Every bit counts

Improved control software and optimized processes are contributing to increased energy efficiency

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Renewables, nuclear power, clean coal – these are among a long list of buzzwords being used to address the future of energy. In the global struggle to match demand with supply, these are only one part of the equation. Increasing the supply inevitably requires resources of some kind, whereas reducing the demand results in a reduction of resource consumption. For decades, environmental organizations have sought to limit the use of energy. In the past, this implied reducing the standard of living – ie, doing less of the same.

A far more convincing idea is doing the same with less – increasing efficiency by applying more efficient technologies. One well-known example is the replacement of incandescent light bulbs with compact fluorescent bulbs or LED lights. And in industry, highly efficient equipment is now available. Efficiency gains are also being made in building technology through better insulation of production sites, re-use of thermal energy generated by the equipment, etc.

This article takes energy efficiency one step further, arguing that the way forward is to make optimal use of existing industrial equipment. Because in most cases equipment is controlled by an automation system, increased energy efficiency can be achieved through improved control software using advanced mathematical optimization techniques and through optimized processes.

To understand what is meant by running a plant with optimized software and processes, one simply needs to think about driving a car. It is highly plausible that a car driven by two different people under the same conditions will not consume the same amount of energy. Why? Because driving techniques differ. In a plant, it is the operation and strategy that governs the actual energy consumption.

The strategies for energy-efficient plant operation are much like those required for energy-efficient driving:
Stop the motor at red lights Produce products according to specs and run the plant only at capacity.
Shift gears early Be open to change.
Keep the appropriate pressure in the tires Run an optimally maintained plant.
Do not accelerate when approaching red lights Run the production predictively in accordance with maintenance and production schedules.

If these strategies are applied properly, there is no need to "slow down" to save on fuel consumption. Experiences from modern eco-drive trainings exemplify this: It is possible to drive faster while consuming less fuel. In a modern, much more complex plant, the lesson is the same: Running a plant optimally leads to greater energy efficiency.

This article focuses on the different levels of the automation hierarchy. The various functions available in an automation system can be improved to make a controlled process more energy efficient. Functions varying in scope (from individual devices to those covering the whole plant) and time horizon (optimization within milliseconds up to the life cycle of a plant) can all have an effect on the plant's efficiency. The following three areas are addressed here:
Advanced control Today's advanced controllers have the ability to solve an optimization problem in every step, and can therefore have minimum energy as one of the target functions or boundary conditions.
Production planning and scheduling Proper planning and optimized scheduling of a plant can reduce waste in terms of time and material, which results in doing more with the same energy.
Monitoring To detect whether a plant is running at its peak efficiency, it must be monitored closely to identify any abnormal behavior that may result in increased energy consumption.

Better control, less energy

Many people may not immediately connect improved control with energy savings, but rather with improved product quality, increased production and reduced chemical addition. But regardless of the intended target for the control, a positive side effect is almost always a reduction in energy usage, or that more product is produced using the same amount of energy as before.

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Just by retuning the basic level-one PID control loops, energy consumption may be significantly impacted. Even though the savings for a single loop may be small, the sheer number of loops (hundreds if not thousands for a large process-industry plant) most often makes the total savings significant.

Sometimes an advanced control or optimization solution targets the energy more directly. Some successful examples where significant energy savings have been verified follow.

Power generation

A good place to start saving energy is of course at the source – ie, where the energy is produced.

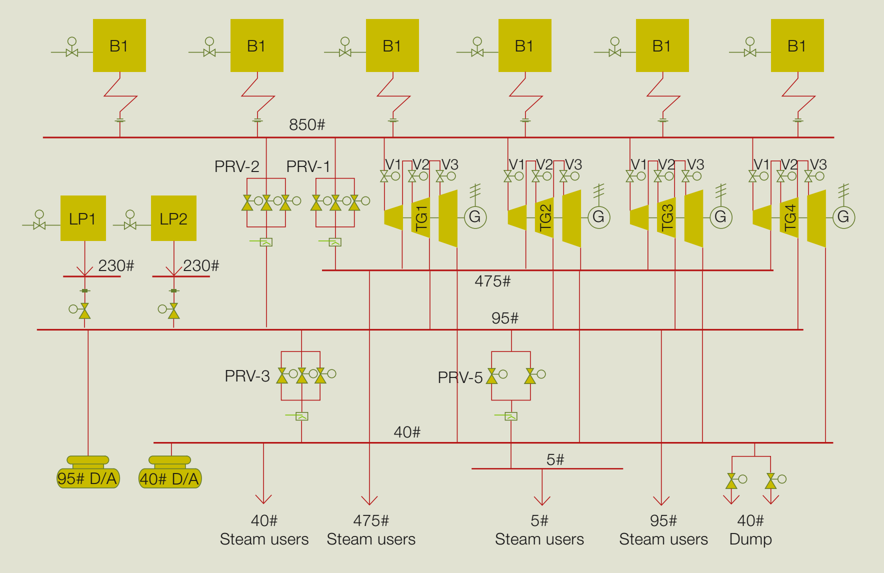
Cogeneration of steam and power

At Point Comfort (in Texas, USA), Alcoa Inc runs a large refinery where bauxite is converted to alumina 1. Since this is a very energy-consuming process, Point Comfort utilizes its own powerhouse with multiple boilers, turbines and steam headers. Most of the energy needed is produced in-house, but electricity is also purchased from the local power grid.

With varying prices of electricity and fuel (ie, natural gas) the first challenge is to determine the optimal mix of in-house versus purchased energy. This is now done by solving a mixed-integer linear program every 15 minutes using the current fuel and electricity prices, which are downloaded from the Internet.

The results from the steady-state optimization are fed to a model-predictive controller (MPC), which runs with a

1 A graphical overview of the Alcoa Point Comfort Power Plant



much faster cycle (< 10 s). The MPC is based on an empirical linear dynamic model, and delivers 28 manipulated control set points.

ABB commissioned this system in 2005 and it immediately led to greatly improved process stability; for example, an 80 percent reduction of steam pressure standard deviation was achieved. A 1 percent savings in overall energy cost was verified, giving the customer six months payback time. A more detailed presentation of the system and the solution can be found in [1].

A novel technique to measure the steam temperature inside the refiner is being used in TMP mills for feedback control.

Power generation: power boiler startup

Another example of energy savings is the optimal startup of fossil-fuelled steam power plants. In the deregulated power market, these power plants are used for more than just base load, and hence encounter many more stops and starts. The startup time for a boiler is highly constrained by thermal stresses; ie, too-high temperature gradients in thick-walled parts of the boiler and turbine may lead to cracks in the material.

Given a model and online measurements, it is possible to calculate the actual thermal stress. Thus a boiler model – which was not allowed to violate the constraint on thermal stress – was developed and used to optimally manipulate the fuel flow rate and high-pressure (HP) bypass valve position.

ABB has installed this technology at seven power plants, with three more installation projects underway 2. The typical fuel savings for a single startup is between 10 and 20 percent. With 50 to 150 startups per year, this corresponds to 0.8 to 8 million kWh per installation. For more details on this application, see [2].

Control of TMP refiners

A more typical control problem is of course at the consumer's end. An example of a very energy-intensive process is the production of thermo-mechanical pulp (TMP). A mix of wood chips and water are ground in a narrow gap (< 1 mm) between two disks, where either one or both may be rotating. The rotors are driven by large electrical machines; for a modern TMP refiner, a 30 MW motor is not unusual.

Much of the electrical power goes into producing steam in the refining zone, and a lesser part into the mechanical work on the wood. Now a novel technique to measure the steam temperature inside the refiner is being used in TMP mills for feedback control 3.

Verified results at the Hallsta Paper Mill, belonging to Holmen Paper in Sweden, show direct energy savings of \$7 to \$13 per metric ton of produced pulp with improved pulp quality. For a TMP line with an annual production of 100,000 tons, the total savings is then \$700,000 to \$1.3 million per year (note that mills usually have more than one line). Add to this indirect savings from fewer production stops for the TMP line and fewer sheet breaks on the paper machines, and the annual savings may be more than \$2 million for one TMP line.

More production – less energy

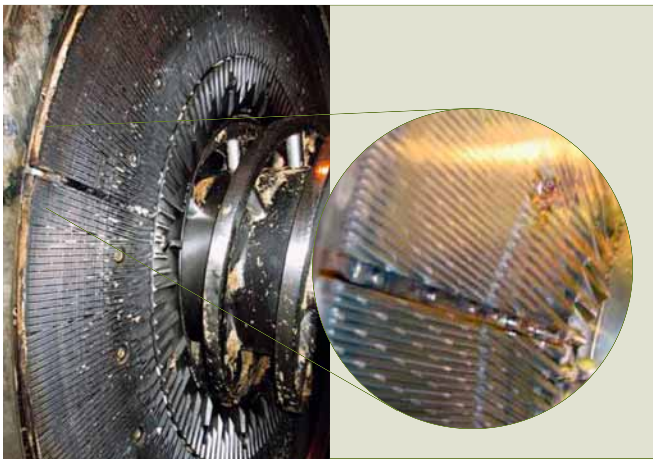
Any plant operation that does not produce quality-as-planned product obviously wastes energy. Therefore, startup times, quality changes and the duration of plant upsets need to be minimized. While these are not new solutions, they have been difficult to manage. Now, with modern optimization methods, it is possible to actually reach optimal operation.

An innovative ABB software solution – quality-based retrim optimization – computes the optimal cutting pattern based on actual quality data.

Plant operation and scheduling strategies are often based on heuristics and experience. This in itself is not a disadvantage but it does hinder the transition toward a truly optimized pro-

2 The Weiher III power plant, location of the first boiler startup installation

3 The stator grinding segments with a close-up of the temperature sensor array used in producing thermo-mechanical pulp (TMP)



duction, with respect to both optimization and scheduling.

The optimal management of plant assets also implies that those assets are at their optimal condition for production. Non-optimal production is often caused by non-optimally working assets, resulting in quality or yield reduction.

Finally, production scheduling is a key for energy-efficient production. The smooth (and truly optimal) use of production assets prevents the use of too much energy at one time whilst wasting it at other times. For instance, plant actuators require energy (eg, pumps, heating, cooling). Any avoidable variance in such process variables immediately implies avoidable variances in manipulated variables.

Paper retrimming optimization

Consider the case of paper production where a predefined cutting pattern has been optimally computed based on customer orders. Due to variation in production, the predefined cutting pattern typically proves to be suboptimal given the actual quality of the jumbo paper reel. This results not only in increased waste paper that needs to be recycled, but also in loss of profit.

An innovative ABB software solution – quality-based retrim optimization – computes the optimal cutting pattern based on actual quality data 4. The underlying patented method is able to solve the extremely complex optimization problem in just seconds. In so doing, more good-quality paper results from each jumbo paper roll, thus decreasing the amount of paper that must be reproduced. Based on the energy consumption per ton of produced paper, a savings of just a fraction of the recycled paper is significant. Assuming an annual production of 400,000 metric tons, preventing just 1 percent of the final paper from being recycled can result in a savings of 10,000 MWh of energy (both electricity and gas).

Coordinated production scheduling

Melt-shop scheduling in steel production is a difficult problem since the amount of different materials and orders is very high. ABB has developed a solution that is able to simplify and solve this complex problem in an optimal way.

Today's automation systems already collect a vast number of data points that can reveal a lot about a plant.

The same solution applies to the next step in steel production – the hot rolling mill 5. Scheduling of hot-rolling production is not as complex as melt-shop scheduling, but still presents significant challenges.

Having solved those two scheduling solutions, considerable energy savings lies in the coordination of both schedules in order to use both production plants optimally and to minimize the residence time of each freshly casted steel slab in the slab yard. This is important since slabs need to be hot before entering the hot rolling mill. The energy required to heat each slab, which is about 1,000 m^3, is 10,000 kW. If one out of 10 slabs can be hot charged, ie, fed directly from the caster into the hot-rolling mill (thus avoiding reheating), a typical mill could save 21,000 tons of CO_2 or, in financial terms, $3.9 million per year.

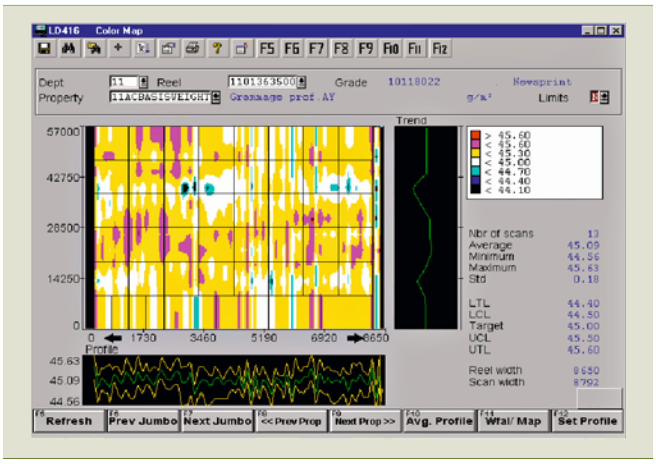
Manually, these scheduling problems cannot be solved. But modern optimization software can now deliver such results, allowing operators and planners to monitor and – if required – change schedules.

Monitoring energy-wasting equipment

Even if plant controllers, planning and scheduling are optimized to perfection, it is clear that over time the performance will deteriorate due to plant aging and process failures. In the case where some equipment breaks, this might be obvious; in many cases, however, deterioration is gradual, or cannot easily be located in the process by relying on traditional operator tools such as process displays, trend curves and alarm lists. But even if not recognizable by even a skilled operator, abnormal process behavior leaves its traces in the measurements collected within the plant.

Taking an in-depth look at these measurements using advanced signal-

4 Two-dimensional quality data from paper production



Dept 11 Reel 1101363500 Grade 10118022 Newsprint
Property 11ACBASISWEIGHT Grammage prof. AY g/m²

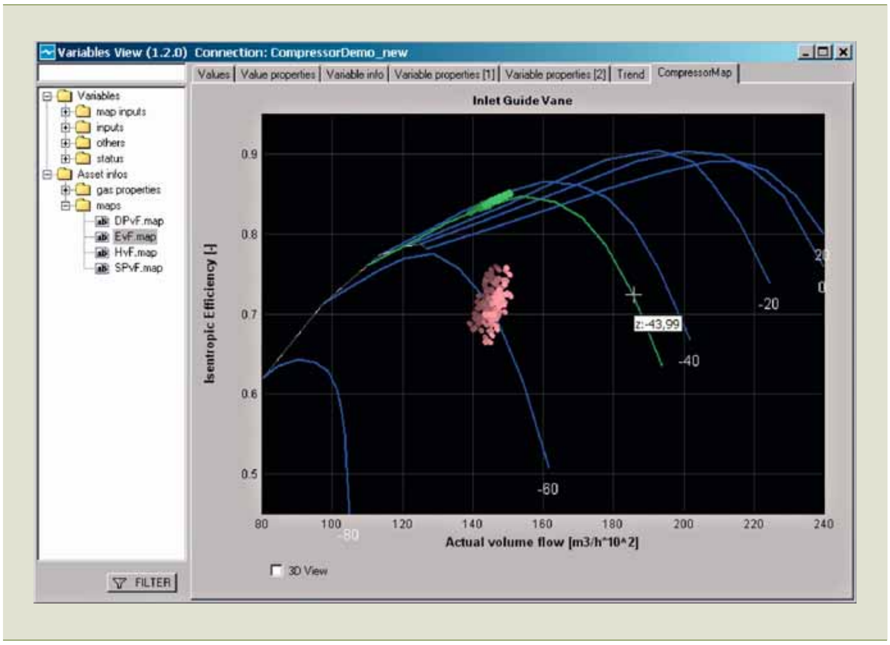
Nbr of scans 13
Average 45.09
Minimum 44.56
Maximum 45.63
Std 0.18

LTL 44.40
LCL 44.50
Target 45.00
UCL 45.50
UTL 45.60

Reel width 8650
Scan width 8792

5 Hot-rolling mill in a steel plant. Slabs coming from the melt shop are being rolled into coils.

6 Compressor map derived from drive signals



analysis algorithms may reveal the behavior more clearly. Some key performance indicators (KPIs) are easily calculated from measurements collected in the distributed control system (DCS). Differences in temperature, together with a flow measurement, can in some cases provide quite a good indication of the energy consumed. Comparing this calculation with a "clean" measurement that was taken when the plant was evidentially operating close to the design (ie, early in its operation or after an overhaul), a degradation in efficiency can be easily detected. To then diagnose the cause of the degradation often requires either an experienced maintenance engineer, or yet another set of algorithms.

More complex monitoring systems not only apply simple calculations to come up with performance indicators, but they also apply more advanced plant models where parameters are identified, so the model matches the plant (degrading) performance. These parameters then give a better view of the internal behavior of the system than the measurements available in the DCS.

Monitoring process equipment through electric drive data

A common conclusion when introducing advanced monitoring is to introduce more sensing equipment – after all, obtaining more information about a process does require more measurements. However, what is very often forgotten is the fact that today's automation systems already collect a vast number of data points that can reveal a lot about a plant. Even in places that are not obvious, data is collected and continuously analyzed.

> Even if not recognizable by even a skilled operator, abnormal process behavior leaves its traces in the measurements collected within the plant.

One example is the drive system. Apart from the algorithms that control the system, it contains a data collector that is normally used to diagnose the drive's behavior. However, the data contained therein does tell a lot about the process that is finally controlled by the motor. By matching the drive system's signal patterns with the observed behavior of the process or by tuning process models to correspond to the observed signals, information about the controlled process can be retrieved by means of signals that are already in the system, without introducing new (and costly) measurements. 6 shows the diagnosis of a compressor by analyzing the signals in the drive system.

A holistic view matters

In addition to the technical complexity of energy savings through optimization, there is also an operational complexity. Modern optimization solvers enable fast and reliable solutions to complex technical problems. Another equally important challenge is to integrate computer-based production scheduling and plant operation into plant work processes.

The buy-in of the production planning and plant operation teams is essential for successful modern plant optimization. Knowing that, topics like usability, maintainability, modularity and proper training will become central concerns for both vendors and users. If these issues are treated comprehensively, production success and energy savings will not be contradictory.

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