Input Waveforms



What About Standards Compliance?

Today, there are no clear product standards governing harmonics. IEEE 519-1992, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, is often referenced when discussing harmonic mitigation. However, this standard was developed to cope with harmonic issues in electrical transmission lines and power grids. IEEE 519-1992 is a systems standard which cannot be effectively applied to individual products.

The international standard IEC 61000-3-12, “Electromagnetic Compatibility (EMC)—Part 3-12 Limits,” is increasingly being referenced. IEC 61000-3-12 discusses harmonic current limits produced by equipment connected to public low voltage systems. This IEC standard provides criteria for evaluating individual products. For compliance to IEC 61000-3-12,Table 4, the THDI must be less than 48%. As previously noted the Altivar 212 drive's THDI is below 35% without AC line reactors or DC chokes.

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Comparison of Harmonic Mitigation Methods

Table 1 provides an overview of various harmonic mitigation solutions, summarizing the advantages, disadvantages, typical THDI, and typical cost ratio.

Table 1: Comparison of Harmonic Mitigation Methods

Solution	Advantage	Disadvantage	Typical THDI (%)	Typical Cost Ratio
Typical 6-pulse—No harmonic mitigation	• Widely used	• No improvement of the current wave shape • Difficult to comply with standards	> 80	1
RHT technology	• Simple design • Lowest cost	• Limited hp range • Difficult to comply with the most severe standards • Poor voltage sag ride-through	< 35	0.90–0.95
AC line reactors or DC choke	• Simple • Medium cost	• Difficult to comply with the most severe standards	< 40	1.05–1.15
Passive filter (broadband)	• Significant improvement of the current wave shape • Possible to install after commissioning (corrective action)	• Separately mounted solution • Potential for resonance issues	5–12	1.35–1.70
Multi-pulse (12- or 18-pulse configuration)	• Significant improvement of the current wave shape • Integrated solution	• Large size, heavy • Expensive for >100 hp • Performance deteriorates in case of voltage unbalance	5–12	1.75–2.5
Active front end (IGBT[1] converter)	• Sinusoidal current • Optional regenerative control is possible	• High cost for pump and fan market • Engineered design	< 5	2.0–3.0

[1] IGBT = Insulated Gate Bipolar Transistor

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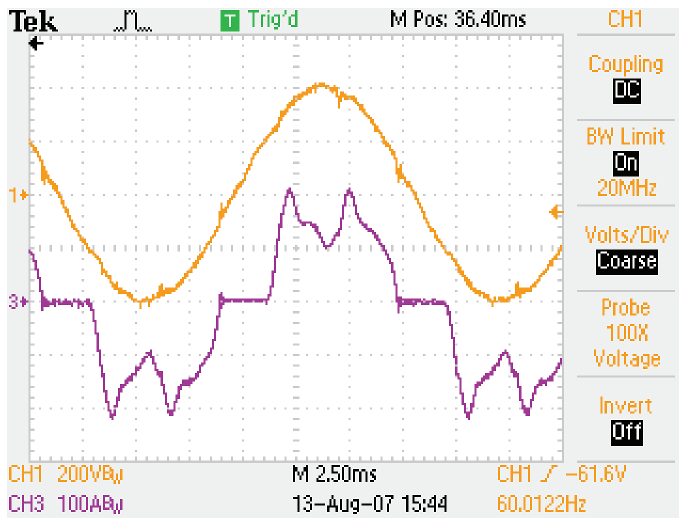
More on RHT in Altivar 212 Drives

There are several other benefits from the reduced harmonics technology used in the Altivar 212 drive. Because the peak current drawn through the input diodes is significantly reduced, the diodes are stressed less, compared to a typical 6-pulse AC drive. The design of the filtering on the diode section and use of long life plastic film capacitors ensure a robust front-end power section on the Altivar 212 drive.

AC line reactors are often used when the incoming AC line power is above voltage specifications to reduce the effect of high line voltage. Adding a line reactor will not significantly reduce or add to the Altivar 212 drive's THDI. Figure 4 shows typical voltage and current waveforms of a 100 hp Altivar 212 drive with a line reactor. The THDI is reduced to 33% in this example.

Figure 4: Typical Altivar 212 AC Drive with Line Reactor Input Waveforms



With lower DC bus capacitance, the Altivar 212 drive has a reduced capacity to ride through AC power line dips or sags. The Altivar 212 drive has an auto-restart feature and a robust catch-on-the-fly algorithm designed to minimize the effect of voltage dips and sags. The catch-on-the-fly algorithm has also proven to do an exceptional job of catching a reverse spinning load, bringing the load to a standstill and accelerating in the proper direction. This catch-on-the-fly algorithm is a useful feature for wind-milling fan loads. If voltage ride-through is a major concern in an installation, the Altivar 61, with its industry leading voltage sag ride-through capability, may be the preferred solution.

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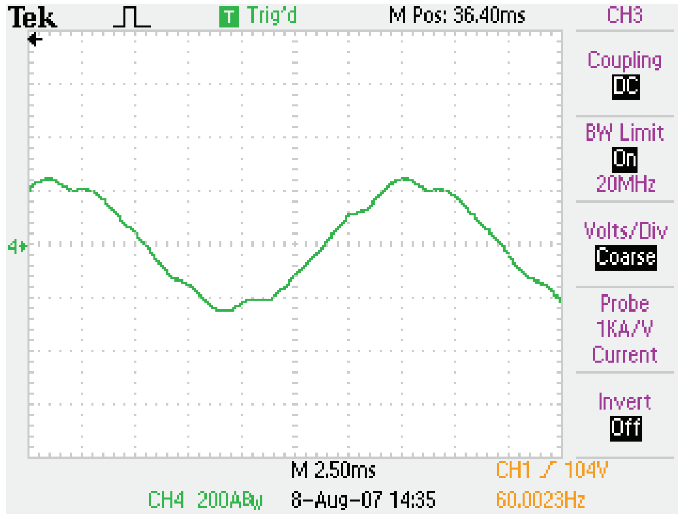
Figure 5 shows a typical waveform of the Altivar 212 drive's output current. The motor control processor and the motor control algorithm are designed to produce a sinusoidal waveform with very little distortion to the motor.

Figure 5: Typical Altivar 212 AC Drive Output Current Waveform



Altivar 212 Drive Benefits

The Altivar 212 drive has many benefits for pump and fan installations.

- Reduces harmonic distortion
- Reduces enclosure size requirements
  - — no line reactor or other external filtering
  - — reduced capacitance
- Reduces heat dissipation
  - — no line reactor or other external filtering
  - — reduced capacitance
- Improves efficiency
  - — no line reactor or other external filtering
- Reduces cost of installation
  - — saves installation time
  - — minimizes wire size
  - — reduces wiring between components

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