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The Energy Efficiency Myth

When Motor Retrofits Go Wrong

by Howard W. Penrose, PhD, CMRP

The application of a machine designated 'Energy Efficient' (EE) or 'Premium Efficient' (PE) does not automatically infer guaranteed savings or payback. In many cases, it does not make economical sense to make a recommendation to replace a standard efficient, or U-Frame, electric motor with a newer EE or PE motor, for energy reasons. It is important to ensure that a retrofit or repair versus replace decision makes sense such that if the decision is made for energy reasons, it will meet expectations in both *perceived* energy savings and reliability. In other cases, it may make sense to replace an older motor with an EE or PE motor strictly for reliability reasons. In any case, it is very important to state the actual reason for the replacement of the original motor.

The Situation

The UAW/WFG Joint Task Team on Construction and Maintenance (JTT) is a joint United Auto Workers and General Motors team working within the Worldwide Facilities Group tasked with developing and implementing construction and maintenance best practices for all General Motors facilities. The scope of responsibility includes all equipment and structures right up to the production equipment. A few of the series of best practices include: Motor-System Maintenance and Management; Energy Efficiency; Equipment Commissioning; and, Condition Assessment. These best practices are implemented and the facilities graded on a red, yellow and green chart with savings (and other benefits) documented over time.

Following the change from U-Frame to T-Frame motors in 1968, most automotive manufacturers insisted that the electric motor industry design and maintain a series of U-Frame automotive duty electric motors. These motors referenced the 1968 version of the National Electrical Manufacturers Association standard MG 1-1968, including efficiency levels. These standards, including the General Motors Specification No. 7EH, identified these ratings that changed, for T-Frame machines, with the Energy Policy Act of 1992. In 2000, GM issued a new electric motor specification entitled: "Electrical Equipment Specification No. 7E-TA: High-Efficiency Industrial AC Electric Motors Totally-Enclosed Types 'T-Frame' Dimensions," which was updated in 2003. The purpose of this standard was to identify the replacement of integral motors to 500 horsepower with energy efficient IEEE-841 standard electric motors. It was expected that this specification would supersede the original 7EH standard. Following an evaluation using MotorMaster Plus, the use of IEEE-841 motors was adopted as a best practice.

In 2003, all of the General Motors Assembly Division plants' Quality Network Planned Maintenance PdM groups were assigned ALL-TEST Pro, LLC, Electrical Motor Diagnostics (EMD) equipment. The purpose has been to implement the next level in condition based assessment capabilities based upon experience at pilot plants throughout GM. Following several years of successful application, UAW/WFG best practices called for the requirement of each facility to use EMD on critical electric motors, where appropriate. Additionally, a series of best practices for commissioning spare and new equipment was established for all critical equipment and machines over specific sizes.

In June of 2006, one of the GM Assembly plants retrofitted a 200 horsepower, Delco, U-Frame electric motor in a critical paint fan application with a new premium efficient, 200 horsepower electric motor. The plant contacted the UAW/WFG JTT with several concerns, including: the motor drew much higher current than the original motor; the motor tripped off-line during operation, causing an interruption in the manufacturing process; and, the manager determined that there would be a moratorium on future EE and PE motor purchases as it appeared that it was unreliable. It was reported that the motor was an IEEE-841 PE motor.

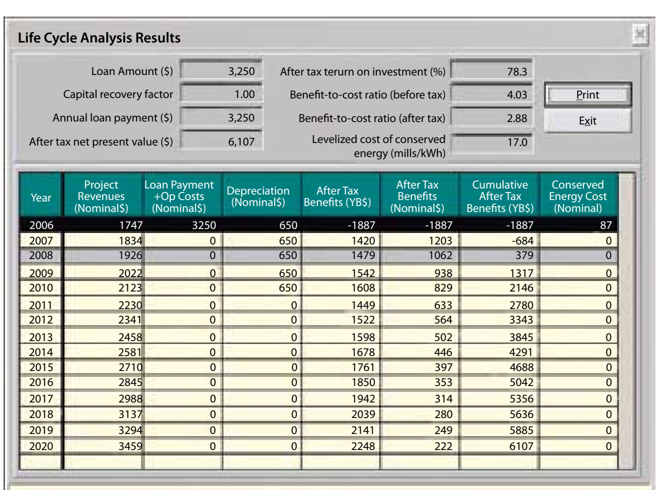
The Site Visit

During the site visit, it was determined that an Electrical Signature Analysis (ESA) evaluation would be performed on the electric motor and compared to another electric motor in order to determine the actual savings versus the original calculated savings. Upon viewing the nameplate, it was immediately apparent that the electric motor was a U-Frame automotive duty electric motor with a nameplate efficiency of 94.5%, which is 1 point higher than the older 7EH standard, but falls below the 95% efficiency of the post 1992 MG-1 energy efficiency rating and well below the later premium efficiency rating of 96.2%. As both the newer and older MG-1 standards do not define premium efficiency for U-Frame motors, the manufacturer was able to call the motor premium efficient per their own internal standard.

Based on ESA data entered into the US Department of Energy's MotorMaster Plus (MM+) comparing this fan application with an original motor next to it, the original motor was determined to be 88.7% loaded and 92.9% efficient while the new motor was 93% loaded and 94.5% efficient. Using the cost of electricity and hours of operation, MM+ compared the average rewind cost to the full installation cost of the new machine, and determined the new machine cost an additional $1,495 per year to operate. However, using MM+, when the team was able to equalize loading to 88.7% and compare the motors, which resulted in an annual savings of $854 (4.1 year payback), well under the $5,000 predicted by the vendor.

MM+calculated that the U-Frame to IEEE-841 Premium Efficient T-Frame, with retrofit base and other required changes, would have had an equivalent cost as the new U-Frame motor that was purchased. Comparing the real data collected on the existing Delco U-Frame motor to the nameplate efficiency of a correct PE IEEE-841 T-Frame would have had a simple payback of 1.97 years, an annual energy savings of $1,761 per year, an After Tax ROI of 78.3% and an After Tax Benefit to Cost Ratio of 2.88 (see Figure 1).

Based on the data, using the IEEE-841 PE motors in any future replacements would clearly result in greater savings.



Life Cycle Analysis Results

Loan Amount ($)	3,250	After tax terurn on investment (%)	78.3
Capital recovery factor	1.00	Benefit-to-cost ratio (before tax)	4.03
Annual loan payment ($)	3,250	Benefit-to-cost ratio (after tax)	2.88
After tax net present value ($)	6,107	Levelized cost of conserved energy (mills/kWh)	17.0

Year	Project Revenues (Nominal$)	Loan Payment +Op Costs (Nominal$)	Depreciation (Nominal$)	After Tax Benefits (YB$)	After Tax Benefits (Nominal$)	Cumulative After Tax Benefits (YB$)	Conserved Energy Cost (Nominal)
2006	1747	3250	650	-1887	-1887	-1887	87
2007	1834	0	650	1420	1203	-684	0
2008	1926	0	650	1479	1062	379	0
2009	2022	0	650	1542	938	1317	0
2010	2123	0	650	1608	829	2146	0
2011	2230	0	0	1449	633	2780	0
2012	2341	0	0	1522	564	3343	0
2013	2458	0	0	1598	502	3845	0
2014	2581	0	0	1678	446	4291	0
2015	2710	0	0	1761	397	4688	0
2016	2845	0	0	1850	353	5042	0
2017	2988	0	0	1942	314	5356	0
2018	3137	0	0	2039	280	5636	0
2019	3294	0	0	2141	249	5885	0
2020	3459	0	0	2248	222	6107	0

Figure 1 - Screenshot of Life Cycle Analysis from MotorMaster Plus

The Actual Motor Opportunities

However, all was not lost. The actual opportunities associated with the changing of the original 35 year-old electric motor related more to reliability and less to the expected energy opportunity. According to the motor vendor's records, there have been 21 failures of these fans over the past five years. This represents 40% of the motors in the application and the results show an average life of less than 11 years. Reliable motors, applied correctly, should be expected to see an average life of 15 to 20 years, or more.

The real risk of failure in these fan motors is the impact on the paint department. The loss of a machine during operation can result in reduced throughput, defective product and a reduction in on-time delivery. Any failure has a serious impact. This should place the energy opportunities at a relatively low priority and the reliability of the fan motors at the highest priority.

The new IEEE-841 motors are designed to assure the reliability needed in this application, which results in a higher initial cost. However, the materials used and the stringent testing required by the motor manufacturers reduces the likelihood of failure for at least the warranty period, which tends to be five or more years.

In this particular application, the ESA testing used to obtain electrical consumption and power quality measurements also provided information on the condition of the electrical and mechanical system associated with the electric motor. Several key items were observed in the application of these machines, new and old, that identified additional opportunities for improved reliability. Belt alignment and tensioning was an area identified for improvement, as well as bearing greasing. While these machines appeared to be operating quite well, it was determined that the proper alignment and tensioning tools were absent. At the time of the writing of this article, Optibelt, a belt alignment and tensioning instrument manufacturer, is working with the UAW/WFG JTT to come up with cutting edge best practices related to reduced belt wear and reduced belt maintenance.

Electrical Signature Analysis

One of the benefits of using the ESA device in collecting the data for MM+ was the ability to detect other electrical and mechanical

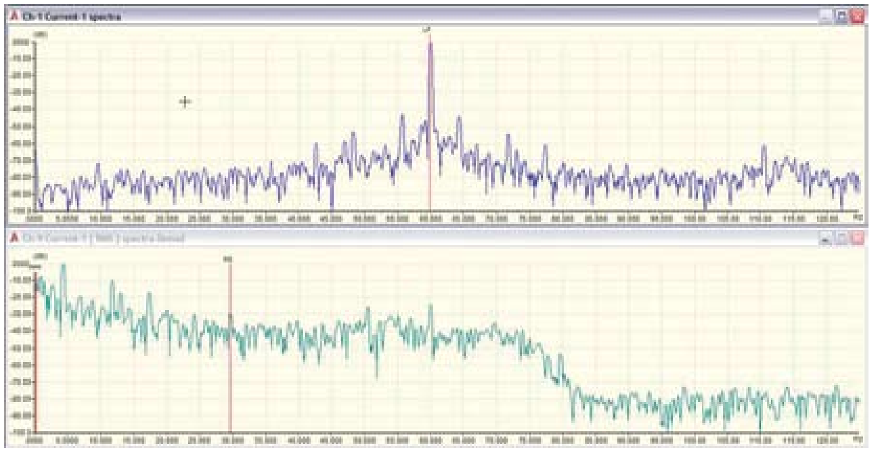


Figure 2- Electrical Signature Analysis of the old U-Frame Motor

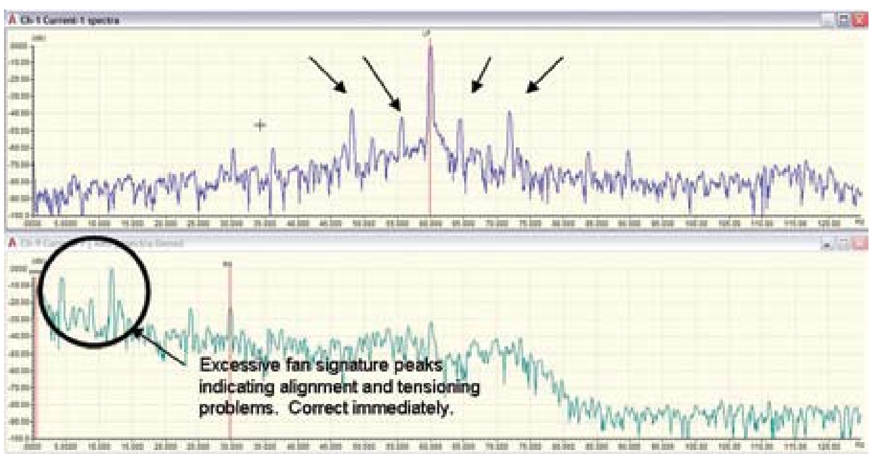


Figure 3- Electrical Signature Analysis of the new U-Frame Motor

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