Motor System Optimization

Motor-driven equipment accounts for 64 percent of industrial electricity use in the United States. According to a recent study by the U.S. Department of Energy (DOE), the average industrial facility can improve the efficiency of its motor systems by 11 to 18 percent through cost-effective practices. Proper motor maintenance is an important first step toward improved reliability and efficiency. This pamphlet focuses on the next steps: developing a plan for upgrading to premium-efficiency motors when replacements are required and making cost-effective improvements to optimize the energy use of your motor systems.

Motor-Replacement Decisions

It is important that you plan ahead for motor replacements—when a motor fails, you do not want to be in a panic to find a new one. Know which motor on the market is a cost-effective replacement for yours, and check with local distributors to make sure your preferred model is available. This kind of planning can result in significant energy and cost savings.

One key decision when a motor fails is whether to repair it (such as by rewinding) or to replace it with a new premium-efficiency motor. In many cases, the latter is actually the smartest choice. Rewinding can degrade the efficiency of a motor by 2 percent (or even as much as 5 percent, if done improperly), while premium-efficiency motors can be 3 or 4 percent more efficient than a standard "efficient" motor. Because the average motor easily consumes 50 to 60 times its initial purchase price in electricity within 10 years of service, those 3 or 4 percentage points of efficiency can make a huge difference in the motor's total lifetime costs. For an example of potential cost savings from a motor-replacement-or-repair decision, see **Table 1**.

Table 1: Cost evaluation for a motor needing repair or replacement

In this example, for a 30-horsepower (hp) motor operating 6,000 hours per year, replacing the motor with a premium-efficiency one rather than rewinding it yields a return on investment of 36 percent. This analysis was performed using MotorMaster+ software from the U.S. Department of Energy's Office of Industrial Technology.

	Repair/rewind (89.3% efficiency)[a]	New premium-efficiency motor by Toshiba (94% efficiency)	Cost differences and economic evaluation
Initial cost ($)	880	1,903	1,023
Annual energy use (kWh)	112,740	107,140	–5,600
Energy usage costs ($)	6,097	5,794	–303
Demand costs ($)	113	107	–6
Total annual energy costs ($)	6,210	5,901	–309
Simple payback period (years)			3.3
Return on investment[b] (%)			36

Note: Assumptions are 30-hp motor, 75 percent load factor, 6,000 hours per year, electricity costs of $0.054 per kilowatt-hour (kWh), demand charge of $0.50 per kilowatt, and other standard assumptions (depreciation and taxes, for example).

a. Based on 1 percent efficiency loss from the rewind.

b. Assuming 10-year life.

Source: Platts

Performing a cost-effectiveness analysis is easy with the use of MotorMaster+ software, which is available free from the DOE's Office of Industrial Technologies (OIT). (MotorMaster+ can be downloaded from the OIT's Motors Best Practices Web site at www.oit.doe.gov/bestpractices/motors.) The software includes a catalog of motors of various sizes, including their costs and rated efficiencies. When you enter data, such as what you pay for electricity, your load factor, and your hours of operation, the software provides the energy and cost savings, the payback period, and the return on investment for each replacement choice.

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Making better decisions about motor replacement or repair is a good start toward improving motor efficiency, but waiting for motors to be repaired or replaced leaves a lot of potential energy savings on the table. According to a recent DOE study, efficiency upgrades for existing motors account for only 29 percent of the total potential efficiency improvements from motor systems. The remaining 71 percent is through improvements in the design, configuration, and control of motor-driven systems.

Motor system optimization involves a systematic analysis of motors and motor systems (including fans and pumps) to match motor output to end-use requirements and to optimize the motor systems' energy efficiency. This detailed review of motor systems begins with an evaluation of the duty cycles and load profiles for all motors at a facility (or at least those operated more than 2,000 hours per year). Potential improvements include replacing oversized motors with smaller, more-efficient ones, and installing adjustable-speed drives (ASDs) when the load varies significantly.

The preferred method for estimating motor loads is the wattmeter method, which involves measuring the three-phase voltage and current to the motor. If you need assistance, a local electrician should be able to determine your motor loads for you. You can also find training on how to do this type of assessment through the OIT. (Information on these written materials and about the OIT's workshops are available from its Motors Best Practices Web site.)

Replacing Oversized Motors

Motors often have more capacity than their loads require, mainly due to conservative design practices. In general, the efficiency of motors decreases as the load factor decreases, although this relationship varies somewhat by size and model of motor. Because of this, considerable energy and cost savings can often be found by replacing an existing oversized motor with a smaller, higher-efficiency one. But how do you decide when such a replacement is cost-effective?

The economics of downsizing improve with the degree to which the existing motor was oversized. For example, according to the *E SOURCE Technology Drivepower Atlas*, if you were to replace a 50 percent loaded, 100/horsepower standard-efficiency motor that has a duty factor of 75 percent with a smaller, premium-efficiency motor, the payback period will be less than three years.

MotorMaster+ can help determine whether replacing an existing motor with a smaller one will be cost-effective. The software automatically accounts for variations in motor speed between the existing motor and the smaller replacement motor, a factor that can affect the calculated efficiency improvement and potential cost savings.

Even when it turns out that it isn't cost-effective to replace the existing motor immediately, motor system

Example: Peabody Holding Co.

According to the OIT's report, "Mining Project Fact Sheet: Optimized Pump Systems Save Coal Preparation Plant Money and Energy," Peabody Holding Co. recently completed a project to improve the performance of a coal-slurry pumping system at its Randolph coal-preparation plant in Illinois. Changes to the coal-washing process resulted in cyclone pump systems that were larger than necessary to meet system requirements. A DOE Motor Challenge Showcase Demonstration team conducted a performance optimization on one of the six cyclone pumps.

Using a systematic approach, the team identified three energy-saving opportunities: replace the pump with a smaller one that was better matched to the system's needs, replace the existing motor with a premium-efficiency motor, and adjust the belt tension. These modifications saved 87,200 kilowatt-hours of electricity per year—saving Peabody $5,231 in energy cost savings annually, for a simple payback of 3.3 years. Maintenance costs were also reduced, and the pumping system's overall energy consumption decreased by approximately 15 percent.

analysis can help identify a properly sized replacement for the future. When a system is underloaded, downsizing the replacement unit will yield much higher cost savings than replacing the existing motor with a premium-efficiency one of the same size. However, we recommend that you don't downsize if the replacement motor will be running above 75 percent of the rated load, because the efficiency of a premium-efficiency motor tends to peak at about that level. It is also wise to have some extra capacity as a safety margin.

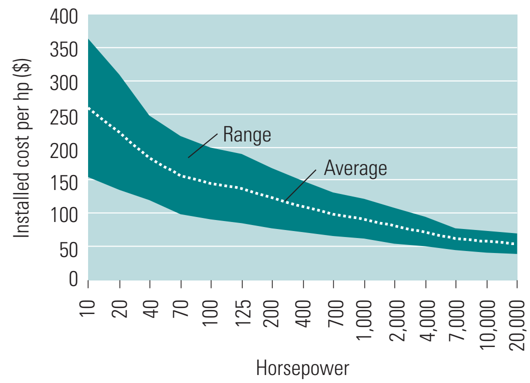
Adjustable-Speed Drives

Many motors are sized to provide the maximum output required under the worst operating conditions. During typical operation, though, motor systems seldom require that much output. The excess energy is usually dissipated through some type of throttling device, such as dampers or valves. For applications in which the loads vary considerably, installing an ASD can be a good investment. But in general, installing an ASD is considerably more expensive than buying a smaller and more-efficient replacement motor, so if the load is consistently low (less than 40 to 50 percent of the rated output), the motor-replacement option is the smarter choice. **Figure 1** shows the typical installed cost per horsepower of ASD systems.

Determining whether a motor system is a good candidate for variable-speed operation requires knowledge of both its loads and its hours of operation per year. Good potential ASD applications have significant hours of operation at less than the rated (or maximum) output. Motors driving pumps and fans should always be evaluated, and potential energy savings from these systems can exceed 50 percent. The average load at which adding an ASD becomes economical depends on the local cost of electricity and on how many hours the motor system operates at what load. Motor and load systems that deliver rated output less than 40 percent of the time or for which the average output is less than 60 percent of the rated output are good variable-speed prospects.

Figure 1: Adjustable-speed drives, installed cost per horsepower including hardware and labor

The average cost per horsepower (hp) decreases as the motor size increases. For a 100-hp motor, the average installed cost should be about $15,000.



Source: Adapted from Bonneville Power Authority *Adjustable Speed Drive Guide Book*

To be economical, the motor system should also be in operation for many hours per year. The *E SOURCE Drivepower Technology Atlas* says that, generally, the payback period will be less than two years for an ASD installed on a pump or fan with an average output of less than 70 percent of the rated load that is operating more than 6,000 hours per year. The OIT has another software tool, ASDMaster, that can assist you in evaluating whether it will be cost-effective to install an ASD for any given motor system. (ASDMaster can be ordered, for a small fee, from a link on the OIT's Motors Best Practices Web site.)

In addition to significant energy savings, ASDs can also increase production, reduce waste, and allow more precise control of the motor system's output, improving process control. For example, as Connors et al. wrote in "Energy Efficiency and Electrical Adjustable-Speed Drives: History, Status, and Future" (*Proceedings of the Great PG&E Energy Expo*, 1986), many continuous processes, such as plastic extrusion or metal annealing, involve continuous heating of materials as they pass through ovens. Since each type of material requires its own heating rate, manufacturers typically have had to stop production or incur large amounts of scrap when changing from one product run to another. But ASDs permit immediate changes in throughput speed to achieve the required heating rates during the changeover period, permitting continuous production with no energy losses (from allowing the materials to cool) and no scrap product.

Significant energy cost savings and improved productivity are possible through optimizing motor systems. We suggest that you start with the free and low-cost tools available, and that you consider requesting technical assistance as needed, from your utility, energy service provider, or a consultant.