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# Advances in Motor Technology and Energy Efficiency Initiatives Demand Next-Generation, Multiple-Capability Drives

WHITE PAPER

## Reduce Total Cost of Ownership

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# Advances in Motor Technology and Energy Efficiency Initiatives Demand Next-Generation, Multiple-Capability Drives

This industry demand calls for an all-in one, variable frequency inverter that delivers outstanding performance in any environment.

***Introduction***

Factories and machine builders are seeking ways to boost motor efficiency to intelligently maximize energy savings. At the same time, these users are transitioning from induction motors to interior permanent motors (IPM).

These trends are propelling the need for higher performance drives that are facilitated through such innovations as variable frequency inverter technology.

Variable frequency drives (VFDs) are electronic systems used to control motor speed by changing the frequency and voltage supplied to the motor. VFDs provide energy savings by matching power consumption to actual power needs.

Any machine or process that can be improved by varying speed or flow is a candidate for a VFD. Variable frequency drives are used in all types of industries to achieve multiple speeds of operation in induction motors. But, industries that are adopting the use of IPMs, such as oil and gas, metals and mining, power generation, water and wastewater, cement, and wind energy, demand high power, high performance drives in order to maximize productivity.

Original equipment manufacturers (OEMs), end users and systems integrators are increasingly seeking a multiple-capability VFD that can be used in both induction motors and next-generation interior permanent motors – one that would be suitable for both low performance applications such as pumps and fans, as well as high performance industrial applications. The drive would have to be fast, dependable, easy to use, easy to integrate and install, and built for the long run. This industry demand calls for an all-in one, variable frequency inverter that delivers outstanding performance in any environment.

***VFD technology drives energy savings***

Specific factors driving the need for VFD technology to increase energy efficiency include rising energy prices and stringent energy efficiency regulations imposed by various regulatory authorities around the world. (In the U.S., the Energy Independence and Security Act (EISA) mandated upgrades to full-load efficiencies, and the Committee of European manufacturers of Electrical Machines and Electronic Power (CEMEP) also developed its efficiency classification for induction motors.) Within the industrial automation market, these factors are compounded by the need for increasing plant and machinery efficiencies, and the demand for higher performance at reduced costs.

Using VFDs for energy efficiency initiatives within HVAC applications is evident, since these drives allow the use of only the power needed to cool or heat a room or building. Conventional building HVAC applications operate fans and pumps at a constant speed. Building loads, however, are not constant. In a conventional system, the use of mechanical throttling can reduce water or air flow in the system. The drive motor, however, continues to operate at full speed, using approximately the same amount of energy regardless of the cooling or heating load on the system. While mechanical throttling can provide a good level of control, it's not efficient. VFDs offer an efficient and effective alternative. Since building systems are sized for peak load conditions, pump and fan motors use more energy than necessary during most of their operating hours. Variable frequency drives allow the use of energy as demand increases, and only in the amounts necessary.

Additionally, using VFDs in air handlers, pumps, chillers and tower fans, for example, not only saves energy, but reduces the motor starting current. Variable frequency drives also reduce thermal and mechanical stresses on motors and belts during starts, resulting in a higher power factor and lower kVA. Consequently, using VFDs not only lowers energy costs, but can also mean greater operational savings.

Variable frequency drives allow the use of energy as demand increases, and only in the amounts necessary.

***Benefits of VFD use beyond pumps and fans***

Beyond its use for energy and cost savings in HVAC applications, VFD technology facilitates energy efficiency in all types of motors used in industrial plants. Electric motors represent nearly 50 percent of industrial energy consumed in the U.S., according to the Natural Resources Defense Council. Consequently, controlling the speed of these motors can have a dramatic impact on a plant's ability to optimize energy use, as well increase machinery efficiencies and meet the demand for higher performance.

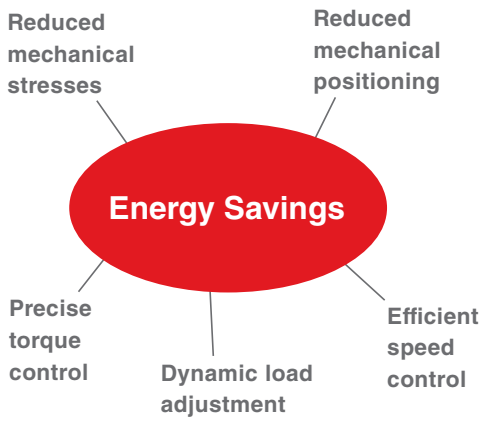
Variable frequency inverters are extremely valuable in applications that require precise speed control. And, by operating motors at the most efficient speed for the application, fewer mistakes occur, and thus, production levels increase.

Variable frequency drives, by controlling the speed of a motor in real time, are able to adjust energy use according to need. By varying motor speed to meet the exact process demand, VFDs eliminate the excess energy used when running a motor at a fixed speed. Consequently, VFDs can lower energy consumption by allowing a motor's power level to be adjusted exactly to performance needs.

In a pipeline, for example, the motor runs at the same speed and consumes virtually the same amount of energy whether it's 20 percent or 100 percent full of fluid. By installing a VFD, the motor can be slowed to 20 percent speed, thus saving money by consuming less energy.

Variable frequency drives offer many advantages beyond energy savings, thus their adoption in industrial applications continues to grow. One such advantage is that VFD driven motors respond rapidly to changing load conditions, for example, in response to shock loads. VFD-driven motors also provide precision torque output.

**FIGURE 1, VFD Benefits**




Additionally, the majority of heavy equipment is designed and manufactured so that it can operate efficiently at peak loads. However, user demand doesn't always necessitate running equipment at peak levels. In fact, in many instances, companies keep equipment running even when it's not needed because of the effort it takes to shut machines down completely, and then ramp them up again. VFDs allow the option to put equipment in idle mode.

VFDs also help to achieve tighter process control. No other AC motor control method compares to variable speed drives when it comes to accurate process control. Variable frequency drives can be programmed to run the motor at a precise speed, stop at a precise position, or apply a specific amount of torque. In addition, VFDs also extend equipment life and reduce downtime. Because of the variable speed drive's optimal control of the motor's frequency and voltage, the VFD will offer better protection of the motor from issues such as electrothermal overloads, phase protection, under voltage and overvoltage.

Also, single-speed starting methods activate motors abruptly, subjecting the motor to a high starting torque and current surges. VFDs, on the other hand, gradually ramp the motor up to operating speed. This lessens mechanical and electrical stress, reducing maintenance and repair costs, and extending the life of the motor and the driven equipment. Variable frequency drives can also run a motor in specialized patterns to further minimize mechanical and electrical stress. For example, an S-curve pattern can be applied to a conveyor application for smoother deceleration/acceleration control, which reduces the backlash that can occur when a conveyor accelerates or decelerates.

Factory automation professionals are continuously pressured to increase productivity by improving equipment reliability and plant availability. However, with the realities of increasing operations costs, decreased operating budgets and rising energy costs, these goals can be at odds with one another. Because of their high performance and lower power consumption, VFDs can help end users achieve these goals in a variety of demanding industrial applications.

IPM motors provide improved motor performance and integrity.

***Increasing use of interior permanent motors (IPMs)***

As adjustable speed drives increase in popularity, interior permanent magnet (IPM) motors are gaining more recognition for highefficiency performance. In principle, there are no size limitations to IPM designs; they can be developed from fractional horsepower to very high HP ratings, making them ideally suited to complex, demanding applications.

A relatively new design, an IPM motor uses reluctance through magnetic resistance in addition to magnetic torque by embedding a permanent magnet in the rotor itself. Because the magnets are mounted within the rotor structure, unlike conventional permanent magnet motors where magnets are mounted on the rotor surface, IPM motors provide improved motor performance and integrity. IPM motors are particularly beneficial when used in conjunction with vector control, in which case, the electronic controller tracks the rotor position with respect to the stator field and injects the current to optimize torque production and efficiency.

In an application requiring constant torque, such as a conveyor, factory energy savings can be achieved by replacing induction motors with IPM motors. IPM motors are more efficient because the current doesn't flow to the rotor, so there is no secondary copper loss. Magnetic flux is generated by the permanent magnets, so less current is required to drive a motor. Thus, an IPM motor used in a conveyor can maintain a constant carrying speed, while saving energy.

Recent advances in IPM motor technology have resulted in motors that are markedly more efficient over a broad operating range compared with AC induction motor designs. These advances, combined with modern control methods, are fueling the acceptance of IPM motors in the most challenging applications. The power density of an IPM motor is greater than an induction motor, so it produces more power at a smaller size. IPM motors can also continuously deliver high torque at low speed. The high power density of IPM motors combined with the ability to deliver high continuous torque over their entire speed range eliminates the need for gearing or other mechanical transmission devices in some applications. They can also reduce maintenance costs and space requirements, while increasing reliability.

IPM motors are gaining increasing popularity in demanding motion control applications because of their high efficiencies and energy-reduction potential across various torque and speed ranges. These next-generation IPM motors, when paired with variable frequency drives, are ideally suited to the most complex and challenging industrial applications.

Variable frequency drives are also seeing increased use in high-speed winding, because of the precision required in such applications.

***IPM motors and increasingly challenging applications are driving VFD demand***

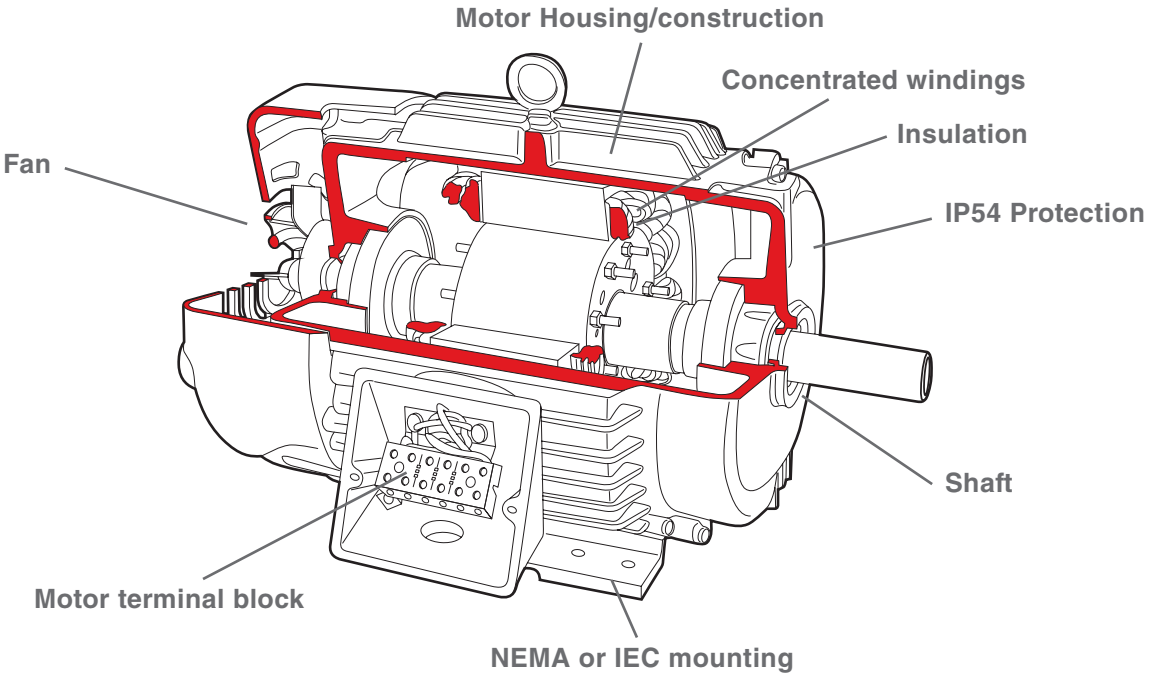
As adjustable speed drives increase in popularity, The union of IPM motors and VFDs in high performance industrial applications creates the need for even greater advances in variable frequency technology to ensure performance, reliability, precision, speed, and networking capabilities.

While the number of applications suitable for early generation VFDs was limited based on the horsepower of the motor, innovations in variable frequency technology now make them well suited to high performance industrial applications. Early generation systems also suffered from low power factor. Today's VFDs operate at a nearly constant power factor over the entire speed range of the motor. As VFDs continue to evolve, they are proving to be more useful and powerful.

For most end users of high performance drives, reliability is an absolute necessity. This is especially true for operations where machines far outnumber personnel, such as in a sawmill. For one employee in a control room loading trees on a conveyor, a failed drive means the entire operation shuts down. In the process of loading trees on a conveyor, analyzing lumber sizes for optimum yield, then cutting up the log, drive reliability is imperative. If the drive trips from overuse or if there is a hiccup in the system, there's a big price tag to find the problem and fix or reset it.

In some applications, such as material handling, speed is just as important as reliability. For mail and package delivery, especially in December when services can increase by as much as 13 percent, a delivery company's reputation is contingent upon ontime delivery. Moving thousands of letters and packages on a large conveyor, scanning bar codes, looking up the bar code information in a database, then sending the signal via the VFD to the diverter requires an extremely high rate of speed. There's a very small window in which the diverter takes that signal and reacts. Only a variable frequency drive offers both the high rate of speed, and the ability to control the speed required in such a demanding application. Similarly, in the food and beverage industry, where speed is critical to throughput and productivity, using a combination of IPM motors and VFDs can help companies stay competitive.

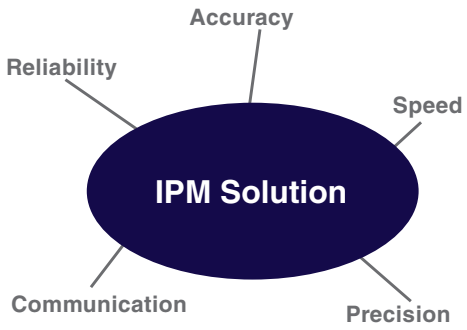
**FIGURE 2, Typical AC Motor**



Engineers can now specify one VFD for all their motor control needs.

Variable frequency drives are also seeing increased use in high-speed winding, because of the precision required in such applications. In the intricate and complex printing process, for example, in order to achieve a crisp image, unfolding the paper and feeding it through the printing press requires tight synchronization. The VFD must control speed and accuracy, and maintain tension as the paper is fed through the machine so the ink is properly distributed and doesn't create a smeared image. Using a VFD with sensorless vector control can further ensure precision because it minimizes speed fluctuations of the ink roller axis and water roller axis to eliminate print unevenness.

**FIGURE 3, IPM Solution Benefits**




Modern VFDs must also provide advanced networking capabilities. Today's automated enterprises are connected and collaborative. An automotive manufacturer, for example, consists of various departments using different technologies from a myriad of manufacturers. A variable frequency drive that could be used interchangeably by welding, painting and other departments, can act as a bridge connecting the departments, with the drive acting as one common hardware component. Only the option card for the network would be different. The drive would have to offer numerous networking options allowing compatibility to various open networks.

***The Mitsubishi Electric FR-A800 Series***

Most variable frequency drives provide improved process control, energy savings and reduced maintenance. Competitive pressures within manufacturing and other industries require that they also provide high performance, reliability, precision and network compatibility, as well as a lower total cost of ownership, reduced spares and a smaller footprint. This can only be achieved with a multi-capability VFD that can be used in induction motors as well as next generation IPM motors, and in low performance applications as well as the most demanding industrial applications.

Until now, engineers had to consider many factors in choosing a VFD or motor controller. Motor variables such as horsepower, full load amps, voltage, RPM, and service factor had to be considered. In addition, other information specific to the needs of the system and application, such as type of load (constant torque or variable torque), speed range, control method, and special enclosure needs, would have to be matched to the drive specifications.

The Mitsubishi Electric FR-A800 all-in-one variable frequency inverter enables engineers to specify a single VFD solution for all their motor control needs. The FR-A800 VFD is designed for maximum capacity, to optimize motor efficiency in peak situations and ensure that there are no failures at times of highest demand. While the FR-A800 provides high performance in severe duty situations, it can be scaled to fit any environment, eliminating the need for multiple solutions to address various motor control challenges. It's also designed for flexibility to grow with an application.

Variable frequency drives can significantly reduce the total cost of ownership of both the motor and the drive.

A permanent motor auto-tuning function allows the FR-A800 to operate with all Mitsubishi Electric induction motors and permanent magnet motors, as well as virtually all induction motors and permanent magnet motors from other manufacturers. This requires fewer spare motors to be stocked.

**FIGURE 4, FR-A800**


The FR-A800 inverter features real sensorless vector control to provide high-precision, fast response speed control. The inverter also offers a choice of V/F control or advanced magnetic flux vector control, allowing simple replacement of a conventional unit inverter drive.

A PLC function has also been added to Mitsubishi Electric's latest generation VFD. Now, when using sensors to check the presence and arrival of goods on a conveyor, for example, the drive can directly receive such signals from sensors and then command the speed accordingly.

The drive system's energy monitor allows users to confirm energy saving at a glance. This provides the ability to visualize energy usage in real time, rather than waiting for energy bills, allowing the management and optimization of energy use. Mitsubishi Electric's energy-optimization software boosts motor efficiency and intelligently maximizes energy savings. Meanwhile, optimum control of the excitation current maximizes motor efficiency for additional energy reduction.

The FR-A800 premium VFD offers compatibility with various open networks. It's equipped with USB, RS485 and Modbus®-RTU interfaces. Communication options are also available for the major network protocols such as CC-Link® IE Field and CC-Link, EtherCat®, and SSCNET III/H as well as DeviceNet™, PROFIBUS®-DP, and LONWORKS®. Other Ethernet networks are also supported. With a 10-year design life, the FR-A800 inverter is built for reliable, long-term operation and is backed by Mitsubishi Electric's superior maintenance and service for the life of the drive. Its total cost of ownership is not only measured by amortizing the cost of the drive over its 10-year life, but by the reduction in energy costs over those 10 years.

Designed for ease of use anywhere in the world, the FR-A800 includes a multilanguage LCD parameter unit and complies with the most demanding global standards. With unparalleled drive precision, speed control, powerful startup, ease of use, simple installation and integration, and long operating life, the FR-A800 all-in-one inverter meets the demands of OEMs, systems integrators and end users for a multiple-capability inverter that can deliver superior performance in any environment.

FIGURE 5, FR-A800 Features and Benefits

| Feature | Benefit |
|---|---|
| Real Sensorless Vector (RSV) Control | High precision and fast response speed control |
| PLC Function | Sequence control and flexibility for complex applications |
| Energy Monitoring | Real-time confirmation and energy savings at a glance |
| Open Network Compatibility | Simple connection to other devices on the plant floor or facility |
| Autotuning | Optimized control for standard induction and IPM motors |
| Reliability | Built with 10-year design life |
| Satisfies Global Standards | Can be used anywhere in the world |


***Summary***

Historically, motor purchases have essentially been based on dollars-per-horsepower costs. Increasingly, savvy buyers are now looking closely at the true cost of ownership for both the motor itself and the drive system. This broad perspective includes the cost of powering the equipment over its useful life and the opportunity to substantially reduce those costs. Short-term hardware expense of motors and drives must be evaluated against the long-term cost savings. With few exceptions, variable frequency drives can significantly reduce the total cost of ownership of both the motor and the drive.

The versatility of the Mitsubishi Electric FR-A800 exponentially reduces total cost of ownership of a typical VFD by decreasing the number of spares required and providing industry-leading energy-savings capabilities. However, even more important than its TOC advantages, the FR-A800 meets industry demands for a fast, reliable, dependable, multi-capability VFD that can deliver superior performance in both induction motors and next-generation interior permanent motors.



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WP-VH-00101