The Concept of Motor-System Maintenance and Management

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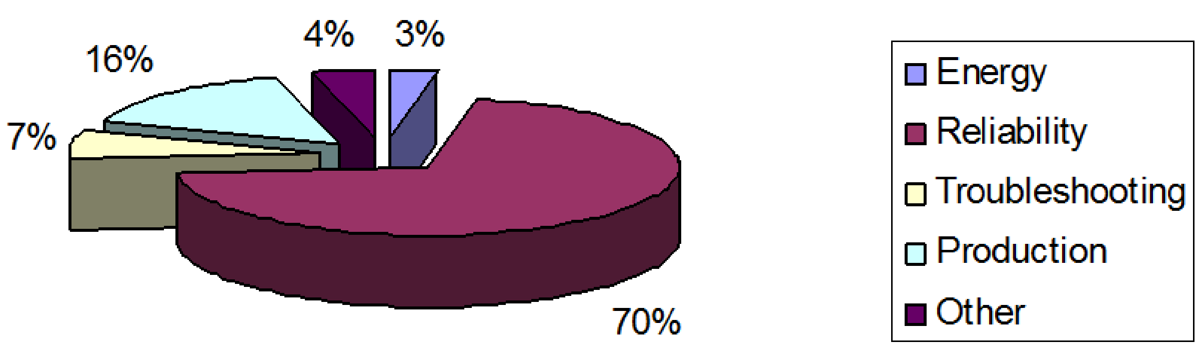
Introduction

A variety of concepts related to the term 'motor management' have been presented within industry since the 1990s. Many of these programs are actually 'energy-efficient electric motor retrofit or repair versus replace' ideas which make up only a small portion of the overall opportunities when properly managing electric motor systems. Such things as preventive maintenance, condition-based maintenance, and other motor-system opportunities are left out of programs that have very narrow views of the overall system. While it is important to view energy and environment when making motor decisions, it is more important to the success of a company to focus on the reliability, life-cycle, and business-related considerations.

In the 2003 "Electrical Motor Diagnostics and Motor Health Study," produced by SUCCESS by DESIGN and ReliabilityWeb.com, a survey of motor decision makers found that only 3% of those considered energy as part of their motor programs while over 70% considered reliability as the first consideration. Even in the present energy environment, while statements are made related to efficiency improvement, if a plant is in a reactive failure condition, the first consideration is getting equipment back online and production running. With over 60% of companies operating their Reliability and Maintenance (R&M) organizations in a reactive mode, energy policies related to manufacturing and support equipment become secondary. Therefore, in order to develop a healthy motor system maintenance and management program, and to improve energy consumption, a robust R&M program must be in place.

Figure 1: Survey of Motor Decision Considerations



The impact of a full motor-system maintenance and management program, or Reliability-Centered Motor Management (RCMM) program, is multi-fold. In the United States alone, approximately $1.2 Trillion is invested in maintenance programs with up to $750 Billion of that amount the direct result of poor R&M practices. An additional $2.5 Trillion in potential business opportunity is lost, per year, as a direct result of poor R&M practices, or 20% of the annual USA GDP. A majority of the systems that fall under this issue are plant motor systems.[1] Energy efficiency in electric motor systems also presents a significant opportunity. In a US Department of Energy report provided by Xenergy, "In 1994, electric motor-driven systems used in industrial processes consumed 679 billion kWh – 23% of all electricity sold in the United States… Implementation of all well-established motor system energy efficiency measures and practices that meet reasonable investment criteria will yield annual energy savings of 75 to 122 billion kWh, with a value of $3.6 to $5.8 Billion…"[2] and the reduction of 74 mega-tons greenhouse gas emissions. "Drivepower users and utilities have made significant investments in recent years to improve the efficiency of motor-driven systems. The longevity of these measures – as well as the amount of energy they save – depends heavily on the quality of the maintenance they receive. Although it is usual to think of motor system maintenance as an activity that follows other drivepower decisions, it is actually the first step for most facilities moving towards more efficient motor systems… The efficiencies of mechanical equipment, in general, can be increased typically 10 to 15 percent by proper maintenance."[3]

To understand the scope, the motor system must be defined:

1. Incoming Power: the power supply, power quality, distribution system, and other components related to supplying power to the motor controls. Depending on how the plant interacts with the power utility, this part of the system may also be a component of overall rotating machine reliability;
2. Controls: whether these controls are starters, control circuits, variable frequency drives, etc., this component involves any part of the system that controls the operation of the electric motor system;
3. Motor: the converter of electrical energy to mechanical torque;
4. Coupling: connects the motor to the driven load. The coupling may be direct, belted, geared, or other;
5. Load: is the component of the system that the motor drives such as a fan, pump, conveyor, compressor, etc.; and,
6. Process: the overall process that the motor system is associated with.

In this article we will discuss both the development of an RCMM program and how it relates to energy.

Concepts of the Program

There is a particular system associated with the development of a program that starts with knowing what you own. In effect, before doing anything else, the equipment that is to be included in the program must be known. It is also important that a 'pilot' area is set up for the development of the program, and expansion of the program is done in small chunks, as a majority of false starts occur when programs are initiated that try to take on too much.

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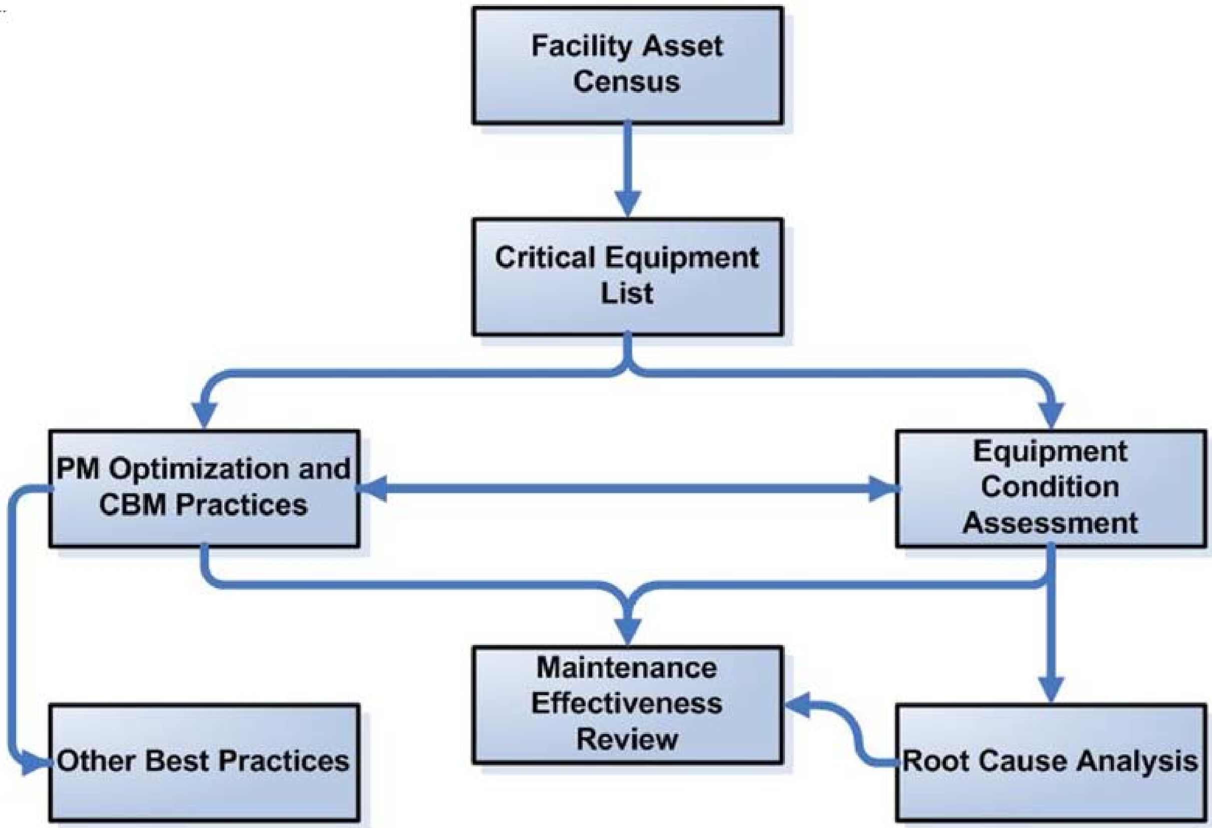
[1] Penrose, Howard W, Physical Asset Management for the Executive: Caution Do Not Read This If You Are On An Airplane, SUCCESS by DESIGN® Publishing, Old Saybrook, CT, 2008

[2] Xenergy, United States Industrial Electric Motor Systems Market Opportunity Assessment, US DOE, December, 1998

[3] E-Source, DrivePower, Chapter 12, 'Motor System Maintenance, E-Source, Boulder, CO, 1996.

Figure 2: Development of the Program – The RCMM Map[4]



Once a census is completed, then critical systems can be selected based upon specific criteria that may include:

1. Personal Safety: if the system involves personal safety if it should fail, then it must be considered critical equipment;
2. Regulatory: if the impact involves regulatory issues such as the environment, then it must be considered;
3. Production: systems that impact production must be included. Some analysts will select production equipment based upon its impact on the overall production within a facility. The greater the impact, the higher the ranking;
4. Cost impact: if a system surpasses a repair or replacement value cost threshold then it should be considered. The average industrial value for consideration is $25,000; and,
5. Other Impacts: such things as working environment, marketing/sales considerations, or other systems deemed important by the organization must be considered. This concept is often at odds with many RCM (Reliability-Centered Maintenance) and similar programs.

The next step is an equipment condition assessment where the condition of critical equipment is evaluated. The tests and inspections may be the ones selected for routine testing through maintenance practice development processes such as RCM. The results should be kept on record and equipment that

[4] Penrose, Howard W, Electrical Motor Diagnostics: 2nd Edition, SUCCESS by DESIGN® Publishing, Old Saybrook, CT, 2008

is in poor condition should be scheduled for repair or replacement, at which time significant energy improvements can be considered.

The equipment condition assessment should be performed in parallel with a Preventive Maintenance Optimization (PMO) and development of Condition-Based Maintenance (CBM) practices. The PMO process can be as simple as a review of the existing processes to eliminate redundancies to more advanced commercial PMO processes. In almost every case, from 1/3rd to 2/3rd of existing planned maintenance procedures can be eliminated or combined. The remaining PM's should be compared to the results of a CBM review involving processes such as RCM or a Maintenance Effectiveness Review (MER).

A MER involves a review of the existing testing that is being performed and comparing that to the failure rate and modes of the equipment. If the failure rate and modes exist and are as high or higher than they were prior to the application of CBM, then improvements to the programs should be considered. The process also provides the opportunity to decrease maintenance as well as identifying new inspections, tests, or processes. A MER should be applied periodically and which equipment is included in the MER is generally selected by an experienced RCM analyst.

Root-Cause-Analysis (RCA) procedures should be selected and personnel trained such that basic RCA can be selected and used by all personnel and more advanced processes can be used by teams with internal or external facilitation. In either case, all personnel should be made aware of the concepts and application of RCA so that when the process is necessary, the required evidence is maintained.

In addition to best practice procedures developed around the above processes, other process-based best practices must be investigated and applied. These best practices must include:

- Motor Repair Versus Replace Decision-Making;
- Motor Repair Specifications;
- Lubrication;
- Storage; and,
- System Energy Improvements: right sizing, application of VFD's, use of MotorMaster Plus, AirMaster, PSAT, and other programs.

All of the findings and feedback feed each of the other parts of the overall program map.

Key Performance Indicators (KPI)

When applying an RCMM program, the appropriate best practices and a method of measuring the application of the program must be considered. At the maintenance manager level of responsibility, a series of KPIs that relate to the components of the program must be developed. The minimum KPI's that must be considered include:

1. Electrical Maintenance: in order for a program to succeed, a healthy electrical maintenance program must be in place. The following components must be considered, at a minimum:
    a. Documentation and drawings that cover critical equipment;
    b. General electrical maintenance practices;
    c. Arc flash and personal protective equipment program;
    d. A review of load and power quality of critical equipment;

    e. An active electrical RCA program;
    f. Electrical safe work practices and corporate safety program; and,
    g. An emergency repair plan for critical equipment.
2. Motor and Driven Equipment Selection Program: a process must be in place for the selection and specification of components for the motor system. This includes right-sizing, selection of controls and VFDs, optimal selection of driven equipment. The use of US DOE best practices in the selection of systems for the complete motor system;
3. Commissioning: new and repaired equipment must be subject to a process of inspection and testing prior to application or storage. This ensures the reliability of the component and ensure changes have not been implemented which may reduce the energy efficiency of the component;
4. Operations and Maintenance: includes repair versus replace decision-making, maintenance training, failure analysis, testing technologies, lubrication, and inspections;
5. Electric Motor System Repair: repair processes, procedures, and specifications, including qualification of the repair shop for specific equipment types and sizes. The primary purpose is to ensure no reduction of reliability or energy efficiency;
6. Plant Inventory and Records: motor system components in operation and maintained as spares. Includes storage procedures and processes; and,
7. Utility Management: the energy efficiency component of motor management programs. This should include the selection of motor systems for evaluation for immediate energy improvement opportunities within the financial project constraints of the company. This includes the use of US DOE best practices for fan systems, pump systems, motors, compressed air, and others from the industrial technology website.

Exact details of each component within the KPIs are selected based upon the company and company goals.

RCMM Team

Through the development of the program, a team must be selected to develop the program and to be involved in the RCM and MER processes. Members must include both in-house and external stakeholders in the motor management program, including:

- R&M Management
- R&M Technicians
- Utility or Energy Management
- Purchasing
- Operations Managers
- Information Technology
- Associated Vendors
- Others, as necessary

When the program is initiated, it should be considered that this team meet as a whole once per month, at a minimum. As the program matures, this time frame should be able to expand such that team meetings are happening quarterly. Assignments should always be given to teams within the RCMM team at the completion of each meeting.

Case Study: Automotive Transmission Manufacturer

An Indianapolis-based transmission manufacturer has implemented a motor management program since 2001. The focus has been on the condition-based inspection, testing, vendor storage, motor repair practices, and RCA practices. The RCMM team consists of internal personnel and skilled trades as well as the contracted electric motor repair facility. The team meets monthly where the repair facility reports volume and repair cost reduction and provides recommendations for reliability improvements in the motors that have been repaired. The internal tradesmen perform RCA and a similar process referred to as 'repetitive failure analysis,' in which they investigate any instance where equipment fails more than once in a given period.

When the initial testing and inspection portion of the program was initiated the repair and replacement costs of the program increased as equipment in poor levels of reliability were identified and corrected. Once the dust settled, it was determined that the average repair or replace decisions per year averaged 720 electric motors. With the focus on just three of the seven KPIs, the number of repair or replace decisions dropped to just over 120 repairs per year with a majority of those being minor repairs. The impact on overall equipment availability has been measurable with the cost per unit manufactured dropping significantly.

The Impact of Warranty Recovery

The silent killer, and opportunity, within many of these programs is warranty recovery. In particular, with both new motors and the repair process, most companies forget to investigate warranty opportunities in failed equipment. The average motor repair vendor warranty is one year with many repair shops increasing their competitiveness by offering warranties as high as five years! New, premium efficient, electric motors will have warranties that range from five to seven years.

Part of the reason that both new motor and repair facilities feel comfortable presenting these warranties is that many companies will not track warranty opportunities. In a great number of facilities, the missed opportunities are not in the thousands of dollars, but actually in the $100's or even $millions in unclaimed warranties. Tracking warranty dates in CMMS programs or third party software can provide immediate impact on the motor management program.

Final Considerations

At this time, a growing number of large and medium sized utilities and industrial companies have noticed and begun to focus on the number one R&M improvement opportunity: electric motors. The impact of all aspects of improvements, partnerships, equipment storage, implementation of best practices, repair standards, energy improvements, and robust maintenance programs have had an impact on overall energy consumption and plant capacity increasing competitiveness and profitability.

While this handful of companies have identified this significant opportunity, reaping immediate impacts on the bottom line with even more significant impacts within 12 to 24 months of program implementation, a growing number of companies have not yet realized these opportunities. In this time of rising energy costs, corporate fiscal issues, the need to improve competitiveness and capacity, motor system maintenance management provides one of the most significant improvements. Take advantage now.

Author Bio

Howard W Penrose, Ph.D., CMRP is the President of SUCCESS by DESIGN, a reliability and maintenance services consultant and publisher. He has 25 years in the reliability and maintenance industry with experience from the shop floor to academia and manufacturing to military. Starting as an electric motor repair journeyman in the US Navy, Dr. Penrose lead and developed maintenance and management programs within industry for service companies, the US Department of Energy, utilities, states, and many others, including reliability modifications to the LEV-VAD Heart Pump in collaboration with the University of Virginia. Dr. Penrose taught engineering at the University of Illinois at Chicago (UIC) as an Adjunct Professor of Industrial Engineering as well as serving as a Senior Research Engineer at the UIC Energy Resources Center performing energy, reliability, waste stream and production industrial surveys. Dr. Penrose is a past Vice-Chair of the Connecticut Section IEEE, a past-Chair of the Chicago Section IEEE, Past Chair of the Chicago Section Chapters of the Dielectric and Electrical Insulation Society (DEIS) and Power Electronics Society of IEEE, is presently on the IEEE DEIS Board of Directors, is a member of the Vibration Institute, SMRP and MENSA. He is a US Department of Energy MotorMaster Certified Professional, as well as a certified maintenance and reliability professional, both a NAVAIR and NAVSEA RCM specialist, and is presently the Founding Executive Director of the Institute of Electrical Motor Diagnostics. In 2008, he became a member of the National Writers Union (UAW Local 1981) as an author and journalist and is an International Federation of Journalists member of the press.

His first two books of 2008 are: ‘Physical Asset Management for the Executive: Caution Don’t Read This If You Are On An Airplane’ a business strategy book designed to communicate the importance of reliability and maintenance to the profitability of a company; and, ‘Electrical Motor Diagnostics: 2nd Edition’ which is a textbook that provides information on motor circuit analysis, electrical and current signature analysis, standard testing technologies, time to failure estimation and the development of your motor management program.