Integrating Fan System Best Practices and Fan System Assessment Tool (FSAT) Programmatically into Motor Management Strategies

Ronald G. Wroblewski, Productive Energy Solutions, LLC
Anthony Radspieler, Jr., Lawrence Berkeley National Laboratory
Mitchell Olszewski, Oak Ridge National Laboratory

ABSTRACT

A U.S. Department of Energy (DOE) report has estimated the potential energy savings for industrial electric motor systems in the U.S. to be between 11 and 18 percent. To help end users of industrial fan systems realize these energy savings opportunities, the DOE's Office of Energy Efficiency and Renewable Energy (EERE) developed the Fan System Assessment Tool (FSAT) and associated trainings in collaboration with the Air Movement and Control Association (AMCA) International, Inc.

With the release of FSAT, a new tool is available for companies to identify optimization opportunities in fan systems. This paper will present programmatic techniques and strategies that companies can use to identify opportunities in their fan systems. By adopting prescreening techniques for narrowing the field of required data, as well as strategies for collecting data and analyzing opportunities, companies can use FSAT to reduce the overall cost of operating fan systems by reducing energy costs and minimizing harmful vibrations and pulsations that destroy bearings and otherwise adversely affect the process.

Introduction

The optimization of industrial fan systems can provide quantifiable benefits in the form of reduced energy costs, as well as other quantifiable and nonquantifiable benefits. The opportunity for capturing reduced energy costs alone is substantial. A 1998 report for the U.S. Department of Energy (DOE) found that in 1994, industrial electric motor systems consumed 747 billion kWh, equivalent to 25 percent of all U.S. electricity sales, or 63 percent of the net industrial electricity used in the U.S. This report estimated that in the manufacturing sector, the potential motor system energy savings using mature, proven, and cost-effective technologies range from 11 to 18 percent (Xenergy, Inc. 1998).

To help end users of industrial fan systems realize these energy savings opportunities, the DOE's Office of Energy Efficiency and Renewable Energy (EERE) developed the Fan System Assessment Tool (FSAT) and associated trainings in collaboration with the Air Movement and Control Association (AMCA) International, Inc.[1] FSAT is one of a suite of software programs available from DOE, including Pumping System Assessment Tool (PSAT), Steam System Assessment Tool (SSAT), AIRMaster, MotorMaster and others. In addition to the FSAT

[1] AMCA International is a non-profit trade association assisting manufacturers, end users and engineers with testing, system design, equipment directories and educational materials, seminars and services.

software, two training courses have been developed, *Fan System Assessment Training* and *FSAT Qualified Specialist Training*.

With the release of FSAT, a new tool is available for companies to identify optimization opportunities in fan systems. This paper will present programmatic techniques and strategies that can help companies achieve maximum benefit from FSAT. By adopting prescreening techniques for narrowing the field of required data, as well as strategies for collecting data and analyzing opportunities, companies can use the software tool as part of a strategy to reduce the overall cost of operating fan systems by lowering energy costs and minimizing harmful vibrations and pulsations that destroy bearings and otherwise adversely affect the process.

FSAT is designed to help quantify the potential benefit of using a more optimally configured fan system to serve industrial processes. FSAT is able to calculate a fan system's energy use, determine how efficiently the system is operating and quantify possible savings from upgrading a system. In this paper, the term fan optimization refers to meeting the stated flow and pressure requirements in a more efficient manner. In some cases greater savings may be realized by reducing the flow or pressure requirements of the process, or even challenging the need for r the fan to begin with.

To further explore how FSAT can be part of a broader strategy to optimize fan systems, an Optimization Action Plan has been developed, as detailed below:

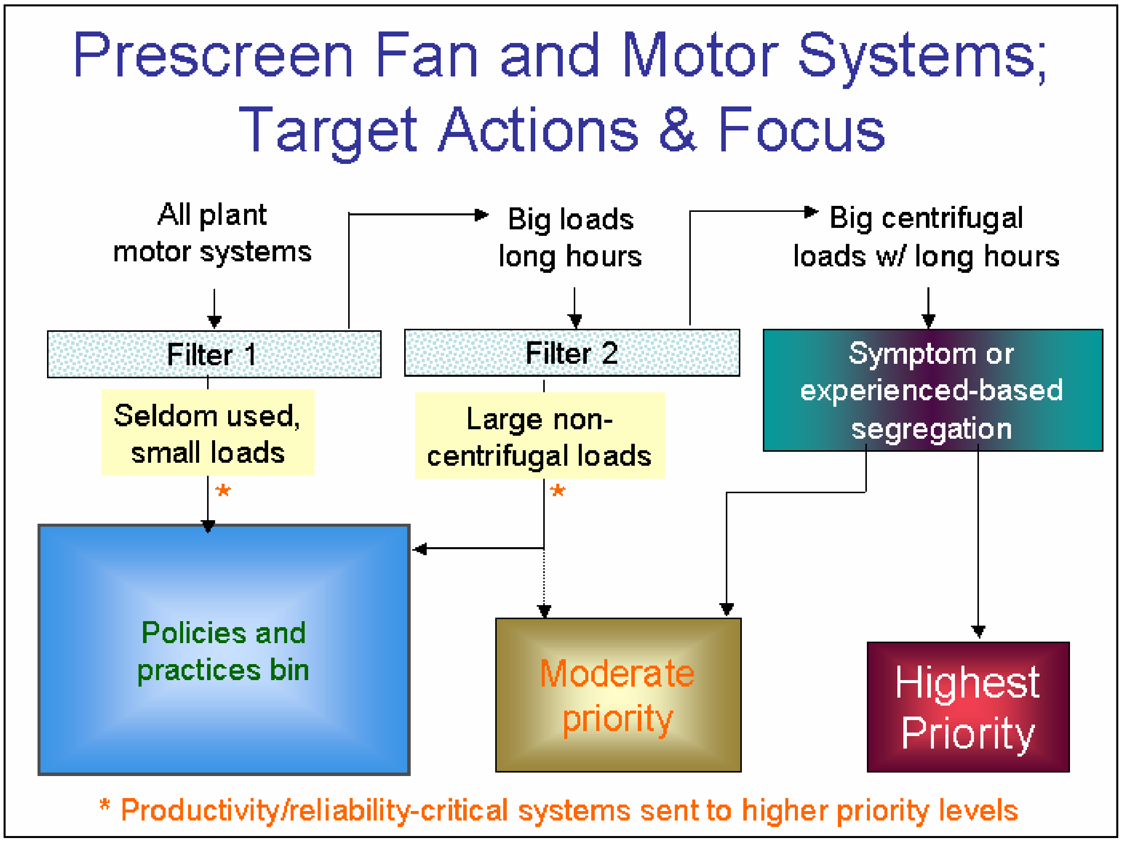
- Prioritize and rank opportunities
- Test highly ranked systems
- Perform FSAT analysis
- Prioritize projects, stating benefits and costs
- Look for co-funders
- Implement top-ranked project
- Verify and report savings

In addition, information will be presented on opportunities for developing in-house fan system knowledge, and ways that management can support the work of increasing the efficiency of fan systems.

Optimization Action Plan

The Optimization Action Plan provides a method to identify fan systems within a plant that will benefit from optimization. The plan is designed to clearly identify the system upgrades that will capture the greatest energy savings. In this way, the most inefficient systems can be addressed first. Figure 1 is a graphic representation of the approach.

Figure 1. Prescreen Fan and Motor Systems Schematic



Source: US DOE

Prioritize and Rank Opportunities

The 19th century Italian economist Vilfredo Pareto made the observation that 20 percent of the population in Italy held 80 percent of the wealth (Pareto 1896). This observation has since been broadened to other fields. Industrial management and energy efficiency experts have restated it as 80 percent of the energy is consumed by 20 percent of the equipment. This rule can be useful in determining where to look first for optimization opportunities. For example, industrial facilities with large fan, pump, compressor or boiler systems should address the largest, most critical pieces of equipment first. The large loads and critical points of the process are where 80% of the potential system optimization benefits are usually found. If the primary loads are air compressors, pumps, boilers or steam then these loads should be examined prior to examining the fan systems. If the priority loads are fans, or if the other loads are already efficiently managed, then suggestions in this article pertaining to fans may be of use.

A selection criterion, such as listing all fans (or other equipment) that are a certain size or larger, is a useful tool. For the plants with the largest equipment, it may be useful to categorize the motor systems by size into primary - 500 hp (370 kW) or greater, secondary - 100 hp (75 kW) to 400 hp (300 kW), and tertiary - 75 hp and smaller.

The Fan System Optimization Checklist, Figure 2, provides a qualitative approach to screening fan systems prior to conducting performance assessment tests. Using the checklist allows companies to focus resources where they will yield the most benefit.

The checklist is organized into three categories: Control, Production & Maintenance and System Effect. The user assigns points based on various conditions that are known to be the result of outdated or poor practices, e.g., "too much flow or pressure for production," "buildup on fan blades," or "system damper." Then the user totals the points and determines whether a good opportunity might exist in that system. While the underlying concepts contained in the checklist are not new, it provides a new way to identify and prioritize fan system opportunities.

Management should consider having plant staff complete a checklist for all fans larger than a certain threshold (over 500 hp, for instance) that run at least 4,000 hours per year or more. Then the results can be ranked and projects prioritized. Note that the checklist is designed for systems over 50 hp (37 kW). The checklist can be used for systems under 50 hp, as long as the points are assigned consistently. In either case, it is a useful prioritization tool.

A high ranking on the qualitative checklist can justify the expense of a performance test of the fan system. The performance test provides complete input information for FSAT software.

Test Highly Ranked Systems

The next step is to conduct performance tests on the top 3 to 5 fan systems ranked highly by the qualitative checklist. The FSAT Data Collection Worksheet, Figure 3, can be used to gather information that the software requires to calculate energy savings.

In addition to straightforward pressure and power measurements, the performance test includes a complex flow measurement, requiring the use of a pitot tube. If in-house expertise is not available, a consultant can be hired to conduct the test. Any performance test should be done according to published standards (AMCA 203, *Field Performance Measurement of Fan Systems*). The test is fairly involved and will not be detailed here. However, some basic requirements include locating a section of duct with a smooth flow profile for the velocity traverse and taking into account the density of the gas.

A good test measures the performance of the system and also establishes the needs of the process, so the fan can be better aligned to the process needs. The ultimate goal is to establish flow, pressure and power as developed by the fan, and also to determine the flow and pressure required by the process. Once that information has been obtained, FSAT can be used to calculate potential savings from optimization.

In some cases, a detailed performance test may not be needed to justify changes to the fan system. An example is a system that uses a smaller fan, 50 hp (19 and 37 kW) or less, operating at low voltage (460 V). When the system pressures are measured, if the damper accounts for a large portion of the system pressure, it may be more cost effective to get an adjustable speed drive and experiment to determine the correct speed, rather than conducting a performance test to calculate the speed. On the other hand, a performance test even on a system this small might identify solutions less expensive or more appropriate than an ASD, such as replacing the fan or impeller, changing to a belt drive, or adjusting the pulleys on a belt drive.

In either case, time and resources are needed to determine the current state of the system and the best avenue for optimization.

Figure 2. Fan System Optimization Checklist

Fan System Optimization Checklist [Copy 1]

For fans over 50 hp that operate more than 4000 hours per year

Instructions: Use this checklist to qualitatively select the top optimization projects for FSAT analysis. Make a copy of this list for each of your major systems, then go through the list and add up the points for the conditions that apply. **If there are any control, production & maintenance, or system effect indicators, <u>then</u> add points for size and run hours as follows:** *If the system operates more than 4000 hours add a point. **If the system is over 100 hp add a point per 100 hp (200 hp = 2 points, 300 hp = 3 pts, etc). Also add a point or points if production or maintenance problems are severe. Two or more points can indicate a good optimization opportunity. Four or more points probably indicate a very good opportunity. ***Note***: Fans with adjustable speed drives usually are <u>not</u> good candidates for optimization.

Fan System ______________________________

Are there problems with the system?______________________________

Points**		Points*		
1 ___	Motor ______ hp	1 ___	Operating hours ____________	Tally the points ____________

Control		Production & Maintenance		System Effect	
Points		Points		Points	
2 ___	Motor overloads unless damper restricts flow	2 ___	Too much flow or pressure for production	2 ___	90° turn *right at* fan outlet or inlet
2 ___	Spill or bypass	2 ___	Unstable or hard to control system	1 ___	90° turn *near* fan outlet or inlet
2 ___	Discharge damper	2 ___	Unreliable system breaks down regularly	2 ___	Dirt leg at bottom of inlet duct
1 ___	Inlet damper	1 ___	Not enough flow or pressure for production	1 ___	No outlet duct
1 ___	Variable inlet vane	1 ___	System is excessively noisy	1 ___	Restricted or sharp inlet
1 ___	System damper	1 ___	Buildup on fan blades		
1 ___	Damper is mostly closed	1 ___	Need to weld ductwork cracks regularly		
		1 ___	Radial fan handling clean air		

Facility/Contact/ phone/fax: ______________________________

Source: *Fan System Assessment Training*, AMCA, U.S. Department of Energy

Figure 3. FSAT Data Collection Worksheet

FSAT Data Collection Worksheet

System Name ______________________________

FAN AND MOTOR

❑ Airfoil SISW	❑ Backward Curved SISW	❑ Backward Inclined SISW
❑ Airfoil DIDW	❑ Backward Curved DIDW	❑ Backward Inclined DIDW
❑ ICF Air Handling	❑ ICF Material Handling	❑ ICF Long Shavings
❑ Radial	❑ Radial Tip	❑ Vane Axial

Fan Speed _______ rpm OR **Fan Diameter** __________ in.

Motor HP __________ hp

Motor Speed __________ rpm

Motor Efficiency Class: ☐ Energy Efficient ☐ Standard Efficient ☐ Unknown (Average)

Nominal Motor Voltage __________ volts

Motor Full Load __________ amps

OPERATING FRACTION AND ELECTRIC RATE

Operating Fraction ___________

Electric Rate ___________ $/kwhr

SYSTEM INFORMATION [MEASURED OR REQUIRED CONDITIONS]

Measured Power ___________ kW OR **Measured Current** ___________ amps

Measured Bus Voltage ___________ volts

Drive Type: ☐ Direct ☐ Belt

Required [not including avoidable pressure drop due to partially closed dampers]

Flow Rate _________ cfm **Fan Static Pressure** _________ in H_2O

Measured [Fan outlet pressure minus fan inlet pressure] – Inlet velocity pressure

Flow Rate _________ cfm **Fan Static Pressure** _________ in H_2O

GAS PROPERTIES [Optional. Complete if non-standard conditions]

Gas Density __________ lbm/cu.ft

If gas is **air**, FSAT can help estimate density:

Inlet Dry Bulb __________ °F

Inlet Wet Bulb __________°F OR **Inlet Relative Humidity** ___________ %

Ambient Pressure _______in Hg OR **Elevation Above Sea Level** _______ Ft.

Air Inlet Pressure Above Ambient __________ in H_2O

Source: *Fan System Assessment Training,* AMCA, U.S. Dept. of Energy

Perform FSAT Analysis

Once the performance test is complete and the data collected, FSAT can be used to calculate the energy savings from optimization. Savings estimates are a very useful and important justification for the capital investment for optimization projects. Figure 4 shows the main screen of the FSAT software. The inputs are on the left hand side of the screen and the outputs on the right hand side.

FSAT is designed to quantify savings by comparing actual field performance numbers to the performance of an ideal fan system, but it does not give direction on what changes to make to optimize the system, or what the root cause of the inefficiency is. The inefficiency could be the result of one or a combination of factors, including a fan oversized for the job, poor inlet or outlet conditions, degradation of the fan wheel due to erosion or corrosion, or perhaps the fan wheel is unsuited for the load. Someone skilled in the operation and optimization of fan systems is needed to determine the cause of the inefficiency.

Some changes that are commonly made to optimize fan systems include:

- Replace the fan or impeller
- Change to new belt drive ratio
- Convert to adjustable speed drive
- Improve system control
- Correct poor inlet/outlet conditions

The advantages and disadvantages of each should be considered.

Prioritize Projects, Stating Benefits and Costs

Once system performance tests and FSAT analysis is completed, the next step is to determine the benefits and cost of the projects, so that projects may be funded for capital improvement.

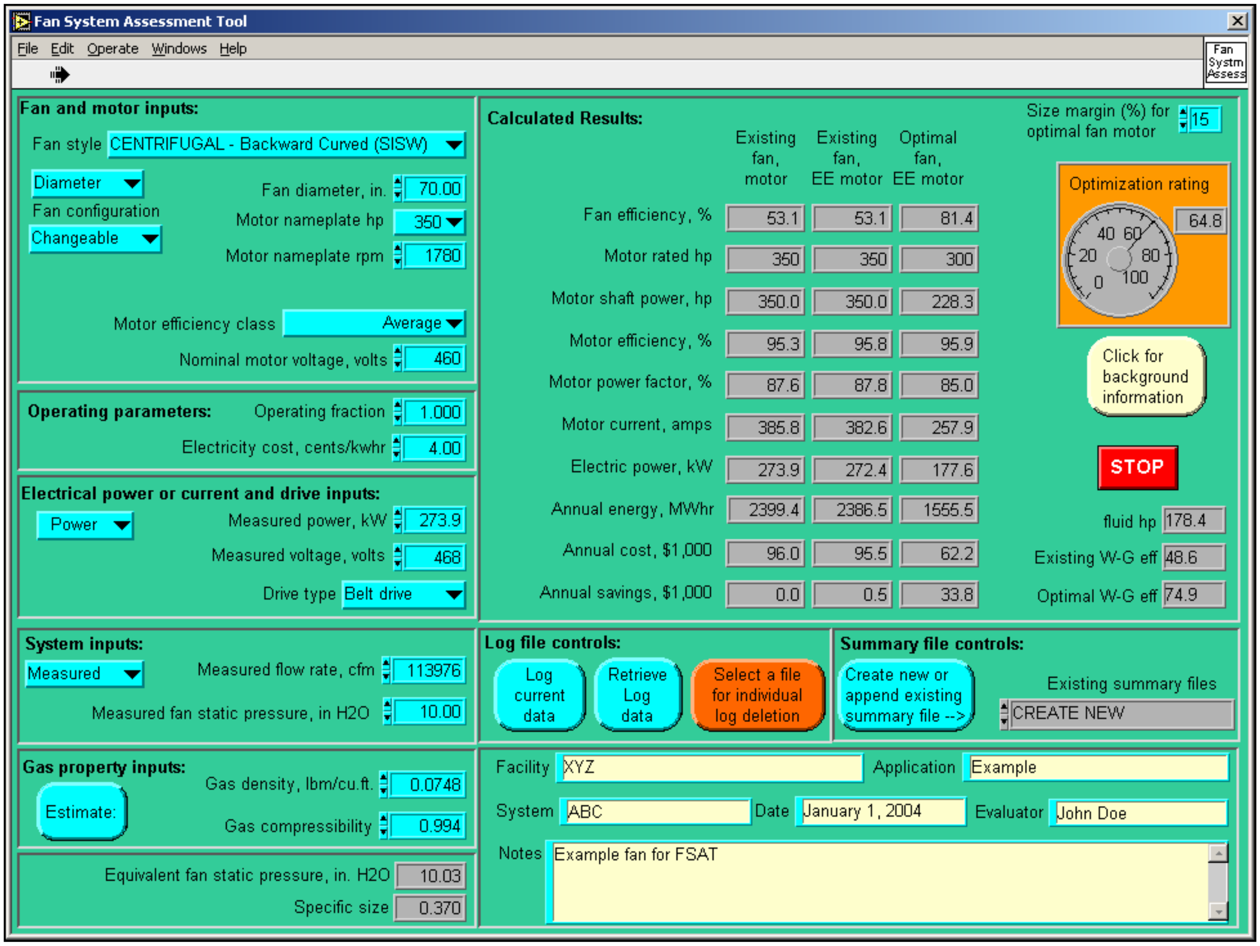
When building a business case for a fan system optimization project, both energy and non-energy benefits should be considered, especially since non-energy benefits may be the most compelling reason to go ahead with the project. Some non-energy benefits are quantifiable, while others are not; all should be considered.

The most obvious example of a quantifiable energy benefit is the FSAT calculation of energy savings. A quantifiable non-energy benefit might be eliminating a maintenance cost such as a one-day shutdown each year to weld stress cracks in ductwork from excessive pulsations. After the optimization project, the shutdown will not be needed, and the savings can be easily calculated.

Examples of nonquantifiable benefits include changes to product quality or improved control because of more stable flow. In addition, the optimization could result in fewer pulsations being transmitted to the bearings and causing damage. Even if it is difficult to determine the dollar value of extended motor life, it is a benefit that can help justify the project.

Below are other benefits that should be considered (not all benefits apply in every case).

Figure 4. FSAT Main Screen



Source: FSAT software, developed jointly by AMCA and Oak Ridge National Laboratory

Financial/corporate and production benefits. Save money and energy while boosting profits, improve quality of finished product, improve productivity with less downtime, avoid purchase of expensive, new equipment by better use of existing equipment, make more money by boosting productivity through fewer scrapped parts, meet corporate energy efficiency goals and meet corporate cost reduction goals.

Maintenance and safety benefits. Provide a safer, more enjoyable environment for workers (a quieter plant protects hearing and causes less fatigue (Kluger 2004), may not require earplugs and improves communication between employees), protect worker health with cleaner indoor air, experience fewer maintenance concerns (including bearing problems and stress cracking in ductwork), reduce or eliminate the need for silencers, justify newer, better equipment based on solid energy savings data, improve process control through more stable air flow, improve performance of filters, coils, silencers and ductwork through more uniform velocity profile and increase the reliability of systems.

Environmental/societal benefits. Reduce plant emissions of particulates and pollutants, save energy, which slows the use of limited fossil fuel resources, build fewer new power plants and transmission lines, lower electric rates and reduce emission of carbon dioxide and other greenhouse gases at the local power plant.

Look for Co-Funders

It may be possible to obtain financial assistance for optimization projects. Local, state or regional authorities may have potential funds available. In some states (California, the Pacific Northwest and New York, for example) electric utilities have public benefits funds that can be used to "purchase" power reductions via energy efficiency. These funds can be used to offset a portion of the capital cost of implementation.

Verify and Report Savings

The power should be measured after the changes have been made for comparison, and the savings reported to management. Then the next project on the list should be implemented, resulting in further savings.

Developing In-House Fan System Knowledge

To facilitate implementation of the Optimization Action Plan, it may be useful for staff members to develop their overall knowledge of fan systems. This can be done by:

- Attending AMCA, DOE or other training courses
- Studying materials from ASHRAE (the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.) and AMCA
- Reviewing case studies from organizations such as the Northwest Energy Efficiency Alliance, the Energy Center of Wisconsin and the DOE

In addition, key staff members should become familiar with the plant's fan systems, as well as indicators of optimization opportunities. This can be accomplished by completing the Fan System Optimization Checklists and sharing that information with management. The goal is to understand the fan systems' capabilities and limitations.

As previously mentioned, training in FSAT is also available. Topics covered in the *Fan System Assessment Training Course* include understanding the benefits of optimizing fan systems, calculating the cost of operating fans in a facility, explaining the interaction between the fan curve and system curve, estimating the overall efficiency of a fan system, analyzing the optimization potential of fan systems, learning how to use the FSAT software and creating an action plan to improve fan system efficiency.

Alternatively, a staff member can train to become an FSAT qualified specialist. A qualified specialist will have been to the training course, *FSAT Qualified Specialist Training,* and passed a test showing proficiency in knowledge of the FSAT software. Participants in the qualified specialist course will be able to use manometers, pitot tubes and other instruments to take fan measurements in the field, develop a measurement plan as part of a performance test, analyze field data, use FSAT to model a field fan system, understand how FSAT handles gas temperature and density, describe how to manage files in FSAT and use FSAT to evaluate fan systems.

Developing in-house expertise can take two to three years. For faster results, a qualified specialist or consultant can be brought in to identify key optimization opportunities.

It should be noted that there is a knowledge gap within the DOE-sponsored trainings. The FSAT software will identify systems that are inefficient, but it does not address how the systems can be made efficient. Knowing what to do to the system to capture the energy savings requires in-depth knowledge of fan systems and optimization techniques not covered in the FSAT training courses. The AMCA fan course addresses some of these topics.

Management Support for Fan System Optimization

Managers can support the work of optimizing fan systems by understanding the perspective of plant personnel, who are often under pressure to maintain production. From their viewpoint, the fan systems need to be operable, not optimized. They may have never been told that optimization is a priority. Managers can refocus staff by providing training and funding so that energy savings can be realized from optimizing fan systems.

Specifically, managers can:

- Request an accounting of energy usage of key equipment with an accompanying analysis of the effectiveness and efficiency of each machine;
- Encourage employees to fill out the Fan System Optimization Checklist for key fans and report back the results;
- Make funding available for the performance testing of key systems;
- Send plant staff to training courses, as discussed above;
- Recognize that while staff members are highly skilled in making the company's products, they probably have not been trained in the theory and nuances of applying fans efficiently;
- Prioritize the implementation of the projects, setting up a timetable and a budget. Take into account the overall company strategy (e.g., if a piece of equipment is going to be shut down soon, it shouldn't be studied);
- Resist the temptation to expect something for nothing. An investment must be made to realize savings. In addition, a judgment call needs to be made on the nonquantifiable benefits. A project with a one-year payback may not be as attractive as a project with a three-year payback that also solves a production problem;
- Consider the broader benefits of improving the efficiency of your company's operations. If industry draws 30 percent of electrical power and 20 to 30 percent of that is wasted, there is a sizeable societal impact in allowing that situation to continue to exist. The extra work in evaluating and optimizing a fan system can be justified as beneficial not only to the company, but to the community as well.

Summary

The high cost of energy for industrial operations can be reduced by addressing the efficiency of fan systems. The FSAT software can be used as part of an overall motor management strategy to recognize fan system optimization opportunities that will result in the greatest payback for the least expenditure of time and resources.

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