Run the Numbers when you Can't Run The Motor

Conscientious Calculations will tell whether to repair or replace

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In the 1990s, it was popular to base repair-versus re-place decisions on energy use and efficiency after the repair. This meant considering the efficiency of a new energy or premium efficient motor, operating hours, and load against the original machine to determine a simple payback, which, if below some threshold, made the replacement economically viable. However, energy is only one aspect. Other considerations include

- The availability of a replacement
- The number of times repaired
- What was repaired and how it was done
- Machine reliability
- General condition
- The effect of downtime on profitability
- The number of inventoried spares.

The first question usually asks which size is the cutoff for a motor repair. The answer: It depends.

ENERGY DECISIONS

How do you weigh the relative values of repairing versus replacing a motor from the standpoint of energy consumption? There are software tools, spreadsheets, and more resources for this decision, including the U.S. Department of Energy's MotorMaster Plus software: *(www1.eere.energy.gov/industry/bestpractices/software.htm.)*

Each method compares the efficiency of the original motor with post-repair energy assumptions and a more efficient electric motor. The result normally is expressed as a simple payback for which the motor owner must decide if it's of value. In the past the normal threshold was two years or fewer. The calculation is simple. You need to know motor horsepower, load (or average load), the original efficiency, energy, and demand costs. The numbers are plugged into a standard set of formulae, as follows.

To find the *power difference*, use *Equation 1:*

Where:
P = power difference (kW)
hp = horsepower
L = load (decimal fraction)
eff_o = original efficiency (decimal fraction)
eff_n = new motor efficiency (decimal fraction)

$$P = 0.746 * hp * L * (1/eff_o - 1/eff_n)$$

To find the *demand charges*, use *Equation 2*:

$$D = 0.746 * hp * 12 * C$$

Where:
D = demand charge ($)
hp = horsepower
C = monthly charge ($/kW/mo)

Then, use *Equation 3* to determine the *usage charges*:

$$U = 0.746 * hp * T * R$$

Where:
U = usage charges ($)
hp = horsepower
T = hours of operation
R = utility rate ($/kWh)

Finally, use *Equation 4* to find the *simple payback:*

$$PB = Diff / (D + U)$$

Where:
PB = simple payback (yrs)
Diff = cost difference to repair/replace ($)
D = demand charge ($)
U = usage charges ($)

Practical Example

Let's make a decision about an older, standard-efficiency motor rated at 50 hp, 92.5% efficient, 80% loaded, with $0.12 usage and $12/kW demand charges for 4,000 hours per year to be replaced with a 95% efficient motor. Assume the difference between the motor replacement cost and repair cost is $900. According to the Department of Energy's publications, you can expect an average of 0.5% efficiency reduction per rewind using standard motor repair practices. Alternate practices can avoid this reduction.

The power difference will be:

P = 0.746 * hp * L * (1/effo -1/effn)
= 0.746 * 50 * 0.8 *(1/0.925 -1/0.95)
= 29.84 * (1.0811 – 1.0526)
= 29.84 * (0.0285)
= 0.85044 kW

The demand charge will be:

D = P * 12 * C
= 0.85044 *12 * 12
= $122.46

The usage charge will be:

U = P * T * R
= 0.85044 * 4,000 * $0.12
= $408.21

The simple payback will be:

PB = Diff / (D + U)
= $900 / ($122.46 + $408.21)
= $900 / $530.67
= 1.7 years

Because the replacement cost is less than two years, this motor would be replaced. Also, if the motor efficiency is assumed to be reduced by 0.5% and because the replacement cost is less than two years, this motor would be replaced. Also, if the motor efficiency is assumed to be reduced by 0.5% and the carbon output is 0.909 tons/MWh, then the energy and environment decision might be improved. Using the above information, the original motor would be assumed at 92% efficient, or a total savings of $637 per year, or a simple payback of 1.4 years. The greenhouse gas emission reduction would be (1.02 kW * 4,000 hrs * (1 MWh/1,000 kWh) * 0.909 tons/MWh = 3.7 tons/year carbon. The combination of both numbers makes the replacement decision even more palatable

Availability of Replacement

On the other hand, if the motor isn't available because of some special part of its design or the delivery lead time, one might opt to repair it, regardless of the energy effect. This is a production-related decision, not a decision concerned with energy or the environment. The replacement or repair cost of a production-related motor that has no immediate spare often is far less than the lost production income. For instance, if a down machine costs $1,000/hr for 80 hr/ week and the new $4,000 motor won't arrive for two weeks, but the motor might be repaired in three days at an expedited cost of $5,000, the economics of repair-versus-replace is straightforward: cost of new, including lost production is $164,000; cost of repair, including lost energy opportunity for five years (using above numbers) is $56,185. (48 hr * $1,000/hr) + ($637/yr * 5 yr) + $5,000 = $56,185, the cost difference between new and repair is $107,815, which isn't acceptable. This doesn't include orders lost, because of late deliveries. These situations ignore the energy, and environmental impact, and repairs might be costing many times the price of the new motor. In extreme cases, the existing motor might be "patched" to operate long enough for the replacement motor to arrive. These instances often are the result of a reliability-based replacement decision.

Reliability-based Replacement

Cost and savings decisions might relate to real or perceived reliability. For instance, if it's been rewound many times using burnout ovens, or if the frame is damaged, or some other reason brings long-term reliability into question, it might be replaced. Often companies have guidelines such as a limit to the number of rewinds during a motor's lifetime. But this foregoes opportunities that might be performed through the repair process. In the case of the number of rewinds, often thought to be a maximum of two or three, one can monitor core losses before and after coil removal. The core loss limit for standard electric motors is about 6 W/lb. Most new motors have a core loss of 2 W/lb to 3 W/lb. Repair standards such as IEEE Std 1068-2009 allow for as much as a 20% increase in core loss before a repair shop must report the increase. For reliability programs, it's important to get this information regardless of this standard practice. The increase can be monitored and a decision should be made to stop rewinding a motor once the cumulative losses increase by 50% to 100%. Note that a core loss increase of 20% reduces efficiency by 0.3% to 0.7%, depending on the core design and materials. As core loss increases, so does the heat the stator produces during operation and current draw as more energy feeds the core losses. Another item to monitor following a repair is soft foot. This indicates temperatures have warped the motor stators, which can result in poor air gap (static eccentricity). For both eccentricity and core loss, compare the results to the first readings taken and referenced to IEEE Std. 432.

Cost-based Replacement

A common guideline is to repair motors only if they don't cost more than 50% to 80% of new. This method often is used if buyers want a simple decision rule. The result often is that the full lifecycle costs aren't realized. This method is usually combined with availability and reliability, but not often. Unfortunately, this practice eventually leads to comparisons against cheap replacements such as replacing severe duty motors with open drip-proof or going from a reliable manufacturer to a less reliable manufacturer. To be successful, use this approach in combination with the other methods described, as well as ensuring original specifications are met or an engineering review confirms it will have the original reliability or better (Figure 1). When considering repair versus replacement, there are more items than energy and the environment to consider. While this has been a primary focus during past years and led to some poor decisions, there are additional considerations such as the motor's impact on production, spares in inventory, motor reliability, suitability, and cost-based replacement. It's important for the reliability or maintenance engineer and the buyer to ensure appropriate decisions take place that consider the complete context of the application.

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Electric Motor Repair or Replace Decision Guidelines

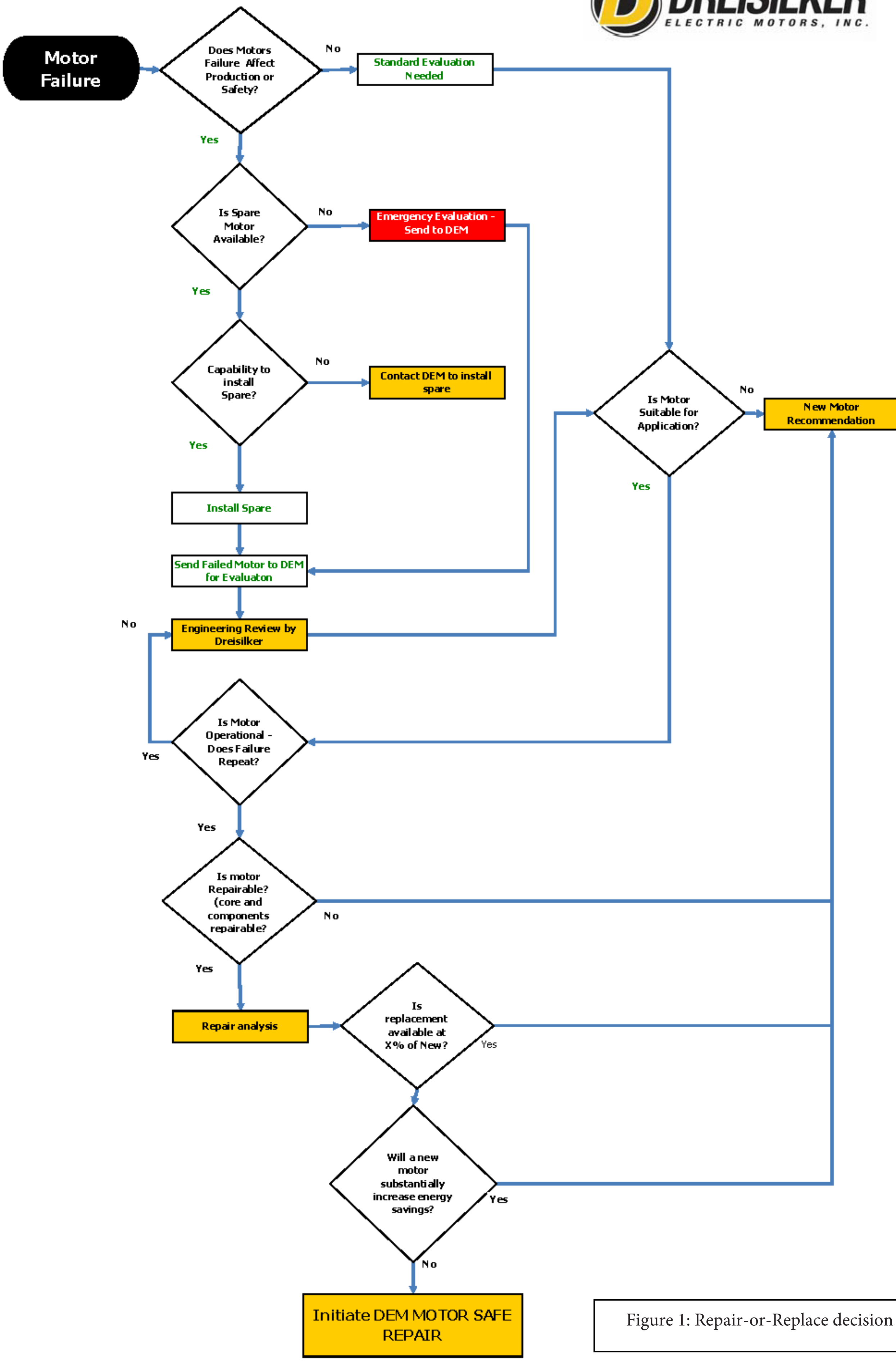

Figure 1: Repair-or-Replace decision tree