THE U.S. DEPARTMENT OF ENERGY'S MOTOR CHALLENGE SHOWCASE DEMONSTRATION PROJECTS – A MODEL OF GOVERNMENT-INDUSTRY PARTNERSHIP FOR THE 21st CENTURY

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BACKGROUND

The U.S. Department of Energy's (DOE's) Motor Challenge program is an industry/government partnership designed to increase the use of energy-efficient industrial electric motor-driven systems in an effort to help industry capture 5 billion kilowatt-hours per year of electricity savings by the year 2000. Since more than 70% of all industrial power is consumed by motor-driven systems, the DOE created the Motor Challenge program in 1993 to "assist our customers in gaining a competitive advantage in managing their electric motor systems while saving energy and enhancing environmental quality." To increase the market penetration of energy-efficient industrial electric motor-driven systems, the program is helping industry adopt a "systems approach" to developing, purchasing, and managing motors, drives, and motor-driven equipment such as pumps, fans, and compressors.

The central element of the Motor Challenge program is its Showcase Demonstration projects. These performance optimization projects address a broad range of technologies, including energy-efficient electric motors, variable frequency drives (VFDs), and motor-driven equipment (e.g., pumps, fans, and compressors), and are intended to demonstrate how the benefits of efficient motor systems can be effectively captured in a wide variety of industrial settings. Each Showcase project is located at a specific U.S. industrial facility that is improving the performance of one or more of its motor systems. Once a project is completed, the results and important lessons learned from the Showcase Demonstration project are publicized in relevant trade publications to encourage other industrial facilities to undertake similar improvement projects.

This paper presents an overview of the how the Showcase Demonstration effort is structured, and highlights two of the program's successful projects.

THE PARTNERSHIP

The key to the Showcase Demonstration program is partnership: partnership between the host site and their Showcase Team, and partnership between the each Showcase Team and DOE.

Showcase Teams

Each Showcase Demonstration motor system improvement project begins when a Showcase Team is formed. This team includes not only host site staff and but also typically involves individuals from engineering firms, the local electric utility, motor systems component equipment manufacturers and distributors, and trade associations. In many cases, Motor Challenge has been instrumental in bringing these organizations together. All funding for the Showcase Demonstrations is borne by the host site and their project partners. They are responsible for project conception, implementation, instrumentation, and collection of the test data necessary to demonstrate the associated energy savings and productivity gains, and retain any proprietary information and intellectual property developed during a Showcase Demonstration project.

DOE's Contribution
DOE, on the other hand, the provides the Showcase Teams with four types of support:

Technical Support and Performance Validation - DOE provides a Independent Performance Validation (IPV) team of consulting engineers which advise the project teams on technical matters and performance validation issues such as: testing procedures, instrumentation techniques, test plan development, and data acquisition. The IPV teams do not witness the actual test data collection, but independently analyze the data supplied by the host site to prepare an IPV report. The IPV ensures that the energy and economic performance of the projects is properly measured, calculated, and documented in an unbiased way. The IPV function is carried out by the Oak Ridge National Laboratory and an engineering consulting firm.

Tools and Best Practice Development - DOE supports the development of design-decision tools, best practices, and guidelines on various electric motor systems applications. Key tools developed include Motor Master Plus software and a series of training modules on motor systems management issues.

Case Study Documentation and Dissemination - Based on the IPV report, DOE prepares a 4-page case study which documents the case history of each Showcase Demonstration project. Each completed Showcase Demonstration Project is then publicized by DOE by means such as working with editors of the appropriate trade journals, through Motor Challenge newsletters, and at trade shows. By making other companies in the U.S. aware of the success of the technologies and techniques demonstrated in the Showcase projects, DOE is encouraging them to improve the performance of their electric motor systems. In addition, this publicity provides the organizations involved in the Showcase effort with national recognition for their efforts.

Showcase Demonstration Workshops - DOE sponsors special Showcase Demonstration Workshops in order to provide team members with a forum for exchanging information; discussing implementation challenges, opportunities, and lessons learned; and learning about new tools and best practices being developed by DOE researchers.

THE PROJECTS
Since 1994 approximately 25 projects have been selected by DOE as Showcase Demonstrations Projects. The project encompass a wide variety of industries and motor systems and are currently in various states of completion. Two recently completed projects, Alumax (an aluminum refiner) and the City of Milford, Connecticut, serve to illustrate the successful partnerships between the host organizations, their Showcase Teams, and DOE's IPV team, as well as the important energy, economic, and environmental benefits achieved by each organization.

ALUMAX
Alumax Inc. is the third largest producer of aluminum in the United States and has more than 100 plants in seven different countries. Their Mount Holly plant, located in Berkeley County, South Carolina, processes alumina (aluminum oxide) into custom alloyed ingots and billets for fabrication into consumer products, employs 625 people and produces 200,000 tons of aluminum annually. One of Alumax's four reduction plants, the Mount Holly plant consumes 300 megawatts of electricity continuously at a cost of $1.7 million per week. With electricity consumption levels of 6.1 kilowatt hours (kWh) per pound of aluminum produced, compared to an industry average of 8 kWh, the Mount Holly plant is extremely energy efficient.

Project Overview
Despite the plant's relative energy efficiency, plant engineers believed there was on opportunity to improve the energy efficiency of the plant's four pot line dust collection systems. To assist them in identifying and implementing the most energy-efficient and economical dust collection method available, Alumax formed a Showcase Demonstration Team with the engineering with the engineering consulting firm of Jacobs-Sirrine Engineers.

The Old System

Reduction of alumina to aluminum occurs in pots of molten cryolite (sodium aluminum fluoride) when a high dc voltage is applied to the bath. Pot line fans are responsible for the removal of dust and other airborne impurities generated during this reduction process. The Mount Holly plant has 360 pots, equally divided into 8 pot lines. Each of the four pot line dust collection systems collects dust from a pair of pot lines. Main headers are connected to individual ducts coming from each pot and direct the dust-laden air through a dry scrubber (baghouse). Once leaving the baghouse, the ducts each split into four individual ducts, channeling the air into four fans, which then deliver the air to a stack for emission. Each of the four dust collection systems has four fans (for a total of 16 fans) and each system has its own stack.

In the original pot line dust collection system, a total of 360,000 cfm was produced by the four fans operating with variable inlet vane (VIV) control. After years of experience, staff engineers found they could partially close the VIVs and operate the system at 325,000 cfm, which resulted in improved bag life. However, as a result of closing the VIVs, the fans operated at an efficiency of only 68 percent, despite the fact that the fans' design point efficiency rating was 87 percent.

Project Implementation

To identify the most economic and energy-efficient system, the Showcase Team measured a variety of performance criteria including fan speed, air temperature, air flow, static pressure, and fan motor power consumption. This data was used to compare four different operating scenarios: (1) operate with four fans using VIV control; (2) operate with three fans using VIV control; (3) operate four fans using variable frequency drive (VFD) control; and (4) operate three fans using VFD control.

After comparing all four methods of operation, the three-fan VIV system proved to be the most efficient and cost-effective. Based on a power consumption cost of $0.031/kWh and the total kW demand of each system, the $786,981 total annual cost of the three-fan VIV system was the lowest of the four systems. The four-fan VFD system was the second least expensive at $806,058; followed by the four-fan VIV (original) system ($890,717) and the three-fan VFD($898,970).

The three-fan VIV system was the most efficient of the four systems tested because the VIVs were open wider and resulted in less pressure loss through the VIVs, resulting in a "wire-to-air" efficiency level of 84 percent; significantly higher than the 68 percent offered by the four-fan VIV system. Because airflow must be split between the ductwork to three fans (rather than four), the three-fan system had higher velocities in the ducts and a marginally higher pressure drop. With more air flow being handled by each fan, the power consumption of each fan was higher in the three-fan VIV scenario. However, because only three fans were operating, the total power consumption of this system was less than in the four-fan VIV mode. The VFD systems were not optimum solutions because they resulted in the fans operating farther away from their best efficiency points, and because of the inefficiencies inherent in the VFDs themselves.

Results

Based on the systems analysis results, Alumax decided to implement the three-fan VIV control method. This method provided Alumax with $103,736 of gross and net savings, as there were no capital costs. Payback was immediate. The resulting demand reduction of 382 kW translated into annual energy savings of approximately 3,350,000 kWh, nearly 12 percent less than the original system. Turning off one of the four fans and changing the VIV controller set points to maintain the required airflow while operating with three fans were the only activities needed to make the transition from the four-fan VIV system.

In addition to the economic and energy-saving benefits, the plant also benefitted from:

- Spare fans, since the fourth fan in each system is no longer used in day-to-day operations;
- Reduced maintenance requirements such as bearing lubrication, bearing failure, balancing, and fan control repairs;
- Reduced noise levels as only three fans now operate; and
- Increased fan control accuracy because there is one less fan operating and the VIVs are more fully open than in the base case.

Lessons Learned
The project also demonstrates that VFD operation is not always the most energy-efficient solution. VIVs are typically efficient in the upper range of operation (where the three-fan VIV mode operated in this case). Fans operating closest to their best efficiency point (BEP) maintain the highest efficiency ratings. Therefore, matching the system demand to the appropriate fan can be more critical to the fan's performance than the type of control system used. In this case, recognizing that the three-fan VIV system operated the fans closest to their BEPs saved the time and cost associated with installing VFD control systems. In addition, this project demonstrates that, through thorough systems analysis, significant energy and cost savings can often be achieved with little or no capital outlay.

THE CITY OF MILFORD
The City of Milford, located just south of New Haven, Connecticut, serves more than 48,000 people with 37 sewage stations that transport more than 7 million gallons of raw sewage each year to one of two city sewage treatment plants. In order to reduce energy consumption at their Welches Point sewage lift station, the city formed a Showcase Demonstration project team with ITT Flygt Corporation (the pump manufacturer that provided the pump used in the project) and the United Illuminating Company (the local electric utility), which provided electric metering services.

Project Overview
A medium-sized sewage station built in 1963, the Welches Point pump station delivers approximately 750 million gallons of raw sewage per year to a local treatment plant and consumes an estimated 240,000 kWh of electricity annually. The system operates with three identical 75-hp pumps which are vertically mounted 40 feet below ground level and are driven by motors positioned directly above each pump at ground level. Each pump is equipped with a 35-foot floating line shaft that pumps raw sewage to a common header which gradually steps up to ground level. From the common header, the sewage flows through the gravity feed header (shared by several sewage stations) to the main treatment plant.

Project Implementation - The Systems Approach
To determine whether or not energy savings could be realized at the lift station, team engineers developed a test plan based upon the systems approach -- a method of increasing the efficiency of an electric motor system by focusing on total system performance rather than individual elements and functions. After performing an analysis of the overall performance of the station's pumping system (volume flow, operating times, and energy use of the pumps), the project team concluded that reducing pump capacity could achieve significant energy savings.

The Old System
The old system was designed to operate with only one pump under normal conditions. One of the pumps begins operating when the water level reaches a set high-water level and remains on until the water drops to a designated low-water level. During periods with very heavy inflow rates, two pumps operate simultaneously. A third pump functions as a back-up pump, operating if another pump is damaged or in repair. Each pump rarely operates for more than 15 minutes during each cycle.

The sewage station was designed to handle peak inflow of 3,000 gallons per minute (gpm). The average inflow rate of sewage is 1,700 gpm. Average flow rates from the station to the local treatment plant were estimated at 3,350 gpm during normal conditions and 4,250 gpm when two pumps operate. Each year, the old system consumed approximately 212,064 kWh of electricity to handle 752 million gallons of sewage. Overall system efficiency was rated at 73 percent.

Alternatives Considered
Several alternatives to improve sewage station efficiency were considered. All centered around finding a way to pump the water out of the sump more slowly, which would reduce dynamic head loss, friction in the piping system, and energy consumption. To reduce the outflow rate, engineers considered installing variable frequency drives (VFDs) on each of the pumps to allow for variable speed control. VFDs can save energy in applications involving fast or frequent changes in flow rates. However, because the sump acted as a buffer in this application, the outflow rate did not need to be changed frequently, so VFDs were not the answer. In addition, VFDs are

not generally recommended for systems with large static heads, like this one. Other options explored involved trimming the impeller or replacing the original pumps. After analyzing the tests performed on the original pumping units, the team concluded that the best solution would be to install a smaller pump to operate at lower outflow rates for longer running periods.

The New System

The new system includes a smaller 4" x 8" pump that replaced one of the original three pumps. The smaller pump is driven by a 35-hp motor. This pump operates for longer periods, one to two hours on average, but at a lower outflow rate. The lower outflow rate results in reduced friction in the piping system, which reduces energy consumption. The original two pumps will no longer operate under normal conditions, but will run during periods with heavy inflow rates.

Results

The optimized system delivers sewage to the main treatment plant at an average flow rate of 1,930 gpm under normal conditions. Energy consumption after installing the smaller pump is estimated to be 175,968 kWh per year, resulting in a reduction of more than 37,000 kWh each year. Compared to the old system, the new system reduces annual energy use by more than 15 percent, equivalent to $2,960 in annual energy savings. With a total project implementation cost of $16,000, the City of Milford will realize a simple payback of 5.4 years.

In addition to the energy savings achieved, other direct benefits from modifying the system include increased equipment life and reduced equipment downtime and repair. Frequent starting and stopping of the pumps contributes significantly to wear-and-tear of the equipment and increases the associated maintenance required. With the new system, less stress is placed on equipment.

CONCLUSIONS

These are just two of many projects that demonstrate how organizations are significantly improving their energy efficiency and system performance by working in partnership with DOE and its allies (equipment manufacturers, utilities, and consultants) through the Motor Challenge's Showcase Demonstration program. In addition, by independently validating the energy savings and publicizing the success stories generated through this program, DOE's Motor Challenge program is serving as a catalyst for energy efficiency and system performance improvements throughout the industrial sector.