Look Beyond General-Purpose Motors for Additional Energy Savings

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ABSTRACT

General-purpose 1 – 200 HP motors have been the focus for energy savings for many years but significant additional electric savings are possible looking beyond these motors to with other mounting configurations. NEMA Premium® motors are available through 500 HP. Newer permanent magnet technologies can offer even higher efficiencies. The conventional energy efficiency programs should be expanded to take advantage of these opportunities for additional savings.

Introduction

The past fifteen years focused on the efficiency of “general-purpose” motors after enactment of the Energy Policy Act (EPAct) of 1992 that covered only AC induction motors of 1 – 200 horsepower with rigid mounting bases. However NEMA energy efficient and Premium® motors are available with many additional mounting configurations and enclosures. Use of Premium Efficient motors can save significant energy – all the more important in today’s higher energy price market. NEMA Premium® defines the minimum efficiency of the motor, not the motor’s mounting configuration. In addition, 250 – 500 HP medium voltage motors are also defined even thought they are excluded from EPAct.

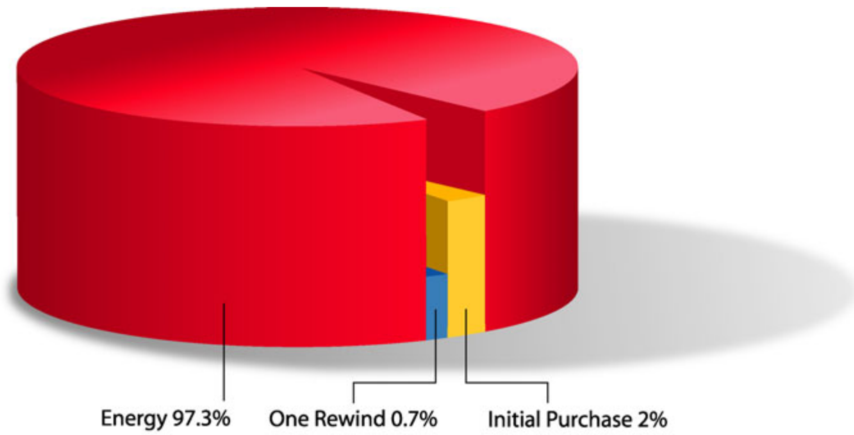
In addition to induction motors, the work horses of industry; permanent magnet rotor AC servomotors have been available for incremental motion applications for years offering significant energy savings in many applications. These motors are now available from fractional through several hundred horsepower.

A typical application such as a tensioning roll on a paper machine will be in the mid-90% range where the old DC motor was in the mid-80% with the gear reducer resulting in a 60% efficiency. In addition, these servomotors offer the potential to replace inefficient pneumatic actuation systems found throughout industry. These permanent magnet rotor motors can also lead to productivity improvements in many applications, resulting in even greater system efficiency.

Life Cycle Costs

Any motor upgrade or purchase should be evaluated by the motor’s life cycle cost, rather than its purchase price alone. Figure 1 shows the life cycle cost of a typical AC induction motor consists of only 2 percent for the purchase price and over 97 percent for the energy used over its life. Thus, looking beyond general-purpose motors can result in significant energy savings.

Figure 1. Life Cycle of an Industrial AC Electric Motor



Low Hanging Fruit First

The Energy Policy Act of 1992 defines the efficiency of general-purpose motors rated at 1 – 200 horsepower. General-purpose means the motor has a base for mounting. It may or may not have a C-face to allow a reducer or pump to be added directly to the motor. If that same motor only has a C-face without a mounting base or a special pump shaft configuration, it does not need to comply with EPAct and can be supplied we a low efficiency. Many C-face and pump motors are used through industry.

NEMA MG 1 defines the efficiency of these EPAct motors in Table 12-11, but extends the ratings through 500 horsepower in 2 through 8-pole speeds. To encourage more savings, the range of NEMA Premium® motors that are covered by incentive programs should be expanded through 500 horsepower and also to cover all continuous duty Design B motor mechanical configurations.

Step up to NEMA Premium® Motors

More energy savings could be obtained by use of the higher efficiency NEMA Premium® motors as defined in tables 12-12 and 12-13 of NEMA MG 1. NEMA Premium® efficient motors are rated at 1 through 500 horsepower in low and medium voltage with Design A and B characteristics. These higher efficiencies are used in most North American rebate programs, Federal Energy Management Program (FEMP) and the Energy Policy Act of 2005. Approximately 22 - 25 percent of motors sold in North America now have these premium efficiencies and use of these motors is growing at a higher rate than EPAct motors.

NEMA does not designate the mechanical configuration for NEMA Premium® motors. Manufacturers are supplying them in all usual configurations and enclosures including C-face and vertical pump mount, explosion proof, washdown duty, IEEE 841, etc. Most any application requiring a Design B motor may be supplied with premium efficiency.

Additional benefits beyond reduced electrical use generally include features that provide for longer life and reduced downtime in the application. A lower temperature rise and better balance provide longer grease and bearing life. Cast iron frames with machined mounting bases provide easier alignment and help to dampen noise and vibration. When upgrading the motor, it is also an opportunity to improve the environmental protection of the motor to reduce bearing and winding failures. Many users will argue that savings from reduced downtime is worth much more than energy savings alone.

Rebates and incentives for premium motors are available in many states and all Canadian Provinces. The states having the lowest costs for electricity generally do not have programs to encourage industry to switch to premium motors. Calculations result in paybacks of over two years resulting in decisions to replace on failure. A U.S. Department of Energy report believed that it would take 18 years to replace all motors based at failure. Incentives, tax credits and accelerated depreciation would help industry quickly upgrade to premium motors.

Proposed Legislation

Our U.S. government is considering legislative proposals from NEMA and ACEEE to address tax credits for use of premium efficient motors. Such tax credits will help shorten the payback time for locations that have lower cost electricity and no rebate programs from the utility. Often these motor upgrades need to offer a payback of two years or less to be considered by users.

Another proposal from NEMA and ACEEE seeks to raise the minimum efficient level for 1 – 200 HP motors to the NEMA Premium® range and to Energy Efficient for 201 – 500 HP motors. This new proposal falls short of the FEMP (Federal Energy Management Program) motor efficiency requirements mandating the purchase of NEMA Premium® efficient motors for government use included with the Energy Policy Act of 2005.

System Review for Maximum Savings

Although electric savings from upgrading to premium motors is significant, analysis of the system generally provides much more savings. The DOE United States Industrial Electric Motor Systems Market Opportunities Assessment report of December 2002 states that adding and adjustable speed drive to a pump or fan could reduce consumption by 30-50 percent. Payback on adding an inverter for an application like this could be in as little as 6 months without incentives. Generally such an upgrade would be done in conjunction with adding a premium motor. The robust insulation system of NEMA Premium® motors are suitable for use with the Pulse Width Modulated (PWM) waveform supplied by inverters.

If possible the system should be analyzed beyond simple motor replacement. Additional savings are possible by replacing V-belts with energy-efficient cogged belts that could raise system efficiency by up to 3 percent and have quick paybacks of less than 6 months.

If a right angle worm speed reducer is used, changing to an inline helical or right angle bevel reducer could raise the efficiency by 20 – 50 percent. This means that a lower horsepower motor could be used to drive the load resulting in a lower initial price and also less electricity consumed.

Pump Systems Matter

The more engineering effort used to analyze the system, the greater the potential for savings. DOE has software available for pump systems analysis (PSAT) and for fan systems (FSAT). This analysis software is available from DOE's Office of Industrial Technologies website at http://www1.eere.energy.gov/industry/bestpractices/software.html. Additional efforts on compressed air analysis have resulted in significant savings.

The Hydraulic Institute and other interested parties have formed a group called Pump Systems Matter to promote energy efficiency through increasing the efficiency and design of pump systems. Certified system analysts use software to analyze existing and new systems and recommend more efficient solutions. NEMA Premium® motors and adjustable speed drives are also recommended by HI.

Increased Productivity and New Technology

As energy surveys are completed, benchmarking of units produced per kWh is established. Servomotors are being used to increase throughput by moving parts from place to place more quickly than on a conventional fixed-speed conveyor. These high efficiency servos are replacing many air and hydraulic actuators. Servos also save in maintenance costs and production downtime.

Several manufacturers are producing higher output versions of these permanent magnet rotor motors through 500 horsepower or more. When compared to NEMA Premium® motors, the efficiencies by be up to 3 percent higher. An additional advantage is in the motor's size and power density.

A paper was presented at the 2006 IEEE Petroleum and Chemical Industry Conference comparing an inverter duty induction motor rated at 75 Hp – 1800 RPM that was built in a 250-frame size. The squirrel-cage rotor was removed and replaced with a surface mounted and an imbedded salient-pole permanent magnet rotor and both produced more output with increased efficiency and greatly reduced temperature rise. Table 1 illustrates the performance differences between these three designs. Although the surface PM motor design can supply more power from the same frame size (power density) as the induction motor, the salient pole PM motor design can supply even more. Looking at these designs, the surface mount PM has a higher efficiency, but the salient pole with embedded magnets has a higher power density. Additional development may also raise the efficiency of the salient pole motor.

Table 1. Comparison of Motor Efficiencies Between AC Induction and PM Rotor Types

	Induction Motor	Surface PM	Salient Pole PM
Horsepower (heat run)	75.5 Hp	75.4 Hp	68.9 Hp
Volts	459 v	405 v	417 v
Base frequency	60 Hz	120 Hz	40.2 Hz
Full load amps	92.3 a	85 a	88 a
Full load speed	1768 rpm	1800 rpm	1206 rpm
Full load efficiency	93.6%	96.2%	96.0%
Full load power factor	82.0%	98.1%	84.0%
Full load torque	224 lb-ft	220 lb-ft	300 lb-ft
Total motor losses	3.88 kW	2.23 kW	2.14 kW
Temperature rise by resistance	111.5° C	70.7° C	90° C

Since this paper was presented in 2006, additional development of these PM-rotor motors has been done. Efficiencies of 98% or more are possible for 400 – 500 HP motor designs. 4-pole TEFC versions of 250 - 500 HP motors would be 96.2% efficiency. Standard versions are in the

95.8% range. Doesn't seem like much difference but with 3 shifts at $0.06 / kWh with a 400 HP, annual savings would be $2351 and 13,000 kWh. These new permanent magnet designs have efficiencies that are well above NEMA Premium®. Some large motors have tested to 98.3% Eff. A 400 HP at 98% would save $4200 a year over the 96.2% premium motor.

Significant electric savings are possible by using these permanent magnet motors and servomotors. Efficiency programs should recognize these PM rotor motors as an acceptable solution that would qualify for incentives and rebates.

Consider Upgrading DC Motors

Many machines in industry such as plastic extruders continue to rely on DC motors for their main power. 40 – 400 horsepower motors that have efficiency in the 88 - 92 percent range typically power extruders. This is not low, but not as high as NEMA Premium® motors at 94 – 96 percent. The DC motors require an SCR (thyristor) adjustable speed control. Energy savings are possible when switching from a DC to AC motor and drive. Additional savings will be seen from eliminating the brush and commutator maintenance on all DC motors. Plus the newer AC vector controls can offer more accurate process control than older analog DC controls. A 40 Hp DC motor with 88% efficiency requires $10,173 worth of electricity ($0.075/kWh) to operate 2-shifts. An AC motor would have 94.5% efficiency and require $9,473 to operate, a $700 per year savings. Additional savings are from elimination of brush and commutator maintenance and eliminating downtime from removing the machine from operation. It may take an hour for brush replacement and three hours to remove the motor and replace it with a spare so commutator service may be performed. At typical downtime of $10,000 per hour, savings from eliminating typical DC maintenance is significant.

Single-Phase Motor Use

Many large capital machines are supplied with three-phase motors for operation. When specifying this equipment, the savvy purchaser would look at life cycle cost and select NEMA Premium® motors where justified. Some machinery may come with PM rotor servos. But some may be supplied with single-phase motors on auxiliary equipment such as a chip conveyor on a high-tech CNC machining center. This single-phase motor is very inefficient and should be replaced with a three-phase motor for electricity savings and to prevent downtime from potential failure of the starting switch or capacitor. Premium efficient motors are available for single phase, but they are not as efficient as general-purpose three-phase motors. Table 2 shows typical efficiency for single and three-phase motors.

Table 2. Comparison of Single vs. Three-phase Efficiencies

Motor Type	Typical Efficiency
General-purpose single-phase motor	80.0%
Premium single-phase motor	86.5%
General-purpose three-phase motor	87.5%
NEMA Premium® three-phase motor	90.2%

Usually the worst three-phase motor has a higher efficiency than the best available single-phase motor. Always specify three-phase motors when possible.

Conclusion

All of these efforts require a market transformation to evaluating equipment and processes based on life cycle costs rather than first cost. As electric rates continue to climb, more industrial companies are beginning to seek solutions to help reduce their electricity costs. Existing technologies and "best practices" are available to reduce energy consumption by 30 – 50 percent according to the DOE's United States Industrial Electric Motor Systems Market Opportunities Assessment report of December 2002. Many of the solutions discussed in this paper are not covered by existing programs and may not even be accepted by today's custom programs, but these technologies need to be added. Adding these newer technologies to programs proposing additional federal tax incentives such as accelerated depreciation would help push along the transformation to more efficient equipment, resulting in less electricity used and less CO_2 emissions.

In summary, the key points to remember are:

- Evaluate motor selection based on life cycle cost, not initial price
- Specify NEMA Premium® efficient motors for continuous duty applications
- Consider further upgrades to permanent magnet rotor motors for even greater efficiency
- System efficiency upgrades are possible to maximize potential gains.
- Grooved high-efficiency V-belts
- Replace DC motors with AC NEMA Premium® efficient motors
- Consider use of high-efficiency helical or bevel gear reducers
- Use pump or fan systems analysis tools
- If possible, specify three-phase motors instead of single-phase motors
- Newer technologies should be accepted into the utility's incentive programs
- Government legislation may add additional tax incentives to reduce payback

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