SAVE ENERGY, REDUCE HARMONICS AND LOWER HVAC AND PUMP SYSTEM INSTALLATION COSTS

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Practically from the first introduction of power semiconductor rectifiers and capacitor banks in AC drives, engineers have been trying to minimize the resulting harmonics and the distortion they can cause in electrical systems. Until recently, adding a line reactor was the most common approach to minimizing harmonics caused by AC drives in HVAC and pump systems. But continuing advances in drive technology have created a streamlined solution that reduces harmonics, while at the same time saving energy and lowering installation costs.

Intermittent current draw caused by the charging cycle of the capacitor bank can cause a building's power grid to carry power flowing at frequencies other than the 60 Hz base frequency. This power, consisting of voltage and current components, is often called harmonic distortion. The impact of these intermittent waveforms on the power grid varies by the amount of power being drawn through a particular device. When that power draw is significant, such as with adjustable speed drives and lighting loads, it can have a pronounced impact on a building's power grid. Harmonics can overheat transformers and conductors, trip circuit breakers, open fuses and interfere with vulnerable communication networks.

Harmonics can lead to improperly sized power conductors and disrupt the operation of sensitive equipment. Other installation variables can reduce or intensify the actual level of harmonics. These include system impedance, line voltage imbalance, transformer size and loading, percent of transformer load that exhibits intermittent current draw and available short circuit current. Installations where loads from AC drives are a significant portion of the transformer load require the most design attention.

An engineering history of harmonic mitigation

One of the earliest approaches to attenuating the harmonics generated by AC and DC drives was the isolation transformer, which ensured proper operating voltage and line isolation. Isolation transformers provided a filtering effect, reduced incoming voltage spikes and also acted as a harmonic filter.

AC drive manufacturers evolved their products to produce various voltage ratings, reducing the need for voltage changes and thereby eliminating the need for isolation transformers. This left the harmonics issue to be solved. HVAC and pump system designers turned to line reactors as a more compact, low-cost way to mitigate harmonics.

Line reactors have done their job credibly for many years. They were a good design solution when energy was cheap and large mechanical rooms were the norm. But today's economic climate and environmental concerns are exposing the drawbacks of line reactors.

Now drive technology is advancing to provide a better alternative.

Reducing harmonics at the source

Several manufacturers have developed new drive technology that enables users to reduce both harmonics and costs by embedding the functions previously performed by a line reactor within the drive itself.

The Altivar® 21 variable frequency drive from Schneider Electric, for example, combines a unique optimized power section and a powerful motor control algorithm and processor to significantly reduce harmonic currents. This innovative reduced harmonics technology (RHT) reduces harmonics by 60 percent or more without the use of a line reactor. It is specifically designed for HVAC and pump applications.

The drive's power section is optimized by reducing the DC bus capacitance value to approximately 3 percent of an equivalent horsepower standard AC drive capacitor. This modifies the input current waveform characteristics to significantly reduce the current spikes typically observed during the capacitor charging cycle. Total current draw is reduced, lowering input current harmonics and input line current values.

A second, equally critical part of the design is a powerful motor control processor and the engineering of the motor control algorithm. Since the power section reduces 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.

Reducing the peak current during the capacitor charging cycle is key to reducing the harmonics.

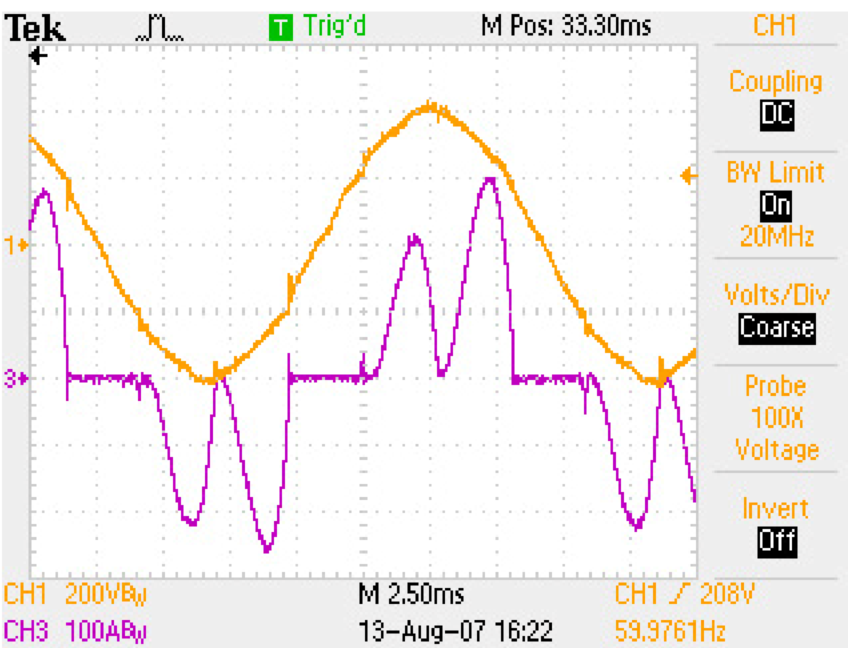

Figure 1 shows typical input voltage and current waveforms of a 100 hp 6-pulse AC drive controller. The double-humped waveform shows the peak current reaching 300 A as the capacitors charge. Total harmonic current distortion (THDI) equals 80% in this example.

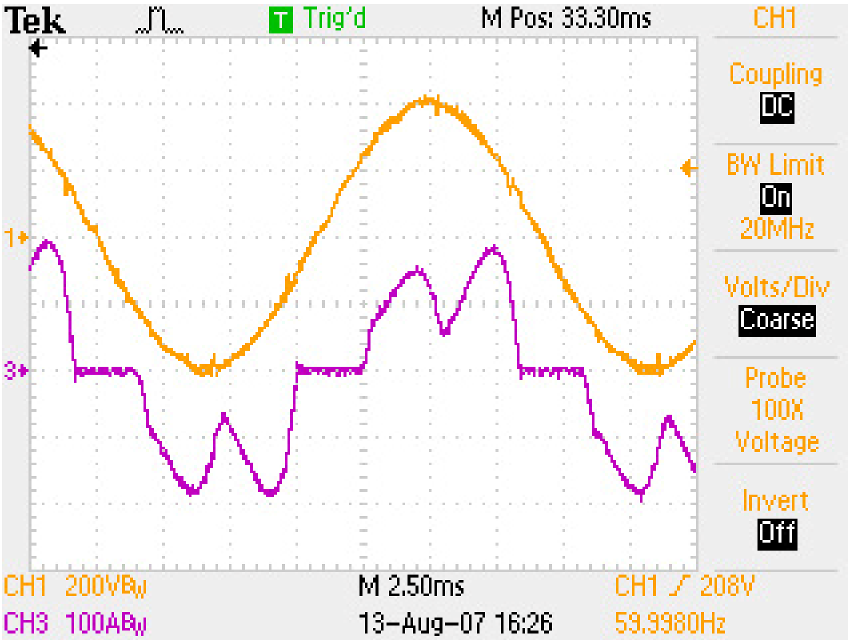

Figure 2 shows typical input voltage and current waveforms of a 100 hp 6-pulse AC drive controller with a 3% input line reactor. The double humped waveform shows the peak current reaching 190 A as the capacitors charge. The peak currents are reduced in comparison to Figure 1. THDI equals 38% in this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

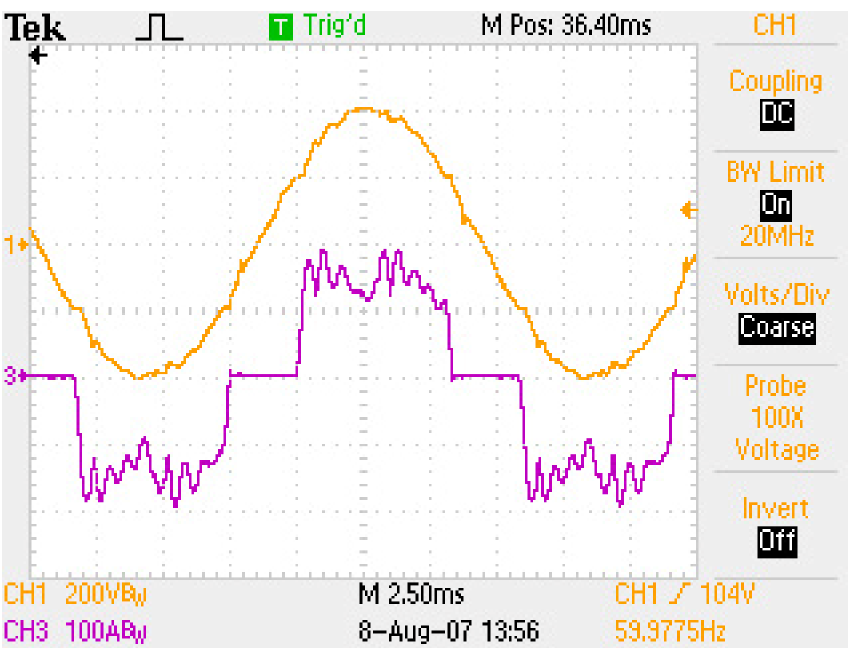

Figure 3 shows typical input voltage and current waveforms of a 100 hp Altivar 21 AC drive controller. Note the dramatic change in the shape of the input current waveform. The current peaks reach up to 190 A, similar to results with a line reactor. Because of the reduced capacitance, the input current is a square shaped waveform, eliminating the large double-humped waveform which generates large harmonic currents. The result is fewer harmonic currents and a THDI of 33%.

Is this the end of line reactors?

While many HVAC and pump applications will no longer require the installation of a line reactor, there are some exceptions. These include installations involving high line voltage or when the available fault current on the line side terminals of the AC drive exceeds the rating of the AC drive.

A line reactor can be used where the line voltage supply consistently measures above the nominal voltage level. For instance, 480 volts is considered a nominal distribution voltage. But due to transformer tap selections or utility supply conditions, the voltage may consistently run high.

While a line reactor will reduce the effect of high line voltage, it is a less than desirable approach. The better solution would be to use the proper transformer taps and/or work with the utility to supply the nominal voltage within specification.

Reactors are sometimes installed on the output of AC drives. They are then referred to as load reactors, since they are typically connected on the load side of the drive. The load reactor reduces the voltage spikes (commonly referred to as dV/dT) seen by the connected motor.

Over the last 5-7 years, motor manufacturers have improved motor insulation. At the same time, drive manufacturers have developed motor control algorithms to better manage the output waveform to reduce voltage spikes. Together, these developments are reducing the need to install load reactors in HVAC and pump systems.

What about standards compliance?

Today there are no well known 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. It cannot be effectively applied to individual products.

The international standard IEC EN61000, Limits for Harmonic Current Emissions, is increasingly being referenced. In part 3-12, the standard discusses harmonic current limits produced by equipment connected to public low voltage systems. To comply with this standard, part 3-12, table 4, the total sum of the harmonic current distortion, often referred to as THDI, must be less than 48 percent. The Altivar 21 drive controller's THDI is below 35 percent without AC line reactors or DC chokes.

Comparison of Harmonic Mitigation Methods

There have been several methods developed over the last 15 years to mitigate harmonics. The table below provides a relative comparison of five of these methods

Solution	Advantage	Disadvantage	Typical THDI (%)	Typical Cost Ratio
Typical 6-pulse	• Widely used	• No improvement of the current wave shape • Difficult to comply with standards	>80	1
RHT technology	• Simple design • Lowest cost	• Limited to range • Difficult to comply with the most severe standards • Poor voltage sag ride-through	<35	0.90-0.95
AC or DC line reactors	• Simple • Low 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 connect after commissionin g (curative 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* converter)	• Sinusoidal current • Optional regenerative control is possible	• High-cost for HVAC and pump and market • Specific design	<5	2.0-3.0

What are the benefits of being line reactor free?

Elevated available fault currents – say above 5 k – are not present in over 85 percent of the HVAC and pump applications in commercial, educational, healthcare or lodging buildings. This presents a significant opportunity to reduce system costs in a majority of these facilities.

When you no longer need to specify or install a line reactor, the savings in installation costs are immediate. Not only do you eliminate the cost of purchasing a line reactor, but you also free up the mounting space in mechanical rooms normally occupied by line reactors. This also lightens the weight of the installation. Drives with RHT designs reduce system installation time, minimize wire size and reduce wiring between components, contributing to the upfront cost savings.

Since line reactors consume energy, their elimination also removes a drag on efficiency and automatically makes your system consume less energy. And because reactors give off heat, system designs without them will mean fewer measures for heat dissipation. In addition, eliminating line reactors does away with the voltage drops they cause.

One drawback of the RHT design of the Altivar 21 drive controller is that the lower DC bus capacitance means it has a reduced capacity to ride through AC power line dips or sags. To compensate, the drive has an auto-restart feature and a robust catch-on-the-fly algorithm designed for the effect of voltage dips and sags. This 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 it in the proper direction. This is a useful feature for wind-milling fan loads.

Integrating harmonic mitigation technology into drives continues the industry trend toward more functional, compact and cost-effective motor control solutions. It enables design engineers to improve pump and fan system performance while lowering energy costs for building owners.

For more information about the Altivar 21 drive and other innovative, energy-saving drive solutions from Schneider Electric, visit www.schneider-electric.us.

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