New Motors Offer Better Performance

High energy costs from motor-driven equipment can have a big impact on an industrial plant's budget. Industrial applications that use motors—such as fans, pumps, and air compressors—consume over 60 percent of the total energy used in the industrial sector. In recent years, a few motor technologies that have the potential to significantly reduce energy costs and provide quick paybacks have advanced to commercialization (see **Table 1**). Also, the National Electrical Manufacturers Association's premium-efficiency-specification (NEMA Premium®) motors, which are more efficient than standard motors, are still widely underutilized even though they have been available for a while and offer cost-effective and long-lasting benefits. This pamphlet highlights some of the newest industrial motor technologies on the market and describes their applicability, cost-effectiveness, benefits, and limitations.

Cast-Copper Rotors

Induction motors with cast-copper rotor (CCR) bars rather than aluminum rotor bars operate at lower temperatures because they are more efficient. The degree to which Siemens' CCR motors exceed the National Electrical Manufacturers Association's premium-efficiency specifications (NEMA Premium) varies with individual motor sizes and speeds. On average, the higher conductivity characteristic of copper reduces motor energy losses by 10 to 20 percent, boosting efficiency 1 to 2 percentage points higher than that of premium-efficiency motors with aluminum rotors, as well as potentially increasing motor life. Improving the efficiency of a NEMA Premium–qualifying 20-horsepower (hp) motor from 93 to 94 percent would save about 750 kilowatt-hours (kWh) of power per year, assuming the motor operates at 75 percent load 16 hours per day, 365 days per year. Other motor types exceed NEMA Premium specifications without resorting to copper rotors, but they often sacrifice motor speed and torque to increase efficiency, which limits the applications in which they can be used. Generally, CCR motors have torque and speed ratings similar to those of aluminum-rotor motors. Because CCR motor efficiency gains decrease as the motors get larger, it is likely that they will be limited to low-horsepower applications. However, for such applications, CCR motors are the most efficient on the market.

Table 1: New industrial-sized motors

Three motor technologies have recently been commercialized that offer efficiency and performance improvements compared to conventional motor technologies.

Motor type	Size range (horsepower)	Application
Cast-copper rotor	1 to 20	Any application that requires a standard NEMA T-frame motor: compressors, pumps, and conveyors
Electrically commutated	0.01 to 5	Variable-speed applications, such as evaporator fans for walk-in refrigerators and freezers and the fans of HVAC mixing boxes
Sensorless alternating current vector drive	1 to 500	Compressors, pumps, fans, and conveyors

Source: E SOURCE

In the past, the problem with manufacturing CCRs was that copper's melting point is more than 400 degrees Celsius (760 degrees Fahrenheit)—higher than that of aluminum. The temperatures necessary to keep copper hot enough for a long enough time to cast high-quality rotors would quickly destroy the conventional steel dies used in the casting process. That problem was resolved in 2001 when a group spearheaded by the Copper Development Association successfully completed research into new die-casting materials. In 2006, Siemens became the first manufacturer to offer CCR motors to the North American market. These motors all surpass the NEMA Premium specification, and in some motor classes they are the most efficient motors available on the North American market. Because copper rotors are heavier than aluminum rotors, acceleration time may be slightly longer, but this limitation does not affect most applications.

The price of CCR motors depends on many factors, including the motor's size and speed specifications, vendor discounts, the cost of copper, and purchase quantities. In some cases, they may cost the same as NEMA Premium motors. In other cases, the cost of CCR motors may be 10 to 20 percent higher than that of other NEMA Premium motors, making them cost-effective for only certain applications.

Although a number of manufacturers worldwide produce CCR motors, Siemens is currently the only manufacturer in North America to make general-purpose CCR motors. Siemens CCR motors are built in NEMA frame series and can be applied just like any industrial motor. They can replace any standard NEMA T-frame industrial motor in sizes ranging from 1 to 20 hp with speeds of 1,800 and 3,600 rpm. They can even be ordered with special shafts or couplings to fit a variety of industrial applications, such as pump, aeronautic, compressor, and conveyor applications.

Electrically Commutated Motors

Electrically commutated motors (ECMs) are direct current (DC) motors that use magnets bonded to the rotor to create a magnetic field that requires no external power or regulation. The rotating magnetic field in the stator is provided by conventional electromagnetic windings arrayed around the circumference of the stator, similar to the arrangement of an induction motor. The DC input to the stator is transferred from coil to coil by an electronic switch called a commutator, which is precisely controlled by an optical or magnetic angular-position sensor on the rotor. This approach entirely eliminates rotor resistive losses because there are no rotor windings or their associated brush friction, voltage drop, and maintenance, yet it permits speed control at least as precise and convenient as that of a traditional DC motor. ECMs cost significantly more than conventional induction motors—3 to 4 times as much in fractional horsepower applications—but energy savings and reduced maintenance costs often result in rapid paybacks.

ECMs offer exceptional efficiency over a wide speed and load range, and their inherent variable-speed capability provides improved load control and precision. They have exceptionally high starting torque and perform well with low-speed, high-torque loads. Although some manufacturers offer integral horsepower sizes, ECMs most frequently displace single-phase, fractional horsepower motors such as shaded-pole (SP) and permanent split capacitor (PSC) designs. Fractional horsepower ECMs have full-load efficiencies ranging from percentages in the low 70s to the mid 80s and suffer relatively minor drops in efficiency at low load. For example, ECM efficiency stays above 60 percent at 10 percent of full load. In comparison, the full-load efficiency of a 0.75-hp PSC motor might be only 65 percent, and it will drop precipitously at low load to as low as 15 to 20 percent.

Due to their efficiency and versatility (variable-speed operation is built in, and a single unit can be configured to provide a broad range of power, speed, and torque), ECMs can often be cost-effective replacements for small SP and PSC motors in a variety of applications, especially in applications where the load varies. Two particularly attractive applications are the evaporator fans for walk-in refrigerators and freezers and the fans of HVAC mixing boxes.

- *Walk-in freezers.* In 2006, researchers at the Food Service Technology Center in California replaced two SP one-fifteenth-hp evaporator fan motors in a walk-in freezer with ECMs. These motors reduced fan energy consumption by 67 percent, producing annual savings of $156 each (at $0.13/kWh) and repaying the $250 installed cost in about 19 months. (All monetary values in this pamphlet are U.S. dollars.)
- *HVAC mixing boxes.* A 2003 report published by HVAC equipment manufacturer Carrier found that ECMs can provide substantial energy savings cost-effectively in this application. Across a broad range of

delivered airflow rates, a 1-hp ECM provided an average power reduction of 335 watts, or about 1,000 kWh annually at 3,000 hours of operation. Given that a large office building can have hundreds of fan terminals, significant demand savings are possible. Taken together, the energy and demand savings that ECMs offer can often provide a payback period of less than two years.

Sensorless Alternating Current Vector Drives

Vector motor drives are a relative newcomer to the variable-speed-drive market. Unlike earlier drive designs that used a constant voltage-to-frequency (volts/hertz [V/Hz]) ratio to adjust motor voltage and speed in lockstep, newer vector drives adjust voltage and frequency independently, thereby controlling motor speed and torque separately and better matching motor performance to the needs of the application. To accomplish this feat, vector drives use microprocessors to interpret feedback from motor operation and adjust their output waveform accordingly. Some vector drives rely on a position sensor called an encoder to provide this feedback, whereas others—the so-called sensorless drives—obtain feedback by analyzing the current drawn by the motor. These sensorless drives, which are available throughout the horsepower range, offer performance almost as good as those that employ encoders but have virtually no price increase over the plain-vanilla V/Hz drives.

In drives with an encoder, real-time information on shaft position is relayed to a microprocessor, which uses this feedback to determine the difference between actual and desired position and speed and adjusts the drive's output voltage and frequency accordingly. These drives provide very precise control over the motor and can even provide full-output torque at zero speed, a characteristic that has allowed them, for example, to displace DC motors in hoist and crane applications. The problem with these drives is that in the past they've been a lot more expensive than V/Hz drives.

Because sensorless vector drives are now cost-competitive with V/Hz drives, they've been gaining widespread acceptance in the market even for applications such as pumps and fans that don't require tight torque and speed control. Some motor-drive professionals expect sensorless vector drives to displace all other designs except in very demanding applications such as machine tools in which an encoder or a DC servomotor is required to provide extremely precise dynamic control.

Because there is little to no price premium for the sensorless vector drive design, these drives can be used in a wide array of applications, even those that don't require tight torque and speed control. Where your application doesn't call for fast dynamic response to load changes, be aware that the vector drive can be less efficient than a V/Hz drive. Unless the vector drive has user settings or adaptive algorithms that override this (and many now do), vector drives achieve their rapid response by keeping magnetic flux between the stator and rotor high. This practice is wasteful when dynamic response is unimportant—as in most pump and fan applications and many conveyor applications. If you're considering a vector drive for such an application, ask your drive distributor whether it can be configured to operate in V/Hz mode to save energy.

NEMA Premium

In 2001 NEMA implemented the NEMA Premium program in the hope of broadening the market share for premium-efficiency motors. Six years later market penetration estimates show that more than 70 percent of motor sales still go to standard-efficiency models, even though NEMA Premium motors could provide cost-effective energy savings in many of these applications. Efficiency specifications for NEMA Premium motors are generally 1 to 2 percentage points higher than the federal minimum standards. That may not sound like much, but when you consider that the cost of operation typically makes up about 95 percent of a motor's life-cycle cost, it often makes sense to spend a bit more up front to gain long-term savings.

NEMA Premium motor standards apply to three-phase low- and medium-voltage induction motors ranging in size from 1 to 500 hp. Manufacturers that participate in the program must sign a licensing agreement that allows them to apply the "NEMA Premium Efficiency" logo on their products. They are then required to properly test the motors, using accepted test procedures to determine efficiency. Currently, 12 major motor manufacturers offer NEMA Premium motors as part of their primary product lines.

Premium-efficiency motors typically cost 10 to 15 percent more than a standard motor, but in many cases that cost can be paid back fairly quickly through energy savings. The cost-effectiveness of a premium-efficiency motor in a given application depends on a variety of factors, such as its load level, its duty cycle, and the proposed efficiency improvement. NEMA Premium motors are particularly cost-effective in applications where the annual operation exceeds 2,000 hours, where utility rates are high, and when rebates or incentives are offered. Estimated annual savings from purchasing a NEMA Premium motor rather than a standard motor are shown in **Table 2** for a range of motor sizes.

Table 2: Energy savings from the National Electrical Manufacturers Association's premium-efficiency (NEMA Premium) motors

With an efficiency gain of about 1 percent over conventional energy-efficient motors, NEMA Premium motors can provide significant savings.

	Full-load motor efficiency (%)		Annual savings from use of a NEMA Premium motor	
Horsepower	Standard energy-efficient motor	NEMA Premium motor	Energy savings (kWh)	Cost savings ($/year)
10	89.5	91.7	1,200	60
25	92.4	93.6	1,553	78
50	93.0	94.5	3,820	191
100	94.5	95.4	4,470	223
200	95.0	96.2	11,755	588

Notes: kWh = kilowatt-hour.
Calculations are based on an 1,800-rpm motor with 8,000 hours per year of operation, 75 percent load, and an electrical rate of $.05/kWh.

Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy