APPLICATION NOTE
ELECTRIC MOTOR ASSET MANAGEMENT

Bruno De Wachter

February 2015

ECI Publication No Cu0104

Available from www.leonardo-energy.org

Document Issue Control Sheet

Document Title:	Application Note – Electric Motor Asset Management
Publication No:	Cu0104
Issue:	0
Release:	February 2015
Author(s):	Bruno De Wachter
Reviewer(s):	Sergio Ferreira, Hans De Keulenaer, Hugh Falkner

Document History

Issue	Date	Purpose
1	July 2011	Initial publication
2	August 2011	Minor edit following the launch of this paper, to correct some errors and add a few references.
3	October 2014	Review by Hugh Falkner

Disclaimer

While this publication has been prepared with care, European Copper Institute and other contributors provide no warranty with regards to the content and shall not be liable for any direct, incidental or consequential damages that may result from the use of the information or the data contained.

Contents

SUMMARY

Electric motors are available for a wide range of applications and in a variety of power outputs. They are the ideal drivers for a huge number of operations. Electric motors are the primary mover for a vast majority of industrial and tertiary sector activities. Some motors are visible as a separate entity; others are built into more complex packaged products such as air compressors, heat pumps, water pumps, and fans. Electric motors account for approximately 65% of the electricity consumed by EU industry.

Despite their importance, they are rarely viewed as a production asset in their own right. However, they should be since the manner in which they are purchased, maintained, and replaced can make a major difference in Overall Equipment Efficiency (OEE) and hence profitability. When motors are not managed optimally, the result is higher energy losses and—even more significantly—a reduced reliability and availability at the production site.

Early replacement of electric motors is unusual, with most companies running motors to failure. Once failure occurs, they are repaired or replaced as quickly as possible. Replacement typically takes place without considering more than the basic technical requirements.

A more detailed look at all cost factors reveals however, that an early replacement of an electric motor is often paid back in a very short time. This payback is fed by improved energy efficiency, by reduced maintenance costs, and by avoiding unplanned outages and their associated losses.

Electric motors are a forgotten asset. By making them subject of a full asset management programme, companies can improve their performance and gain a competitive advantage.

WHY ASSET MANAGEMENT FOR ELECTRIC MOTORS?

In the continuous stress of a production environment, there is often little opportunity to pause and reconsider the way in which electric motors are purchased, maintained, and replaced. As long as nobody is given the responsibility for company-wide electric motor asset management, employees in the production environment will continue to act on an ad hoc basis, maintaining, repairing, and replacing motors in the same way they have in the past, without insight into the Total Cost of Ownership (TCO). The obvious driver for change usually escapes notice since the losses that are generated by a sub-optimal motor are scattered among different cost centres: energy consumption, material waste, lost revenue, extra working hours, reduced productivity, reduced production quality, et cetera. By assigning an empowered individual — either inside the company or outsourced — to electric motor asset management, electric motors will receive the focus they deserve.

WHAT DOES MOTOR ASSET MANAGEMENT TAKE INTO ACCOUNT?

Management commitment: First of all, the strategic decisions on asset management should be executed outside the chain of daily operations. This will enable the necessary focus on total cost and the longer term. Likewise, a clear management commitment is indispensable to ensuring the required cooperation of all employees involved.

A motor database: A motor database can keep track of all electric motors in a building, plant, or company. It can list purchase characteristics, operational data, maintenance actions, and measurement data (if available).

Predictive maintenance: Motors should be maintained and replaced based on their actual condition. The question arises how can the actual state of a motor be assessed? For large or crucial motors in the production chain, measurements can be carried out such as vibration analysis, Resistance to Ground (RTG) testing or thermography Based on these measurement results, the appropriate maintenance actions can be scheduled and the optimal moment for replacement calculated. For smaller motors, such tests are generally too far-reaching, but an estimation of the motor condition can be made based on approximated operational data.

Precision maintenance: All maintenance actions on electric motors should be executed with care and a high degree of precision. The installation of new motors should follow a strict, systematic procedure to ensure safe and reliable operation.

The repair/replace decision process: What is the strategy for a minimal TCO of the motors? Is it repairing a motor when it fails or when replacement becomes unavoidable? This is rarely the best option. In many cases, replacing the motor before it fails is financially advantageous, as it will reduce downtime and energy losses. A decision process for when to replace or repair a motor should be developed that takes into account motor characteristics, operational conditions, actual measurements, and estimated operating hours.

Reduce the inventory of spare motors: One of the advantages of early motor replacements and the resulting reduction in unforeseen motor failures is that it becomes unnecessary to keep a large inventory of spare parts and motors. A small inventory, kept in-house or by the supplier, will be enough to enable planned motor replacements and to have a spare motor at hand for the odd premature failure. The small time penalty of using an external supplier should be balanced against the saving in tied up capital, the care needed to maintain stored motors in good condition, and the opportunity to use the latest models.

In-house or outsourced? The task of motor asset management is not one that necessarily needs to be executed in-house. An in-house coordinator combined with outsourced specialists will often be the most efficient approach.

THE ADVANTAGES OF MOTOR ASSET MANAGEMENT

1) **Improved energy efficiency**: New motors have to meet the Minimum Energy Performance Standards (MEPS) of the EU. As a result, new motors are likely to be more energy efficient than motors currently in service. In many applications, a Variable Speed Drive (VSD) can further increase the operational efficiency of the motor system. The total efficiency gain can make a significant difference on the annual energy consumption of the site.
2) **Reduced maintenance costs:** Trending motor performance condition monitoring information over time enables the prediction of the next service intervals. Improved planning and reduced outage time will reduce overall maintenance costs.
3) **Reduced risk of unplanned outages:** Asset management incorporating motor replacement before failure greatly reduces the risk of unplanned outages. Unplanned outages can have an impact in many ways. In manufacturing, for example, they can slow **down production, destroy g**oods, lead to equipment damage and additional maintenance, and leave the involved staff idle until the line is running again. In refrigeration rooms, a failure of a cooling system motor can allow the temperature rise to the level where all stored goods are lost. In offices, outages of the HVAC system due to motor failure will affect the productivity of the staff as well as the quality of their work. With motor asset management, the risk for all of these types of losses due to unexpected motor failure is reduced to a minimum.
4) **TCO minimized:** Asset management aims at a minimum TCO for the motor. It is not just the purchasing and installation cost that must be taken into account; the energy consumption, production efficiency and maintenance costs should also be included in the TCO calculation.

ESTIMATING THE INTENSITY OF MOTOR USE

The intensity of use of the motor has to be known in order to work out an accurate predictive maintenance plan, to calculate the best moment for replacement, and to decide on purchase specifications. Specifically, the number of hours the motor has run must be known, as well as its load pattern. It is often a complex task to establish such figures with a satisfactory degree of precision. Fortunately, good estimates will in most cases be enough on which to base sound motor management decisions.

1) **Estimating the motor load**
    a. **Electrical power measurement** is time consuming and requires skilled technicians, as it involves access to the motor control center. It will only be cost effective for larger motors.
    b. When operating in the range between 50% and 100% of the load, the current is approximately proportional to the load. In this region, the results of a **current measurement** with a well-calibrated metering device can be used.
    c. Induction motors have a well-defined slip. This means the motor speed is proportional to the torque and hence the load. A stroboscope can be used to measure the **motor speed**.
    d. Packaged products such as air compressors, heat pumps, and refrigeration compressors will run at 100% when operating. For other motors with system integration, such as those of many HVAC systems and industrial processes, a **default load of 75%** is a good estimate.
2) **Estimating the operating time:** This varies greatly, depending on the application of the motor. An accurate estimation of the time requires data logging over a representative period, which is costly and time-consuming. In most cases, a knowledgeable plant manager will be able to make fair estimates, based on the weekly operating hours of the plant (single shift/double shift, continuous operation or not, et cetera).

A MODEL FOR THE REPAIR/REPLACE DECISION

Motor asset management requires a good model for comparing the TCO of various replace or repair scenarios.

The model used here, gives a graphical representation of the TCO, based on the relative cost difference between two scenarios. It can be used to quantify the benefits of early motor repair or replacement actions. It can also be used to compare the TCO of repairing versus replacing failed motors.

The model considers the following factors:

1) The purchasing/rewind cost
2) The initial energy efficiency of a new motor and the annual decrease in efficiency during operation
3) The electricity tariff and its annual increase
4) The daily running hours of the motor
5) The average loading of the motor
6) The estimated (remaining) technical lifetime
7) The cost of motor downtime
8) The motor resale value

Note that the energy efficiency of the motor and the electricity tariff used in this model are variable over time. Many models suppose those variables to be constant, but this does not reflect reality.

- The electricity tariffs evolve over time due to a number of market driven factors.
- The efficiency of a motor under ideal operating conditions should remain almost as good as it was when new, but accidental damage, additional heating through build-up of dirt, and mechanical wear can lead to a steady decline in efficiency.

Repairing a motor also degrades its energy efficiency, except when it is carried out with extreme care and by highly skilled technicians. By making small improvements to the motor design, a motor can even be made more efficient during repair works, but this is unfortunately a fairly rare practice.

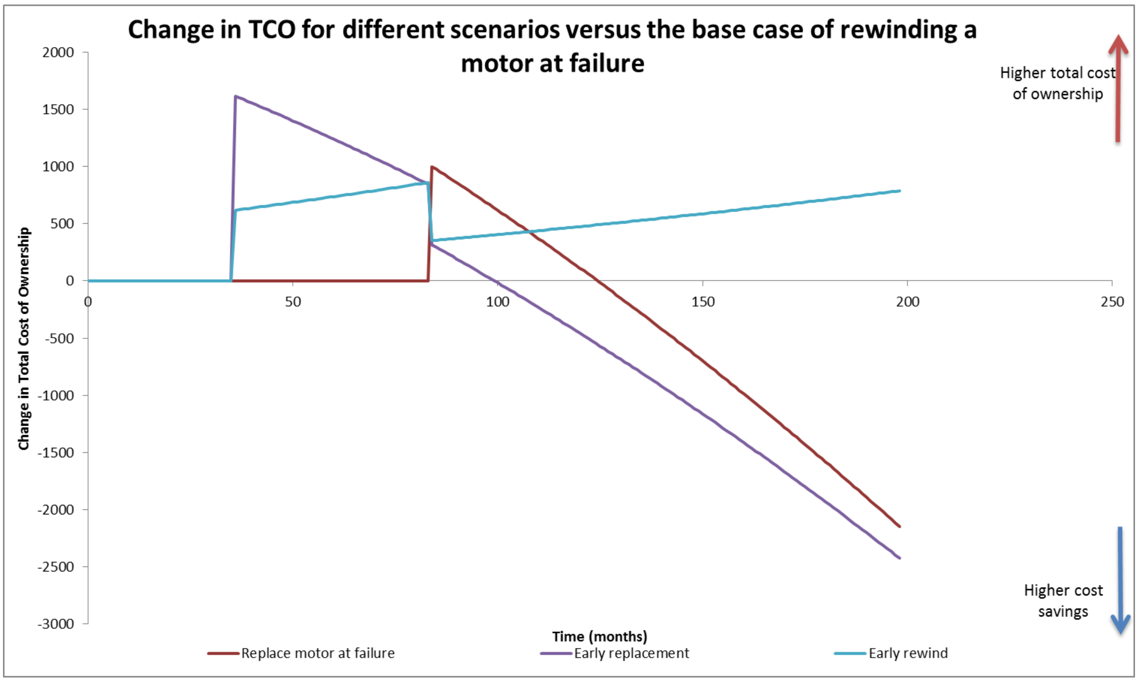
COMPARING VARIOUS SCENARIOS

The model explained above is used here to compare the cost curves of four different scenarios. The baseline scenario is 'rewinding at moment of failure', restoring the motor to the same level of energy efficiency as before the failure. A second scenario is an early rewinding of the motor, but with a small loss in energy efficiency. A third scenario is a replacement of the motor by a high efficiency type at the moment of failure. The fourth scenario is an early replacement of the motor by a high efficiency one, before failure.

In **the initial calculation**, no cost for downtime at failure and no resale value for the motor are assumed.

Scenario	Motor power	Initial motor cost	Motor efficiency at loading	Energy cost	Daily running hours	Average motor life	Annual increment in electricity costs	Annual decrease in efficiency
no	kW	€	%	€/kWh	Hours	Years	€	%
1	12	2000	87,0%	0,1	12	7	0,005	0,1%

Scenario	Early retirement period	Motor resale value	Cost of downtime	Motor rewind cost	Rewind motor efficiency	Motor replacement cost	Replacement motor efficiency
no	Months	€	€	€	%	€	%
1	48	0	0	1200	86%	2200	89%



- The line of ‘Zero change in TCO’ is the rewinding at the point of failure scenario.
- The line of the early rewinding scenario goes up because of the higher energy losses after rewinding.
- The lines of both of the replacement scenarios go down because of the reduced energy losses.
- At the point of failure, a ‘rewind cost’ is reduced from all three curves. Since the rewind in the baseline scenario occurs at this point, all three of the other scenarios include an ‘avoided rewind cost’ here.

We see that:

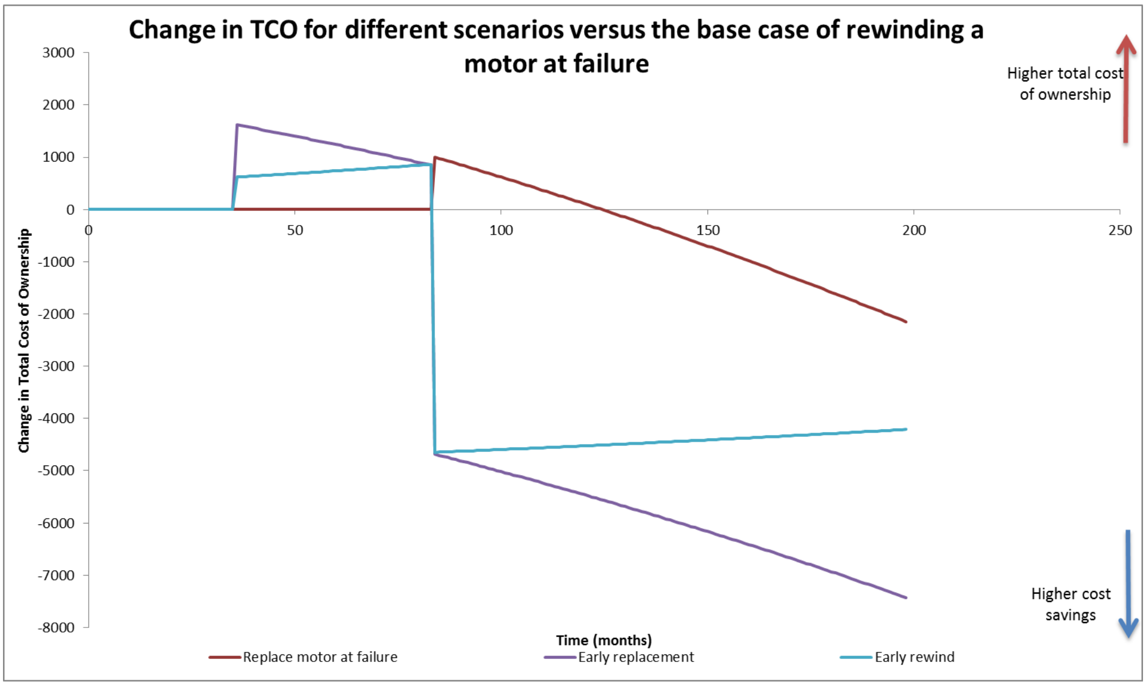
1) The early rewinding scenario has a higher TCO than the baseline scenario because of its loss in energy efficiency.
2) ‘Replacement at point of failure’ is more advantageous than ‘rewinding at point of failure’.
3) The lowest TCO comes from the ‘early replacement’ scenario.

In **the second calculation**, a $5,000 cost is assumed for the downtime during an unanticipated motor failure. All the other conditions remain the same as in the initial calculation.

This downtime cost assumption may seem high, but it is actually still moderate. A case study at a Canadian Pulp mill revealed an hourly production value of $25,000. In such a production environment, €5,000 represents a downtime of only 12 minutes.

Scenario	Motor power	Initial motor cost	Motor efficiency at loading	Energy cost	Daily running hours	Average motor life	Annual increment in electricity costs	Annual decrease in efficiency
no	kW	€	%	€/kWh	Hours	Years	€	%
1	12	2000	87,0%	0,1	12	7	0,005	0,1%

Scenario	Early retirement period	Motor resale value	Cost of downtime	Motor rewind cost	Rewind motor efficiency	Motor replacement cost	Replacement motor efficiency
no	Months	€	€	€	%	€	%
1	48	0	5000	1200	86%	2200	89%



Now we see that:

1) Downtime cost completely dominates the TCO.
2) As might be expected, early action (before failure) results in the lowest TCO. The most advantageous is an early motor replacement, followed by an early rewinding.
3) Replacement at the point of failure is a bit more advantageous than rewinding at the point of failure, but as the downtime cost is dominant, the relative difference between those two scenarios has diminished.

THREE EXAMPLES FROM REAL LIFE

NEW YORK STATE WATER TREATMENT PLANTS

A sewage treatment plant in Albany was used as a test case to compare the performance of new motors with that of older but fully serviceable models. A motor of 7.5 kW and another of 15 kW were replaced by high efficiency types. The study calculated a payback time of approximately two years. This would be even less if a Variable Speed Drive (VSD) had also been installed. The company has strong indications that the lower operating temperature of the new motors will result in longer service lifetimes, thereby extending the savings even further.

BRYANT UNIVERSITY

To keep computers cool and students comfortable, Bryant University in Rhode Island, USA requires a large HVAC system, containing a large number of electric motors. The university has had an energy efficiency programme in effect for several years. As a result, most of its motors meet the NEMA Premium efficiency requirements. The only exceptions are a few special purpose models. Conscious that small savings can add up to big returns over time, the following actions have been carried out:

- Four hot and cold water circulation pumps of 18.75 kW were replaced. The old motors were installed in 1988 and had a high efficiency for that time. However, the motor market has evolved rapidly since then. Replacing the motors with new and up-to-date high efficiency models led to an annual saving of $679 each, resulting in a pay-back period of only 1.5 years.
- A 30 kW motor with standard efficiency driving the water pump of a condenser was replaced with a new more efficient model. This resulted in an annual saving of 10.3 MWh and $1,059. The payback time was 1.5 years.

QUBICAAMF BOWLING PIN MANUFACTURER

The bowling pin manufacturer QuibicaAMF located in Virginia, USA, operates 232 motors, many of them driving blowers and fans on large air-handling equipment. The company decided to replace a few motors that were old and inefficient, although still serviceable. For example, a 750 kW motor with an efficiency of 91.2% was replaced by a NEMA Premium rated model with an efficiency of 95.4%. The improvement in efficiency resulted in annual savings of 14,464 kWh and $1,880. The additional purchasing cost for the NEMA Premium model (compared to the 91.2% efficiency model) had a payback time of 2.5 years.

RECAPITULATION

Electric motors are quite often overlooked as a production asset. Even though they are the primary driver in most industrial and tertiary sector companies, electric motors are rarely managed optimally. Improving their energy efficiency, reliability, and availability, usually results in large gains in their TCO. It takes a genuine motor asset management scheme to achieve this; one incorporating a model for the early replacement of motors.

Waiting until the motor fails is seldom the best option, since the cost of motor downtime can mount very rapidly to a high level and will in most cases dominate the TCO. Repairing the motor instead of purchasing a new one is advantageous only if the cost of a new motor is prohibitively high, or if the motor has only low operating hours. The best option in the large majority of the cases is an early replacement of the motor.

A calculation model can provide the required information for taking sound replace/repair decisions.

These models require the average load and operation time of the motor as input. Measuring those values is time-consuming, but they can be estimated with sufficient accuracy.

An additional advantage of the early replacement practice is that it becomes unnecessary to keep a large stock of spare motors on site.

INTERESTING LINKS AND PAPERS

- Article in Uptime Magazine: 'Electric Motors and Their Management'
- Association of Electrical and Mechanical Trades
- Article by the Plant Maintenance Resource Centre (Industrial Maintenance Portal): 'Motor Predictive Maintenance (PDM)'
- Whitepaper by the Electrical Apparatus Service Association (EASA): 'The results are in: motor repair's impact on efficiency'
- Motor Decisions Matter: tools and resources available from http://www.motorsmatter.org/index.asp
- EASA/AEMT study: 'The Effect of Repair/Rewinding on Motor Efficiency'
- John A. "Skip" Laitner, Michael Ruth, and Ernst Worrell, 'Incorporating the Productivity Benefits into the Assessment of Cost-Effective Energy Savings Potential Using Conservation Supply Curves', Proc ACEEE 2001 Vol.1, Summer Study
- Bryant University Saves Energy, Cuts Costs With All-Copper Systems: http://goo.gl/xBEBY