E-Notes

Energy Efficiency Notes

Energy Efficient Electric Motors and Drive Systems

Background

Conventional electric motors are large users of energy. It is estimated that 62% of all the electricity in the United States is used to drive electric motors. In many industries, about 70% of all the electricity used is for electric motors.

Increasing the efficiency of drivepower systems can save large amounts of energy and money.

Motors are **parts** of drivepower systems. For optimum performance, all parts of the drivepower systems must be carefully designed.

In a typical belt-driven fan application in a building, the following drivepower system exists.

Transformer--circuit breaker--electric wiring--motor panel--power factor correction equipment--electric wiring--electric motor--fan belts--fan wheel and casing--duct system.

The electric motor is only one element out of ten in the total drivepower system for the fan. To optimize efficiency, all the elements in the drivepower system should be carefully designed.

A high efficiency drivepower system for a fan and duct system should normally include all the following:

1. **Efficient Duct System**

The duct system should be designed using an optimization tool such as life-cycle costing. In addition, a very careful analysis should be made of the actual volume of air required for the application. Excessive air flows result in extra costs both in the initial design and in the electricity costs.

The horsepower requirements of ducts increases inversely as the fifth power of the diameter of the ducts. Thus a round duct system that was undersized in diameter by 50% would require 3100% percent more power to deliver the same amount of air!

2. **Fan Wheel and Casing**

The fan wheel and casing must be carefully chosen. In many applications, backward curved fans are the most efficient designs. Inlet and outlet conditions are also very important to minimize unnecessary losses.

3. **Fan Belts**

Fan belts are important. Conventional belts lose about 4% to 10% of the energy supplied. Cogged V-belts have lower flexing losses, and so they deliver 1 to 3% better efficiency than standard V-belts. A sketch of a cogged belt is shown in figure 1. Cogged belts are widely available now, and can be directly substituted for standard V-belts, with payback periods typically less than a year.

Figure 1. Cogged V-belts

The most efficient belt is the synchronous belt, which loses only 1 or 2% in energy. As this belt has no slip, however, it may not be appropriate for many applications.

4. **Alignment**

Alignment between the motor and the load is very important.

Poorly aligned motors will increase energy use. It is important to align the driving and the driven v-belt sheaves using a string or other alignment device. For direct-drive applications, alignment is also very important.

5. **Electric Motor Efficiency**

Most electric motors in use today are standard efficiency. There are several advantages to high efficiency motors:

1. Lower energy costs.
2. Higher power factor. With higher power factor, the amperage draw of the high efficiency motors is lower, and the electrical demand charges are reduced.
3. High efficiency motors tend to run cooler. As a consequence, the life of the motor is expected to be longer.
4. Smaller, less expensive power factor correction equipment is needed with high efficiency motors.

Although the cost of high efficiency motors is greater than standard efficiency motors, the incremental cost for the high efficiency motor is usually paid back in a short time. The longer the run-time of the motor each day, the shorter will be the payback period on the incremental cost.

An example for a 10 horsepower, 2 pole, totally-enclosed fan cooled, electric motor is as follows:

Comparison of Energy Efficient and Standard Efficiency Electric Motors

	Energy Efficient Motor	**Standard Efficiency Motor**
Full load efficiency	91.1%	84.8%
Capital Cost	$840	$700
Full load speed (rpm)	3510	3480
Power factor at full load (%)	89.7%	86.9%
kVA demand at full load	8.32	8.58
Annual energy cost at 3.72 cents/kWh for 4000 hours at full load	1219	$1277
Annual demand charge at $14.53 per kVA per month	1451	1496
Total annual energy plus demand charges	$2670	$2773

The simple payback period on the incremental cost = ($840-$700)/($2773-2670) = 1.4 years

Points to consider:

1. Note that for the example used, the annual electricity cost ($2670) of the motor is considerably higher than the motor purchase price ($740)
2. The energy savings ($103 per year) are paid back in about 1.4 years, for a 73% annual return on the incremental cost ($140) of the energy efficient 10 horsepower motor.
3. The energy efficient motor has a higher full load speed (3510 rpm) compared with the standard efficiency motor (3480 rpm). Higher efficiency motors have less slip than the standard motors. As a consequence, the v-belt sheaves should be changed to lower the speed of the fan to its original value. If this is not done, the greater load on the motor from the higher fan speed will tend to negate the efficiency improvement.
4. The high efficiency motors of some companies are less efficient than the standard efficiency motors of other companies. Buyer beware. The following companies have high efficiency motors in the 1-200 hp range which are endorsed by the Power Smart Organization.

Company Name	Brand
Baldor Electric Co.	Super-E
GE Motors	Energy $aver
Leeson Canada Inc.	Wattsaver

6. **Power Factor Correction**

Increasing power factor has impressive savings. Increasing the power factor from 75% to 95% reduces cable and transformer copper losses by 38%. With improved power factor, the amperage requirements for the load are reduced (assuming the power factor correction equipment is located at or near the motor). With reduced amperages, the heating losses in the wires and transformers are reduced. Another E-note presents more information on power factor correction. It is usually very cost-effective.

7. Electric Wiring

Electric wiring is normally sized so that a voltage drop up to 5% occurs along the wiring. The electrical code, which governs minimum wire sizes, is **not** an energy efficiency code. With a 5% voltage drop along the wires, a considerable amount of heat is developed in the wires. This heat represents a loss in efficiency. Larger wires than the minimum specified in the code can often be cost-effective.

It is also cost-effective to wire dual-voltage electric motors to run on the higher voltage. For instance, an electric motor able to run on either 120 volts or 240 volts should be wired to run on the higher voltage. For the same motor horsepower, a motor running at twice the voltage will require only one-half of the electrical current.

The Southwire Company of the U.S., a billion dollar industrial firm, has a policy of wiring all new loads under 100 amperes with conductors one size larger than the code requirement. For loads above 100 amperes, an economic study is performed. The company's corporate energy manager concludes that the policy saves the firm money, energy and time.

8. Running Time for the Motor

A key question that should be asked is whether the motor system should be running as many hours as it is.

For instance, a very cost-effective way to save energy with a ventilation fan system in a building such as an office is to only run the ventilation system when the building is occupied. Normally the ventilation fan system is not required to operate 24 hours per day. Indoor air quality concerns must be addressed, however.

9. Use of Variable Speed Drives for Electric Motors

In many applications, the use of a variable speed drive can be cost-effective. With many pump and fan loads, the power required to run the motor increases as the cube of the speed. Another E-note has further information on this technology.

Summary

An energy efficient drive system is more than an efficient electric motor. Wire sizing, power factor correction, careful end load designs, drive belt selection, reducing unnecessary operating hours--these are all important elements in an efficient drivepower system.

Reference

Energy Efficient Motor Systems: A Handbook on Technology, Program, and Policy Opportunities (1992), Steven Nadel et al, American Council for an Energy Efficient Economy, 1001 Connecticut Avenue N.W., Suite 801, Washington, D.C. 20036, U.S.A.