Implementing Motor Decision Plans

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ABSTRACT

In spite of the significant savings that could be realized from improved motor decisions, most industrial facilities do not have plans in place. A number of factors contribute to this, including lack of resources to pay attention to these motors and a perception that the implementation of a plan is challenging and time consuming. In reality, motor plans can be represented as a continuum from simple motor decision rules coupled with key motor identification, to comprehensive motor inventory programs integrated with a plant-wide predictive maintenance program. While a comprehensive motor inventory program can deliver maximum savings, a simple plan can achieve significant savings with modest effort.

To encourage facilities to implement motor decision plans, the staff need to be made aware of the range of programs that can be implemented, and also provided the tools necessary to implement the plan most appropriate to their situation. Achieving this goal may require making corporate management aware of the benefits of motor decision planning, which goes beyond just energy savings.

Introduction

The energy savings that can be realized from making "proper" motor selection replacement and repair decisions have been recognized for almost two decades. However, recent surveys (DOE 1998; Stout 2000) indicate that many industrial firms have yet to implement motor decision plans. In this paper we will discuss reasons for this behavior, conceptually map out how to develop plans appropriate to the needs of particular facilities, and offer suggestions for policymakers to promote adoption of the plans.

Background

While opportunities exist to specify efficient motors in new equipment purchases, replacement of failed motors occurs more frequently than initial purchases and should be the focus of most motor efficiency efforts. The first step to reducing motor energy costs and increasing reliability is to establish a motor decision plan. A motor plan allows decisions to be made in advance of motor failure, and increases the available options. By contrast, most motor "business as usual" (BAU) decisions are made at the time of motor failure, when the immediate costs of the downtime are apparent and large while the other costs are vaguely understood and occur sometime in the future. As a result, the quickest option to get a working motor is chosen with limited regard to the short- or long-term cost. This is represented in Figure 1.

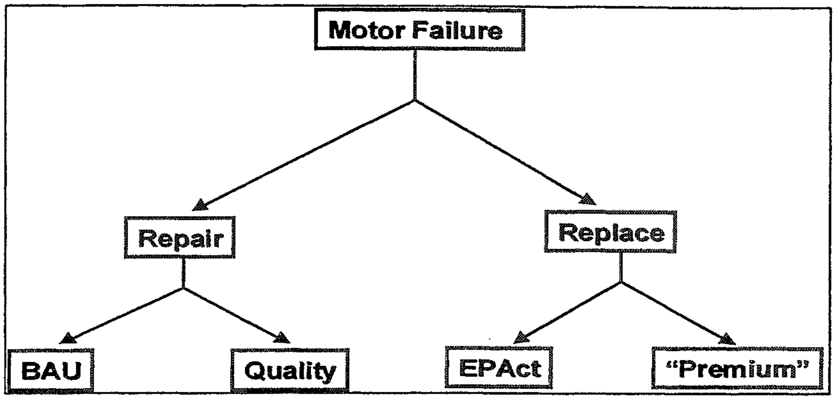

Figure 1. Motor Decision Points

When purchasing a motor for a new application, time is usually available to consider various options. However, once a motor has failed, the decision between repair or replace must be made quickly. If an energy-efficient motor is not immediately available, the motor will usually be either repaired or replaced with a standard-efficiency motor.

Therefore, it is important to move motor decisions from *panic* to *planning*. By implementing a management plan to deal with motor failures, a facility can determine the best course of action. The facility manager can work with suppliers to ensure that the products and services are available when needed, either by purchasing a spare motor or having the supplier stock a replacement. If a facility does not already have a motor replacement strategy, some type of planning can be implemented immediately to avoid bad decisions and capture opportunities for significant long-term cost savings.

There are several strategies available for developing a motor management plan. They range from simple decision rules to a comprehensive inventory:

- Develop a set of criteria for repair/replace decisions. This aspect must be approached with some caution because simplistic rules, such as "repair any motor over 50 hp and replace any smaller motor," can lead to bad decisions,
- Make repair/replace decisions in advance on specific critical application motors, and
- Develop a comprehensive motor inventory, a repair/replace decision for each motor in the inventory, and a list of all spares available and their best placement.

Benefits

Numerous benefits accrue to facilities that adopt one of these policies:

- Improved productivity from increased uptime (this alone can justify additional investment required for energy-efficient motors),
- Fewer breakdowns and their associated incidental damages and human costs—i.e., fewer "fire drills" since the new motors tend to be more reliable and to last longed than do repaired motors, and
- Lower energy costs due to installation of premium-efficiency motors (in many cases this alone justifies the investment).

These benefits can be large but also vague and difficult to quantify. Furthermore, many occur at some nonspecific time in the future.

Costs

The costs imposed upon the facilities that adopt these motor decision plans are usually much smaller than the benefits. Unfortunately, these costs are easy to calculate:

- Motor survey costs,
- Additional cost to purchase a new motor compared to repairing the old one,
- An anticipation that premium-efficiency motors will cost more than standard EPACT motors, and
- New motor purchases may come out of an annual capital budget.

The additional costs of buying premium-efficiency motors need not be large. Data from *MotorMaster+®* (WSU 1999) indicates that some premium-efficiency motors are now available for the same price or less than the price of typical EPAct motors (Wroblewski 2001). Since most motors are obtained at a substantial discount from retail (which is the cost listed in *MotorMaster+®),* the cost increment can be even less (Nadel et al. 2001).

Simple Decision Rules

Each facility must develop motor decisions that fit its unique situation based on factors such as electricity price, cost of motor repair, and new motor discounts. A reference, like the *Energy-Efficient Electric Motor Selection Handbook* (McCoy, Litman, & Douglass 1993) or a tool, like the *MotorMaster+®* computer program (WSU 1999)—both available through DOE's *BestPractices: Motor Systems* program—can provide some guidance into the economics of different motor choices.

Following is a general example of simple motor decision rules:

- Replace all failed standard-efficiency motors that operate continuously with the highest-efficiency new motors available,
- Repair all other failed standard-efficiency motors greater than (some size) and replace smaller motors with new standard-efficiency motors,
- Repair all failed energy-efficient motors greater than (some size) and replace smaller motors with new energy-efficient motors, and
- Replace any motor for which the repair cost exceeds 60 percent of a new motor cost.

In general, the threshold at which replacement is more cost-effective than repair varies from 40 to 75 hp among facilities that use this approach, depending upon electricity cost and new motor discount. For failed energy-efficient motors, the threshold is usually one or two sizes smaller.

In all cases where repair is called for, it is important to have the motor service shop evaluate the motor before repairing it. Some types of failures may significantly damage the motor such that it cannot be restored to reliable and efficient operation (Nadel et al. 2001).

It is also important to note that since October 1997, by law, only general-purpose motors meeting minimum energy efficiency levels have been manufactured. Most manufacturer and dealer inventories have been depleted, such that general purpose, 1–200 hp standard-efficiency motors are no longer available (Nadel et al. 2001).

Special ODP Motor Considerations

Enclosed motors (e.g., totally enclosed fan-cooled motors [TEFC]) predominate on the industrial plant floor (XENERGY 1998) so most motor efficiency programs focus on this class of motor. Many industrial facilities also have significant HVAC equipment used for plant conditioning or office space. Open motors (e.g., open drip proof [ODP]) predominate in these systems.

Older, standard-efficiency motors, especially in facilities that are more than 5 years old, primarily drive this HVAC equipment. Since these motors operate for many hours annually, these motors should not be repaired but should be replaced with new, efficient motors. Only premium-efficiency ODP motors should be repaired; however, the event of a premium-efficiency ODP motor needing to be replaced is unlikely. These motors are not usually heavily loaded and moreover they operate in a clean environment and so are unlikely to experience the overloading and hostile environments that contribute to premature failure. In an HVAC setting the motors normally last 15 years or more.

Standard-efficiency motors also represent a significant opportunity at commercial properties since many of these facilities are built on speculation and tend to these motors driving their air conditioning fans and pumps. When they do break down, the contractor usually reduces its costs by using rebuilt motors or repairing motors that should be scraped. Typically, this is done in a misguided attempt to save the customer money.

Unique Motors and Large Motors

Most users are predisposed to repair unique and large motors because of the substantial cost of replacement. Most of the published literature promoting motor policies focuses on 1,800 and 3,600 rpm, general purpose motors and makes only passing mention of the fact that these are usually rewound. Unless the user has prepared for its demise, the motor will almost certainly be repaired because no replacement will be available in a timely manner. For critical applications, the facility can work with its motor supplier to arrange for a special order in advance of failure.

Key Motor Identification

A more comprehensive approach to planning motor decisions is to survey the most important motors in the facility. During the survey, a determination is made and recorded about which motors should be repaired and which should be replaced on failure. Data is collected on nameplate characteristics. In the past, some electric utilities have offered this service at a nominal charge, though this is becoming less common. Consultants, motor suppliers, and some state energy efficiency programs also offer this service.

A Carolina Power and Light (CP&L) program that was implemented in the 1980s provides a successful example of the deployment of this program approach. The utility assisted customers in identifying, through audits, which motors should be repaired and which replaced with energy-efficient motors upon failure. The auditors identified motors with high operating hours for which energy-efficient motors offered a good payback at time of motor replacement. Customers were then encouraged to mark these motors with a large yellow dot, and maintenance crews were instructed to install a new efficient motor when a yellow dot motor fails (Nadel & Jordan 1994).

Motor Inventory

The most comprehensive approach to planning motor decisions requires developing an inventory, or listing of motors at the facility, that includes (at the very least) the large and critical application motors. Many facilities engineers mistakenly assume that anything less than this level of effort isn't effective in implementing a motor management plan, and are thus discouraged from doing anything.

The comprehensive approach involves recording motor location, application, size, speed, electrical specifications, date installed, and estimated load and operating hours. In addition, some facilities also record measured data such as motor speed, voltage and current (by phase), and vibration. These data can then be used as part of a preventive or predictive maintenance program to identify problem motors before they fail. These motors can be replaced or removed for repair as part of the routine maintenance schedule.

An overview of how to set up a motor inventory program is available from DOE's *BestPractices: Motor Systems* program, as well as from many utilities and motor suppliers. Since most facilities have numerous motors, it is often attractive to use a computer program to maintain the motor inventory. A number of inventory tools exist, developed by private parties, government, and utilities. *BestPractices* is making a powerful management software tool available, with user training, through its Allied Partners.[1] This updated successful motor selection program, *MotorMaster+*®, combines all the motor selection features of the original program with motor inventory and management functions. The program maintains the inventory, allows advance planning for motor repair/replace decisions, and tracks individual motor operations as part of a predictive maintenance program. A repair or replace suggestion is made for each motor based on the user's particular conditions.

The effort and cost of collecting the information, however, can be high. One approach is to build the inventory gradually, starting with key motors and adding additional motors as repairs or maintenance are performed in the area where the motors are located. Another challenge that facilities face when trying to keep track of their motors is that, despite the additional features added in the last release of *MotorMaster+*® (WSU 1999), it still does not fully meet the needs of maintenance departments that are practicing preventive maintenance. For these facilities, two lists must be maintained: one for motor preventative maintenance (PM) and one for motor repair/replace. For large facilities that buy a hundred or more motors per year, the cost of maintaining the motor inventory list is large.

Alternatively, many consultants and motor suppliers are beginning to offer this inventory management as a service. The service might take several forms. In one form, a motor supplier may provide motor inventory and management for a customer. In another, a contractor may survey all motors in a facility and do routine checks of key motor performance in an attempt to predict failures and implement preventative actions. Upon failure, the contractor may replace or repair the motor depending upon economic and operating conditions.

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[1] For a current list of Allied Partners, contact DOE's OIT Clearinghouse at 800-862-2086 or visit the website at: www.oit.doe.gov/bestpractices.

What Data to Collect

A wide range of specification and operating data can be collected on motors. However, collecting information serves no purpose unless it supports the management plan. The data requirement of each facility needs to be considered when choosing what data to collect. We break the suggested data down into motor specification and operating categories. Under the specification, the goal is to have that data necessary to characterize the motor and allow failure decisions to be made. The motor parameters, many of which are on the nameplate, include:

- motor horsepower,
- design,
- enclosure,
- frame size and special mounting features (e.g., C-face),
- full-load efficiency, and
- full-load speed.

The operational parameters might include:

- when the motor was placed in service,
- when the motor was last repaired,
- who repaired the motor last,
- how many times has the motor been repaired,
- what is the lubrication schedule, and
- approximate motor loading and hours of operation.

Several additional parameters, which if routinely recorded, can contribute toward a preventative or predictive maintenance program, including:

- motor bearing temperature or vibration measurements, which can help predict bearing failure,
- motor input voltage by phase, which can identify potential electrical supply problems,
- motor current by phase, which can reflect loading and potential electrical problems, and
- information on past failures in the application, which can help identify application problems.

Who Is Inventorying their Motors?

Unfortunately, many end-users are not familiar with the meaning of motor inventory as we use it. The term is ambiguous, and many people assume the other meaning of the word inventory. At one plant, when asked if they had a motor inventory, the maintenance supervisor said, "We do that. Our motor inventory is in Warehouse C. I've got a half-dozen spares out there." The collection in Warehouse C turned out to be an assortment of repaired back-up motors that were resurrected from the scrap heap. It is clear that people think of "inventory" as stock available on-hand.

The companies that have a motor inventory (as we use the term) tend to be larger, more sophisticated companies that have a facilities engineering department that tracks productivity and plans preventive and predictive maintenance, as well as facility upgrades. Large, continuous process manufacturing plants may have thousands of motors, many of which are in abusive and damaging environments. The large population coupled with the short life means that these folks are constantly dealing with broken-down motors. Largely out of necessity, some of them have figured out a system of cataloging or inventorying their motors (or at least tracking spare parts), either on index cards or in a computer spreadsheet. For these customers, adopting *MotorMaster+®* to maintain their inventory is a daunting task since it would usually mean implementing and maintaining a whole new management information system, while at the same time still continuing and maintaining the old system during the transition.

Considerations in Selecting a Replacement Motor

The predominance of National Electrical Manufacturers Association (NEMA) design specifications (NEMA 1999) for motors have created both a benefit and a risk for facilities. The advantage is that motors of the same enclosure, design, and speed are interchangeable. If they are placed in service they will function acceptably. However, there are subtle differences between these motors that can have profound differences in the amount of energy used. The most important parameter is full-load speed. A motor with a given synchronous speed will have an operating speed somewhat less than the synchronous speed due to a characteristic of induction motors called slip. The amount of slip will vary from one motor design to another. While the difference may appear small, the energy implications can be large for centrifugal loads like pumps and fans. For these loads, the power use varies somewhere between the square and the cube of the speed so small changes in speed can result in large changes in energy use. This phenomenon is particularly important for energy-efficient motors, which tend to have lower slip than do older, standard motors. In most applications, the correction is not costly, but it is important to check the full-load speed on the nameplate of both the old and new motor, or measure the speed with a strobe tachometer (for further discussion, see Nadel et al. 2001).

Specifying a New Motor

Specifying a new motor should be much easier than procuring a replacement motor because there is usually less of time constraint in making a decision. For most continuous duty applications it will make sense to purchase a premium-efficiency motor, such as those specified by the Consortium for Energy Efficiency (CEE 1996) or under the new NEMA Premium Motor (NEMA 2000) program. While premium motors are becoming more well known, a recent DOE study still indicates a low level of awareness (DOE 1998).

Problems can, however, be encountered in procuring these motors because most new motors entering a facility come as part of a piece of equipment. While some original equipment manufacturers offer premium motors as an extra-cost option, this option is frequently discouraged or in some cases not offered at all by the original equipment manufacturer (OEM). The OEM has limited incentive to offer the premium motor because it doesn't receive any of the operational savings, and it realizes little benefit from additional cost and hassle of stocking two motors of different efficiency for an application. From the facility's standpoint, operations staff may also encounter internal resistance from the purchasing department, which may not wish to expend the additional effort to request and ensure that the vendor is providing a premium motor.

Policy Implications and Market Analysis

In the past, some electric utilities have offered motor surveys as a customer service at a nominal change, though this is becoming less common. Consultants, motor suppliers, and some state government, energy efficiency programs also offer this service. Whether or not utilities continue to offer the service at a reduced price will have less of an impact than will utilities ability to motivate their customers to act on their own. Utility programs can be quite effective at implementing this change, but the effects would only be felt among their customers (Nadel et al. 2001). Market evidence suggests that a different approach is necessary, depending on size and corporate infrastructure.

Currently, market penetration seems mostly limited to Fortune 100 companies. It stands to reason from an overall business perspective that well-managed companies are the same ones who would adopt a proactive motor policy. A company first and foremost needs to have a good product or service that they can bring to the market in a reliable and timely manner. Secondly, all their fundamental business systems (such as accounting, inventory, materials procurement, and personnel) need to be in good shape before it makes sense to apply the constant improvement principles to the way motors are procured. In a large organization, the allocation of staff, at least at the corporate level, can be justified in implementing a program. Many understand that motor-downtime affects their margin. Another factor is that some big manufacturing companies often include large continuous feed processes that run 24 hours per day, seven days per week, and a critical motor failure anywhere on the line can shut down the whole line.

This is a very different situation from the small manufacturing or job shop that makes parts and assemblies 5 days a week. For instance, a small manufacturing company may have only a few motor breakdowns per year to begin with, then when you allow for the fact that some are in the rooftop HVAC units and/or under service contract, there are not enough breakdowns to create the connection between motor policies and productivity. Also, productivity has a different meaning to a small plant that can have an operator come in to work a Saturday shift and catch up on the downtime, as opposed to the continuous process, where a breakdown represents fewer units shipped, and therefore lost revenue and profit.

Unfortunately, because of this market barrier, it is likely that only a few small companies will ever embrace a proactive motor management plan on their own initiative, but they may be good candidates for ratepayer or public benefit-funded initiatives. For medium and large companies, and those that have continuous processes, an information campaign aimed at senior management to point out what intervention may be appropriate. This approach is being used by the new *Motor Decisions Matter* initiative (CEE 2001) being launched by the Consortium for Energy Efficiency (CEE), NEMA, and the Electrical Apparatus Service Association (EASA).

To further break down the barriers that prevent customers from implementing a motor inventory, suppliers of preventive maintenance software should be encouraged to include key elements of *MotorMaster* in their offering, rather than to convince companies to adopt *MotorMaster* in addition to their existing PM software.

Conclusions

Establishing a motor decision plan opens up opportunities for significant energy savings and increases in operational reliability. For many industrial facilities, establishing a motor plan may appear intimidating. It need not be. A simple plan, such as the CP&L "dot" model, can be very effective for many small and medium-sized firms. For a larger firm, establishing a database starting with only critical motors may be a good start. The journey begins with a single step; small or large firms can start with an index card for every motor. These plans can grow and evolve as understanding and needs change.

The important point is that, without a plan, the facility is at the mercy of fortune. With a plan, the facility staff gains control over their future.

References

Advanced Energy. *Horsepower Bulletin.* Raleigh, NC, 1993.

[CEE] Consortium for Energy Efficiency. 1996. *Premium Efficiency Motor Initiative.* Boston, Ma.

[CEE] Consortium for Energy Efficiency. 2001. *Motor Decisions Matter Business Plan.* Boston, Ma.

[DOE] U.S. Department of Energy. 1998. *United States Industrial Electric Motor Systems Market Opportunities Assessment.* Washington, D.C.: Office of Industrial Technologies.

McCoy, G.A., T. Litman, and J.G. Douglass. 1993. *Energy-Efficient Electric Motor Selection Handbook-Revision 3.* Washington, DC: Department of Energy.

Nadel, S., and J. Jordan. 1994. *Designing Industrial DSM Programs that Work.* Washington, DC: American Council for an Energy-Efficient Economy.

Nadel, S., R.N. Elliott, Michael Shepard, Steve Greenberg, Gail Katz, and Anibal T. De Almeida. 2001. *Energy Efficient Motor Systems: 2nd Edition.* Washington, DC: American Council for an Energy-Efficient Economy.

[NEMA] National Electrical Manufacturers' Association. 2000. "NEMA Announces Premium Motor Label," press release. Arlington, Va.

Stout, Jennifer. 2000. Personal communication, October. Lake Oswego, Org.: Water and Energy Consulting.

[WSU] Washington State University Energy Program. 1999. *MotorMaster, Version 3.01.* Olympia, Wash.: Washington State University.

Wroblewski, R. 2001. "Efficient, Inexpensive Motors, A New Trend in the Motors Market" in the proceedings of the Industrial Energy Technology Conference. May 2-3. College Station, Tex..: Texas A&M University.