Drive System Energy Savings Considerations – Common Pitfalls

Introduction

The electric motor is the primary consumer of power in industrial applications. The Department of Energy estimates that up to 70% of electricity used in these applications can be attributed to electric motors.

Sometimes electric motors are connected directly to process equipment. You often see direct connected motors on process fans and pumps. In other applications, the motor is connected to a power transmission system designed to convert motor speed and torque to suit the application requirements. V-belt drives, chain drives, and gear reducers are the most popular methods. Occasionally, mechanical starting aids like fluid or magnetic couplings are introduced to the drive train to control torque and adjust starting time.

It is important to consider all related costs and savings when justifying a project. The challenge is to correctly quantify electrical energy savings. This paper is written to identify a few key points to consider when making this analysis.

System Efficiency

The efficiency of a system is defined by the formula:

$$Efficiency = Power\ Out\ /\ Power\ In$$

The unit of measure for electrical power is the kilowatt (kW). A kilowatt is equal to 1000 watts of electrical power. A Watt is equal to one-volt times one ampere.

Efficiency is a measure of the useful work that comes out of a system or component for a given input. The laws of physics teach that each conversion of energy results in an associated energy loss; therefore, efficiency will always be less than 100%.

To calculate the efficiency of a given electromechanical drive system, you must determine the efficiency of each component in the system. The product of those individual component efficiencies is equal to the total system efficiency.

Consider a 100 HP EPAct efficient motor with a stated efficiency of 94.5%. The motor is connected to a three-stage helical gear reducer with an estimated efficiency per gear stage of 98%. The efficiency of this system is determined by multiplying these component efficiencies together.

$$Efficeiency = .945\ x\ .98\ x\ .98\ x\ .98 = .889$$

The pitfalls listed are examples taken from actual, published savings calculations.

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First potential pitfall

Determining the efficiency of existing installed components can be a challenge. It is important to be reasonable with assumptions. Sound project management should require an after-action review to close the project. This review often requires that the project manager reconcile the stated with the realized savings.

How do you determine the efficiency of an existing motor with many years of operation and an undocumented number of rewinds? Does gearing efficiency change with the gearing type or system loading? What is the efficiency of a v-belt drive or chain drive?

Some documents claim that motors lose efficiency with each rewind. Meanwhile, certified EASA motor repair facilities will state that motors can be rebuilt to the original specifications without a loss in efficiency.

When deciding on the efficiency to attribute to a motor, without accompanying documentation, consider the motor age. If it is not stamped as NEMA Premium efficient, then it is usually conservative to use values from the EPAct efficiency tables when making the analysis.

For power transmission components, research each component and consult with the original OEM when possible. If the original OEM is no longer in business, then seek the advice of reputable OEMs with knowledge of the technology. V-belt efficiency differs with the type of belt adherence to installation procedures and the quality of maintenance. Gear reducer efficiency differs based on gear technology and loading, so it is important to collect details of these components to make the correct efficiency estimate.

To reinforce this point, consider the true efficiency of an existing system and then insert an erroneous assumption. In this example, we have an existing belt conveyor driven by a 100 HP EPAct efficient motor and a two-stage helical gear reducer. The reducer output is connected to the conveyor drive pulley using a chain drive.

Assuming 94.5% efficiency for the motor, 98% efficiency for each reduction stage in the gear reducer, and 98% efficiency for the chain drive results in a total system efficiency of:

$$System\ effciency = 0.945 * \ .98 * .98 * .98 = \ .889$$

A potential project will eliminate the chain drive and introduce a new three-stage reducer. The efficiency of the entire system should remain unchanged since chain drives are usually considered to be 98% efficient (equal to the proposed, additional stage of gearing). The justification should stand on other potential savings since the energy savings would be negligible.

However, assume that the analyst makes the erroneous assumption that the chain drive efficiency is 75%. Using this information, the efficiency of the system is:

$$System\ efficency = 0.945 * 0.98 * 0.98 * 0.75 = 0.671$$

The project manager will expect a reduction in energy losses of approximately 30% but will not actually realize any energy savings after this project is commissioned.

Second potential pitfall

Electric motors are rated according to the maximum mechanical power they can deliver to the connected load. NEMA motor ratings are expressed in horsepower (HP). IEC motor ratings are expressed in kW. A 100 HP motor will deliver 100 HP only if the load demands it. The 100 HP value can be converted to kW using the formula:

$$kW = HP * 0.745 = 100\ HP * .745 = 74.5\ kW$$

Often, comparisons are made between two different systems using the full load nameplate rating of the motor. However, to do a proper analysis, actual motor load (load factor) should be considered. To determine the load on larger motors, record the motor amperage during typical operating conditions. If the amperage measurements are above 50% of the motor nameplate rating, then dividing measured motor current by nameplate rated current should produce a reasonable motor load factor result. For more accurate results, monitor the energy demand with a power meter. This method would improve accuracy, especially for small or fractional HP motors.

Assume that a 100HP motor is loaded to 65% of rated capacity. One proposal might be to replace the 100 HP motor with a 75 HP motor. The 75 HP motor would reduce purchase costs and would be 87% loaded. There could be other advantages to this swap that we will not consider in this paper.

It would not be appropriate to compare the 100 HP and 75 HP scenarios using the nameplate HP of each motor as the assumed motor load. The load demands 65 HP in both cases, so all analyses should be made using the actual load, not the nameplate rating of either motor.

Third potential pitfall

The electric power supplier bills power measured in kilowatt-hours (kWh). kWh is a measure of the amount of energy used. Power demand of 75 kW operated for one hour would be equal to 75 kWh. Runtime is an important component of this kWh usage calculation.

It is a common mistake to generalize runtime. “Our plant operates 52 weeks a year, 5 days per week, with 2, 8-hour shifts.” Taking this comment at face value results in a total number of runtime hours.

$Runtime\ Hours =\ 52\ weeks * 5\ days * 16\ hours = 4160$ hours per year

It is better to incorporate equipment availably (the percentage of time the machine is operating) into the runtime calculation. This metric considers maintenance downtime, breakdowns, and the time you are not operating due to safety meetings and pre-shift inspections. Assuming 90% equipment availability, the runtime hours are adjusted.

$$Runtime\ Hours =\ 52\ weeks * 5\ days * 16\ hours * 0.9 = 3744 \text{ hours per year}$$

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Final potential pitfall

The final pitfall is the cost of power. Industrial power bills can be complicated. Sometimes the standard rate charge is used from the power bill, without a thorough review. Other times, national averages are applied that might not fit your billing situation.

Accurate power cost requires consideration of the entirety of the bill. Firm power charges versus interruptible charges can change your cost depending on monthly usage. Utilities charge a monthly demand charge based on the peak power draw over a set period (15 – 30 minutes). This demand charge is billed regardless of how that demand is utilized. Rates can sometimes change based on power usage at specific times of the day. There are penalties for power factors as well as potential credits.

The best way to determine power cost is to review a full year of billing. Sum all the monthly charges and divide that by the total kWh consumed for the year. This considers all the different charges. It also accounts for monthly operation variance, ensuring that the calculated cost is not influenced by a one-time event or seasonality of business.

Summary

Expenditure of capital requires a thorough analysis of all cost savings associated with a potential project. It is important to accurately account for the energy consumed by a given scenario. Component efficiency, load factor, runtime hours, and the actual cost of power are all important inputs to the cost justification. Misrepresenting any of these factors can skew the results significantly. This skew sometimes makes projects more attractive than can be realized, resulting in the expenditure of capital without gaining the promised benefit.

Proper attention to these pitfalls will result in an increased likelihood of realizing the promised results and help to ensure that limited capital is utilized in the most efficient means possible.

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