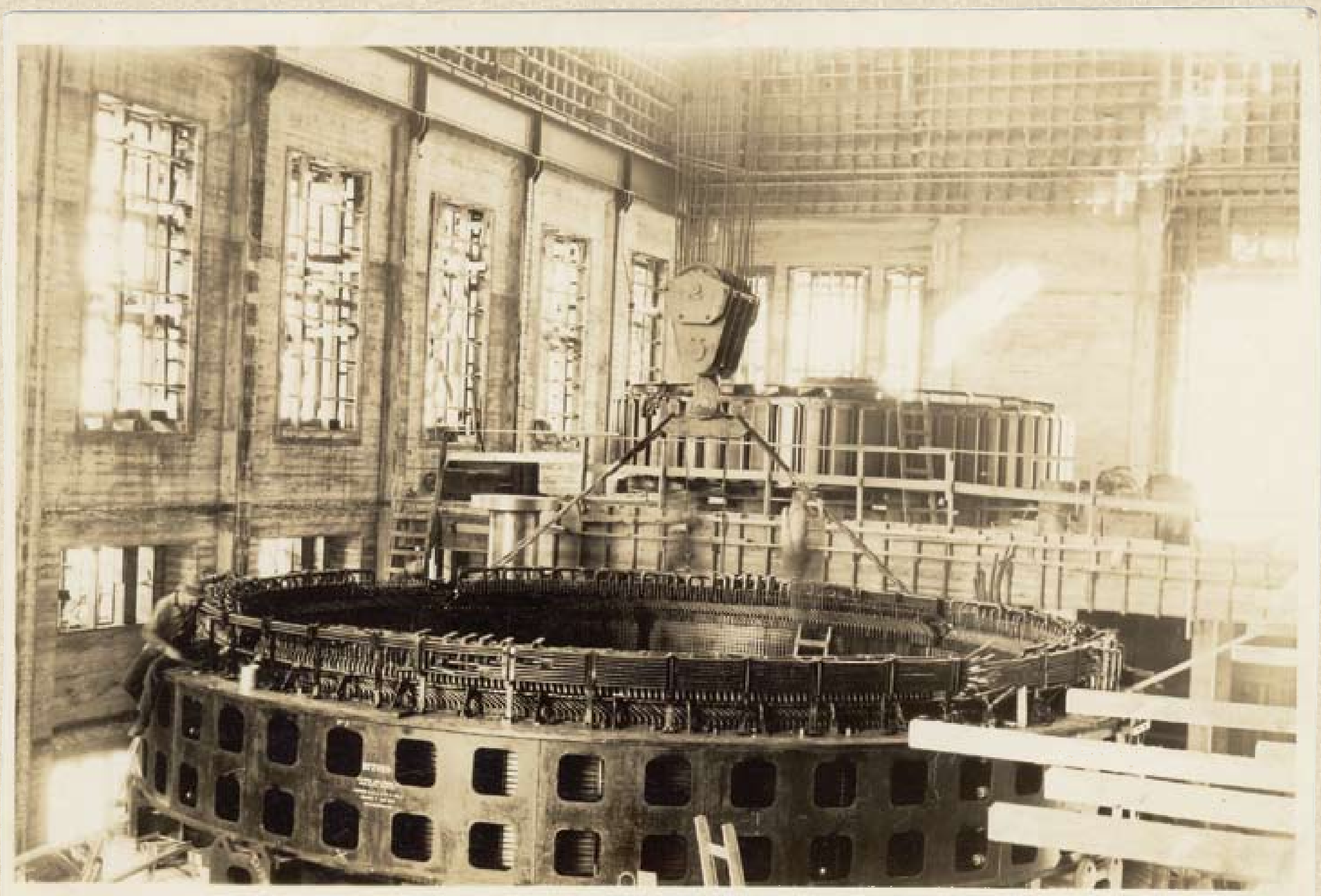
Back to the Future

Electrical Motor System Maintenance and Management

by Howard Penrose, Ph.D., CMRP



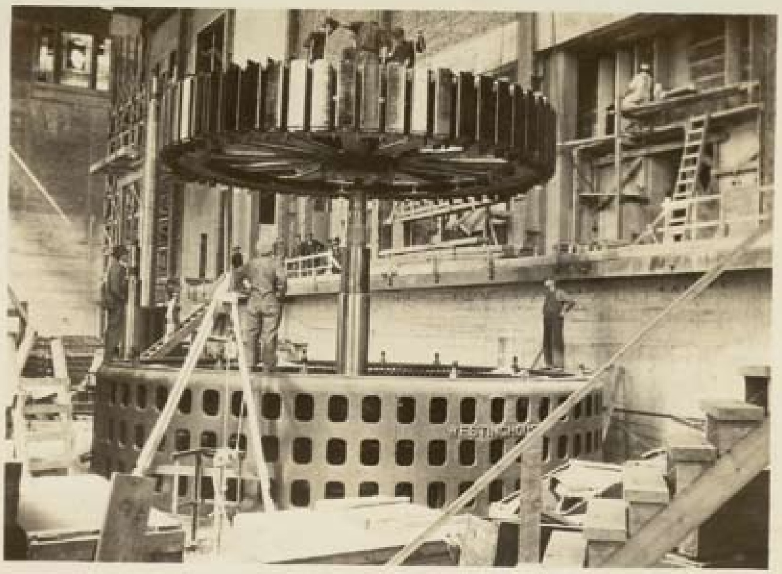
Electric motors and related systems. They are things we often overlook when thinking about factors that allow industry and manufacturing to compete in a modern economy. Yet electrical motors are, figuratively *and* literally, the engine that drives our economy. In production facilities and processing plants, electric motor systems consume approximately 90%, or more, of the electrical energy used by the facility. The invention of the AC induction motor, and the ability of AC power to be transformed and delivered over long distances, gave the industrial revolution a major shot in the arm following the development of the steam engine. Its greater efficiency and robustness reduced maintenance headaches that older power systems generated.

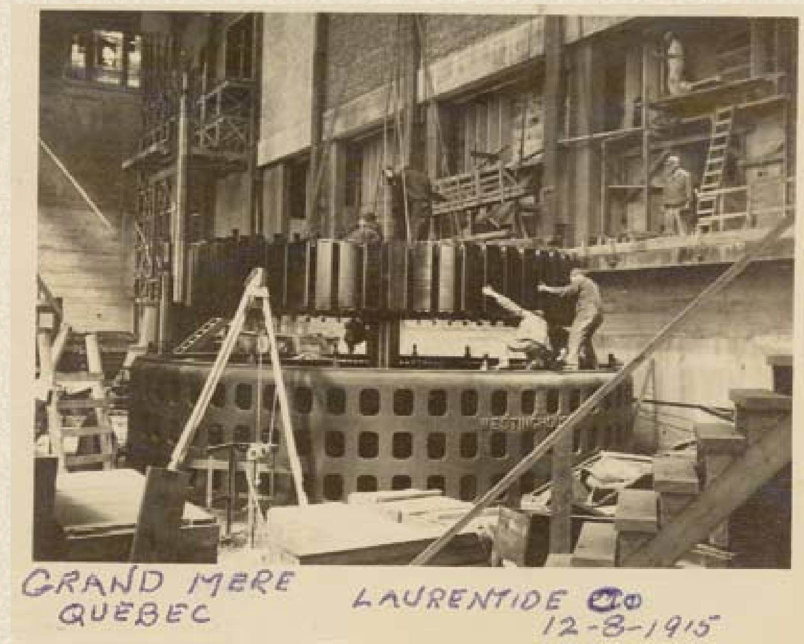
Electrical motors are - figuratively and literally - the engine that drives the economy.

Yet, here we are, over 118 years following the invention of the AC electric motor system, AC power generation and transformation and distribution systems by Nikola Tesla, and we are still maintaining these vital components of our economy much the same way that they were managed in the early 1900's. In fact, an associate of mine gave me a book called "The D'Este Steam Engineers' Manual: Electrical Appendix"[1] written by Charles Penrose, EE, in 1913. It describes the same systems, functions and basic maintenance for rotating machines that I can find in books and manuals on motor system maintenance as late as 2005. The electrical generation and distribution system of the early 1900's, both internal and external to the facility, appear very similar to those that we deal with today.

Between 1910 and 1920, technical papers were published in how to provide specialty testing of rotating machines (motors and generators) and their insulation systems. These tests are the ancestors, the great grandfathers, if you will, of more recently introduced test methods, including surge comparison testing, then motor circuit analysis in the 1980's and motor current signature analysis and electrical signature analysis, also in the 1980's. Additional advances in vibration analysis, infrared analysis, ultrasonics, partial discharge, and a great many other tests, along with advances in computer technology and software systems, have all provided us with opportunities today that our predecessors could only dream of.

The electric motor system has not remained stagnant, either. From





insulation systems made of tar then oil and paper, we have made staggering improvements to electrical insulation systems that have only accelerated over the past four decades, to advanced electronic controls such as variable frequency drives and machine tool systems. Improvements in materials have improved electric motor efficiency while decreasing weight, dimensions and expense to manufacture and purchase.

For all of this technological improvement, the philosophy of *managing* the electric motor system has lagged far behind. It is fascinating to think that we have created, adapted and evolved on the technological side, but have made so little progress in our management skills of overall motor systems programs. Why is this?

Perhaps it is because a great many people see the motor as a mysterious method of converting electrical energy to mechanical torque, and, therefore, view it as a system that either works, or does not. That is, until something in the distribution system, control, motor, coupling or driven equipment stops providing some vital function. Of course, then we see a mad scramble to fix the system – to get the engine of production moving again, at basically any cost. The result has been patched fixes, increased motor system spares inventories, increased downtime, reduced efficiency, wasted money and far more.

In the early 1990's, the US Department of Energy, in collaboration with industry, motor manufacturers and vendors, developed motor management strategies with the focus on improving electrical energy consumption. This was given 'teeth' with the Energy Policy Act of 1992 (EPAct), and was expanded, based upon recommendations of industry, to include the full motor system - from incoming power to driven equipment. Many other companies, in particular, motor repair vendors, developed differing flavors of motor management. The one that I developed, the 'Dreisilker Total Motor System Maintenance and Management Program' (DTM2), in 1993, was one of the first that took responsibility for complete system and manpower issues. In fact, the first site that we concentrated on was a paperboard company with over 26% unplanned downtime. By focusing on just the motor system alone, and using a percentage of the savings to bolster the maintenance budget, we were able to decrease the unplanned downtime to about 6% without a negative impact on profitability! In fact, the program improved throughput, inventory and profitability significantly.

The Impact of a Motor Management Program On Business and the Environment

Overall, the implementation of condition-based maintenance programs has a significant, some might say major, impact. The related maintenance costs are reduced by 24 - 30%; associated breakdowns by 70-75%; related downtime by 30-40%; throughput increases by 20-25%; planned maintenance tasks reduced by 33-66%; and man-hour utilization by 40-50%. Through the monitoring of several successful motor system maintenance and management programs, these results can be considered average to conservative.

In addition to the above CBM potential, motor system maintenance and management programs have had the following impacts:

- Troubleshooting and evaluation time improved by over 50%
- Motor repair costs decreased by over 30%

- General motor system related labor reduced by up to 50%; and,
- Motor system related inventory reductions by over 50%.

In general, successfully applying and sustaining a motor system maintenance and management program will have simple paybacks of well under two years from the initial investment, with a majority seeing under one year simple payback.

The United States generated over 3,848 billion kWh of electricity in 2003m, of which approximately 2,270 billion kWh (59%) were consumed by electric motor systems. The application of motor system maintenance and management programs has the potential impact of saving industry an initial $26.5 billion in electrical energy costs while reducing greenhouse gas emissions by over 3,000 Giga-Tons per year, most of which would be directly related to the emissions by power plants of all types. An additional positive impact of these energy savings would be reducing the need for building additional power plants.

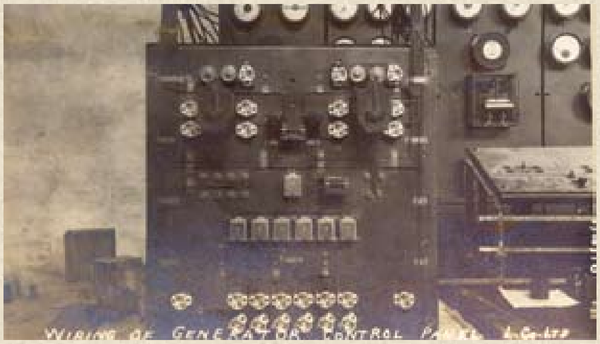
Defining Motor Management

"Modern management practices often do not take into account the importance of motor systems maintenance and management requirements. Through efforts in cost control, many industrial and commercial firms will reduce maintenance staffs, take least cost approaches to corrective actions, and sacrifice preventive maintenance programs. The result has been increased energy costs and downtime resulting from equipment not operating to full potential and failing unexpectedly. The problem results in billions of dollars of additional energy consumption and lost revenue." [2]

As noted in the "Motor Diagnostics and Motor Health Study" (MDMH)[3] , 68% of those surveyed felt that they had a motor management program in place. Of those programs in place, 72% failed and less than half of the remaining programs were considered effective. Of the effective programs, 66% of the program recommendations were ignored. These these results mean that overall, 7% of those surveyed had effective motor management programs.

In properly applied programs, over 91% identified immediate returns on investment. These high quality programs were found to be fairly consistent in their outline and implementation. Defining the philosophy of motor management is an issue in and of itself. Many view motor management as energy management, others view it as motor testing, storage, greasing or some other individual function(s). The programs that were formed under these belief systems have been found lacking as they are not long-term strategies. A true motor management program, one that has an overall strategy and holistic philosophy, will have both immediate impact and long term results.

The definition of motor management put forward by the Institute for Electrical Motor



Diagnostics is: "Motor system maintenance and management is the philosophy of continuous improvement of all aspects of the motor system from incoming power to the driven load. It involves all components of energy, maintenance and reliability from system cradle to grave." [4]

This provides the outline for any true motor management program which is intended to extend the useful life of the motor system combined with continuous improvement of the system. In addition, the focus is where it should be; on a systems approach where the system includes: incoming power and distribution, controls, motor, coupling, load and, process.

The successful motor management program will partner with company departments and outside vendors in covering condition-based maintenance and reliability-centered maintenance, commissioning, repair standards, spare management, condition testing and other strategies. The result is a philosophy that reduces motor system related unplanned downtime in such a way that it is non-intrusive and provides a significant return on investment.

Motor System Management Overview

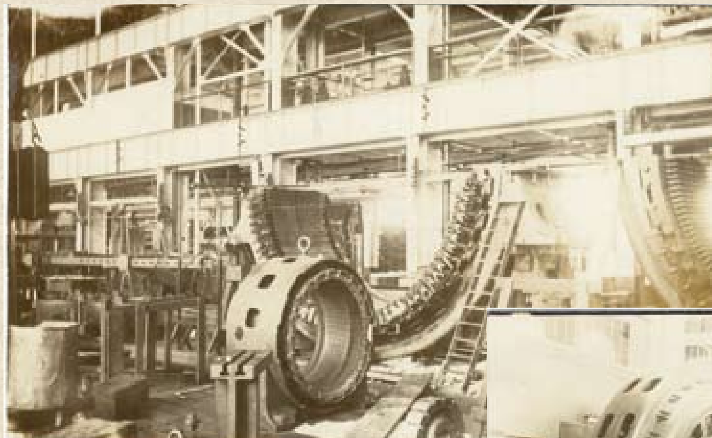
One of the most common questions in any new program is: Where do I start? My favorite answer is, "From the beginning."

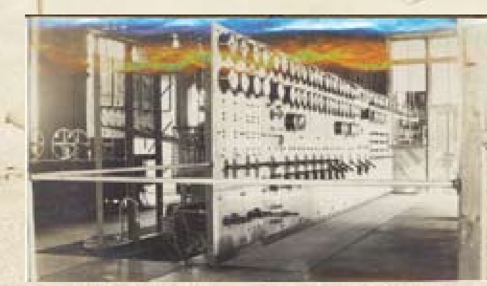
In order to start any successful program, you must know what you have and where to focus your energy. The answer to this is quite simple: You must survey your assets in order to determine your areas of responsibility. Then, you must identify critical machines and equipment. There are many different methods of determining criticality. However, typically, criticality is determined from a combination of four basic criteria:

1. Systems that impact safety;
2. Systems that impact regulatory requirements;
3. Systems that impact production; and,
4. Systems that have a high repair or replacement cost. This value averages about $25,000, in the USA.

You will also want to include equipment that has a high rate of failure, if your CMMS/EAM and/or equipment histories are accurate.

Once you have selected your critical systems, you will want to concentrate on a reasonable sized pilot area. A great many motor management program failures occur because companies took on far more, initially, than they could handle. The programs would then lose momentum because you can expect to see an average of one in four to one in six systems with issues that should be addressed. By starting with a more manageable grouping, the motor management team can gain experience in setting condemning criteria and prioritizing corrective actions on the systems.





Develop your motor management team. The team should include stakeholders from both within and outside the company, including:

1. System and component vendors;
2. Associated maintenance staff;
3. Maintenance management and senior management;
4. Purchasing;
5. Engineering;
6. Production; and
7. Others with a stake in the operation of the equipment.

Vendors can be an important part of the team. In particular, you will find that some vendors will be willing to take responsibility for associated inventory, on or off-site. This is considered good business as the vendor then has responsibility for the condition of the equipment, right up to use, and they are guaranteed the business. For instance, with the electric motors themselves, there are motor repair and distribution vendors that will alter internal inventory, maintain customer inventory on and off-site and some that will even consign motors to a facility.

By this time, or even before knowing what assets are owned, many companies will purchase, or will have purchased, condition-based monitoring technologies. The most common are vibration analysis, infrared, ultrasonics, insulation resistance, motor circuit analysis, motor current signature analysis, electrical signature analysis, etc. Unfortunately, while good for the instrument vendors, it can end up as 1000's of dollars worth of equipment sitting on storage shelves, or testing being done just for the sake of testing. In reality, the next steps should be *understanding* planned maintenance and condition monitoring needs.

There should be a fairly rigorous overview of the existing planned maintenance program, any existing condition-based testing, motor purchasing and repair specifications (if any) and lubrication program. With a careful eye on planned maintenance, it is possible to reduce unnecessary planned maintenance by 1/3rd, or more, before even adding condition testing. Then, utilizing a tool such as Reliability-Centered Maintenance (RCM), that meets MIL-P or SAE specifications, review the selected critical systems. This will identify which planned maintenance can be used, eliminated or replaced with condition testing, and which condition testing will provide the best information. You will also find that this process will evaluate the abilities of your CMMS/EAM systems as you gather necessary information, or will help identify those needs, if one does not exist.

Once technology requirements have been identified, and at least rudimentary condemning criteria, through the analysis, you will have enough information to develop a specification for your testing technologies. This can be used as a comparison, along with 'The Multi-Technology Approach to Motor Diagnostics,'[5] to select appropriate test technologies, skills requirements, training and associated requirements. The cost of the technologies is almost always a concern. However, startup cost should be less of a concern than it usually is. This is because, if properly implemented, most condition testing technologies will have returns on investment measured in days, weeks or months, when properly selected and utilized.

Following the purchasing of equipment, and associated training, baselines must be performed on the selected systems. This will provide both the beginning of trending and a good overview of the general condition of the associated systems.

The next step is the development of specifications for reconditioning, corrective actions and the purchasing of new equipment. It is important to communicate and set the conditions for commissioning new and repaired systems. For instance, if you have selected to perform motor circuit analysis testing on all electric motors that are repaired or purchased, you will want to communicate, in writing, what you will be performing and your acceptance criteria. This will reduce conflict should a motor not pass the commissioning inspection. According to an Electrical Apparatus and Service Association (EASA) study, over 81% of motor repair shops modify the windings of your electric motors through the repair process[6], with most of them performing the change for ease of rewinding and speed.

Implementation of a Root-Cause-Analysis (RCA) program for critical systems and systems that have repetitive failures. This should be a full RCA program that will identify the actual root cause, not just the component that failed. There are several different flavors of RCA programs, select a process that meets the requirements of your process and industry. Ensure that all findings are recorded and shared amongst each facility that has similar systems and in your CMMS/EAM system.

Ensure that scheduled, corrective and proactive maintenance tasks are managed through the CMMS/EAM system. This is critical for the Maintenance Effectiveness Review (MER) process which is the continuous improvement portion of the program. Periodically, systems are to be selected for review and the MER process. Outlined in “Your Maintenance is Effective… Isn’t It?”[7] article in the December issue of Uptime, this process reviews the existing program for effectiveness and provides a means for improvements to the program based upon new findings, inspections and technologies.

The Key to Success

One of the key issues to the success of any program is to ensure that it does not suffer from ‘Maintenance Entropy.’ This is the case when a program has become successful and there are few opportunities that show new short-term simple payback, so resources are cut. Simple payback identified through maintenance is a score of things which are not being done, or completed correctly, in the existing maintenance program. In effect, the maintenance program should be ordered as:

1. Proactive Maintenance
2. Preventive Maintenance
3. Corrective Maintenance
4. Reactive Maintenance

Unfortunately, most companies’ maintenance programs are ordered:

1. Reactive Maintenance
2. Corrective Maintenance
3. Preventive Maintenance
4. Rarely: Proactive Maintenance

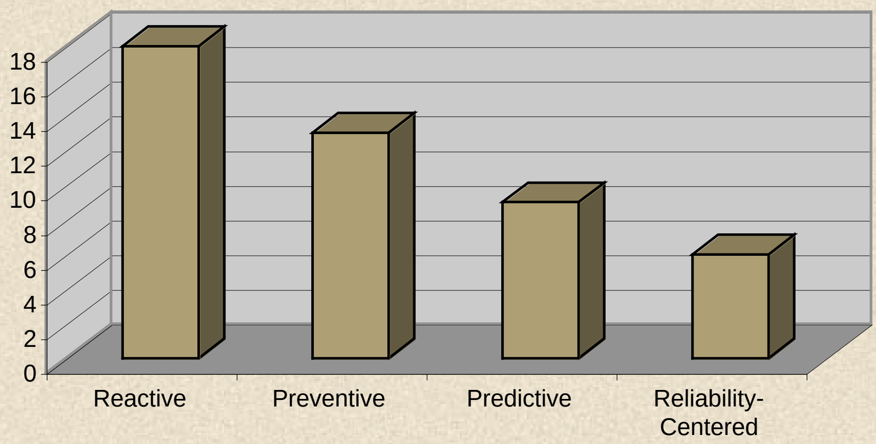
There is a cost associated with this order of doing maintenance, as shown in Figure 1.

In effect, the implementation of a full motor system maintenance and management program should reduce associated maintenance costs by about 1/3rd.

Conclusion

The implementation of a motor system maintenance and management program will have a significant impact on your company’s bottom line, inventory, costs, profitability, energy and uptime. The motor system consists of the power distribution, control, motor, coupling, driven equipment and the process itself. A full program consists of selecting critical equipment, putting together a motor management team, setting up a pilot project, a rigorous review of the existing PM program and an RCM analysis, select equipment, set up repair and new equipment specifications, an RCA program, ensure that the associated

Figure 1: Cost Impact of Maintenance $/hp/yr



CMMS/EAM program is being properly utilized and implement a MER process.

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