How motor upgrades can improve pump system efficiency

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Overview

Electric motors are responsible for more than one-third of the world's energy usage, and in the U.S., pumps consume 40 percent of the total industrial motor systems' electricity[1]. These pump systems heat and cool buildings, irrigate farms and move chemicals, petroleum, food and beverages. New pumps are inherently efficient; however, there are many old pumps still in operation with efficiency that is poor compared to the pumps developed and available today. Energy regulations have played a significant role in the increased focus on efficiency; not only for the motor, but also for the pump and system as a whole. Facilities can achieve dramatic electricity and cost savings from their pump systems by applying energy management best practices and purchasing energy-efficient equipment.

An industrial facility can reduce electricity costs associated with its pumping systems by reducing the pumping system flow rate, lowering the operating pressure, operating the system for a shorter period each day and, perhaps most importantly, improving the system's overall efficiency. Energy-efficient solutions include using multiple pumps, adding smaller auxiliary pumps, replacing impellers or adding a variable speed drive (VSD). In addition to lower electricity costs, a more efficient pump system also means reduced preventative maintenance, longer time between repairs, reduced CO_2 emissions and a more reliable system overall.

This article focuses on the benefits of optimizing an older pump system by replacing a standard motor with a more energy efficient motor; for example, moving from a NEMA Standard Efficiency (comparable to the International Electrotechnical Commission IE1 efficiency rating) to a NEMA Premium Efficiency (IE3) motor. Even greater cost savings can be realized by upgrading to a NEMA Super Premium Efficiency (IE4) motor or a motor/VSD pairing that reaches even higher efficiency levels not yet defined by NEMA (Ultra Premium or IE5+ equivalent).

Purchase price vs. operating costs

The increase in active materials, including copper and high-grade electrical steel, required to meet the Premium Efficiency level may add cost to the motor, but the higher efficiency translates into more energy savings and reduced total cost of ownership. To compare the operating cost of an existing standard motor with an appropriately sized energy-efficient replacement, it is necessary to determine operating hours, efficiency improvement values and load. Operating cost is an important factor in a motor upgrade since the annual energy cost of running a motor is usually many times greater than its initial purchase price. For example, even at the relatively low electricity rate of $0.08/kWh, a typical 25 horsepower motor running continuously uses almost $6,000 worth of electricity annually - about six times its initial purchase price.

Table 1
Annual savings for Premium Efficiency versus Standard Efficiency motors, based on purchase of an 1,800 RPM totally enclosed fan cooled motor in operation 8,000 hours per year at 75% load at a cost of $0.08/kilowatt-hour (kWh)[2].

	Motor efficiency at 75% load			Annual savings from using a premium efficiency motor	
Horsepower	**Standard Efficiency motor**	**Premium Efficiency motor**	**List price (example only)**	**Annual electricity savings, kWh**	**Dollar savings, $/year**
10	86.7	92.2	$1,329	3,105	250
25	89.9	93.8	$ 3,246	5,160	410
50	91.6	95.0	$ 7,050	8,630	690
100	92.2	95.3	$12,952	15,680	1,255
200	**93.3**	**96.2**	**$ 23,119**	**29,350**	**2,350**

As shown in table 1, the extra cost of an energy-efficient motor is often repaid quickly in electricity savings, and thereby dollar savings. Widely available utility rebate programs may enhance the benefits of installing an energy-efficient motor even further.

To add to the simple electricity cost savings, newer motors utilize improved designs and manufacturing techniques, as well as higher-quality, more sustainable materials. These developments improve the finished product’s overall quality and enable energy-efficient motors to accomplish more work per unit of electricity consumed. Newer motors usually have higher service factors, longer internal component life, lower heat and vibration - all of which increase reliability. In addition, many industrial motors are now offered with condition monitoring sensor technology as an option. Sensors can remotely collect data on vibration, temperature and other parameters to gain meaningful information on the condition and performance of the motor. This technology converts traditional motors into smart, wireless connected devices, enabling users to safely monitor the health of their motors and plan maintenance in advance.

Full-load efficiency
To be considered energy efficient, a motor’s performance must equal or exceed the nominal full-load efficiency values provided by the National Electrical Manufacturers Association (NEMA) in publication MG 1[3]. Specific full-load nominal efficiency values are defined for each horsepower, enclosure type and speed combination.

Department of Energy efficiency regulations
Premium Efficiency (IE3) motors were introduced in the early 1980s, but NEMA did not publish its first, official, standard until 2001. Simply by implementing more-efficient motors, the U.S. Department of Energy estimated that the program could save 5,800 gigawatt-hours of electricity for U.S. homes and businesses and prevent the emission of 80 million metric tons of carbon (the equivalent of removing 16 million cars from circulation) in its first decade alone[4]. Upgrading to Premium Efficiency motors was voluntary until December 2010, but as of June 2016, almost all 1 to 500 Hp, three-phase, motors manufactured for sale in the United States are Premium Efficiency or higher (certain specialized motors, such as submersible and water-cooled motors, are exempt from the rules). Super Premium Efficiency (IE4) and higher motors are readily available from a variety of motor manufacturers; however, there are no government regulations requiring their usage.

Considerations when upgrading a motor on an older pump system

Size and weight
In many cases, a new motor will not match the physical size of the motor being replaced. While standardized NEMA dimensions assure that the frame, footprint, shaft position and other mounting dimensions will be the same, the physical size of the more efficient motor may be larger or smaller, and the weight may differ as well. A standard Premium Efficiency motor body may be longer to hold the additional active material - such as copper and high-grade electrical steel - needed for higher efficiency or larger starter heaters needed to accommodate a higher inrush current. Inversely, a more power-dense Premium Efficiency motor or a newer motor reaching ratings beyond Premium Efficiency may be smaller because of the reduced size of newer technologies or because of the integration of components. In either case, there may be form, fit and function issues that must be resolved.

Speed and load point
When replacing a motor on an older pump, it must be understood that a higher-efficiency motor will have less slip than a standard-efficiency motor, so it will run at higher speeds, resulting in the pump producing more flow and pressure and operating the motor above its rated load point. A valve or a VSD may need to be added to operate the motor at speeds to match the flow requirement. However, even while running at a higher speed, a high-efficiency motor will have a lower temperature rise, which extends motor life.

Current draw
A highly efficient motor running at a higher speed will draw an equal - or even greater - current than a comparable low-efficiency motor because the new motor is producing more work. Another factor that affects current draw is the NEMA design code. Design A motors have a higher inrush current than B designs, which is the instantaneous input current required when the motor is first powered on. NEMA design code B is the most prevalent design and is found in many installed pump applications; however, in some cases, a motor must be designed to NEMA design code A rather than B to achieve the required efficiency level. When energized for a few cycles of the input waveform, electric motors may draw several times their normal full-load current. The selection of overcurrent-protection devices such as fuses and circuit breakers are more complicated when high inrush currents are taken into consideration. The selected overcurrent protection must react quickly to overload or short-circuit faults but must not interrupt the circuit when the inrush current flows.

The bottom line: Will a higher efficiency motor optimize a pump system?

Incorporating a more efficient motor in a pump system is a step in the right direction, but one must be mindful of the overall efficiency of the system. The combined efficiencies of each component in the system must be taken into consideration. Optimizing each individual component may improve or reduce overall (wire-to-water) efficiency because of the cause and effect of each component, perhaps causing a particular component to operate in a less efficient manner. A user must consider how each effort to reduce energy consumption and cost affects the entire pump system. System optimization must include an examination of how each component functions in conjunction with the other system components. The benefits of an optimized pump system include reduction in energy waste, maintenance cost and downtime, and a motor upgrade is the first step toward achieving these benefits.

[1] Overview on Energy Saving Opportunities in Electric Driven Systems Part 1: System Efficiency Improvement, Ferreira and Almeida, 2016-ESC-0071, p. 35. 1, IEEE 2016 – IEEE Explore
[2] Energy Tips: Motor Systems, When to Purchase Premium Efficiency Motors, p. 1, US Department of Energy
[3] ANSI/NEMA MG 1-2016, Section II, Part 12, p. 37, National Electrical Manufacturers Association (NEMA)
[4] Evaluating Motor Energy Efficiency Opportunities, p. 3-7, US Department of Energy

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