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Increasing Motor Efficiency With Power Factor Control

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"Global Warming, Carbon Footprint, and Energy Efficiency" are becoming mantras for the industrial manufacturing sector. With energy costs constantly rising leading to increased overhead costs, the need to use electrical energy in a more efficient manner by reducing the amount is at the fundamental basis of this crisis.

Over 40 million electric motors are used in manufacturing operations in the United States alone (1). Electric motors account for 65 to 70 percent of industrial electrical energy consumption and approximately 57 percent of all electrical consumption worldwide (2). Saving even a few percent of the world's estimated 16,000-plus terawatt-hours (TWh) annual consumption of electricity (3) amounts to several hundreds of trillions of watt-hours per year.

Governments around the world are mandating regulatory pressure to increase motor efficiency. In the United States, EISA (aka Energy Independence & Security Act - Public Law 110-140) was signed by President Bush on December 19, 2007 and will become effective on December 19, 2010. Beginning on December 19, 2010, motor manufacturers may not sell motors built after December 19, 2010 with a lower nameplate efficiency than EISA allows.

EISA applies to both NEMA and IEC motors with features described in the details of the law. EISA allows motors that are considered "finished goods" or are shipped from the factory before December 19, 2010 to be sold after December 19, 2010. In March 2009, the European Union passed Minimum Efficiency Performance Standards (MEPS) for motors.



Brazil and China have current or planned mandatory electrical motor standards. Many motor applications will utilize an oversize motor for the required mechanical load. Some applications employ a motor's full speed operation and control the output by mechanical means. These types of implementation for motor applications waste precious energy, since they are ran at full speed operation.

Currently, the average motor in use today has an efficiency of 88 percent in converting electrical into mechanical energy. Even an efficient compliant motor can reduce energy by no more than 10 percent, even under optimum operating conditions (i.e. full line voltage). Industrial motor users are finding that further energy savings can be realized by using electronic speed controls (i.e. inverter based), which can reduce energy by 30 percent, and mechanical energy by 60 percent (4).

Numerous motors operate at light loads. According to a Department of Energy study, 44 percent of motors in industrial facilities operate at 40 percent or less of full load and are thus, operating inefficiently. A drive's contribution to energy savings lies in its ability to allow you to

manage motor operations to reduce output power by controlling its speed. Managing motor speeds, ramps, and available torque translates directly into managing power consumption (5).

Power Factor

Electronic designers are now looking to maximize the energy efficiency of a motor drive application using Power Factor Control (i.e. PFC). Utilizing an electronic drive to regulating the output speed of the motor for the mechanical load required, with the addition of Power Factor Control improves efficiency of the drive by correcting the out of phase voltage and current being used.

Power factor is defined by the relationship between the instantaneous voltage and current waveform being applied. When the PF=1 (maximum), both the voltage and current are completely in phase with one another. This happens when the load is purely resistive. If the current and voltage are out of phase, the power factor is less than one. This happens in the case of a motor.

The load looks inductive, which causes an out of phase condition. Thus power being applied will not be used optimally, wasting energy. Since the voltage at the motor input is fixed, the current increases to compensate for this phase shift to supply the necessary mechanical power required. Not only does this situation cost more money to operate, it impacts infrastructure cost having to use larger conductors to power motors and larger circuit breakers.

Finally, more heat is generated by the motor yielding a shorter operating life for it. Thus implementing a power factor design in a drive will yield less energy usage, lower implementation cost (size, mechanical, wiring, safety), flexibility (speed), and longer motor life.

Types Of Power Factor Control

Classic Power Factor Control (i.e. PFC) circuits used in many drive applications have been the single boost topology. Recently, Interleave Power Factor has gained much interest in the drive community. Each of these types of PFC topologies has distinct benefits. Let's take a closer look at what each has to offer the designer.

Cost

Inductors

The single boost PFC requires a single boost inductor and power switch. However, in high power motor applications (i.e. 3HP or greater), the boost inductor becomes quite large. In addition, this larger coil has increased losses, is bulky, and costly due to the large amount of copper being used.

The Interleave PFC has two parallel boost stages working 180° out-of-phase with each other. This results in the requirement to use smaller boost inductors. Two small current sense transformers are also need for feedback control.

The two smaller inductor sizes are the result of the two boost circuits working 180° out-of-phase. This unique technique reduces both the input and output ripple current. The results of this lower ripple current will reduce total inductor boost volume and the size of the EMI filter. Thus overall lower systems costs are realized.

Link Capacitors

Depending on the allowable motor ripple current, the single boost inductor will require a large amount of electrolytic capacitors to smooth the output from the PFC. The Interleave PFC has roughly 50 percent less high-frequency output capacitor current requirements compared to a single-stage topology. This reduction in current can result up to a savings of 25 percent reduction in boost capacitor volume.

Complexity

Single boost PFC circuits are supported by a wide variety of controllers. Thus as a mature technology, advanced designs by IC suppliers in reducing the amount of support circuitry (i.e. discrete components) required by integrating functionality into the controller have been realized. Therefore, these types of circuits are easily implemented.

Previously, designing an Interleave PFC circuit was rather complex requiring a lot of analog circuitry. However, Texas Instruments has made designing this topology much simpler using their UCC28070 controller. Although more support discrete components are required over the single boost type of PFC, the two out of phase boost circuits are identical making the design simple.

Efficiency

Both the single boost and interleave will increase the drive's efficiency over the ±10 percent input voltage range. The TI UCC28070 Interleave Controller has additional provisions to improve light load conditions by turning off a phase under these conditions.

Increased Power Density & Size

Reduction in size and volume of the boost inductors, along with lower electrolytic capacitor requirements, give the Interleave a clear advantage over single boost PFC in both density and size of the drive. Thus, integrating both the drive and motor as a single unit is technically feasible.

Power Module Solutions

VincoTech GmbH, a leading manufacture of both IGBT and Mosfet based power modules, has a wide variety of PFC module solutions for the motor drive designer to choose. Whether the choice is single boost or Interleave, the right module for the application is available for the design.

Based upon these two power switch technologies, a designer can choose a module which is based upon performance using silicon carbide boost diodes, or stealth types for lower cost considerations. The selection of the type of power switch and diode combination will be based upon the designer's requirement of switching frequencies, losses, and cost.

Module vs. Discrete Solution

With drives becoming a commodity product, especially in the lower horsepower ranges, cost is a driving factor. Many designers have utilized low cost discrete packaged power switches and have ignored using the benefits of a module solution. From a design standpoint, VincoTech's modules are designed to have very low inductance and extremely tight current loops.

This keeps the effects of electrical noise to a minimum. Savings in using less noise components to counter these effects are realized. Modules, which are assembled and fully tested for conformity, offer a higher reliability component than multiple point to point connections for discrettes. Using VincoTech's flowSIM simulator, a designer can determine the exact losses, die temperature, and other electrical characteristics for a given drive application.

Each component that VincoTech qualifies, have numerous actual measurements taken under a wide range of electrical test conditions. This results in a very accurate model for each component used in the database's simulator. Thus, the results of any VincoTech module selected for an application's electrical parameters are true to real world results. This saves design time and guess work.

Finally, assembly becomes much easier since a single component (versus many discrettes) is used in the PCB. Reduced design time, increase reliability, and ease of assembly are thus realized. These overlooked facts lead to a much lower "total ownership cost" over discrete solutions.

Single Boost Type

Providing the designer with a diode bridge (D30) or ½ controlled inrush SCR (D40) front end plus a 500V CoolMOS power switch, the V2390-P802 will be the module choice for the application.

Interleave Type

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In the case where small size and low losses are the driving factor, a PFC module utilizing advanced CoolMOS CP plus SiC boost diode will be the best solution. If the designer needs to keep the magnetics and capacitance small by using a high switching frequency, the FZ062TA99FH-P980D18 will give the designer the ability to switch up to 200 KHz.

In applications where size or bulkiness is not a major consideration but cost is, the FZ062TA030FB-P983D18 using IGBT plus Stealth diode technology is available. As in the single boost type, either a full diode bridge or a 1/2 control SCR can be specified.

Integrated With Inverter

If the designer wishes to take a more integrated approach such as incorporating a six pack inverter with a PFC solution, VincoTech has a broad range of modules to meet these types of applications. Available in a low cost but ruggedize flow0 package, the PIM [PIM (C +PFC) i.e. P37x series] will meet both performance and cost considerations for single boost PFC applications on motor sizes 2HP to 3HP range.

Conclusion

As the industrial market looks to replace old inefficient motors, and new equipment manufactures look to make use of better variable speed motor solutions, high efficient drives will be the solution. Manufactures that offer motor drives with power factor control will be able to work with OEM customers meeting the needs of energy efficiency, low installation cost, and flexibility.

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