

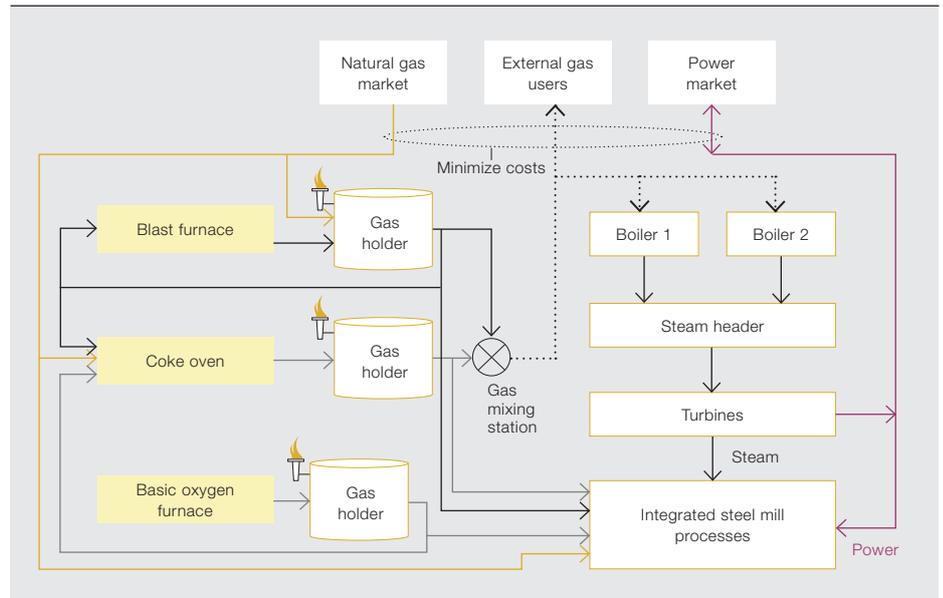


# Optimizing energy flows

Improving energy efficiency in steelmaking by modeling and managing energy flows with ABB's cpmPlus Energy Manager

JOUKO KARJALAINEN, TONI KYMÄLÄINEN, JUHA MÄNTYSAARI, TUA KAUPPALA – Energy constitutes about 20 percent of the total production cost in an integrated steel mill. Energy efficiency is, therefore, crucial for profitability. Within the mill, energy is distributed through complex networks carrying

electricity, steam, by-product gases and imported fuels. Understanding this system and controlling it in an optimal way is the key to improving energy efficiency and competitiveness while reducing environmental impact.



**M**aking iron and steel requires complex gas networks that can reliably supply a wide variety of gas grades and blends to a large number of process consumers → 1. Due to the critical nature of production scheduling, these gases must always be available when needed. This necessitates the use of gas storage holders to accommodate temporary shortages or surpluses.

When gas demand exceeds supply, supplementary fuel must be bought at volatile – and often higher – market prices. When supply exceeds demand, excess gas must be flared off from the holders. This wastes energy and increases the plant’s carbon footprint.

In addition to process needs, many mills have power plants in which the boilers are fired with a combination of fuels, including by-product gases from blast, coke and basic oxygen furnaces. This energy is balanced with electricity purchased from the grid to meet the total plant demand. If the

plant is able to predict this electrical power demand accurately, it can be purchased at a lower price.

The challenge is therefore to optimize the plant’s entire energy system so that the needs of all consumers can be met at minimum cost. This results in reduced flaring, reduced purchases of electricity and supplementary fuels, and lower prices for the electricity that does have to be purchased.

**Systematic solution**

Since the different forms of energy generated and consumed at a steel mill are highly interdependent, it makes sense to optimize them as a whole. This can produce the greatest benefit for the mill’s competitiveness in terms of energy costs and carbon emissions, as well as minimizing the penalties for underestimating or overestimating demand.

ABB’s cpmPlus Energy Manager (EM) is a software solution that models and visualizes the entire plant’s energy flows. It calculates optimum schedules for by-product gas distribution to process consumers and power plant boilers. This optimization ensures 100 percent by-product gas availability while minimizing wasteful flaring.

Additionally, cpmPlus EM accommodates plant processes – such as the gas network and mixing station configuration – as well as financial considerations, including boiler start-up costs. It can help

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maintain optimal energy efficiency despite unplanned production changes or energy price volatility. The system can even help optimize the export of electricity or by-product gases when this is feasible and economical.

**Efficient modeling tools**

In cpmPlus EM, the modeling principle is known as the economic flow network (EFN). The EFN provides tools that graphically configure the entire energy system model as an interconnected flow network, where each flow is represented with an allowed range of values and a unit price. Logical constraints can be specified for the various process conditions. Based on the configured model, the optimization problems are automatically created and solved by a mixed-integer linear programming (MILP) solver.

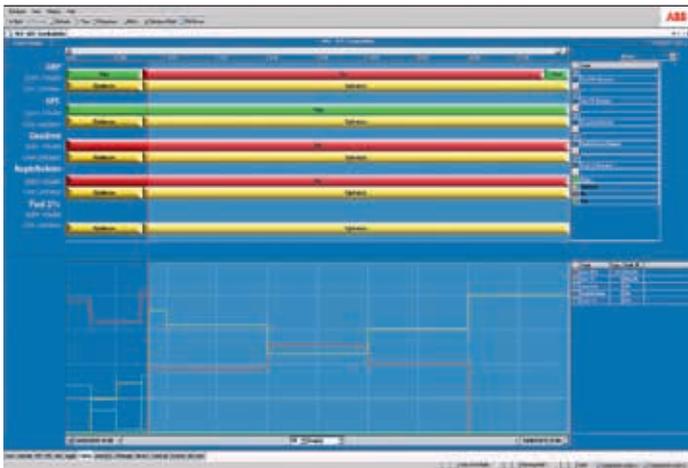
**Energy efficiency dashboards**

Another feature of cpmPlus EM is that it provides dashboards to display energy

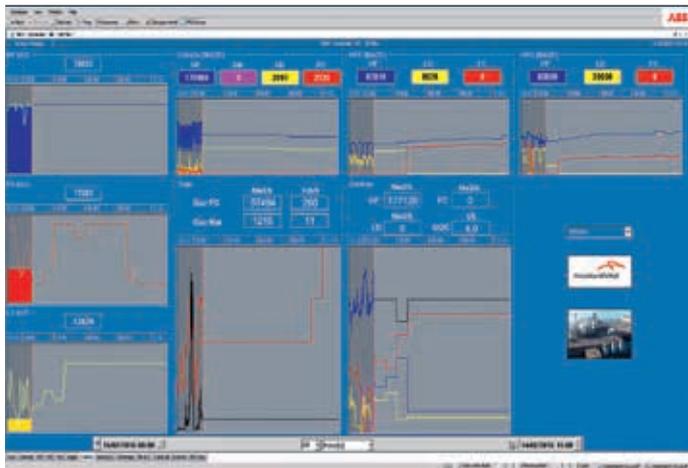
**Title picture**

With intricate flows of electricity, steam and gas, the energy topography of a steel mill is complex. How does ABB’s cpmPlus Energy Manager help master the complexity of the energy flows and improve energy efficiency?

## 2 Boiler fuel usage control view



## 3 Gas utilization overview



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performance, from the level of individual production processes to the entire plant → 2–3. This allows energy performance indicators to be monitored and targeted, and enables analysis and reporting to verify the performance improvements that result from the implemented activities and projects.

Dedicated dashboards for each production station allow operators to act on deviations from the optimum that are often hidden behind different energy and material flows. Operators can also validate the planned schedules for gas, electricity and steam demand, as well as the generation of by-product gas compared with the day's production schedule.

At the same time, site power plant operators can use optimization results to select the best combination of on-site power generation and external supply. This allows energy efficiency to be managed as a key performance indicator, alongside production quality and throughput.

The power plant and process schedules calculated by cpmPlus EM can also be implemented automatically by sending scheduled set points to the advanced process control level, which then coordinates the power plant control systems to run the processes in an optimal way.

### Case study at ArcelorMittal steel mill

Steel mills utilize production planning systems to enable them to manufacture to order. In ArcelorMittal's Fos-sur-Mer mill, in France, such a system allowed the company to plan production and predict energy consumption in the production planning process. However, the mill set

itself a more ambitious goal: to optimize its energy procurement, steam yield and consumption of by-product gases – and thereby optimize the energy consumption of the entire mill's steelmaking process.

ArcelorMittal's own research center had conducted preliminary studies and developed models to manage energy and by-product gases at the mill. They had clear requirements and expectations for the modeling process, but they still needed to find the right industrial supplier.

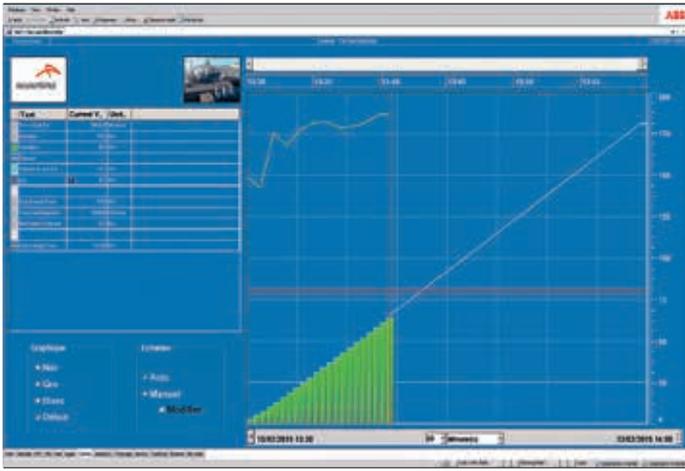
### Successful prototype model

ArcelorMittal chose to work with ABB because there was no other supplier with an equivalent industrial-scale product. The project was demanding, but the ABB team approached it in a systematic way by performing modeling on the basis of ArcelorMittal's preliminary investigations, ie, by carrying out a case study. As soon as ABB had completed its prototype modeling, the work was submitted to ArcelorMittal for evaluation and was approved.

### Insights and innovations

The ultimate aim of the project was to model the mill's entire energy procurement and production processes. As mentioned above, the steel manufacturing process involves both the production and consumption of gases. A mill's external energy procurement is usually regarded as including only electricity and steam, but this time the modeling process also covered the management of by-product gases and gases sourced from elsewhere. The ABB system indicates how much gas needs to be purchased from outside sources.

#### 4 Electricity tie line monitoring view



The system is in continuous use in an industrial environment and therefore faces special challenges. Finding high-quality optimal solutions – as input data constantly changes – reliably and quickly enough was something that needed to be given extra attention.

In ArcelorMittal's case, the optimization time horizon must be continuously calculated. In other words, the optimal production plan must be repeatedly resolved on an ongoing basis. In the context of optimization modeling this is a major challenge; to make it possible ABB had to develop completely new techniques and solutions.

#### Technical solutions for industrial-scale optimization

The system supplied to the ArcelorMittal mill incorporates three technical solutions that support fast and high-quality optimization with varying input data. These are: two-level optimization with base model inheritance to different time levels; the sliding time horizon approach; and the use of multiple search parameters for solvers.

#### Two-level optimization using base model inheritance

To make it possible for the whole power generation process to be continuously optimized, it was initially necessary to produce state decisions for the major equipment in the production plant by projecting a crude resolution into the future. Based on these, it was then possible to calculate the use of energy storage equipment like boilers or gas holders with a finer resolution.

#### 5 Department electricity forecast view



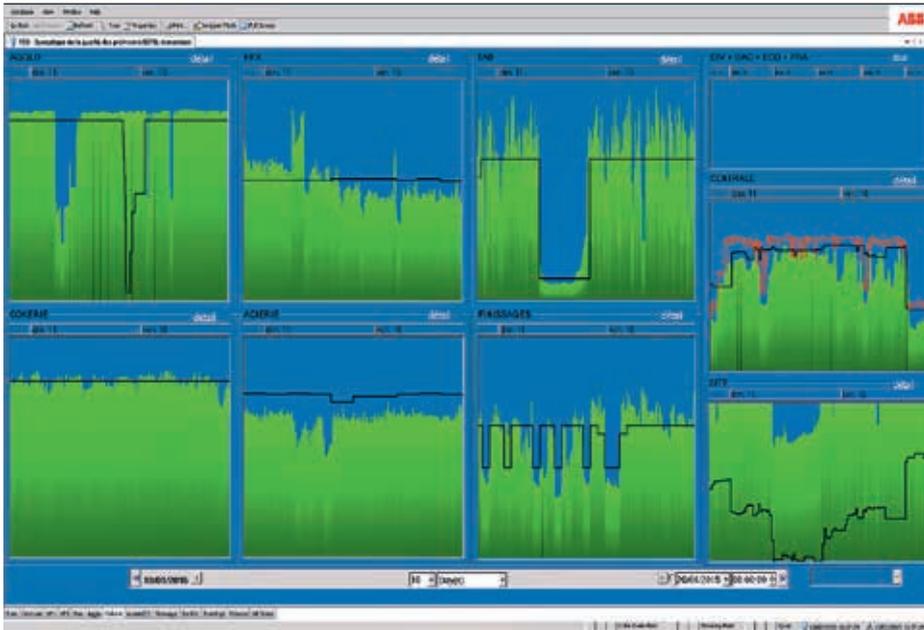
This was done using modeling in two different time resolutions: one of 2 hours, in which the optimal states of key equipment such as boilers were fixed, and one of 30 minutes, in which these states are taken as given and fine-granularity optimization of continuous operation is performed. The models used in both time resolutions are inherited from a base model containing common structures and constraints.

Because electricity is billed in periods of 30 minutes in France, the customer required the system to update twice during that time, ie, approximately every 15 minutes. At this 30-minute level it is possible to make major state decisions and resolve utilization two days ahead. The two-day plan provides optimized data for all external energy procurement, electricity and gas forecasts, and gas holder levels. The system also enables forward monitoring of the weekly plan.

#### Sliding time horizon

The second technique incorporated into the system supplied to the ArcelorMittal mill was the sliding time horizon approach. When data that updates every half hour is used to predict two days ahead, this forecast cannot be done in a single step that incorporates the whole time horizon in the model. This would be too resource-intensive and time-consuming for the optimization. The sliding time horizon approach looks ahead over a shorter time slot and provides an initial solution for that. Then this solution is entered into the system, the slot is moved forward by one period and the process is repeated. This is done until the whole two-day time slot has been processed.

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The cpmPlus EM accommodates plant processes such as the gas network and mixing station configuration, as well as financial considerations, including boiler start-up costs.

The time horizon therefore moves forward one period at a time. This maintains the continuity of results over time, allowing for more stable solutions. If a whole 24-hour period is optimized at one time, the continuity from one day to the next is lost because the determining factor is the 24-hour time slot and the optimization model cannot “see” far enough beyond that.

#### Broad selection of solver search parameters

The third technique made it possible to achieve a sufficiently fast numerical solution with varying input data. Most of the time, the system can quickly solve optimization problems with a given selection of parameters. However, there are occasions when solution times can be long. The ABB team came up with the idea of allowing the system to send the problems simultaneously to two different solvers with different search parameters. Then it is simply matter of waiting to see which solver finds a solution first and cancelling the slower one. This competitive solving is constantly repeated around the clock, in line with the requirements of an industrial-scale system.

#### cpmPlus EM objectively searches for the most economical solution

cpmPlus EM shows the operator the most economical way of running the mill. It can also identify completely new operating practices → 4–6. This was the case with the turbines at Fos-sur-Mer: The ABB system suggested an operating

practice that differed significantly from what had been done before. This new method was adopted at the mill.

Optimizing all energy procurement processes has brought significant savings in raw materials and costs at ArcelorMittal’s Fos-sur-Mer mill, boosting the productivity of the steel manufacturing process. At present, the most clearly visible result of this is an improvement of some 15 percent in the accuracy of the mill’s external electricity procurement forecasts. This translates into savings of around 15,000 euros (\$17,000) per month (averaged over 2013).

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