Kaman Industrial Technologies

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PRACTICAL PERSPECTIVES ON MOTOR MANAGEMENT

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"There are a variety of reasons why careful attention should be paid to motor management. One of the most critical is to be able to maintain production uptime. A 2003 EASA (Electrical Apparatus Service Association) survey found that the cost of downtime ranges from as high as $200,000 to $1 million per day. Motor management supports the need for improved reliability in a number of ways."

EXECUTIVE SUMMARY

Electric motors represent a significant cost to industry, not just in their purchase and maintenance, but in the energy they consume. Ineffective — or non-existent — motor management policies can burden a manufacturing or process facility with unnecessary costs and preventable downtime.

Contrary to many of the traditional assumptions regarding motor management, the practice is not only for large users, nor does it need to be a tremendously time-consuming initiative. This white paper provides an overview of what constitutes a “best practices” approach to effective motor management. Topics that are addressed include:

- The true value of effective motor management
- Reliability – the “trump card” over all other issues
- Creating a scalable program for any electric motor user
- Employing an incremental approach to implementation
- Harvesting the low-hanging fruit
- Cost-effective motor specification
- Repair vs replace
- Maintenance and repair standards
- Measuring the results

The ultimate goal of this document is to provide the reader with guidance and suggestions for developing a useful motor management program based on simple, actionable methods and processes. Adopting a more practical approach to motor management allows new and existing implementers to achieve more rapid and substantial gains from their motor management initiatives.

OVERVIEW

According to the most recent U.S. Census Bureau statistics, motor purchases in the United States were $3.9 billion in 2003 (down from $4.4 billion in 2002). Latest statistics show that there are 470 motor and generator manufacturing companies in the U.S., employing 54,112 workers. While reliable global statistics are hard to come by, it would not be difficult to speculate that over one billion motors are now in use worldwide. Repair and rebuild services represent another significant economic segment of the overall motor marketplace.

One of the most critical – and most easily identifiable – factors driving the total cost of motor ownership is energy efficiency. According to the U.S. Department of Energy (DOE), manufacturing companies consume roughly 25% of all the electricity used in the United States. Electric motors use approximately 70% of that total. The DOE estimates that if more attention were paid to motor system management, electricity costs for manufacturing companies would go down as much as 18%.

The Motor Resource Center has cited energy experts who believe that "even a one percent improvement in efficiency could translate into millions of dollars in savings" among U.S. industrial consumers. The Motor Resource Center is a collaborative effort between Washington State University's Cooperative Extension Energy Program and Advanced Energy in Charlotte, NC. As a result of steadily increasing energy costs, more and more companies are starting to focus their attention on conservation efforts while looking for ways to reduce overall production costs.

The annual expense to operate a motor far exceeds its purchase price. The Motor Resource Center estimates that the cost of a large industrial motor (100 HP and above) amounts to just 0.5% to 1% of the total cost to operate it over its useful life. The Consortium for Energy Efficiency agrees, stating that energy consumption represents 97% of the total cost to operate a motor. The purchase-cost-to-operating-cost ratios are similarly astounding in the commonly occurring 5 to 15 HP range. What is the significance of this?

To draw a contrast to a more common cost of ownership scenario, the average automobile will cost a buyer somewhere between $20,000 and $25,000 to purchase and will require approximately $1,200 to $1,500 in fuel, fluids and other operating expenses. In this case, the cost of operation is only 6% to 8% of the car's value per year.

Compare this to the typical scenario for a 100 HP motor. The purchase cost will be approximately $3,000 to $4,000, however the average annual operating costs can approach $50,000 or up to 12-1/2 times the purchase cost each year. An understanding of this disproportionate ration helps to underscore the importance of focusing your attention on managing the operating expenses associated with electric motor use rather than the purchase cost.

THE BUSINESS CASE FOR MOTOR MANAGEMENT

Motors are a critical link in the manufacturing process, and represent a sizeable investment in both direct costs (purchase, operation, maintenance and repair), and indirect costs (production efficiency, product quality, etc.). In fact, these "prime movers" of industry typically represent one of the top three operating costs for the average user including payroll, building and inventory expenses.

There are a variety of reasons why careful attention should be paid to motor management. One of the most critical is to be able to maintain production uptime. A 2003 EASA (Electrical Apparatus Service Association) survey found that the cost of downtime ranges from as high as $200,000 to $1 million per day. Motor management supports the need for improved reliability in a number of ways.

In total, an effective motor management plan provides opportunities for:

- Lower operating costs:
  - Increased reliability
  - Reduced downtime
  - Enhanced process efficiencies
  - Quality improvement
  - Less waste heat

- Lower maintenance and production costs:
  - Lower energy consumption
  - Greater energy efficiency
  - Less rush motor repair/rewinding

- Increased motor life through reduced heat generation:
  - Increased insulation life
  - Increased lubricant life
  - Increased bearing life

- Better motor application and allocation decisions with considerations for:
  - Inverter duty requirements
  - HP optimization
  - Power quality
  - Nominal efficiency
  - Necessary feature sets (such as high ambient temperatures and other environmental issues requiring an IP55 rating or better)

Other areas of opportunity that fall under the motor management umbrella include the appropriate use of related peripherals, components and processes such as:

- Inventory level optimization
- Helical bevel gear reducers
- Variable frequency drives
- Chain and positive tooth belt drives (synchronous)
- Condition monitoring
- Lubrication management systems
- Predictive/preventive maintenance
- Product standardization

USER CONCERNS REGARDING MOTOR MANAGEMENT IMPLEMENTATION

There is a growing interest in finding ways to manage motor populations more effectively, but end-users still have a long way to go. A U.S. Industrial Motor Systems Market Opportunity Assessment report illustrates the point. Just 22% of companies have purchased premium energy efficient motors, and only 3% have a motor efficiency policy in place. Fully 69% of motor purchasers were not aware of the availability of the industry standard NEMA Premium® energy efficient products. NEMA (National Electrical Manufacturers Association) estimates that if new, more energy efficient motors replaced old inefficient motors still in use, 5,800 gigawatts of electricity would be conserved over 10 years (roughly the equivalent of removing 16 million cars from American highways).

Most leading motor manufacturers have addressed user concerns about motor efficiency and reliability and can offer expertise and assistance on the topic of motor management. Additionally, various non-profit and governmental resources such as the U.S. Department of Energy, Washington State University, Motor Decisions Matter, and others, have prepared guidelines for the development of motor management programs.

Still, many companies are hesitant to implement motor management programs because they fear that the process will be capital intensive, difficult to implement and time consuming. The issue also transcends departmental boundaries as the user’s purchasing department is frequently asked to pay a premium for more efficient, more reliable replacement motors. However effective motor management does not have to be painful if approached in manageable stages. Organizations can still reap meaningful benefits even with only incremental improvements to their motor management practices.

Many forward-thinking companies already have quality programs such as QC/QA, ISO or Six Sigma programs in place. These programs help to drive the company towards practical and profitable, long-term operating decisions. Instituting the same philosophy when it comes to motor management by making such a program part of your “best practices” portfolio will pay big dividends over time.

GETTING STARTED

Academic institutions and some other advocates tend to overcomplicate the issue of motor management. Many of the highlighted cases are of larger organizations that are able to implement rather comprehensive programs. Such programs can frequently address more than a dozen different topics. Many of these topics support efficiency and reliability “best practices” and are outstanding examples of what is possible. However, they may represent more than a typical end-use can implement. There is enough industry knowledge on this topic to establish a workable foundation that allows the average user to jump-start a new motor management program.

Like many process-oriented initiatives, there are four general phases involved in the traditional model for implementing a comprehensive motor management program:

1. Data Collection
2. Analysis and Conclusions
3. Plan Development
4. Plan Implementation

These phases may branch off into a number of sub-initiatives, each requiring further study and analysis to identify the most cost effective strategies and solutions. Each application, motor and related technology can appear to be a distinct requirement. The problem is that some users become discouraged, confused or intimidated by the potential detail and complexity of this approach.

The unfortunate result of this approach is that relatively few motor management programs ever really get going, and even fewer are completed. In fact, many programs never get beyond the Data Collection phase as the user becomes overwhelmed by the prospect of collecting what can be a dizzying array of data for the company’s entire motor population including such factors as:

- Motor type (AC, DC, servo, stepper, miniature, etc.)
- Frame size & mounting configuration (NEMA 56, -C, -D, etc.)
- Enclosure type (ODP, TEFC, AO, AOBC, etc.)
- HP rating
- Speed rating (RPM)
- Full-load torque rating
- Efficiency rating (nominal vs. guaranteed)
- Insulation class (B, F, H)
- Voltage requirement
- Frequency (applied vs. design – 50/60 Hz.)
- Phase (single-phase, three-phase)
- Manufacturer
- Model number
- Serial number
- Date of manufacture
- Date of purchase
- Date motor put into service (if taken from storeroom stock)
- Quantity in use
- Spares in inventory
- Purchase cost
- Warranty expiration date
- Service and repair history
- Facility asset number
- Lubrication requirement (if applicable)
- Service Factor (% load above nameplate allowed)
- Motor location (by department and/or equipment where motor is being used)
- Application (description or motor function)
- Additional equipment in use (e.g. gear reducers, clutches, brakes).

It is easy to see how a new motor management project leader could become bogged-down in the details. Thankfully, there are sensible and effective ways to avoid some of this work and cut right to the heart of the matter.

A MORE PRACTICAL APPROACH

There are many potential benefits to a comprehensive motor management program, and each may have their own place for a particular user. However, a straightforward approach will focus on the following:

Establishing a logical purchase policy for new motors

A sound "New Motor Purchase Policy" is the cornerstone to any solid motor management program. Just like managing a successful sports team, the job is a lot easier when you start with good players. Specify top quality motors for performance, reliability and efficiency, and taking advantage of consolidation opportunities will provide a great start in reaping the benefits of motor management.

Determining a cost-effective repair/replace breakpoint

The traditional paradigm of assuming that it is more cost effective to repair a failed motor than to purchase a new one has shifted dramatically due to advances in motor manufacturing practices as well as new perspectives on the value of productivity. In fact, many users are surprised by what they find when they take the time to calculate the breakpoint below which it is more advantageous to simply replace a motor and take advantage of the enhanced performance and reliability that comes with the latest technology (see table, pg 8). The main benefit however comes from knowing what you are going to do before a motor fails so that you can make a logical decision and be prepared to act upon it.

Defining and documenting appropriate repair standards

Once the decision has been made to repair a failed motor, it is important to know that you are dealing with a thorough, reliable and professional repair facility. Often times, a repair facility can do as much harm as good (particularly when handling rush repairs) if they do not follow proper procedures. Insist on adherence to a documented repair standard and require your authorization prior to proceeding with repairs in order to be sure that you are maximizing your return on the investment you've made in the repair.

The three critical steps described above are not the sum-total of a comprehensive motor management program. However, they are an excellent and manageable place to start that will help your company capture a majority of the cost savings that an effective motor management program can generate.

A DEEPER LOOK

It may seem illogical to jump right to implementation without having conducted your own survey and analysis work up front. It is a natural tendency to want to follow the type of scientific method that we were taught in school. While there is certainly no harm in conducting this survey work (and it will in fact assist you in making more specific decisions down-the-line), the results of numerous other users' survey work consistently points to certain findings across a broad spectrum of various sized users and industries. The suggestion is simply to capitalize on the work that others have done before you and take advantage of the most beneficial aspects of motor management up front.

The general "assumptions" that support this idea are reinforced by many of the most commonly accepted industry rules-of-thumb within the field of plant management. Accepting these findings as a baseline for implementing your own motor management program allows a company to fast-forward beyond the elements of the "traditional plan" that tend to bog down most new initiatives.

A deeper look at the policies and recommendations involved in each of the 3 core initiatives will help to illustrate exactly how this makes practical sense.

THE NEW MOTOR PURCHASE POLICY — GUIDELINES FOR ACHIEVING THE BEST VALUE

Reliability and efficiency improvements are the goals of any well thought out New Motor Purchase Policy. Investing in current motor technology will quickly generate savings in operating costs, reduced energy consumption and downtime avoidance that will vastly outweigh any additional costs associated with buying the latest technology.

Companies that have adopted lean manufacturing policies and practices are already familiar with the principles of:

> stripping away any unnecessary complication in order to achieve maximum flexibility and responsiveness

> engineering operating policies and practices with the ultimate goal being to ensure consistent and reliable operation above all others

Today's motors are designed to operate at lower temperatures. In cooler-running environments, insulation, bearing and lubricant life are extended, reducing the need for maintenance and increasing uptime. These newer designs are also better equipped to deal with phase voltage imbalance and off-design voltages.

Size optimization is another advantage: Newer designs are more efficient over a wider load range which means the same motor type can be used in different applications reducing the need to keep a number of different types of spares in inventory.

A new motor purchase policy should:

- Specify NEMA Premium® motors
- Specify TE (totally enclosed) designs
- Include special application considerations
- Allow product standardization (manufacturer, HP, speed rating, frame, etc.)

Some companies bristle at the idea of specifying premium grade motors across the full spectrum of applications within an operation. However when you consider the relative cost of one hour of downtime in comparison to the additional cost of a NEMA Premium® motor the rationale is clear.

The industry rule of thumb relative to downtime is if twice the cost of a new motor is less than the hourly cost of the downtime – replace the motor. With an hour of downtime often running as high as $1,500/hr to as much as $25,000/hr in heavy industries such as mining and steel making, a NEMA Premium® motor needs to last just one hour longer in order to justify it's cost over a general duty motor (approximately $1,500 for a 50HP motor). This example does not take into consideration the additional energy savings associated with using the more efficient motor.

Additionally, standardizing your motor specifications as much as possible across your full range of applications will allow you to create circumstances through which you can take your "standard" 5HP motor off the inventory shelf and plug it in to any 5HP application within your plant – without having to make mounting adjustments. Your technicians will become more completely familiar with the construction and subtleties of each of the motors that they service, and motor and spare parts inventories can be reduced as "exceptions" are minimized. Finally, purchasing and replenishment requirements will be simplified as replacement motors are standardized across the operation.

THE REPAIR/REPLACE DECISION

A commonly accepted standard within manufacturing industries is to allow up to 60% of the cost of a new motor for the repair of a failed motor. In other words, if the cost to purchase a new motor is $500.00, the user is willing to pay up to $300.00 to have their old motor repaired.

Surprisingly, relatively few users actually make this calculation when it comes time to make the repair/ replace decision. A study conducted in 2003 by EASA indicated that the typical "large" user (500 employees or more) operated under a general policy of repairing any failed motor 17HP or above (based on an average of the standard nominal HP ratings sited). The average "small" user (less than 50 employees) indicated that they would generally repair any failed motor of only 6HP or above.

A simple comparison of the average rewind cost across a range of motor HP ratings to the typical cost of buying a new energy efficient motor indicates that the Repair/Replace Breakpoint should more logically be set at a rating of 50HP and above (see table on page-8). In fact, this comparison indicates that at a HP rating of 10HP and below, it actually costs you more to rewind the motor than to simply replace it.

However with larger, more expensive motors (≥60 HP), rewinding costs are typically half the cost of purchasing new. Larger motors are also generally easier to repair because internal components are more accessible.

(Table-1) Repair/Replace Decision Chart (Motor type: 1800 RPM TEFC)

Motor HP	Rewind Cost*	% of New	New Cost	Conclusion
200	$2,985.00	49.0%	$6,087.55	Repair
150	$2,420.00	48.9%	$4,950.00	Repair
125	$2,028.00	48.0%	$4,224.98	Repair
100	$1,716.00	56.5%	$3,037.54	Repair
75	$1,365.00	54.1%	$2,525.29	Repair
60	$1,171.00	57.3%	$2,043.73	Repair
50	$1,033.00	83.9%	$1,231.65	Replace
40	$ 858.00	73.1%	$1,173.00	Replace
30	$ 722.00	80.5%	$ 896.75	Replace
25	$ 614.00	81.3%	$ 755.23	Replace
20	$ 536.00	87.4%	$ 613.28	Replace
15	$ 463.00	92.6%	$ 499.80	Replace
10	$ 377.00	110.4%	$ 341.60	Replace
7.5	$ 319.00	106.3%	$ 300.00	Replace
5	$ 271.00	120.1%	$ 225.60	Replace
3	$ 249.00	133.3%	$ 186.80	Replace

* Rewind costs are taken from the DOE Motor Master, Version 4.0

The value comparisons described through the above chart are relatively conservative in their calculation. These calculations do not even take into account the related costs associated with the paperwork and transportation of a failed motor to and from a repair facility. They also do not take into account the related benefits associated with consistently upgrading your motor population to take advantage of the latest technology.

Purchasing a new motor generally means:

> Greater product reliability
> A new product warranty of two, three or even five years
> Improved efficiency savings
> Longer life via cooler operation

Other considerations that tend to weigh against the repair decision over time include the motor's maintenance/ repair history, number of rewinds and its present efficiency. A DOE-sponsored study is currently underway to ascertain the progressive deterioration of a motor's performance over successive rewinds. However it is generally assumed that the more times a motor has been repaired, the lower it's value relative to a new product.

THINGS TO CONSIDER WHEN CHOOSING A REPAIR FACILITY

Once the decision has been made to repair a failed motor, it is critically important to ensure that the repair is conducted in such a way that allows you to achieve the anticipated performance and output from the refurbished motor. Cost and convenience considerations are frequently the primary drivers when choosing a motor repair provider. However, obtaining the best VALUE requires a bit more attention to the standards and practices that your service provider adheres to.

Without standards there can be confusion about what is expected. Not following proper procedures during a repair can do considerable harm. For example, few end-users understand the significance of a “rush” repair to operating cost. A rush repair frequently requires excessive burnout temperatures to remove the old windings. The high temperature introduces additional efficiency losses in the remaining stator materials. These losses result in higher operating costs (electricity consumption) from that point forward.

There are numerous sources (such as EASA and Advanced Energy) that can provide you with their recommended policies for conducting quality motor repairs. Depending on the nature of your industry, applications and the types of motors that you use, you may need to tailor these standards to your particular circumstances. In most cases however, working from industry standards is a quick, easy and effective method for ensuring that the motors you repair will perform well once they are put back into service.

If you repair, rebuild or rewind motors using an outside service and repair facility, there are a few important things to keep in mind:

> Make sure that they:
  - record core loss before and after stripping
  - repair or replace defective laminations
  - calibrate their instruments at least annually, if not more often
  - measure and record winding resistance
  - measure and record no-load amps and voltage during final test
  - make sure they have a quality assurance program in place

> Insist that they DO NOT:
  - heat stators above 650° F
  - sandblast the iron core
  - knurl, peen or paint bearing fits
  - use an open flame for stripping
  - grind laminations or file slots
  - increase the air gap
  - increase stator winding resistance
  - make mechanical modifications without approval
  - change the winding design

> Other qualities to look for in a well-run shop:
  - equipment in good condition
  - compliance with all safety standards
  - organization and cleanliness of work areas
  - employee knowledge
  - a variety of wire sizes/shapes in stock, including half sizes for foreign motors
  - appropriate test equipment
  - membership in EASA (Electrical Apparatus Service Association)
  - standards compliance (EASA Q, ISO 9000 or other QA program)

MAINTENANCE GUIDELINES

While much of the focus of the typical motor management plan is on the Repair/Replace Decision and Documented Repair Standards, it is always important to ensure that attention be given to preventive maintenance programs. After all, the best way to manage your repair/replace decision is to avoid the need for repair in the first place. Here is a list of critical areas to watch out for:

A. Dirt and Contamination

In dusty or chip-laden environments, the motor frame and air passages can become clogged. This debris reduces airflow and causes motors to run at higher temperatures leading to loss of lubricant and premature bearing and insulation failure. Dirt and contamination introduced into bearings is one of the primary causes of motor failure.

B. Corrosion

Motor enclosures showing signs of corrosion are an obvious indicator of a potential problem, but some types of corrosion may not be visible from the outside. Damp or humid environments are particularly destructive if the wrong motor type is used. Internal corrosion may not be easy to detect, but it can severely damage motor components, leading to poor performance and catastrophic failure.

C. Bearing Lubrication

Small motor bearings are typically "lubed for life" by the manufacturer and require no user-performed lubrication. Larger motors, however, need regular attention to lube quality and quantity. Be aware that using too much grease can be just as harmful as lube contamination. Bearings packed with too much grease will overheat which leads to premature wear and eventual bearing failure.

D. Excessive Heat

Excessive operating temperatures are a sign that something is wrong. Motors are rated to perform at different temperature ranges, and should be matched to the application and surrounding operating environment. In particular, make sure that the duty, load and torque ratings are appropriate for the work being performed.

E. Noise and Vibration

Noise does not cause problems, but it is a key indicator that problems exist. Noise is frequently caused by shaft, rotor or bearing misalignment and is usually accompanied by excessive vibration. Left unchecked, vibration can shake windings loose and damage rotor lamination by cracking it, flaking it or abrading it. Additionally, vibration is an effective indication of pending bearing failure.

F. Windings and Insulation

Care should be taken to keep corrosive solvents away from internal elements (like insulation). Dirt and dust can also abrade coil noses and damage windings. Moisture affects dielectric strength of the insulation, which can lead to shorts.

G. Brushes and Commutators

In DC motors, brushes must ride on the commutator smoothly with no excessive sparking or chatter. Extreme wear, chipping, or a rough and dirty commutator indicate a problem that must be addressed.

PLAN IMPLEMENTATION

Virtually every organization can benefit from a motor management plan, regardless of its size. Kaman Industrial Technologies has developed custom-tailored, scalable programs for both large and small motor users. By carefully assessing each individual situation and setting realistic, attainable goals, a practical and cost-effective program can be achieved for any user. Our experience in establishing useful motor management policies runs from small users operating just 20 motors, to major global manufacturers with motor populations over 75,000 units.

Once a motor management plan has been established, some of the key operational decisions will involve inventory management, which includes areas such as motor consolidation opportunities (i.e. standardization), size optimization and establishing a practical number of critical spares to have on hand. In most cases, all but the most critical and unique replacements can be sourced from a reliable distribution partner through a pre-arranged inventory management program. Your distributor should also be prepared to assist you with other strategic decisions related to motor use such as application & design, evaluating energy efficiency and systems integration needs.

MEASURING THE RESULTS

The implementation of even a fundamental motor management program represents a significant but worthwhile investment in time and effort. Additionally, some may be skeptical regarding the true value that is derived from the decision to be more aggressive in upgrading the quality of your new motor specifications and the increased frequency of replacing vs repairing failed motors. Like any investment of this magnitude, careful analysis of the resulting benefits is always warranted and will help to validate the wisdom of these decisions.

Kaman developed the concept of Documented Savings™ nearly 30 years ago in response to customer demands for cost reductions, and ROI justification. Through this program, we monitor product and application performance, document the results and maintain a database of case histories and best practices. Our Documented Savings™ program helps to demonstrate the value of taking an objective approach to MRO product, service and engineering decisions. These same principles can be applied to an effective motor management program.

Typical savings captured through the implementation of a motor management plan can range from $10's of thousands to even millions of dollars per year. Recently, an organization operating just 22 motors was able to identify $50,000 to $100,000 of related savings opportunities. Conversely, a larger user has saved roughly $10 million over a period of years since implementing an aggressive, plant-wide motor management program.

Savings can be found in a number of ways – through improved process efficiencies, product reliability, lower energy costs, product standardization and better inventory management. It can often be difficult to measure and calculate an accurate value for some of the more abstract savings such as downtime avoidance. However there is no denying that these factors often represent some of the most significant savings. Comparison to your facilities historical averages for downtime, repair expenses, throughput and other existing metrics can provide a basis for at least a conservative estimate of the derived benefits.

CONCLUSION

Practical Perspectives on Motor Management outlines some simple steps that any user can take to quickly begin reaping the rewards of a motor management program. Establishing a purchase policy; defining your HP Breakpoint and developing even a basic set of repair standards will pay dividends in efficiency and reliability to your motor assets and thus, your facility. Look to the related equipment and motor driven processes to capture additional savings and to further drive down operating costs.

Once committed to a motor management process, there will be almost no end to the opportunities for achieving greater efficiencies, reliability and savings. Still, while it may seem obvious, the most important thing to do is to get started.

INFORMATION RESOURCES

Advanced Energy, Inc.

Baldor Electric Company

Consortium for Energy Efficiency, Inc.,
The Electrical Apparatus Service Association (EASA)

Electrostatic Motors: Their History, Types and Principles of Operation.
Oleg D. Jefimenko, 1973.

Indian River Consulting Group

Kaman Industrial Technologies — Documented Savings™ Reports

Motor Decisions Matter (www.motorsmatter.org)

Motor Resource Center (www.motorresourcecenter.org)

National Electrical Manufacturers Association [NEMA] (www.nema.org)

New York State Energy Research and Development Authority

Penton Media/Machine Design

Rockwell Automation/Reliance Electric

Siemens

U.S. Census Bureau, 2002 Economic Census report: (NAICS 335312, Motor
and Generator Manufacturing: 2002)

U.S. Department of Commerce

U.S. Department of Energy, Energy Efficiency and Renewable Energy
Information Center (formerly known as the Office of Industrial Technologies Clearinghouse)

U.S. Industrial Motor Systems Market Opportunity Assessment

Washington State University

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