energydesignresources

design brief

DRIVEPOWER

Summary

In a typical building, motors are used in a variety of applications to provide (among other things) ventilation, cooling, and vertical transportation. An average building may contain literally hundreds of motors, and their collective energy use can account for as much as one-quarter of a building's energy costs. Even so, all too often designers give the selection and sizing of motors short shrift—as can be seen by the prevalence of oversized, inefficient induction motors.

The establishment of national standards for motor efficiency have improved this situation somewhat, but many designers still mistakenly believe that simply specifying an energy-efficient motor is enough to ensure efficient operation. To truly minimize the energy use of a drivepower system—which includes the motor, its controls, and the connection between the motor and the equipment it drives—designers need to consider how these components operate as a *system* rather than looking at them on an individual basis.

Undertaking a critical evaluation of the entire drivepower system and combining good engineering with efficient components such as premium efficiency motors and variable-speed drives can reduce the energy use of motor-driven systems by 50 percent or more. When you consider that in a single year, a motor often consumes energy worth about 10 times the unit's initial cost, system improvements can easily pay for themselves within the first few months of operation.

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Introduction

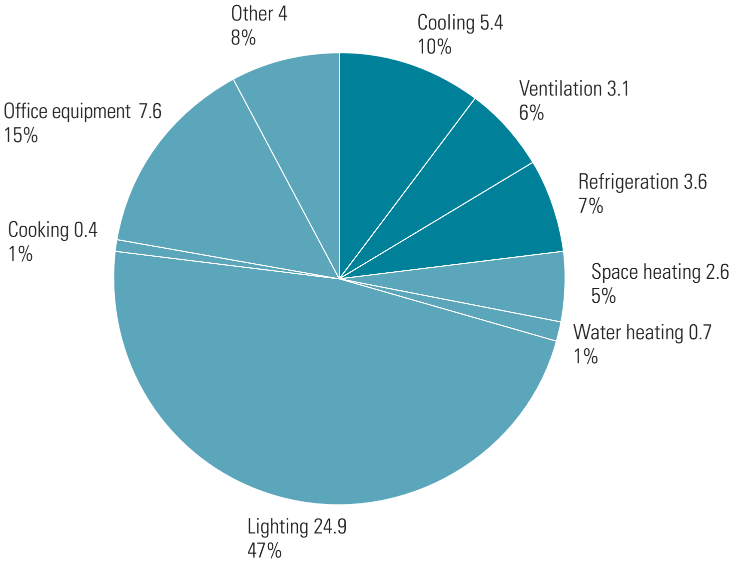
In the five-state Pacific region that includes California, electric motors account for about 23 percent of all electricity consumed in commercial buildings.[1] Most of these motors are used in heating, ventilating, and air conditioning (HVAC) applications as drivers for fans, pumps, and air-conditioning compressors (see **Figure 1**). The operating cost for these motors can be as much as 50 to 75 cents per square foot per year.

Although there are certainly benefits to improving motor efficiency, that is only one facet of reducing the cost of an entire system.

In the past, some attention was given to improving the efficiency of motor-driven systems through utility demand-side management (DSM) programs, but more often than not those programs addressed only the most obvious target—the efficiency of the motor itself. Although there are certainly benefits to improving motor efficiency, that is only one facet of reducing the cost of an entire system. An evaluation that considers how the motor, controls, and drive system work together—and how they influence other building systems—can make it possible to significantly reduce the cost of purchasing, operating, and maintaining the equipment. For example, focusing solely on motor efficiency

Figure 1: Electrical use by end use for the Pacific region

Typically, motors used to drive fans, compressors, and pumps in commercial buildings account for about 23 percent of all electricity consumed. Numbers shown are thousands of Btu per square foot per year out of a total of 52.3 MBtu per year.



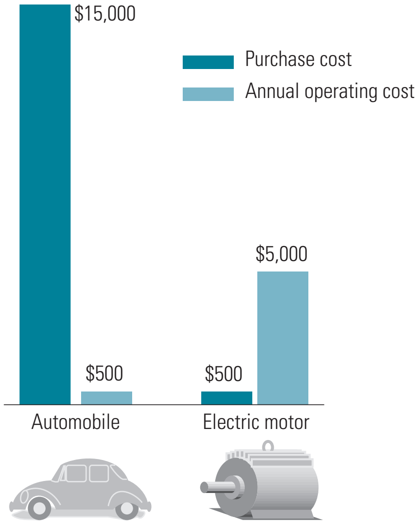
Source: Energy Information Administration may yield a one to five percent reduction in operating cost, but improvements that take into account the entire drivepower system may provide savings of 50 percent or more.

The systems approach often provides opportunities to reduce the cost of other building systems as well. For example, reducing the necessary size of motors and transformers reduces cooling loads in electrical rooms, which in turn makes it possible to install smaller, less-expensive cooling systems for those spaces.

Many electric devices cost much more to buy than to operate for a single year, but electric motors are a notable exception to that rule of thumb. Under typical operating conditions, an electric motor that drives a pump or fan will consume on the order of 10 times its capital cost in electricity *every year*. (See **Figure 2**.) For this reason, the extra cost of a more efficient motor system can often be recovered quickly, and given the long life span of most motors, small improvements in efficiency can rack up huge savings over the 10 to 15 years that they may be in service.

Figure 2: Relationship of purchase price to operating costs for electric motors and automobiles

A car costs much more to purchase than to operate, but the cost of a motor is small relative to its annual operating costs. Because the operating costs far exceed a motor's purchase price, it is usually a financially sound decision to pay more up front to get a more efficient model.



Source: E SOURCE

Designing an Efficient Drivepower System

The gains in efficiency that can be realized by installing a premium efficiency motor can easily be offset by the negative impact of oversizing the motor, improperly connecting it to the driven load, or choosing the wrong type of controls for it. (See **Figure 3** on page 4.) To minimize the overall energy impact of drivepower systems, the designer must "start at the load"— the reason for installing the drivepower in the first place—and work back through the entire system, paying attention to:

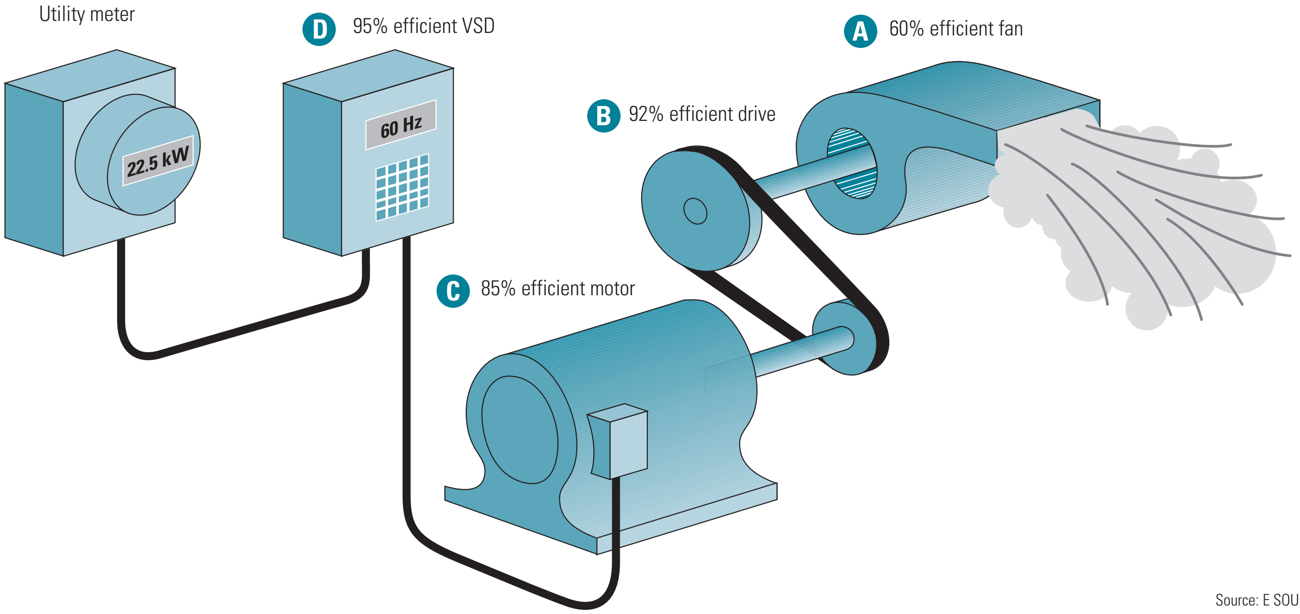
- *The efficiency of the driven equipment* (A). Don't underestimate the value of selecting an efficient pump or fan, for there can be vast differences in efficiency between seemingly similar equipment. For example, an airfoil centrifugal fan can be as much as 30 percent more efficient than the typical forward-curved fan, although the two provide about the same performance. Choosing the more efficient centrifugal fan can translate into more than a 30 percent decrease in the horsepower requirements.

- *The connection between the driven equipment and the motor* (B). The efficiency of a drivepower system will also be affected by the way the motor is connected to the driven equipment. For example, the standard v-belts used to connect fans to motors typically cause a three to five percent reduction in motor horsepower due to simple frictional losses. Instead of driving the equipment, this lost motor power is dissipated as waste heat. The use of efficient belts or direct-drive connections can cut such frictional losses in half.

- *The size and efficiency of the motor driving the load* (C). When it comes to efficiency, all motors are *not* created equal. The difference between two seemingly identical

Figure 3: Typical drivepower system

If this fan system were perfectly efficient, only 10 kW of power would be needed to achieve the desired airflow. Unfortunately, in the real world, the inefficiency of each component in the system (including the fan, fan belt, motor, and variable-speed drive) will increase the power measured at the electricity meter. This example shows how those inefficiencies add up, ultimately making it necessary to draw 22.5 kW to deliver the desired amount of air to the conditioned space. Thoughtful design and efficient equipment selection could reduce the power requirement for this system to about 15 kW—an improvement of about 33 percent.



Source: E SOURCE

motors can be vast, especially in the case of small, single-phase motors. Efficiency varies according to how heavily the motor is loaded, so an oversized high-efficiency motor may actually operate less efficiently than a properly sized standard-efficiency motor.

- *The controls regulating motor operation* (D). For motors driving centrifugal loads, such as pumps and fans, the controls used to regulate the flow of air or water can also have a profound impact on energy consumption. Choosing the right means of control can make the difference between an average system and an efficient one.

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- *The power quality implications of the drivepower system.* If not carefully selected for the job, motors and their controls (including options such as variable-speed drives) can have a negative impact on power quality. Selecting appropriate, compatible components—and installing them correctly—can go a long way toward minimizing potential power quality problems.

To get the best possible energy and cost savings, use the system approach: "right-size" the motor for the task, select a premium efficiency motor, pick the most efficient motor controls, and properly install the drivepower components to minimize power quality problems.

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Size the Motor for the Task

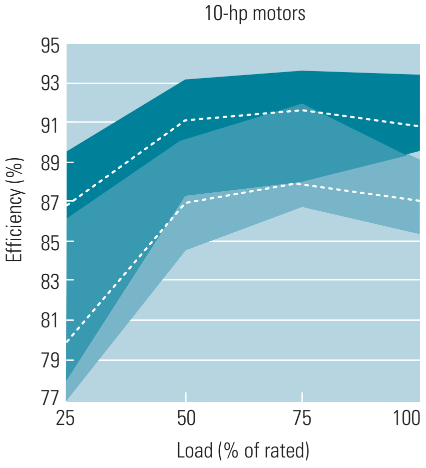
Traditionally, drivepower engineers have conservatively calculated the actual horsepower required for a task and then selected a larger motor than is absolutely required. This routine oversizing is usually done with the best of intentions—the designer wants to avoid problems associated with overloaded motors and to allow for variations in the assumed operating environment. But an oversized electric motor has distinct disadvantages when compared to one that has been right-sized. An oversized motor can make for:

An oversized motor is often needlessly inefficient because of light-load operation.

- *Poor efficiency.* Electric motors are generally most efficient when operating from 80 to 100 percent of full load capability. An oversized motor is often needlessly inefficient because of light-load operation—particularly if it is operating at less than 50 percent of full load. The extent to which efficiency changes on the basis of the load usually varies according to motor size, mostly because of different construction practices for small, medium, and large motors. **Figure 4** shows typical partial-load efficiency curves for a 10-horsepower (hp) induction motor.

Figure 4: Efficiency versus load for a 10-hp induction motor

Many larger motors achieve peak efficiency at close to 75 percent load. This graph assumes a 460-volt, 1,800-rpm, TEFC (totally enclosed fan-cooled) motor.



Source: E SOURCE

- *Reduced power factor.* A lightly loaded motor operates at lower power factor than a fully loaded motor, and low power factor will increase energy costs in regions where utilities charge for it. The major electric utilities in Southern California, for example, already charge at least some of their customers for low power factor.

- *Higher first cost.* Oversized motors cost more than smaller, properly sized motors. An oversized motor also requires a more robust electrical system, including the cost for wiring to the motor, the starter, and the disconnect switch.

- *Drain on building electrical systems.* Oversized electric motors needlessly tax a building's electrical system. The energy required to energize the magnetic fields for inductive loads (such as motors and fluorescent ballasts) reduces the amount of energy available to serve other loads in the building. In new construction, the capacity of the entire electrical system—including conductors and transformers—must often be increased to accommodate the power requirements of oversized motors.

"Service factor" is one reason that oversizing is usually unnecessary. It is the percentage by which a motor can safely exceed its nameplate horsepower rating—and it can range from 0 to 25 percent of full load output. Given that 88 percent of the motors in service today have a service factor of 1.15 (meaning that the motor can safely operate at 115 percent of full load output),[2] most motors already have a reasonable tolerance built in for changes in operating conditions that increase motor load. The service factor for a motor is almost always stamped on the nameplate.

To maximize overall efficiency, carefully and realistically calculate the horsepower requirements for a given application. Avoid applying excessive factors of safety at every step of the calculation. The final motor selection should include a modest margin of safety[3] on the horsepower, and that should make additional safety factors redundant.[4]

Select a Premium Efficiency Motor

In new construction applications, it is almost always economically attractive to purchase premium efficiency motors over standard efficiency models. For example, consider an 1,800-rpm, 20-hp motor that will drive a constant-speed pump. One manufacturer's standard efficiency motor for this application has a full-load efficiency of 91.0 percent, with a purchase price of $1,149. An energy-efficient motor that meets these same requirements has a full-load efficiency of 93.6 percent, with a purchase price of $1,331. Under typical operating conditions,[5] the energy-efficient motor will save about $164 per year as compared to the standard efficiency motor. Considering the incremental cost for the energy-efficient motor of $183, this investment will pay for itself in a little over one year—a payback that is likely to meet any organization's rate-of-return requirement for an investment. More significantly, over the course of the motor's life span of about 15 years, the energy-efficient motor will save about three times its initial cost.

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HOW TO CALCULATE EFFICIENT MOTOR SAVINGS

For applications in which a motor will operate at constant speed according to a well-defined schedule, calculating the savings for motor efficiency upgrades is a fairly straightforward exercise. Here's how it is done:

$$S = 0.746 \times C \times LF \times N \times [(100 / E_S) - (100 / E_H)] \times P_{AVG}$$

Where:

S = Annual cost savings

0.746 = conversion from horsepower to kilowatts

C = nameplate horsepower of the motor

LF = load factor for application

N = number of operating hours per year

E_S = efficiency of existing motor

E_H = efficiency of proposed motor

P_{AVG} = average cost per kilowatt-hour for electricity

For evaluations of more complicated applications, or if hand calculations aren't your cup of tea, consider using a computer program called MotorMaster+. It contains an extensive database of motors, including efficiency and price for each, which allows the user to easily compare the economics of different motor selections.

Although the economics of premium efficiency motors will vary according to the specific application, in most cases there is a sound financial argument for investing in more efficient motors. In addition, the economics of a motor upgrade can be evaluated without too much difficulty (see sidebar, this page).

Since the time when more efficient motors were first made available, confusion has arisen over the different designations manufacturers have used to denote motor efficiency. The Energy Policy Act of 1992 (EPACT) mandates that nearly all three-phase, general-purpose motors manufactured for sale in the U.S. after October 24, 1997, meet new minimum efficiency levels. But EPACT standards only apply to motors up to 200 hp. (See **Table 1**, next page.)

Prior to the implementation of EPACT, some manufacturers labeled their motors as "high efficiency," knowing that in the absence of a rigid definition, some purchasers would interpret this labeling to mean "energy efficient." Indeed, some businesses that purchased "high efficiency" motors as part of energy retrofit projects were disappointed by the relatively small savings that were realized.

To obtain maximum energy savings, buyers should specify "premium efficiency" motors. That term is universally accepted to mean the best efficiency available. Buyers should explicitly state the required minimum efficiency levels according to motor size in their specifications and carefully review contractor bids to be sure that the required efficiency level has been met.

Although the nationwide motor efficiency standard is a step in the right direction, it does not ensure that all motors sold will be efficient. For example, the EPACT standards do not apply to single-phase, fractional-horsepower motors. That's unfortunate because many pieces of equipment in a building—including exhaust fans, refrigerated drinking fountains, and certain types of HVAC equipment such as fan coil units or fan-powered, variable-air-volume (VAV) zone terminals—are driven by such small, single-phase motors. If those motors are not carefully specified, their efficiency can vary by as much as 50 percent for two seemingly identical units.

The impact of inefficient fractional-horsepower motors can be severe in buildings with a lot of them, as would be the case when fan-powered VAV terminals are used to distribute air. In such an installation, there may be one small, inefficient motor for every 500 to 1,000 square feet of conditioned space, and that can add up to hundreds of little energy-wasters hidden away above the ceiling.

Another thing to watch for is the availability and use of "special purpose" motors. EPACT standards only apply to general purpose motors; special purpose motors are not governed by any standards for efficiency. In some cases, what a manufacturer refers to as a "special purpose" motor is really just a relabeled version of their standard-efficiency product line. Because the difference between a special purpose versus a general purpose motor is not rigidly defined, some original equipment manufacturers (OEMs) have decreed that their equipment requires special purpose (read inexpensive and inefficient) motors. Specifying minimum efficiency requirements for all single- and polyphase motors provided as part of OEM equipment will ensure that inefficient motors are not hidden deep within the units.[6]

The savings that can be achieved by installing premium efficiency motors varies with motor size and load factor (that is, the percentage of nameplate horsepower that the motor delivers under typical operating conditions). **Table 2** shows the energy cost savings for energy-efficient motors versus EPACT standard motors in new applications.

As noted earlier, right-sizing a motor can often more than offset the incremental cost of purchasing premium efficiency motors. **Table 3** shows that in nearly all cases the payback on installing a smaller premium efficiency motor versus an oversized EPACT standard efficiency motor is instantaneous.

Table 1: EPACT minimum full-load efficiency requirements for general purpose motors

Horsepower	Enclosed motors (TEFC) 1,800 rpm	Open motors 1,800 rpm
1	82.5	82.5
5	87.5	87.5
10	89.5	89.5
50	93.0	93.0
100	94.5	94.1

Source: E SOURCE

Table 2: Comparison between EPACT minimum standard and premium efficiency motors

Horsepower	Annual energy cost savings*	Average incremental motor cost*	Simple payback
1	$10	$12	1.2 years
20	$91	$81	0.9 years
75	$153	$314	2.1 years
100	$188	$498	2.7 years

*Based on average price and performance data for a number of 1,800-rpm, TEFC motors. Price and performance data taken from MotorMaster+ software.

Source: E SOURCE

Table 3: Comparison between oversized EPACT minimum efficiency and right-sized premium effiency motors

Horsepower	Annual energy cost savings*	Average incremental motor cost*	Simple payback
1	$8	($5)	immediate
20	$34	($200)	immediate
75	$95	($850)	immediate
100	$188	($617)	immediate

*Based on average price and performance data for a number of 1,800-rpm, TEFC motors. Price and performance data taken from MotorMaster+ software.

Source: E SOURCE

CASE STUDY: GETTING IT RIGHT

On a recent new construction project, the mechanical engineer was reviewing the manufacturer's submittal for a condenser water pump.[7] The submittal indicated that a 30-hp energy-efficient motor would be provided to drive the pump, despite the fact that the engineer had specified a 25-hp premium efficiency motor. The engineer took a look at the pump performance curve and confirmed that the horsepower requirement for this application was 23.1 hp. When he called the pump manufacturer, he learned that the application engineer who made the pump/motor selection felt that a 25-hp motor was "too small"—even though the performance requirements for this pump were well understood and the calculations had already been reasonably conservative. The application engineer had substituted the 30-hp motor and selected an energy-efficient model, rather than the specified premium efficiency motor, in order to minimize the cost impact of the larger motor.

The mechanical engineer knew that the motor would have a service factor of 1.15 and that a 25-hp motor would provide about 10 percent oversizing for the 23-hp load, so he rejected the submittal. In the revised submittal, the manufacturer specified the pump with the requested 25-hp premium efficiency motor. The new motor was two full percentage points higher in efficiency than the motor that was previously submitted, and it only cost $200 more.

One of the most user-friendly tools available for assessing the economics of installing premium efficiency motors is a computer program called MotorMaster+. Developed by the Washington State University Energy Program and the U.S. Department of Energy, MotorMaster+ allows the user to identify a range of efficient motors from different manufacturers to meet specific design criteria. MotorMaster+ is provided free of charge to participants in Department of Energy's Motor Challenge Program. (To learn how to become a partner in this program, see page 16.

Use Efficient Motor Controls

When applied to HVAC systems where heating and cooling loads vary significantly over time, a motor controlled by a variable-speed drive (VSD) provides an efficient means for regulating fan or pump operation. Induction motors are designed to run at a fixed speed that is proportional to their input power frequency—normally 60 Hz in the United States. A VSD is an electronic device that provides power at varying frequencies, making it possible for induction motors to operate at anywhere from 10 to 300 percent of their nominal, fixed speed. For applications as small as 1 hp or as large as 5,000 hp, VSDs can cut energy use by 50 percent or more.

VSDs have been promoted for their ability to boost energy savings and improve motor performance. Because the power consumption of a VSD-controlled fan or pump varies in just about direct proportion to flow multiplied to the third power, it consumes less energy than a fan or pump with traditional methods of flow control. For example, when a pump controlled by a VSD only provides 50 percent of its design flow, the horsepower requirement will be approximately 0.50 x 0.50 x 0.50 = 0.125, or only 12.5 percent of the full-load horsepower.

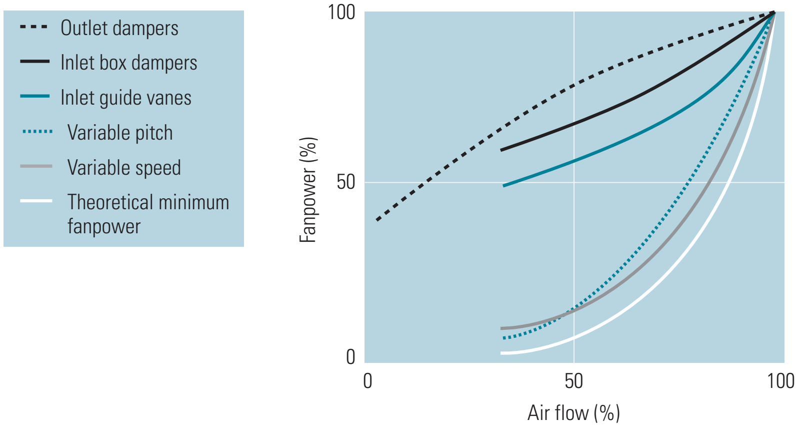
The application of VSDs for variable-air-volume air-handling systems has become increasingly common in new construction in Southern California. This is due in part to the requirements of the California Energy Commission's Title 24 for fan capacity control on larger air-handling systems. Title 24 specifies that only certain types of fan capacity controls (those that consume 50 percent or less of design horsepower at 50 percent of design flow) can be used in new construction. From a practical standpoint, this requirement has limited the HVAC designer to using either inlet guide vanes (also sometimes referred to as pre-rotation vanes)[8] or a VSD to control airflow for a centrifugal fan, or to using variable-pitch fan blades in axial fan applications. **Figure 5** depicts the energy input as a function of airflow for the most common means of fan capacity control. Basically, the more closely the curve for a specific fan control strategy matches that of the theoretical limit curve (the bottom curve), the more efficient this method will be.

Revisions to the Title 24 Standards—due to become effective on January 1, 1999—will further reduce the choices available for fan capacity control. The new standards will require that the fan capacity control method consume only 30 percent or less of design horsepower when providing 50 percent of design airflow. This means that inlet guide vanes will no longer be a compliant method for controlling fan flow—only a VSD or variable-

As of January 1, 1999, the Title 24 standards will require that the fan capacity control method consume only 30 percent or less of design horsepower when providing 50 percent of design airflow.

Figure 5: The performance of different fan capacity control strategies

Previous Title 24 standards allowed the use of fan capacity controls that consumed 50 percent or less of design horsepower when providing 50 percent of design airflow. The 1998 standards raise the bar a good bit. Under the new standards, only flow-control methods that consume 30 percent or less of design horsepower at 50 percent of design airflow are permitted.



Source: E SOURCE

pitch axial fan will comply with the more rigorous new standards. As a result, those engineers who have resisted using VSDs because of preconceived notions about their operating complexity or reliability will have to learn to work with this soon-to-be mainstream technology.

Although Title 24 does not have many explicit requirements for pumping systems, the application of VSDs to variable-flow chilled and hot water pumping systems can provide substantial energy savings and should therefore be considered in new construction projects of medium to large size. For example, a variable-flow chilled water pumping system in a typical large office building will often consume only 30 to 50 percent of the energy consumed by a constant-flow system.

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During the design phase for a recently constructed 300,000-square-foot commercial office building in Los Angeles, the cooling plant designer performed an economic analysis for installing a variable-flow chilled-water pumping system using variable-speed drives. He projected that the incremental cost for the VSDs, additional piping, controls, and pumps was about $28,000 when compared to a constant-flow system. A computer-based energy simulation revealed that the variable-flow system would save about $7,800 per year when compared to the constant-flow system, resulting in a payback of less than four years. On the basis of these favorable economics, the developer approved the variable-flow system. The building is now occupied and savings have exceeded the projections—largely because operating hours for the building have been a bit longer than anticipated.[9]

There are a few critical issues that need to be considered when selecting a VSD for a specific application:

- *Load profile.* VSDs are not 100 percent efficient—the drive's efficiency varies with load. If a VSD is misapplied to a constant-speed system, not only will there be no energy savings, but energy use may actually increase by three to five percent due to the inefficiency of the drive. In such cases, it is probably more efficient (and less expensive) to omit the VSD and use another strategy to regulate flow, such as a two-speed motor or riding the fan or pump curve.

- *Power quality features.* If harmonic distortion is a concern, consider specifying a VSD that includes integral power quality features such as line reactors and isolation transformers.

In addition to these issues, would-be buyers should know that when a TEFC (totally enclosed fan-cooled) motor with a VSD runs at reduced speed, the cooling fan mounted on the rotor spins at a slower speed, providing a reduced cooling effect on the motor windings, which can lead to overheating.

To provide reliable performance under variable-speed operation, many building operators and design engineers specify “inverter grade” electric motors. These motors usually feature better insulation, improved construction that results in cooler operation, and (sometimes) a separate constant-speed cooling fan to prevent motor windings from overheating when the motor is operating at low speeds. When possible, it is best to require that the motor and VSD (1) be provided by the same manufacturer and (2) be designed to operate synergistically. (See sidebar, this page.)

In general, energy-efficient motors offer better compatibility with VSDs than standard efficiency motors. Their increased efficiency means that less heat is generated within the motor, which results in lower operating temperatures at all operating speeds.

Install Drivepower Components to Maximize Power Quality

Power quality has become increasingly important in recent years because poor power quality can increase electric costs and may also cause malfunction or failure of certain equipment. Most building operators are concerned with two elements of power quality.

INTEGRATED MOTOR/VSD SYSTEMS

In response to concerns about compatibility between motors and VSDs, a number of manufacturers now offer integrated systems (see **Figure 6**).[10] These systems combine a motor, a compatible VSD, and a keypad for programming the unit in one space-saving package. (Note that the buyer must provide any sensors or controls that are to direct the operation of the VSD.) In this integrated system, the motor is placed close to the VSD, minimizing long cable runs that can lead to power quality problems. In addition, the compatibility between the motor and VSD is pre-engineered by the manufacturer, which may minimize the possibility of a motor failure due to a poor match between the two.

Figure 6: An integrated motor/ VSD system

Source: MagneTek [10]

FRACTIONAL-HORSEPOWER VSDs

Although VSDs have traditionally been applied to polyphase motors larger than 5 hp, new fractional-horsepower VSDs—or microdrives—are becoming more commonly available. (See **Figure 7**.) These fractional-horsepower VSDs can be used with exhaust fans, small circulating pumps, and other fractional-horsepower loads to improve overall performance and efficiency. VSD control usually improves energy efficiency when compared to other methods of changing the operating speed of small motors.

Figure 7: Fractional-horsepower variable-speed drive

Source: MagneTek [10]

Power factor. Power factor is an indicator of how much of a power system's capacity is available for productive work. Utilities are concerned with low power factor because they must generate sufficient electricity to meet both the "real" power (the actual power consumed, which registers on the electric meter) as well as "reactive" power (the power used to energize magnetic fields, which doesn't register on the electric meter) loads in a building. Utilities generally do not charge most customers for "reactive" power, but low power factor makes it necessary to install larger wire and a larger transformer, which raises equipment costs, increases electrical losses, and makes the equipment require more space in what is usually an already cramped electrical room.

In most buildings, good ways to maintain high power factor include the following:

1. *Right-size all electric motors.* Power factor is lower when a motor is lightly loaded.

2. *Specify motors that have a high power factor.* Note that high power factor sometimes comes at the cost of high efficiency, so a balance must be struck between the two. If a facility contains a lot of motors, then power factor may be the more significant issue. For typical commercial buildings, the designer may opt to focus on motor efficiency over power factor, because at present the penalty charges for low power are small in relation to the total cost of electricity for a typical facility. If, in the future, a designer knows that a new building will be subject to power factor penalty charges, an economic analysis can be performed to weigh the benefits of improved efficiency against the power factor penalty charges that might be incurred.

3. *When low power factor cannot be avoided, apply power factor correction.* For example, in facilities that have a large number of fractional-horsepower motors, power factor correction devices such as capacitor banks should be installed.

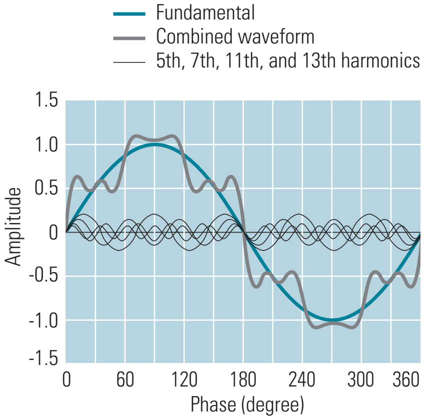
Harmonics. Harmonics are voltage and current frequencies in the power system that are either above or below the normal 60-Hz sinusoidal power provided by utilities in the U.S. (see **Figure 8**). Harmonics are introduced into the power system by a variety of electronic devices, including VSDs and electronic lighting ballasts. Although harmonics are a necessary side effect of modern switching power supplies and electronics, they can harm other electrical equipment. For example, harmonics can affect the performance of motors and can interfere with the function of VSDs.

Two main strategies can be employed to reduce the impact of harmonics:

1. Locate motors within 50 feet of the variable-speed drive that controls them.
2. In particularly sensitive environments (or when longer cable runs are necessary), install line reactors or isolation transformers to minimize the propagation of harmonics.

Figure 8: Waveform with VSD harmonics

This graph shows how harmonics distort the fundamental waveform.



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FOR MORE INFORMATION

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NEMA is one of the leading standards-development organizations for electrical equipment. The current EPACT motor efficiency standards are based on standards developed by NEMA.

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IEEE is the world's largest technical professional society. It seeks to advance the theory and practice of electrical engineering, through sponsorship of seminars, symposia, and research. IEEE publishes about 25 percent of the world's technical papers on electrical engineering topics and is a valuable source of technical information on issues such as power quality and motor/VSD compatibility.

MotorMaster+
Those who are interested in analyzing the cost-effectiveness of energy efficient motors will benefit from using the MotorMaster+ software. It is distributed free of charge to anyone who participates in the free Motor Challenge Program. For further information, contact the program distributor:
Motor Challenge Information Clearinghouse
P.O. Box 43171
Olympia, WA 98504-3171
tel 800-862-2086
fax 206-586-8303
web www.wseo.wa.gov/cfpro/motors/motorhome.htm

E SOURCE Drivepower Technology Atlas
This highly acclaimed, regularly updated reference manual has earned a reputation as the most detailed "encyclopedia" available on end-use drivepower efficiency. (The Atlas series also includes volumes on *Lighting, Space Cooling and Air Handling,* and *Residential Appliances*.) To obtain a copy of the *Drivepower Atlas*, contact:
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web www.esource.com

Notes

1 "1992 Commercial Energy Use by End-Use," from the *1992 Commercial Buildings Energy Consumption Survey*, Office of Energy Markets and End Use, National Energy Information Center, Energy Information Administration, EI-30, Forrestal Building, Washington, DC 20585, tel 202-586-8800, fax, 202-586-0727, e-mail infoctr@eic.doe.gov, web www.eia.doe.gov.

2 "Energy Efficient Motors: Thirty Questions and Answers," MotorMaster+ software documentation (1998), U.S. Department of Energy, Motor Challenge Information Clearinghouse, P.O. Box 43171, Olympia, WA 98504-3171, tel 800-862-2086, fax 206-586-8303, web www.wseo.wa.gov/cfpro/motors/motorhome.htm.

3 Margin of safety is an intentional oversizing factor applied to motor size to account for unforeseen variations in operation. For example, if a 10 percent margin of safety is applied to a motor application with a calculated requirement of 27.3 hp, the installed motor will have a nameplate horsepower of 27.3 hp + (10 percent x 27.3 hp) = 30 hp.

4 The appropriate margin of safety is application-specific and should be established by the Engineer of Record. Sometimes, motor-driven loads that are thought to be strictly constant actually do vary over time. For example, the load on a constant-volume fan motor will vary slightly over time due to the temperature and humidity (and therefore the density) of the air it moves.

5 Which would be 4,000 hours per year of operation at a load factor of 80 percent, with an average electric cost of $0.09 per kilowatt-hour. This example was developed with MotorMaster+.

6 The ability to control the efficiency of motors in OEM equipment will vary according to manufacturer and type of equipment. In general, if large quantities of equipment are involved, the manufacturer will be more willing to consider motor substitutions. For some types of equipment—such as refrigerated water coolers that contain small, hermetic compressors—it will often not be possible to make motor substitutions.

7 Craig Hofferber, personal communication (August 18, 1998), Director of Commissioning Services, CFH Systems, 24712 Rollingwood Road, Lake Forest, CA 92630-3120, tel 949-837-7641, fax 949-830-4114, e-mail chofferber@clubnet.net.

8 Inlet vanes are airflow control devices that are mounted in the inlet of a centrifugal fan to induce a circular flow pattern as air enters the fan. This pre-rotation of the incoming air lessens the airflow generated by the fan. Changing the position of the inlet vanes allows fan airflow and pressure to be accurately controlled.

9 Scot Duncan, personal communication (August 25, 1998), Vice President of Energy Conservation, Retrofit Originality Inc., 25 Mauchly, Suite 314, Irvine, CA 92618, tel 949-859-5986, fax 949-830-4114, e-mail sduncan@dubnet.net

10 MagneTek, 26 Century Boulevard, Suite 600, Nashville, TN 37214, tel 800-624-6383, fax 615-316-5158, e-mail productinfo@magnetek.com.

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