Saving energy through drive efficiency

Per Wikstroem, Jukka Tolvananen, Akseli Savolainen, Peter Barbosa

Of all resources on which modern manufacturing is dependent, energy is arguably the most fundamental. It is also a resource that has long been taken for granted. Rising energy prices and concerns over greenhouse gas emissions are increasingly leading operators to critically assess their energy usage.

In many sectors, the potential for energy savings is minor and gains of a couple of percent in terms of energy efficiency are celebrated as breakthroughs. Under such conditions, the prospects of achieving major energy savings seem bleak. There are technologies, however, that can deliver very significant reductions. Foremost among these is a device that – at first sight – lacks the spectacular note of high-power, high-volume processes. It doesn't make much noise or develop extreme temperatures or go through complex motions. In fact it sits in a cabinet and usually doesn't even get a mention when the overall process is explained. However, it can cut energy consumption by 42 percent, and if applied in all relevant plants worldwide, it can deliver energy savings that equate to the electrical consumption of a country such as Spain. This device is the drive.

The principle is simple: In the past, the motors that powered pumps were usually run at full power all the time, with the regulation of output being achieved through valves. A drive regulates flow through direct control of the electrical power fed to the motor, so permitting friction-based controls and the associated losses to be dispensed with. The following stories provide insight into several applications and show how drives technology can and do make a difference.

The lack of system standards

A lack of system standards for energy efficiency may result in up to 90 percent of pump installations being incorrectly sized – leading to wasted energy.

"Now hold it," you may say, "we have standards for everything". Alas, the world is not that simple and in the area of energy efficiency there are still important gaps. The authors of this article were shown an ACEEE[1] presentation that made them aware of the fact that, whereas there are standards for pump designs[2] and for many for the hydraulic data such as developed head[3], efficiency and NPSH[4], the search for standards providing guidance in system design is less likely to produce a result. To use an analogy, if somebody were to buy a three-ton truck for use on shopping tours, it would not be a demonstration of energy efficiency – even if the truck selected boasted the best efficiency figures for three-ton trucks.

The ACEEE presentation mentioned above refers to a study that looked into the internal practices of a leading chemical company and of two major engineering contractors that company used on recent projects. The focus of the study was to identify whether the size of the installed pumps matched the real need. The result showed that 90 percent of pumps were not correctly sized. This deficiency is a witness to the lack of standards or guidelines. If 90 percent of installations are incorrectly matched in this company, how many are equally so in other companies around the world?

1 illustrates the problem faced by system design engineers. When projecting a system, there is a degree of

Footnotes

[1] ACEEE Summer Study on Energy Efficiency for Industry July 20, 2005 by Robert Asdal – Hydraulic Institute, Vestal Tutterow – Alliance to Save Energy and Aimee KcKane –Lawrence Berkeley National Laboratory

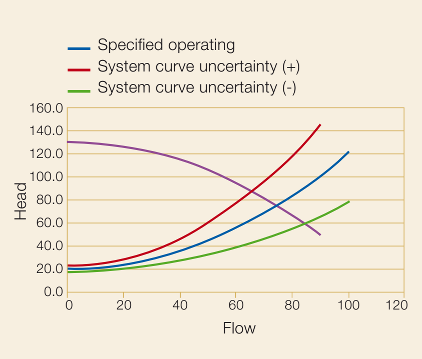
[2] eg, HI, API, ANSI, ISO

[3] The developed head is a measure of the mechanical energy per unit weight of fluid transferred by the pump. Numerically, the developed head is equivalent to the height to which the pump can elevate the fluid in a frictionless system.

[4] NPSH: Net Positive Suction Head

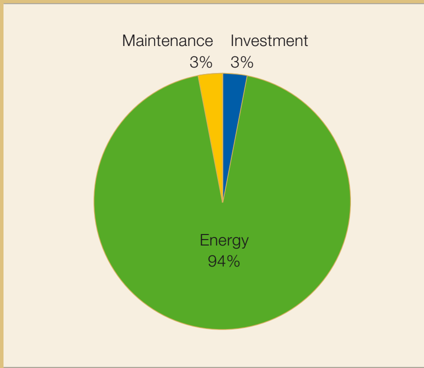
uncertainty as to the shape of the system curves (friction, pipe cross section changes and the number of 90° turns in the final pipe layout all take their toll). These factors all add to the

1 In designing a system, a certain degree of uncertainty in the pump curves must be taken into account



risk that the expected operating conditions will not be met. There are three basic ways to address the changed operating conditions:

2 Energy costs account for the largest part of the total costs of operating a pump or fan motor



- If the changed condition is permanent, then the pump or fan size should be changed to match the load.
- The pump or the fan speed can be changed.
- A throttling device (such as a valve, damper or guide vane) can be added. This is wasteful of energy.

The cost of energy is the all-dominating part of the lifecycle cost of a pump or a fan motor 2. Energy consumption is the best place for optimization to start.

How systems get over-dimensioned

Through an example, ABB Review demonstrates how systems get oversized throughout the design process, and how variable speed drives can be used to conserve energy.

Despite careful analysis and design, many systems do not operate optimally. One reason is that many systems are simply sized too large to start with, resulting in higher operating and investment cost. To illustrate this, the case is considered of a system with a fan in a process industry.

In this example, it is assumed that the "true" condition of the application, 100 units flow, requires 4000 units of pressure 3a.

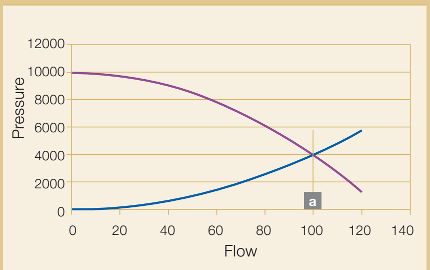
In order to be on the safe side concerning the maximum flow, the figure for the fan that is communicated to the engineer is 110 units of flow 4b. With the assumed system graph, this would require a fan with a higher capacity (dashed yellow line) that can deliver 110 flow units and 5000 pressure units.

It is rare that 100 percent of the design flow will be needed other than for very short bursts.

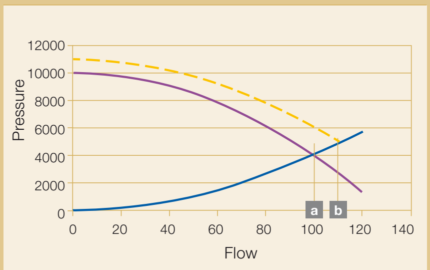
When establishing the fan capacity, the fan-system engineer estimates the overall pressure drop that these 110 flow units will cause 5c. The pressure drop value that is calculated is increased by a 10 percent margin 5d because is difficult to foresee whether the assumed number of 90° turns in the duct will conform to that estimated (possibly the contractor installing the fan will have to add turns to bypass other equipment). Also, the cross-section of the duct may be uncertain. A smaller cross section would lead to a higher pressure drop. Such a 10 percent margin is therefore not unreasonable.

So what data are finally sent out in the requests for tender? Flow: 110 units at a pressure of 5500 units 6e. If the original assumptions were correct, the fan is now grossly oversized. At 100 units flow the necessary additional pressure drop over the damper

3 The application for which a fan motor is sought: The pressure drop is shown in blue and the fan characteristic in purple



4 10 percent reserve b is added to the fan specification a

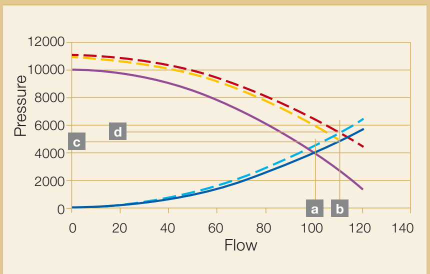


must be about 2800 units (6f minus 6g). This corresponds to 70 percent of the assumed correct total pressure. However, it is rare that 100 percent of the design flow will be needed other than for very short bursts. Assuming that most of the time, 80 percent of the flow rate will be required; the additional throttling needed in the damper will be about 6000 units (6h minus 6i). This corresponds to 150 percent of the assumed correct total pressure.

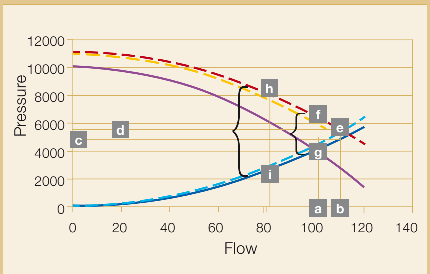
The steps illustrated in this example are more common than they may seem. An additional factor is that when it comes to the selection of a fan, this choice must be made from a standard range of fixed sizes. The next larger one will usually be chosen.

The correctly sized fan for this example should be 100 × 4000 = 400,000 power units. The case above produces a requirement for a fan of at least 605,000 power units (150 percent of the optimum). Correcting this with damper control leads to high levels of wasted energy. The additional losses at the 80 percent flow point amount to 480,000 power units (120 percent of the full power of a correctly sized fan). With a speed controlled fan instead of damper control, most of this energy can be saved

5 The corresponding pressure drop is also increased by 10 percent d



6 The system finally installed is heavily overdimensioned



Energy saving for medium voltage drives

227 TWh is the annual output of 144 fossil fuel type power plants[5], or equivalent to the total energy consumption in Spain. It is also the potential global energy savings that can be attained through the adoption of MV drives.

Energy efficiency is on everyone's mind today. It has taken a long time to raise the awareness to the level where it is now. Al Gore's movie, An Inconvenient Truth, has shaken many and given birth to the acronym AIT. Some readers may have had to cancel their skiing holiday due to lack of snow; such incidents also probably contribute to a raised awareness on global warming issues.

Under Kyoto, the EU's 15 member states committed themselves to an 8 percent reduction in emissions by 2008-2012 compared to 1990 levels. By 2004, they had achieved a reduction of only 0.9 percent, and if current trends continue the reduction will be just 0.6 percent by 2010. Such results make the prospects of success seem pessimistic.

The World Energy Outlook 2006 states in chapter 2, Global Energy Trends: *"Global primary energy is projected to increase by 53 percent between 2004 and 2030 – an average annual increase of 1.6 percent. Over 70 percent of this increase comes from developing countries."* So how are the reduction targets to be reached?

Fortunately, there are areas in which a huge savings potential exist. A few successful examples from industry are highlighted in Factbox 1.

In weighted average, these installations have slashed energy consumption by

7 Medium voltage drive ACS 6000 – such equipment can play a huge role in fulfilling the requirements of the Kyoto protocol

Factbox 1 Savings achievable through the use of drives in selected industries

Company	Industry	Application	Installed Power [kW]	Confirmed savings [kWh]	%-saved
Peña Colorada	Mining	Fan in palletising plant	1250	2'423'750	35%
China Steel Taiwan	Metals	Booster pumps	672	3'030'720	61%
Cruz Azul, Mexico	Cement	Kiln ID fan 1+2	1470	5'309'640	54%
Repsol YPF, Argentina	Petro-chemical	Blower (steam turbine replacement)	3000	7'560'000	43%
Daqing Plastic Factory, China	Petro-chemical	Mixer	1300	2'600'000	31%

Energy efficient products

42 percent. A third to three quarters of all motors operate pumps, fans or compressors. In these applications adjustable speeds are necessary for optimal operation, making them well suited for drives. Looking just at the MV motors and drives, it can be roughly estimated the potential savings are as in Factbox 2.

It is a remarkable coincidence that the EU15 target for drives is exactly 45 TWh per annum. This power corresponds to almost 30 power stations of fossil fuel type[5] or the complete electric energy consumption of Romania in 2000. However, this target comprises both LV and MV installations and the current calculation considers just MV installations! The cumulative installed LV motor power is close to 10 times that of MV motors.

A third to three quarters of all motors operate pumps, fans or compressors. These applications are ideally suited for drives.

So this article can close on the positive note that with an estimated savings potential of 45 TWh by MV drives applications only 7, there is hope that the 45 TWh saving target set by the EU under the Kyoto protocol can be reached.

Factbox 2 Medium voltage drives can deliver global savings of 227 TWh per year

Installed MV motors (world estimation based on 20 year lifespan of motor)	500,000	Pcs
Motors used for square torque loads (at least)	333,000	Pcs
Installed power used to drive square torque loads (average power 1500 kW per MV motor)	500,000,000	kW
Less than 4 percent MV motors have a frequency converter, remaining at least	300,000	Pcs
Assuming that only 30 percent of these motors have an energy saving potential in the same order of magnitude as the sample testimonies above	90,000	Pcs
These 90,000 motors consume *)	569	TWh
Assuming the energy saving potential of 40% (similar to the testimonies above)	227	TWh
The EU-15 share can be estimated to be 20%	45	TWh

*) Assumptions: 2/3 of the motors operate 7500h/yr and 1/3 operate 1850 h/yr. Average load 75 percent of rated power.

Footnote

[5] Assuming an average plant produces 350 MW for 4500 hours/year

Optimizing pump speed to save energy

A study by the Lappeenranta University of Technology and a Finnish paper mill reveals that the consumption of specific energy using throttling control may require up to three times the energy compared to a solution using variable speed drives combined with optimized pump control.

According to a study by Lappeenranta University of Technology (LUT) in Finland, pump control based on variable speed drives can deliver energy savings of up to approximately 70 percent in parallel pumping installations. The biggest savings can be achieved in situations where there are significant fluctuations in the flow. The project leading to this remarkable conclusion involved both computer simulations and practical work on laboratory-scale equipment.

The project was undertaken at the LUT's Department of Energy and Environmental Technology. It set out to quantify the differences in energy consumption in four applications with three different flow control methods. The simulations were performed with Matlab v 6.1 and Simulink software, and the results were verified with actual measurements. The control methods compared were throttle control, standard pump control and optimized pump control.

Throttle control: one pump is throttled and the others are on/off controlled.

Standard pump control: one pump is controlled by a variable speed drive (VSD) and the others are on/off controlled.

In optimized pump control, each pump has its own VSD and the required flow is divided evenly between all the pumps. As a result, their rotational speed is the same. This case differs from the standard model in that the pumps are switched on and off in an optimized way. Optimized pump control technology is

Factbox 3 Energy consumption at one Finnish paper mill, chemically treated water

Control methods	Energy consumption (J/24 h)	(%)	Flow (m³)	E_s (J/m³)
Throttle control	177 114	0.0	2254	78.58
Standard pump control	102 786	-42	2257	45.54
Optimized pump control	57 050	-68	2256	25.29

subject to a patent application by ABB.

The first simulated industrial example is typical of real-life industrial pumping situations where new control technology can be applied. The example was taken from a Finnish paper mill, where Ahlstrom APP22-65 centrifugal pumps are used to pump chemically treated water to a desalination unit. An energy analysis of the pumping facility was used as the basis for the simulations. In this case, a lack of background information made it difficult to draw the system curve.

The simulations, which relied on simplified system and duration curves, showed that in this case, throttle control uses considerably more energy than the other control methods. Optimized pump control is by far the most energy efficient method. The difference between standard and optimized pump control is over 45 percent. The consumption of specific energy with throttling is almost the threefold of that used with optimized pump control Factbox 3.

Mallorca's wastewater pumping system

An above-ground wastewater storage and old pumping station required modernization and eliminaton of odors. Intelligent Pump Control delivered energy savings of at least 20 percent.

EMAYA SA, the water supply and waste utility for the Spanish city of Palma de Mallorca, recently launched a project to upgrade its wastewater pumping stations. The capital city of the holiday island of Mallorca has 380,000 inhabitants. Its sewage system consists of a chain of tanks in which wastewater is rapidly transferred from one tank to the next and finally to a treatment plant. At the first pumping station to be upgraded, the wastewater was previously stored in a tower. This has now been replaced with a 15,000 liter underground holding tank – inconspicuous to most tourists and residents alike 8.

8 Inconspicuous to most – but making a huge contribution to the comfort of holidaymakers and residents: The holding tank of Palma de Mallorca's wastewater system

> The four drives and pumps provide an unprecedented level of fail-safety. If a pump should fail, another one immediately takes over.

Four 60 kW submersible pumps have been installed at the station. Each pump is operated by an ABB industrial drive running intelligent pump control (IPC) software. "This pumping station was old, and there were also odor problems. Simply put, the local environment needed improving," says Lorenzo Mestre, industrial engineer at EMAYA. The four drives and pumps provide an unprecedented level of fail-safety. Even at peak times, only two pumps are required to empty the tank, and one pump can cope during lighter loads. Two pumps are always ready to start up if necessary. Thus, if a pump should fail, another one immediately takes over. The pumping station is also equipped with a diesel generator to ensure a continuous supply of energy in case of a power outage.

Intelligent pump control saves energy

IPC software can significantly improve the energy efficiency of a pumping system. Compared to conventional methods of controlling sewage pumps, IPC can easily deliver energy savings of 20 percent. IPC also includes a number of other features specially designed for pumping systems. The pump priority control function balances the operating time of all the pumps over the long term. All four pumps are run (two at a time) and maintenance can be scheduled so that all the pumps can be serviced at the same time.

The software anti-jam function enables the drive to perform preventive maintenance on the pump. When the function is triggered, the pump spins at high speed and is then either reversed or stopped in a number of user-defined cleaning cycles. This helps prevent congestion through the build-up of particles, and therefore helps to further reduce pump maintenance needs. IPC also enables the drive to monitor the motor temperature more closely than standard systems, further enhancing the overall system reliability.

Straightforward system

The system consists only of ABB drives and pumps, with no need for a dedicated control unit that would introduce additional wiring and complexity. ABB worked together with Cobelsa SA, a panel builder, to deliver an easy-to-use solution to EMAYA. Cobelsa designed the system layout and took care of the installation, and also offers engineering support to the customer. ABB additionally provided assistance during the implementation stage.

Energy efficient products

ABB drives UPM Shotton to a greener future

Paper manufacturer UPM's plant at Shotton (UK) has achieved its goal of producing its entire output from waste paper, rather than using virgin wood. And it is powered by ABB variable speed drives.

The so called "100% Shotton" project involved the building of a new recycled fiber plant, a sludge plant and modifications to two paper machines.

In this process, ABB drives are used mainly on pumps – matching the speed of the pump to the production rate 9. Drives are additionally used on chemical dosing pumps to accurately add chemicals to the pulp. Some conveyors on the process also use ABB variable speed drives.

The drives help achieve a better control of the process, adjusting the inputs to the plant to maintain the correct pressure and temperature conditions. The drives also make it easier to control the production rate. Additionally, they contribute to energy savings by reducing the power drawn.

Ray von der Fecht, Project Automation Manager on the "100% Shotton" project says, "we chose ABB variable speed drives because ABB is a respected name, well known in the paper industry. Also, we know the products and the people. Overall, ABB offered a very good solution along with the best price."

So well did the implementation phase work out, that the drives and automation system could be started-up, not only according to plan, but at the exact minute scheduled. "It was like switching on a light," says von der Fecht.

9 ABB drives at UPM's recycled-paper plant, Shotton (UK) – ABB drives save energy by matching the pump speed to the production rate

One of UPM's major criteria for the drives was maintainability. The drives had to be capable of being exchanged quickly in the event of failure and also had to be easy to move. Interchangeable cards were also considered an advantage, allowing the company to keep drives running by simply changing some of the critical components.

Compact size was also part of the demand to be able to save on space, improve efficiency and heat loss and cut cooling costs. ABB's drives scored on all these points. Another useful feature was their ability to communicate using Profibus – the communication standard in the paper industry. The drives also feature input line chokes to reduce harmonics fed to the network and output filters to reduce the electrical stresses on the motor windings.

High reliability was the most important criterion. Von der Fecht says, "we have had good experience with the ABB drives. They are certainly reliable and fulfil our needs".

Fertilizing with low energy

A project to upgrade five process fans at a Kemira GrowHow fertilizer plant in Finland has delivered a reduction in annual electricity consumption of more than 4000 MWh. The project involved installation of new ABB motors and ABB industrial drives to replace the existing motors and mechanical flow control systems. The equipment is paying for itself through the energy it saves!

Based in Finland, Kemira GrowHow Oy is one of Europe's leading producers of fertilizers and animal feed phosphates 10. With net sales of EUR 1.26 billion (2005), the company has 2,700 employees and production sites located throughout Europe.

The Kemira GrowHow plant in Uusikaupunki on Finland's south-western coast has two fertilizer production lines and two nitric acid production units. The project to upgrade process fans in one of the plant's fertilizer lines was undertaken in 2005. Following a comprehensive energy analysis at the plant, Kemira GrowHow turned

10 Kemira GrowHow's Uusikaupunki plant in Finland produces industrial chemicals and fertilizers. ABB drives installed here cut the plant's energy bill by 4000 MWh annually

to Inesco Oy, an energy service company (ESCO), to study the potential for energy saving with special reference to the air and gas flows in the fertilizer plant.

The new motors and drives permitted savings of more than 4000 MWh a year. This equates to € 150,000 or 2800 tonnes of CO_2.

Accurate speed control with drives

Like many other processes in the chemical industry, fertilizer production lines 11 feature numerous fans for moving gases, fumes and air. Inesco examined nine fans rated 132– 630 kW, and selected five for more detailed study. The five fans in question were operated by electric motors connected directly to the mains power supply and running at full speed. Inlet vanes were used to provide mechanical control of the rate of flow. Some of the vane installations were approaching the end of their service life and would soon need replacing at a cost of tens of thousands of Euros per fan.

Faced with this considerable investment, and based on the results of Inesco's energy efficiency pre study, Kemira GrowHow opted instead to replace the mechanical flow control systems on the five fans by retrofitting them with AC drives and new motors. ABB was selected to supply the new motors and drives to control the motor speed according to actual flow requirements.

Significant energy savings

"Since installing the new ABB motors and drives we have been saving more than 4000 MWh of electricity a year", says Jari Lintula, Head of Automation at the plant. This equates to an annual saving of some € 150,000, calculated on the basis of local electricity tariffs for industrial users, or a reduction of CO_2 emissions by 2800 tonnes.

A further benefit of the project derives from the fact that the ABB drives deliver an improved power factor[6]. This has resolved an overheating problem in one of the transformers used to supply power to the fan motors.

Realistic forecasts

The upgrade project was carried out during scheduled plant downtime and caused little disturbance to production. It required only a minimal contribution from the plant staff. Jari Lintula emphasizes that real savings have been achieved:

"The new motors and drives have logged thousands of operating hours, so we know how they perform. The forecasts showing how much energy we could save have proven very realistic. In fact, we've been amazed at the accuracy of the calculations. It seems that the energy saving potential of drives in this type of fan application can be predicted with a high degree of reliability. The savings are real – they are not just claims by equipment vendors eager to make a sale."

He also confirms that the use of AC drive control within a chemical production process is extremely trouble-free from the control engineering point of view. In addition to reliable process control, he stresses the importance of energy efficiency:

"We are actively seeking new opportunities to save energy – I'm sure we can utilize AC drives elsewhere as well."

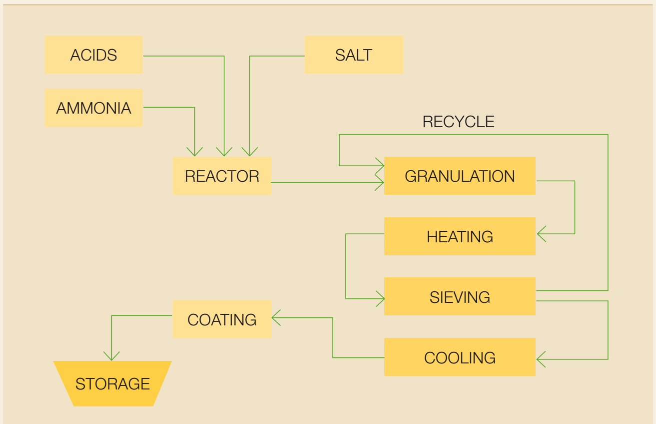
Efficient ESCO model

From the various alternatives available, Kemira GrowHow opted to implement the upgrade project on an ESCO basis and chose Inesco as its ESCO partner. ESCO companies develop, install, and finance projects with the aim of providing increased energy efficiency and lower maintenance costs for their customers' facilities over a period of several years.

Inesco is a pioneer in its field in Finland and has already completed successful ESCO projects in various sectors, including the energy-intensive pulp and paper, metal, and chemical industries.

For Kemira GrowHow, the main advantage of the ESCO approach in this case was the opportunity to outsource most of the engineering work, procurement and associated routines. An additional element of the ESCO agreement is that the fan upgrade project is being paid for by the energy savings it realizes. During the three-year term of the agreement, Kemira GrowHow will pay a service fee to Inesco, which is calculated as 80 percent of the reduction in energy costs achieved. At the end of the three-year agreement Kemira GrowHow will take full ownership of the installed equipment and all the savings.

11 The fertilizer production process (courtesy of Kemira GrowHow)



For more information about Kemira GrowHow, visit www.kemira-growhow.com. Information about Inesco can be found at www.inesco.fi.

Footnote

[6] Power factor is the ratio between real and apparent power. High power factors lead to lower losses

University saves millions through boiler retrofit

An emissions-control project provides 746,000 kWh in electrical energy savings a year, and hundreds of millions of BTUs [hundreds of gigajoules] in fuel. The investment outlay was completely recovered in less than a year

The University of Texas at Austin, UTA, is the flagship institution of the University of Texas system. Academic home to 50,000 students, the campus is contained on 424-acres [170 hectares] adjacent to downtown Austin. The University's heating and energy demands are supplied through the boilers and gas turbines at the Hal C. Weaver Power Plant, which provides power, steam, chilled and demineralized water, and compressed air to approximately 200 campus buildings.

Savings from boiler retrofit

In the process of satisfying state air-quality compliance requirements for its power plant emissions, UTA reaped an unexpected windfall – $ 500,000 annually in energy savings. The savings are the result of a retrofit of one 150,000 lb [68-tonne] boiler with an innovative system called Compu-NOx™. This controls emissions of nitrogen oxides, commonly referred to as NO_x, a group of gases that cause acid rain and other environmental problems. Prior to the upgrade, Boiler 3 alone emitted 151.7 tons [137 tonnes] of nitrogen oxide per year. Following the upgrade, the emission rate was reduced to 21.0 tons [19 tonnes] per year.

12 Variable frequency drives provide precise airflow control. This in turn permits optimal combustion control in the boiler's forced-draft system

> The investment payback for UTA is less then 12 months. The system will continue to produce savings for years to come.

Compu-NOx is a state-of-the-art patented combustion control system developed by Benz Air Engineering of Las Vegas, Nevada. "Our objective as we began the boiler retrofit was to reduce NO_x emissions, but the process resulted in us producing more energy with less gas by improving our combustion efficiency. This allowed us to bank our standby boilers saving us hundreds of thousands of dollars per year," said Juan M. Ontiveros, director of Utility and Energy Management at UTA.

"Initial projections targeted a savings of $ 500,000 annually for the first boiler retrofit, but due to ongoing fuel price increases, the university stands to save an additional $ 1 million from the retrofit of Boiler 3 alone" says Robert Benz, president of Benz Air Engineering Company.

Drives provide control of airflow for combustion air

For precise metering of airflow, Benz Air's Compu-NOx control platform uses variable frequency drive (VFD) technology for fans 12, rather than attempting to achieve the same with dampers. "The Compu-NOx control system utilizes the absolute linear relationship of fan speed to fan airflow as the basis of combustion control," explains Benz.

With ABB drives, a very precise control of the airflow is achieved, which makes all the difference in terms of fuel efficiencies and emissions. Emissions from Boiler 3 were reduced from 175 ppm NO_x to less than 25 ppm without installing new burners. With the use of the ABB ACS800 AC drives, savings are projected to be 746,000 kWh per year in electrical and 320,000 million BTUs [338,000 GJ] per year in fuel.

The investment payback for UTA is less then 12 months. And the system will continue to produce savings for years to come from the flue gas recirculation and variable frequency drive fan-control.

Per Wikstroem
ABB Switzerland Ltd.
Turgi, Switzerland
per.wikstroem@ch.abb.com

Jukka Tolvananen
Akseli Savolainen
ABB Oy, Drives
Helsinki, Finland
jukka.tolvananen@fi.abb.com
akseli.savolainen@fi.abb.com

Peter Barbosa
ABB Corporate Research
Baden-Dättwil, Switzerland
peter.barbosa@ch.abb.com

Acknowledgments
ABB Review would like to acknowledge the contributions of the following additional authors: Steve Ruddel, ABB UK (ABB drives UPM Shotton to a greener future) and Ken J. Graber, ABB USA (University saves millions through boiler retrofit).

Factbox **Drives and ABB**

ABB is the world's largest manufacturer of electric drives. In close cooperation with its channel partners, ABB provides a complete line of energy-efficient electric drives and drive systems to a wide range of industries and applications. Products manufactured include AC and DC variable-speed drives from 180 W to 100 MW (1/4 to 135,000 hp), and application-specific drive system solutions to meet diverse customer needs. This line of products is complemented with a comprehensive set of services to make sure ABB's customers get the highest possible return on their investments.

For further information on energy efficiency contact energy@fi.abb.com (LV Drives) or mvdrives@ch.abb.com (MV Drives).