INDUSTRIAL APPLICATIONS OF INFORMATION TECHNOLOGY – COST-EFFECTIVE WAYS TO ENHANCE ENERGY EFFICIENCY

Anders Mårtensson, Environmental and Energy Systems Studies, Lund University, Sweden

ABSTRACT

Links between efficient energy use for industrial processes and the utilization of information technology have been analyzed. Two case studies are reported showing that it is possible to improve energy efficiency simultaneously with other process improvements when using measurement and control equipment. Also, the analyses show that a careful selection of process-operation strategies is important if both low energy costs and low emissions are required. Payback times for information technology investments are generally short and several benefits are often achieved simultaneously.

INTRODUCTION

Industries account for more than 1/3 of the world-wide energy use. In Sweden 1343 PJ (36%) was used in the industry in 1993. The energy efficiency in most industrial processes are still far below the technical potential[1]. For some industries energy constitutes a small portion of the production costs. However, in some branches energy costs are considerable, for example, the iron and steel and the mechanical pulping industries. In Sweden, energy contributes 12-14% to the finished product cost in the iron and steel industry.

In many countries environmental pollution caused by industrial energy use has been subject to restrictions and fees. This is a further incentive to increase energy efficiency. Obviously, the cost effectiveness of a measure to improve energy efficiency is higher if both energy expenditures and costs related to environmental fees and taxes are decreased. Measures which increase energy efficiency also frequently improve other production parameters such as productivity, quality, and flexibility. In fact, measures are often motivated by the latter reasons and energy efficiency is gained as a side-effect.

Cost-effective measures to increase energy efficiency in many industries include application of advanced information technology (IT). Information technology is here defined as systems consisting of electronic equipment, methods, and programs aimed to retrieve, process, store, and output data originating from, or used to describe, physical or technical processes. Of particular interest is information collected from measurements of physical variables. Such information may be processed to aid the analysis and control of industrial processes. This involves, e.g., model-based process control, "mill-wide" information systems, and operator guidance equipment. With the rapid development of IT, involving continuously decreasing cost/performance ratio, there are reasons to expect that a further potential exist for cost-effective implementation of IT leading to enhanced energy efficiency.[2]

This paper describes the results from a research project exploring the links between energy efficiency and the use of IT, in particular *measurement and control* equipment. Case studies are included from the iron and steel industry and are complemented by examples from the pulp and paper industry. The aim of the research has been to analyze the possibilities and limitations for energy efficiency improvements in industrial processes from increased use of IT. Focus has been on "add-on" technologies, i.e., additional equipment installed to improve existing plants and processes.

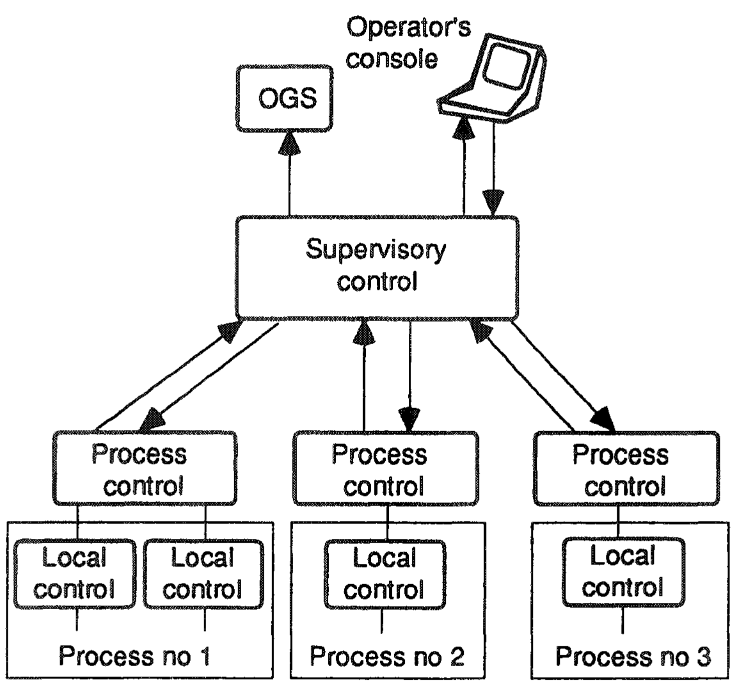
IT APPLICATIONS IN PROCESS INDUSTRIES

Electronic equipment such as controllers, sensors, and computers have been used for industrial purposes for decades. However, IT has developed very rapidly during the last 10 to 15 years and today computers are indispensable for the operation of industrial production. IT is found at different sectors in a plant: accounting, forecasting, recording, and analysis of production data. Process control computers are now gradually integrated with other plant computers, such as, management decision tools, so that production data is available on-line over the entire plant.[3,4]

IT plays an important role already at the design stage for a new plant or process. Design and construction computer tools help the designers to optimize the plant layout and may be used also to find solutions which minimize process energy demand. However, in this paper focus is on IT used to facilitate the *operation* of processes according to specific goals regarding, e.g., quality, production cost, and/or energy use.

For process-control purposes several levels of IT can be identified, Figure 1. At the lowest level, controllers keep process variables at predetermined set-points. At the next higher level, computers retrieve and process measurement data and control several variables in a process step, for example, a boiler or a furnace. At the highest level, supervisory-process control can be used to control several process steps or a whole plant.

Figure 1. Levels of information technology for industrial process control. Three processes are indicated. The integration of an operator guidance system (OGS) is also suggested.



The role of the operator is mainly to supervise the control performance of the computers. Operator intervention is needed when process parameters are changed, at start-up and shut-down, and when problems occur. At process-upset situations the workload on the operator may be very heavy with considerable amounts of information, e.g., alarm messages, to handle. Hence, efforts have been made lately to develop systems which can help operators to make the correct decisions so that optimal process operation is maintained according to predetermined goals. Such systems are called operator-guidance systems (OGS) or decision support systems.

LINKS TO ENERGY EFFICIENCY

The main goal for IT investments is usually to decrease production costs. This can be achieved through a more accurate control of a process so that energy and raw material is used as efficiently as possible. A second goal is often to increase product quality, which indirectly influences the economy of the industry. Furthermore, a higher degree of flexibility with respect both to raw material quality and to product features can be accomplished by using IT.

It has been shown that many process-performance enhancements, not directly related to energy, also can improve energy efficiency. For example, enhanced process control aimed to provide a uniform steel-plate structure, indirectly also leads to energy-efficiency improvements. The following are examples of factors which influence the energy efficiency of a process and which have links to IT:[5]

- Accuracy and precision in the control of process variables, such as, temperatures and flows are important for an energy-efficient operation. Generally, automatic control is superior to manual control in most processes.

- Adaptation of the process parameters to raw material quality variations can be facilitated by measurement and control. This can provide higher product quality and less rejected products.

- Information derived from process measurements and refined by computer analysis can provide early warnings about process problems. Thus, production disturbances may be prevented.

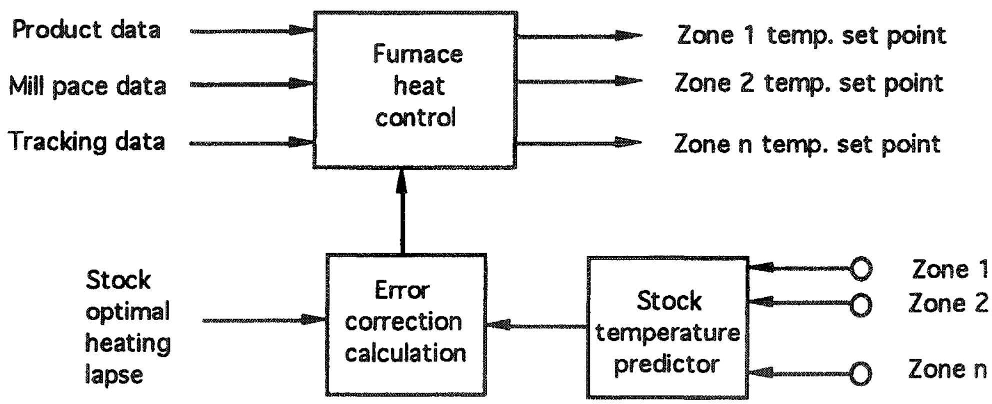
- Undesired variations in process operation due to differences in operator skills can be mitigated by computerized control.

The research behind this paper has been aimed to analyze these links. The following case-study reports contain further analyses and evaluations of achieved energy-efficiency improvements.

ANALYSIS METHODS USED IN THE CASE STUDIES

The methods used in the research involve: (1) an analysis of the actual process in terms of possible energy-efficiency increase as a function of improved information extraction, processing and feedback; (2) an evaluation of the change in process performance as a result of the implementation of IT. Further, in the second case study an extended IT system has been proposed and simulation (3) has been used to get an indication of possible results. Finally in one of the case studies, analysis of the cost-effectiveness of the implemented IT was done by conventional methods (4), such as calculation of payback time and cost-of-saved-energy.

Figure 2. Principal diagram of the furnace-control system as implemented at SSAB Oxelösund AB, Sweden. Set points for all furnace zone temperatures are computed and transferred to the lower control level. Feedback from sensors in the furnace zones are used to predict the steel temperature. Differences from the optimal-heating function are computed and corrected.



For the evaluation of achieved energy-efficiency improvements, as a result of implemented IT, the following method was found useful. An identification of a statistical model of the process was made based on historical data. Prediction of energy use from this model was then compared to measured values with the new IT in operation. Measured values lower than predicted were taken as indications that the implementation had improved the performance of the process.

CASE STUDY 1: REHEATING FURNACES

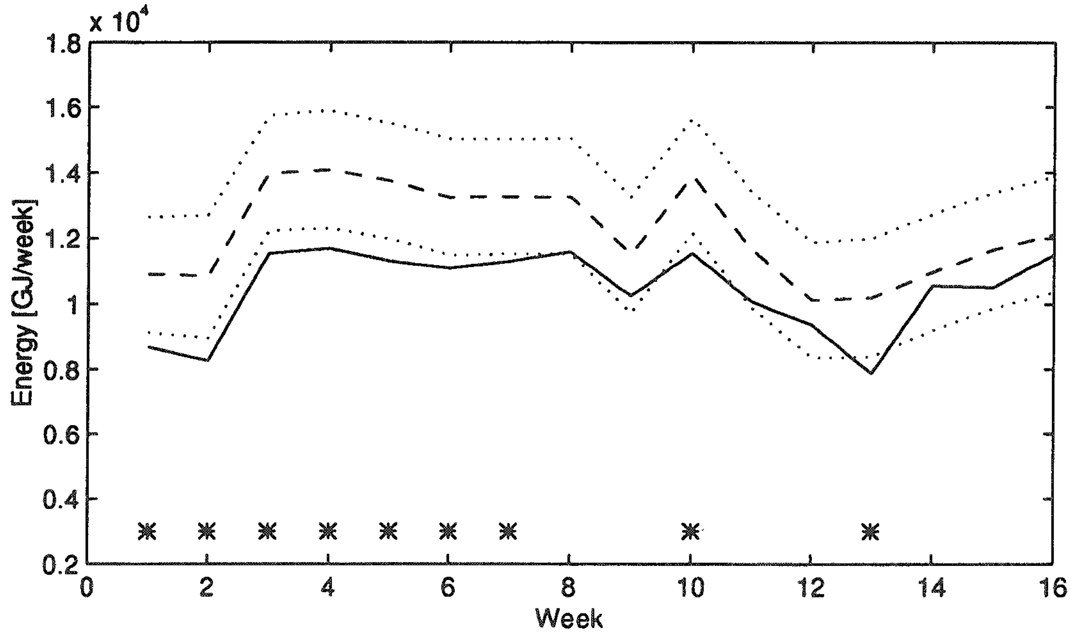
In an integrated steel plant, a new process control of the reheating furnaces was installed to improve product quality and to enhance energy efficiency. It was estimated that the improved process performance would pay back the investment in less than a year.

A reheating furnace is the link between the casting and the rolling processes in a steel plant. It is needed in most situations as it is generally not possible to roll the steel directly after casting. In the studied plant fuel-based energy of about 1.6 GJ/tonne were used for reheating of the cast steel. This corresponds to about 10% of all energy used for the production of hot-rolled steel from iron ore, or about 30% of all energy used when steel is produced from scrap.

The quality of the rolled steel is very much dependant on the reheating process. A precise control of the heating temperature at each moment during the heating cycle is essential. Deviations in heating conditions caused quality problems which was one reason to implement an advanced process control system, Figure 2.

An analysis of the opportunities for energy-efficiency improvements has been made by studying the factors which have an influence on energy use, directly and indirectly, and which can be improved by process control.[6] This analysis included a cost-performance evaluation of different solutions of IT applications. The study showed that payback times less than a year could be achieved due to gains in energy efficiency.

Figure 3. Results from case study 1, steel-reheating furnace process control. Weekly average energy-use data predicted from model (dashed line) and measured (full line). Confidence intervals for predicted values are indicated (dotted lines). Measured values above this interval are marked (o) as well as values below the interval (*). Confidence intervals are computed with a 95% confidence degree.



The influence of the implemented system on energy efficiency was evaluated by means of a regression model.[7] The model describes the performance of the furnaces based on recorded data for about ten years before the new IT was installed. Measured data and model predicted data for specific energy use were compared during a number of weeks after the installation, Figure 3. It was found that specific energy use, at a 95% confidence level, in 9 out of 11 weeks was lower than predicted. On average, specific energy use was about 17% lower after the completed installation of the IT compared to the historical performance.

It was concluded in this study that energy-efficiency improvement had been achieved as a result of enhanced process control. This resulted in a more precise heating procedure, providing accurate temperature and timing, adapted to the various types and dimensions of steel. This also led to higher quality of the rolled steel. During the observed period after the installation of the new IT, the number of rejected steel plates was about 20% less than before the installation. The main part of this achievement was determined to be a result of improved process control. Some of the gains, it was assumed, should only indirectly be accounted to the implemented IT: increased attention to the operation and maintenance of the furnaces in connection with the planning and implementation of the system might contribute.

Cost reductions as a result of improved furnace control were achieved both through reduced energy costs and through higher product quality; the latter being the most important factor.

CASE STUDY 2: PLANT ENERGY MANAGEMENT

An operator-guidance system in an integrated steel plant was studied. It was developed by the steel company in order to assist the operator of the plant energy production and distribution system. This system contains several energy carriers, oil, coke oven gas (COG), blast furnace gas (BFG), steam, and electricity. Electricity can be produced in the plant or be purchased from external producers. In certain operational situations it is possible to substitute one energy carrier for the other. Electricity, for example, can be produced by combustion of oil, COG, or BFG. Depending on the general production situation in the steel plant the operational costs for the energy system can be minimized by a proper selection of energy sources and carriers at each moment.

The operator-guidance system was implemented as a prototype. Minimization of the use of oil is the operational goal that is the basis for the advice given to the operator. If the operation of the energy system deviates from this goal, an alarm is issued to the operator. Each type of alarm is associated with an explanation of the cause of the alarm and with an advice on how to change the operation to achieve the desired goal.

This prototype system was evaluated to find out how energy use was affected. Two periods were compared, in one period the system was in use, in the other it was functioning but the alarms (and advice) were not given to the operator. The periods were chosen so that the production situations were as similar as possible.

It was concluded from the evaluation that those operational costs which could be influenced by the operator were about 50% lower during the guided period, Figure 4. The energy waste during this period was also about 50% lower than in the non-guided period. This means that the total energy efficiency of the plant was higher during the guided period.

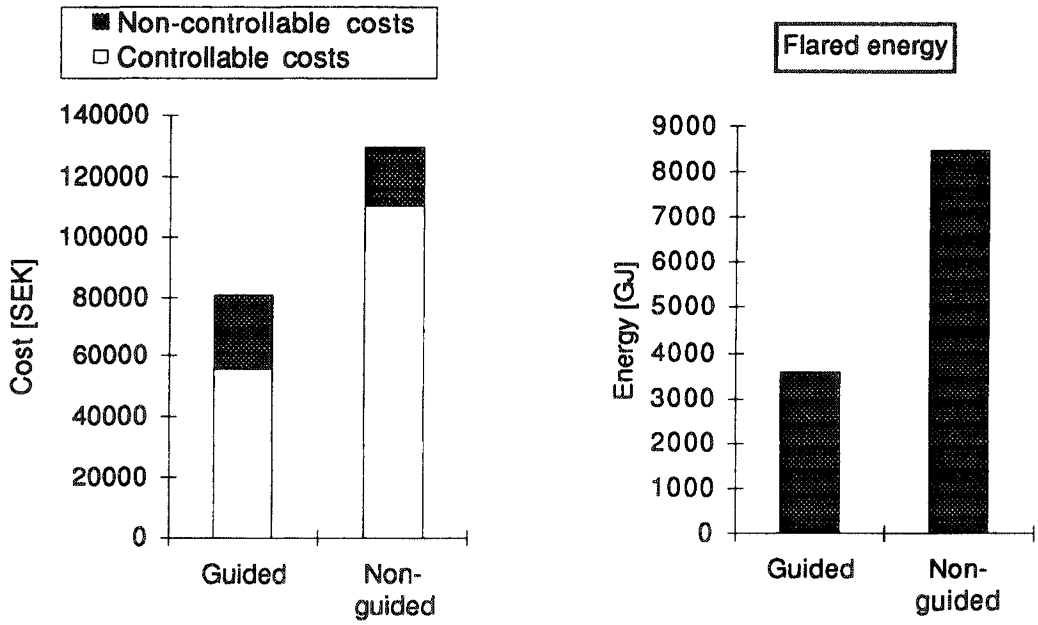
As an extension of the prototype system it was proposed as part of this case study that also NO_x emission fees should be included in the cost calculation. This would likely lead to different optimal operation of the energy system at certain conditions. A theoretical study was made of such an extended system by simulation. An important subject of the study was to compare the operational advice that would be given when different operational goals were chosen. Two goals were compared—minimum operational cost and minimum NO_x emission.

It was found in this theoretical study that the choice of operational goal influences the advice to the operator providing very different operation in certain conditions. Thus, when gas resources are low, minimization of cost would not lead to minimization of NO_x emissions and vice versa. It was also found that the construction of the emission-fee rules is crucial if both minimum cost and minimum NO_x emissions should be achieved simultaneously.

CONCLUSIONS

The results from this research project indicate that energy efficiency of many industrial processes can be improved by increased use of advanced IT. Most investments in IT show very short payback times, in particular for those cases where enhancements of multiple factors such as productivity, quality, and energy efficiency are achieved simultaneously. With the rapid development of IT, involving continuously decreasing cost/performance ratio, there are reasons to expect that a further potential exist for cost-effective implementation of IT leading to enhanced energy efficiency.

Figure 4. Results from case study 2, operator-guidance system for energy management in a steel plant. Costs and wasted energy due to non-optimal operation of the energy system shown for a period with the operator-guidance system in use ("Guided") and disconnected ("Non-guided"). "Controllable" refers to costs which could be directly influenced by the operator, while "Non-controllable" are costs which the operator has no direct means to decrease.



ACKNOWLEDGEMENTS

SSAB Oxelösund AB, Sweden made the research possible, which is gratefully acknowledged. The work was financed by the Swedish National Board for Industrial and Technical Development (NUTEK, formerly STU).

REFERENCES

[1]E. Worrell, R.F. A. Cuelenaere, K. Blok, and W.C. Turkenburg, *Energy–The International Journal* **19**, 1113 (1994).

[2]W. Walker, *Energy Policy* 13, 458 (1985).

[3]G. L. Stephens, *TAPPI Journal*, March, 1992. 127-131.

[4]R. Klinetob, *TAPPI Journal*, June, 1990, 261-265.

[5]F. G. Shinskey, *Energy Conservation through Control*, Academic Press, London, 1978.

[6]A. Mårtensson, *A case study of reheating furnaces in the steel industry* . IMES/EESS Report No 8, Environmental and Energy Systems Studies, Lund University, Lund, Sweden. March 1992

[7]A. Mårtensson, *Energy–The International Journal* 19, 717 (1994).