Appendix D. Motors and Pumps/Fans

The U.S. Department of Energy estimated in a 1994 study that electrical motors in industrial facilities use roughly 23% of the electricity sold in the country. Motors are widely used by industry, and efficiencies have increased in recent years due to market pressure and regulations.

ENERGY SAVINGS OPPORTUNITIES AND RELATED BEST PRACTICES

The following paragraphs describe various factors that can result in energy savings; if available, the accepted best practices associated with each factor are also given. Motor upgrades should be considered since, in large applications, energy savings would quickly offset the initial investment.

<u>Power Factor</u>

Motor windings require both magnetizing current as well as the work-producing current that is used to drive the equipment. The power factor is the ratio of the work-producing current to the total current (work-producing plus magnetizing). It’s an important component of controlling energy costs because, when it’s too low, utility companies may assess reactive demand charges. (See the energy cost structure chapter for more details.) Installing capacitors is a simple and effective way to bring the power factor near 1.0, thus eliminating reactive demand charges.

<u>Motor Efficiency Upgrades</u>

Always consider purchasing the most efficient motor available when replacing an existing motor. Energy-efficient motors can cost 10-20% more than standard motors but energy savings normally offset this cost in less than two years. Oftentimes, motors are replaced by low-efficiency equipment because a fast work order is needed. To ensure the availability of energy-efficient equipment, make advanced purchases of replacement motors for equipment that tends to fail.

<u>Motor Sizing and Loading</u>

Most industrial motors are most efficient when running from 65% to 100% of the rated power. The maximum efficiency is normally 75% of the load. Most motors tend to dramatically lose efficiency at loads below 50%. Power factor also deteriorates as loads decrease. Motors are considered underloaded when running below 65% load. On the other hand, motors are considered overloaded when running for long periods of time above their rated power. Overloaded motors will overheat and lose efficiency. Consider replacing all motors operating constantly below 40% or at any point above the rated load.

In many cases, motors are oversized because of safety factors incorporated during the design stage. All systems, including pumps, fans, and compressors, are designed to accommodate changes in the system, but designers should size motors to run within the best efficiency band (65-100% of the load). In the cases of fans and pumps, impeller sizes can be changed to better fit the load and accommodate a change in the process without having to purchase new equipment. VFDs or variable speed motors can accommodate changes in the load as well. Following are some opportunities for reducing the load requirements on the system:

- Eliminate bypass loops and unnecessary flows.
- Increase pipe diameter to reduce friction.
- Use holding tanks to better match pumping flows and production requirements.
- Reduce equipment (e.g., pump, fan, etc.) size to match load.
- Install parallel systems for varying loads.
- Reduce system pressure.

Pumps and Fans in Parallel or in Series

Pumps and fans can be arranged in series or in parallel in order to provide sufficient pressure or flow rate. When the necessary flow is not achieved with a single pump or fan, an additional pump or fan can be installed in parallel to the existing equipment, thereby increasing the flow rate and eliminating the need to install a much larger pump or fan.

On the other hand, when the desired pressure is not achieved, an additional pump or a booster fan can be installed in series. This action increases the pressure provided by the equipment, eliminating the need to install a larger pump or fan for the entire system.

Furthermore, when a system utilizes multiple pumps or fans in parallel, motor speed can be controlled in one of the motors to effectively manage the flow.[36] For example, when two pumps are operating in parallel, a VFD can be installed in one. The VFD enables this pump to reduce its speed as the demand for flow is reduced. If this pump speed is reduced to its minimum, the other pump can be shut off and the controllable pump can speed up again. In this way, the necessary amount of fluid can be pumped without wasting energy.

Control Motor Speed

Motor speed controls should be considered for any application that has variable loads. In many variable load applications, such as cooling tower pumps, a mechanical device like a throttling valve is used to control flow. These devices can reduce flow, but they will not significantly reduce energy consumption. According to commonly used fan laws, the required fan power[37] varies as the cube of the rotational speed and the volume flow rate[38] (CFM) delivered varies directly with the speed. Therefore, substantial energy savings can be achieved if motor speed is controlled. Changing the voltage supply will control the speed of DC motors. In contrast, AC-motor speed control can be achieved with

- multi-speed motors
- multi-motor drives
- VFD or variable speed drives

For the most part, multi-speed motors are equipped with dual speeds. They are simple to use and relatively inexpensive, but their ability to improve efficiency is limited. For

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[36] More information on motor speed control can be found in the control motor speed section.

[37] $FP_2 = (RPM_2/RPM_1)^3 \times FP_1$ where: FP = Fan power and RPM = Fan speed.

[38] $CFM_2 = (RPM_2/RPM_1) \times CFM_1$ where: CFM = Fan air delivery and RPM = Fan speed.

applications with varying load levels, much greater gains in efficiency can be realized with VFDs.

Multi-motor drives, commonly seen in cooling tower fan operations, utilize more than one motor with different speeds to control a single application. Because these motors are of different speeds, they allow for a wide range of configurations for the application. In cooling tower applications, it is common to see two motors connected to a single shaft. The motors operate separately depending on the speed needed for the fans.

Unlike the other applications, a VFD can be installed to ordinary AC motors to control the frequency of the current. A VFD can precisely control the speed of the application, making it energy efficient. Therefore, VFDs are, in many cases, the best option for speed control. An application controlled by a VFD wastes some energy since heat is formed from the transformation of the current; this loss depends on the speed reduction and the motor load. A VFD cannot reduce the speed of the motor to near zero.[39] The drive has limitations as to the maximum allowable frequency reduction. On fan and pump applications, the VFD normally is set to control a constant pressure for the system, thus it modulates speeds according to the flow but keeps constant pressures.

Voltage Unbalance

Voltage unbalance occurs when there are different voltages on the lines of a polyphase motor. This leads to vibrations and stress on the motor as well as overheating and reductions in shaft power. It is recommended that the electrical distribution system be checked for voltage unbalances in excess of 1%. Polyphase motors with unequal voltage supplies lose efficiency. The losses are drastic for unbalances beyond 1%. According to the DOE,[40] common causes of unbalances include:

- faulty operation of power factor correction equipment
- unbalanced or unstable utility supply
- unbalanced transformer bank supplying a three-phase load that is too large for the bank
- unevenly distributed single-phase loads on the same power system
- unidentified single-phase to ground faults
- an open circuit on the distribution system primary

Maintenance

A well-controlled and well-documented maintenance program can identify problems before they happen. Check regularly for noise and vibration as well as motor temperature. Always use good quality oil for lubrication and follow manufacturers' instructions.

Power Transmission

Transmission equipment such as gears, belts, and shafts should be properly maintained to remain efficient. Common V-belts tend to slip on drive sheaves. Therefore, notched V-

[39] VFDs have a limited maximum speed reduction allowed that is in the range of 40% to 50%.

[40] Motor Tip Sheets, Eliminate Voltage Unbalance, www.oit.doe.gov/bestpractices/pdfs/motor2.pdf.

belts should be used instead. They offer more friction during operation and still allow for startup slippage. Some manufacturers estimate about 3% losses from standard V-belts. Notched V-belts also tend to run cooler and for longer periods of time. Chains or gears can reduce losses even further. However, worm gears should only be used in small applications with motors smaller than 10 hp.

RESOURCES

Printed Material

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McQuiston, F.C., Parker, J.D., and Spitler, J.D., Heating, Ventilating, and Air Conditioning: Analysis and Design, Willey & Sons, 5th ed., 2000.

O'Callaghan, P.W., Energy Management, McGraw-Hill, 1993.

Wulfinghoff, D.R., Energy Efficiency Manual, Energy Institute, MD, 1999.

On-Line Tools

U.S. Department of Energy
Energy Efficiency and Renewable Energy – Industrial Technologies Program
Energy Savers: www.eere.energy.gov/consumerinfo
Best Practices: www.oit.doe.gov/bestpractices
Motors: www.oit.doe.gov/bestpractices/motors

- Motor Tip Sheets
- Motor Efficiency Case Studies
- Technical Publications

Software Tools: www.oit.doe.gov/bestpractices/software_tools.shtml

- MotorMaster+ 4.0
- MotorMaster+ International

Energy Information Bridge: www.osti.gov/bridge
Energy Matters: www.oit.doe.gov/bestpractices/energymatters/energy_matters.shtml

Energy Services, Energy Solutions Database: www.energyexperts.org/energy_solutions

Bonneville Power Administration: www.bpa.gov

Alliance to Save Energy: www.ase.org

Organizations

Alliance to Save Energy: www.ase.org

The Carbon Trust: www.thecarbontrust.co.uk/energy

Iowa State University Industrial Assessment Center (IAC): (515) 294-3080 or www.me.iastate.edu/iac

National Electrical Manufacturers Association: www.nema.org