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How process automation can increase energy efficiency

Energy efficiency is a fundamental element in the journey toward a sustainable energy future. As global energy demand continues to grow to meet the needs and aspirations of people across the globe, actions to increase energy efficiency are essential.

Optimizing energy utilization is of paramount importance in the industrial sector where energy efficiency doesn't imply producing less to reduce energy consumptions, but rather improving plant productivity and effectiveness, allowing plants to produce the same amount of product with fewer resources.

Therefore, in industry more than anywhere else, energy efficiency has heavy implications (and brings large promises) on both production profitability and production sustainability. From a profitability perspective, energy represents the most relevant operating expenses in many industrial productions; an effective usage of energy represents an attractive, low-hanging fruit in any cost-reduction-oriented policy.

However big the impact on the bottom line, the outcomes of energy efficiency programs extend beyond accounting books. The last decades have seen environmental regulations grow stronger. Being in compliance with environmental regulations is by no means a secondary concern for any production site; rather, it is a basic requirement to operate and succeed. Energy efficiency is a technology-driven, politically neutral practice that should be viewed as the main sustainability enabler in the industrial world.

Performance improvements. Industry is the single largest energy consuming sector in the world. Looking at US data, in 2008 it represented over 30% of total energy consumption with about 30 QBtus.

Taking the US as a reference, it is possible to see that process industries like oil and gas, mining, pulp and paper, and chemicals are the most energy-intensive (FIG. 1). This means that no serious energy efficiency program can be designed and deployed without taking into consideration actions in the process industries sector.

The industrial community has understandably focused on improving energy efficiency mainly in electrical components and equipment, which is basically low-hanging fruit in the quest to quickly reduce energy costs. When looking at energy savings per year, as estimated by the International Energy Agency (FIG. 2), it should be noted that, although motor systems provide the highest potential savings contribution with about 7 exajoule (1 exajoule is equal to the yearly production of 47 660-MW power plants), the sum of other items (from combined heat and power to steam systems, from process integration to increased recycling) is bigger than that, with a sum of about 8.5 to 9 exajoule.

Process automation can contribute to improving the energy efficiency of industrial production plants in many ways. Implementing better monitoring, control and optimization strategies improves energy performance directly, through reduced waste (very often associated with undue oscillations in main process parameters), and indirectly, through better maintenance practices that help to prevent an increase in energy use due to plant downtime and the resulting startup and shutdown processes, as well as defective products.

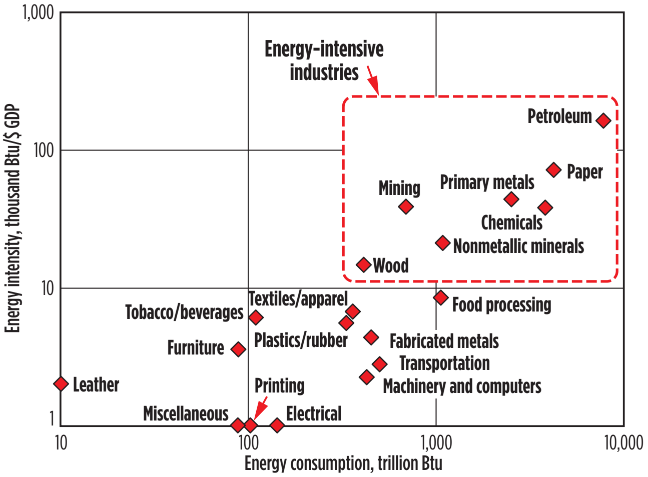

FIG. 1. Industrial energy intensity vs. energy consumption.

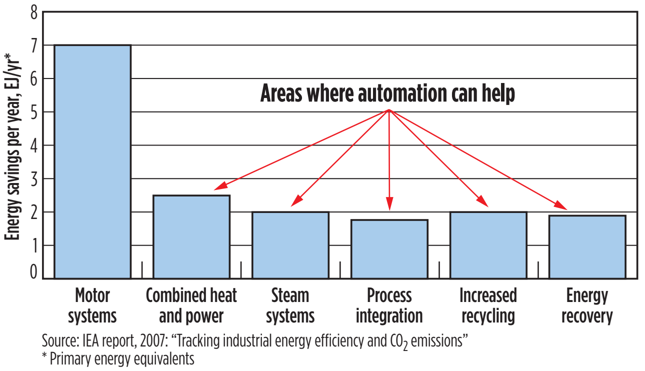

FIG. 2. Savings from the adoption of best practices in commercial technologies for the manufacturing industries.

With energy consumption emerging as a top priority for process and plant managers, much room for improvement is available, providing opportunities for advanced automation suppliers. In fact only a minority of process plants have proper energy monitoring tools, able to provide real-time energy-related key performance indicators (KPIs) to control room operators, and even less benefit from advanced process control strategies able to reduce waste and consumption.

Determine ideal conditions. A modern industrial plant is an extremely complex system that can be run over an almost innumerable range of operating conditions, each characterized by specific energy consumption. Achieving optimum efficiency is the dream of every plant manager. This dream is a never-ending pursuit to be continuously executed and monitored, using timely and reliable real-time process data.

Determining and maintaining ideal operating conditions is a key challenge that requires the involvement of the latest automation technologies, each one contributing to allow not only the acquisition, processing, storage, retrieval and visualization of data, but also the implementation of automatic control strategies that can expand the achievement envelope in terms of production, safety and energy efficiency. The challenge extends beyond technology, involving also organizational and even psychological aspects that actually impact and limit production and energy efficiency.

One such aspect is related to an underlying and unexpressed conflict of interest between plant managers and plant operators. Given the many risks involved in industrial plants, it is natural that a plant operator seeks to preserve a safety margin from the danger zone (safety, economic and environmental). And it is quite normal that the operator is inclined to overestimate this safety margin's size, placing the operating point centrally in a comfort zone. **FIG. 3** represents this tendency in the case of an operator summoned to control a distillation column with multiple constraints. The obvious behavior will be to operate the plant by keeping a reasonable margin (the orange area in **FIG. 3**) from the limits, even if this means operating considerably away from the economic optimum. The fewer the details available, the bigger the operator's comfort zone extension will become.

Exploiting advanced automation technologies, it is possible to reduce the amount of uncertainty both in process knowledge performance and in execution capabilities. The ultimate goal here is to reduce the size of the operator's comfort zone.

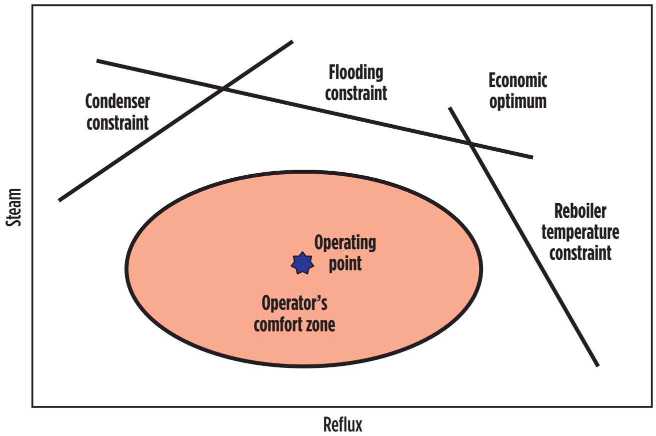

FIG. 3. Operator's comfort zone in standard conditions.

How can automation improve detailed process know-how and execution accuracy? Three main tool and device sub-classes that support this undertaking are identified here.

Instrumentation and sensors have the obvious but unavoidable scope of providing timely and accurate physical variable measurements. This includes not only traditional measurement devices (thermocouples, flowmeters, pressure and level sensors) but also more complex equipment like analyzers or advanced instrumentation (devices designed for specific processes like cement kilns, blast furnaces or sulfur recovery units). The portfolio also includes so-called soft sensors, which are used to decipher online process data that can reveal the actual value of difficult-to-measure variables.

Performance monitoring tools are software solutions that exploit cutting-edge technologies in statistics, data processing and control theory to extract information hidden in process data that is crucial to accurately monitor processes and equipment operation. This class includes control loop monitoring, multivariate statistical process control (MvSPC) and disturbance analysis modules, which can correlate apparently unrelated disturbances to identify root causes, thereby reducing maintenance efforts and shutdowns.

Improved control tools are the actual energy efficiency enforcer. Improving control performance has a direct impact on energy consumption at different levels. Better tuned base controllers (typically utilizing computer-aided control loop tuning products) represent the first step in a journey that encompasses advanced regulatory control up to multivariable model predictive control (MPC). The impact on energy efficiency can be quite relevant, thanks mainly to the reduction of process variable variation, often related to energy waste and off-spec production.

Process management. Once the ideal operating conditions have been identified and enforced, process management can improve a plant even further. This involves evaluating the available process information as a whole and elaborating the best strategy for achieving the economic goals.

The foundation for this undertaking is information management systems (IMSs), which provide the crucial infrastructure to obtain real-time, reliable figures and key performance indicators (KPIs) for devising and implementing profitable production plans and strategies. At least three different systems can be grouped into the IMS category.

Process information management systems (PIMSs) are designed to manage information and data to give a unified picture of the process, a prerequisite to supporting technical and executive decisions related to process profitability.

Laboratory information management systems (LIMSs) are designed to manage the quality of information at plant laboratories, covering tasks from raw material and intermediate product quality control to final product tests and compliance certificates.

Manufacturing execution systems (MESs) provide real-time visibility of activities, material and resource conditions. From a production point of view, MES have a more active role than PIMSs because MESs can dispatch orders related to manufacturing execution.

The information made available by information management systems (IMSs) can be utilized by additional, specific tools that improve overall plant operation. Asset management plays a relevant role, offering the possibility to assess in real time the performance of process equipment and devices such as:

- Heat exchangers, furnaces, boilers and chillers
- Pumping equipment
- Instrumentation and field devices
- Network and software.

Condition monitoring tools are important. They collect and analyze real-time equipment and process data; allow for the effective implementation of predictive maintenance practices that have a direct impact on energy efficiency; reduce waste and inefficiencies; and extend production periods.

IMSs and asset management provide the necessary infrastructure for implementing energy management strategies. Industrial sites are often characterized by the presence of several sources and consumers of energy vectors, both internal (industrial utilities) and external (the electrical grid or external steam suppliers). The total energy bill can be determined by the combination of energy sources/consumers, based on a number of possible factors (local energy costs, specific energy contracts and production policies). These factors are almost always highly variable day-by-day or even hour-by-hour. Any energy cost reduction program will seek to replace high cost energy forms with lower ones.

Field sensors and plant information technology (IT) allow for the gathering, storage, processing and display of all relevant energy consumption data coming from manufacturing plant and production equipment. Using this information properly provides significant financial advantages and ultimately lowers energy costs.

Using a comprehensive and effective energy management platform can lead to energy cost savings, usually in the range of 2% to 5%. This gain comes from different contributors, including:

- Availability of real-time information on energy consumption, by unit and by equipment, which can reveal underperforming areas, devices or procedures
- Adoption of accurate consumption plans, allowing access to lower electricity purchase prices and employing optimal resources in the supply of electric power
- Exploitation of advanced features like simulation and optimization to perform scenario analysis that can identify potential areas of energy efficiency improvements
- When coupled with additional advanced tools like advanced process control (APC) or MESs, it is possible to decrease specific energy consumption and increase energy cost effectiveness.

Practical issues. The last few years have seen major changes in the process industry environment. Downsizing and a global shortage of skilled resources have affected production sites, limiting the ability to introduce and properly manage innovative automation solutions. This is a main reason why industrial customers are not yet fully exploiting process automation for energy efficiency purposes. Achieving higher energy efficiency through process automation is not just a matter of buying and installing advanced products, software or equipment; rather, it is the result of properly blending technology, best practices and training activities.

Finding a different way to manage the relationship between customers and suppliers is essential to successfully bridging the present gap between existing constraints (limited access to professional capabilities) and what is potentially achievable (lower energy consumption).

Because significant improvement in energy efficiency is achieved via different automation technologies, it is critical to draw upon a strong track record of collaboration among different specialists. Very few end users can afford to maintain an internal pool of resources that can manage such a wide variety of technologies and applications.

A real partnership between process owner and automation provider can yield positive returns for every actor. End users would benefit from accessing experienced professionals, who could be leveraged to benchmark their energy performances against industry-specific standards and to improve energy balance and costs. For automation providers, it is a unique opportunity to upgrade and improve service capabilities that will in turn elevate the technology level.

Process automation-related professional services deliver specific benefits through a few channels that can be grouped in three main categories.

Direct consultancy. Sometimes plant managers are not aware of the condition that their process equipment, devices and control systems are in. They also may not understand how this can affect the overall energy bill. A small team of control experts that can visit the plant and quickly measure its performances against an established benchmark and identify areas for profitable improvement is crucial in assisting end-users with their process control-based energy efficiency plans.

Energy assessment. The objective of an assessment is to identify and estimate energy savings. Energy assessments are usually performed by multidisciplinary teams, where a process control expert will work side-by-side with energy consultants, electrical engineers and process engineers to deliver a comprehensive picture of the plant's health and a list of suggestions with an estimate of the related payback periods.

Remote services. This is a fast growing way to deliver value-added services in remote or inconvenient locations. Remote services can reduce cost and intervention time when an unscheduled maintenance activity is urgently needed. Since a wide array of skills are required for process control-based energy efficiency intervention, remote services can be the only practical way to provide support for many customers in many sites from a single location. In the remote services model, experts in disciplines like loop tuning, energy management, advanced alarm management and IMSs can offer expertise on improving plant operations at an affordable rate.

FIG. 4 shows the different and complementary channels that allow process automation to contribute to upgrading energy efficiency in industrial plants.

Success stories. The impact of advanced automation strategies on energy efficiency and business bottom line has already been proven in many industrial plants. At an industrial plant in Termoli, Italy, control loop optimization and monitoring allowed for a substantial reduction in energy consumption.[1] The plant produces advanced materials and is characterized by complex chemical processes, controlled by more than 500 feedback control loops.

In 2006, the company leadership required plant managers to achieve a 10% reduction in energy consumption. This resulted in overall basic control loop retuning being performed. Later,

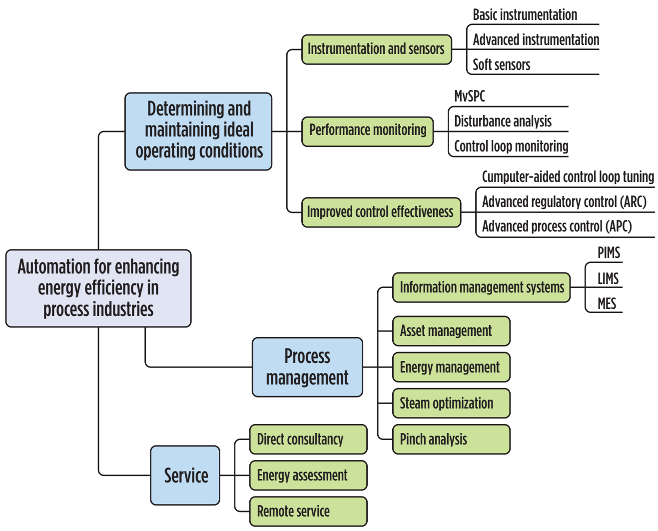

FIG. 4. Automation technologies and practices for energy efficiency.

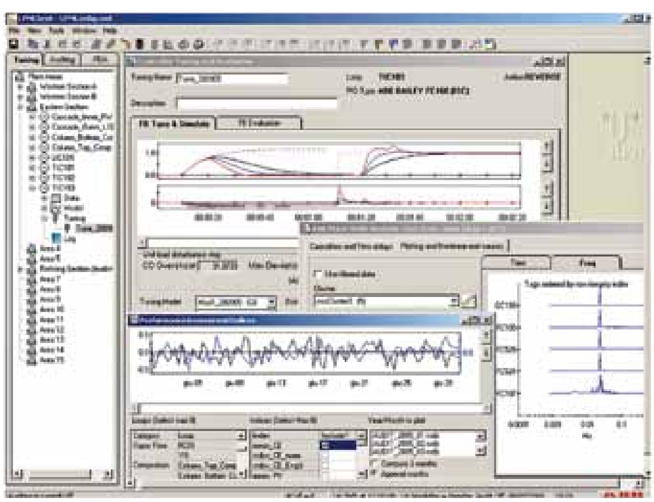

FIG. 5. Control loop monitoring and tuning tool.

a performance monitoring program was established though a software toolkit.

The first activity consisted of retuning the loops whose performances were suboptimal. In a short time, more than 250 loops were retuned, and it was possible to remove many oscillation problems caused by proportional-integral-derivative parameters that were given an excessively aggressive setting. After the general plant retuning, the software's auditing functionality was used to monitor the control system's behavior. The software was put online to collect data and generate reports every week.

This application allowed a single skilled engineer to tune more than 250 loops in less than a month, a task that otherwise would have taken several months. After the retuning, an audit kept running silently in the background and made reports available each week (with no additional manpower required). Plant engineers have estimated that the improved control performances obtained in the project allowed for a 5% savings of the methane used in process steam generation.

IGCC plant. An advanced process control application was used to great success at an integrated gasification and combined cycle plant (IGCC).[2] These plants are among the most advanced and effective systems for electric energy generation from refinery residuals and they have become popular in many regions worldwide. From a control perspective, IGCC plants represent a significant challenge. Complex reactions take place in an IGCC plant, as highly integrated design and variable feed compositions come together, requiring coordinated control to simultaneously satisfy production, controllability, operability and environmental objectives.

In order to improve the overall plant efficiency and profitability, the owner of an IGCC plant in Priolo, Italy, decided to gradually introduce APC. The project team was asked to introduce unit optimization on some of the most critical areas—in particular, the acid gas removal (AGR) section. Such optimization was achieved by using latest generation multivariable process controllers and inferential models.[3]

The APC application on the AGR section covered two columns: absorber and regenerator. The absorber column used methyl diethanolamine (MDEA) to separate H_2S from syngas. The regenerator column used high quantity LP steam to strip H_2S from MDEA.

The advanced control strategy proved to drastically reduce steam usage while maintaining controlled variables to their setpoints or within constraints. As a result, the unit operating conditions moved (**FIG. 6**), reducing both the steam usage and MDEA circulation rate. The overall energy savings were considerable. Steam consumption went from 35.1 t/h to 26.1 t/h. This reduction was due to several improvements including optimized regenerator operating conditions, reduced steam usage and a better control that allowed unit operation closer to H_2S specification.

Analysis showed that the reflux flow also decreased by about 50%. This was remarkable, given the fact that the original reflux flow was not far from the design value for the unit. HP

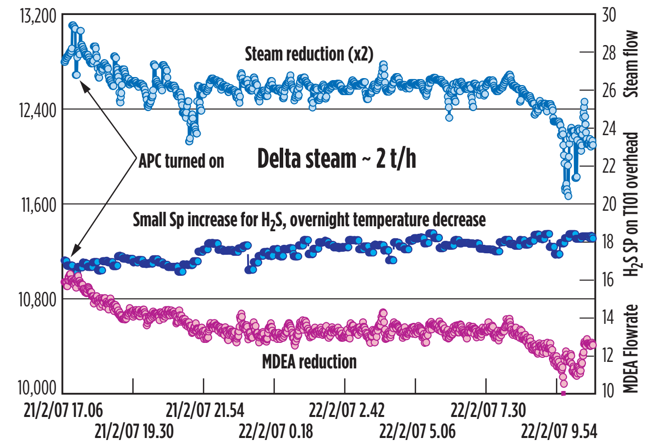

FIG. 6. Steam consumption reduction.

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