Selecting an Energy-Efficient Motor

An Online Continuing Education Course for Engineers

Course Number: E-1001

Credit: 1 Hour / 1 PDH / 1 CPD

Selecting an Energy-Efficient Electric Motor

Efficiency is an important factor to consider when buying or rewinding an electric motor. This course shows you how to obtain the most efficient motor at the lowest price and avoid common problems. It answers the following frequently asked questions:

1. Why is improving motor efficiency important?

2. What is an energy-efficient motor?

3. What efficiency values should I use when comparing motors?

4. When should I consider buying an energy-efficient motor?

5. When is an energy-efficient motor cost effective?

6. Should I rewind a failed motor?

7. What design factors should I consider when choosing a new motor?

8. How should I begin a motor efficiency improvement program?

1. Why is improving motor efficiency important?

Over half of all electrical energy consumed in the United States is used by electric motors. Improving the efficiency of electric motors and the equipment they drive can save energy, reduce operating costs, and improve our nation's productivity.

Energy efficiency should be a major consideration when you purchase or rewind a motor. 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 energy rate of $0.04/kWh, a typical 20-horsepower (hp) continuously running motor uses almost $6,000 worth of electricity annually, which is many times its initial purchase price.

2. What is an energy-efficient motor?

Motor efficiency is the ratio of mechanical power output to the electrical power input, usually ex pressed as a percentage. Considerable variation exists between the performance of standard and energy-efficient motors (see Figure 1). Improved design, materials, and manufacturing techniques enable energy-efficient motors to accomplish more work per unit of electricity consumed.

Energy-efficient motors offer other benefits. Because they are constructed with improved manufacturing techniques and superior materials, energy-efficient motors usually have higher service factors, longer insulation and bearing lives, lower waste heat output, and less vibration, all of which increase reliability. Most motor manufacturers offer longer warranties for their most efficient models.

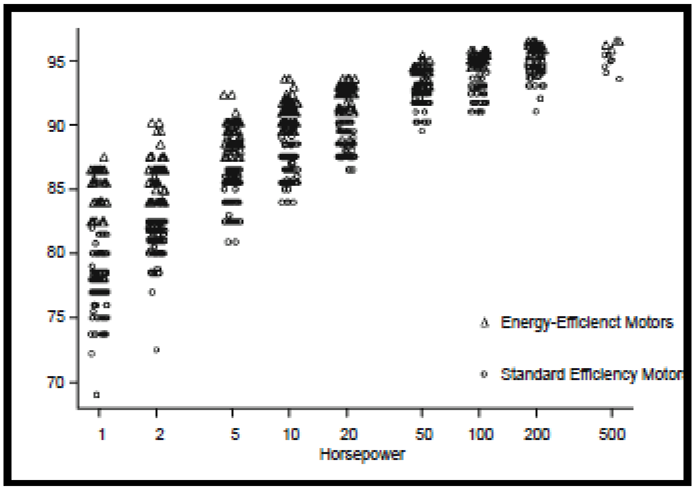

Figure 1
Standard and Energy-Efficient Motor Performances

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. Specific full-load nominal efficiency values are provided for each horsepower, enclosure type, and speed combination. A motor's performance must equal or exceed the efficiency levels given in Table 1 of this course (reprinted from Table 12-10 of NEMA MG-1-1993, Rev. 1) for it to be classified as "energy efficient."

The Energy Policy Act of 1992 (EPACT) requires that most general purpose motors manufactured for sale in the United States after October 24, 1997, meet new minimum efficiency standards. These standards are identical to the shaded area of Table 1. The Act applies to 1- through 200-hp general-purpose, T-frame, single-speed, foot-mounted, continuous-rated, polyphase, squirrel-cage, induction motors conforming to NEMA designs A and B. Covered motors are designed to operate with 230 or 460 volt power supplies, have open or "closed" (totally enclosed) enclosures, and operate at speeds of 1200, 1800, or 3600 rpm.

3. What efficiency values should I use when comparing motors?

When comparing motor efficiencies, be sure to use a consistent measure of efficiency. Nominal efficiency is best. Nominal efficiency is an average value obtained through standardized testing of a population of motors. Minimum guaranteed efficiency, which is based on nominal efficiency, is slightly lower to take into account typical population variations. Minimum guaranteed efficiency is also less accurate, because the value is rounded. Other efficiency ratings, including apparent and calculated, should not be used.

In the United States, the recognized motor efficiency testing protocol is the Institute of Electrical and Electronics Engineers (IEEE) 112 Method B, which uses a dynamometer to measure motor output under load. Different testing methods yielding significantly different results are used in other countries. The NEMA nameplate labeling system for design A and B motors in the 1- to 500-hp range uses bands of efficiency values based on IEEE 112 testing.

4. When should I consider buying an energy-efficient motor?

Energy-efficient motors should be considered in the following circumstances:

• For all new installations

• When purchasing equipment packages, such as compressors, HVAC systems, and pumps

• When major modifications are made to facilities or processes

• Instead of rewinding older, standard efficiency units

• To replace oversized and underloaded motors

• As part of a preventive maintenance or energy conservation program.

The cost effectiveness of an energy-efficient motor in a specific situation depends on several factors, including motor price, efficiency rating, annual hours of use, energy rates, costs of installation and downtime, your firm's payback criteria, and the availability of utility rebates. Check with your utility to determine whether it can fund a portion of your motor replacement costs through its energy conservation programs. Question 5 addresses methods for evaluating the cost effectiveness of energy-efficient motors.

Table 1
NEMA Threshold Full-Load Nominal Efficiency Values for Energy-Efficient Motors (from NEMA MG1 Table 12-10)[1].

Open Motors						Enclosed Motors				
hp	3600	1800	1200	900		hp	3600	1800	1200	900
1	—	82.5	80.0	74.0		1	72.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5		1.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5		2	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5		3	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5		5	87.5	87.5	87.5	85.5
7.5	87.5	88.5	88.5	88.5		7.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5		10	89.5	89.5	89.5	88.5
15	89.5	91.0	90.2	89.5		15	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2		20	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2		25	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0		30	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0		40	91.7	93.0	91.7	91.0
50	92.4	93.0	93.0	91.7		50	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4		60	93.0	93.6	93.0	91.7
75	93.0	94.1	93.6	93.6		75	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6		100	93.6	94.5	93.6	93.0
125	93.6	94.5	94.1	93.6		125	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6		150	94.5	95.0	94.1	93.6
200	94.5	95.0	94.5	93.6		200	95.0	95.0	95.0	94.1
250	94.5	95.4	95.4	94.5		250	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	—		300	95.4	95.4	95.0	—
350	95.0	95.4	95.4	—		350	95.4	95.4	95.0	—
400	95.4	95.4	—	—		400	95.4	95.4	—	—
450	95.8	95.8	—	—		450	95.4	95.4	—	—
500	95.8	95.8	—	—		500	95.4	95.8	—	—

[1] The shaded area indicates motor classes covered by the efficiency standards contained within the Energy Policy Act of 1992.

5. When is an energy-efficient motor cost effective?

The extra cost of an energy-efficient motor is often quickly repaid in energy savings. As illustrated in Table 2, each point of improved motor efficiency can save significant amounts of money each year. In typical industrial applications, energy-efficient motors are cost effective when they operate more than 4000 hours a year, given a 2-year simple payback criterion. For example, with an energy cost of $0.04/kWh, a single point of efficiency gain for a continuously operating 50-hp motor with a 75% load factor saves 4079 kWh, or $163 annually. Thus, an energy-efficient motor that offers four points of efficiency gain can cost up to $1,304 more than a standard model and still meet a 2-year simple payback criterion. A utility rebate program would further enhance the benefits of an energy-efficient motor.

Table 2

Annual Value of a One-Point Efficiency Gain (Based on $0.04/kWh, 8000 Hours of Use, Full Load)

Horsepower	Annual Savings
5	$17
10	$32
20	$61
50	$142
100	$278
200	$537

Whenever possible, obtain actual price quotes from motor distributors to calculate simple paybacks. Motors rarely sell at full list price. You can typically obtain a 20% to 60% discount from vendors, with specific prices depending on the distributor's pricing policies, the number and type of motors you buy, and fluctuations in the motor market. Comparison shop when purchasing motors. The following three techniques can help you determine whether an energy efficient motor is cost effective:

1. Use the Department of Energy's MotorMaster+ software program to calculate the dollar savings and simple payback from using a more efficient motor, taking into account motor size, price, efficiency, annual hours of use, load factor, electricity costs, and utility rebates. MotorMaster can be used to analyze a new motor purchase, rewind of a failed motor, or replacement of a working motor.

2. Use the following formulas to calculate the annual energy savings and simple payback from selecting a more efficient motor. Simple payback is defined as the time required for the savings from an investment to equal the initial or incremental cost.

Annual Energy Savings

$$\text{Savings} = hp \times L \times 0.746 \times hr \times C \times \left[\frac{100}{Estd} - \frac{100}{Eee}\right]$$

E Savings	=	Expected annual dollar savings
hp	=	Motor rated horsepower
L	=	Load factor (percentage of full load/100)
hr	=	Annual operating hours
C	=	Average energy costs ($/kWh)
Estd	=	Standard motor efficiency rating, %
Eee	=	Energy-efficient motor efficiency rating, %
0.746	=	Conversion from horsepower to kW units

Simple Payback

For a new motor purchase, the simple payback is the price premium minus any utility rebate for energy-efficient motors, divided by the annual dollar savings:

$$\text{Simple payback (years)} = \frac{\text{Price premium} - \text{Utility rebate}}{\text{Annual dollar savings}}$$

When calculating the simple payback for replacing an operating motor, you must include the full purchase price of the m... installation costs:

Simple payback (years) = M...

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3. Use Table 3 to d... ll meet common payback criteria. T... es and prices, indicates the minimum num... s energy prices in order to obtain a 2-... less accurate than a more detailed analy... that an energy-efficient motor has ... , and it ignores other benefits of energy-e... rogram, or reliability benefits make energ...

Choose a new energy-effi... the indicated number of hours each yea...