Concrete energy savings

Effective energy management in cement production

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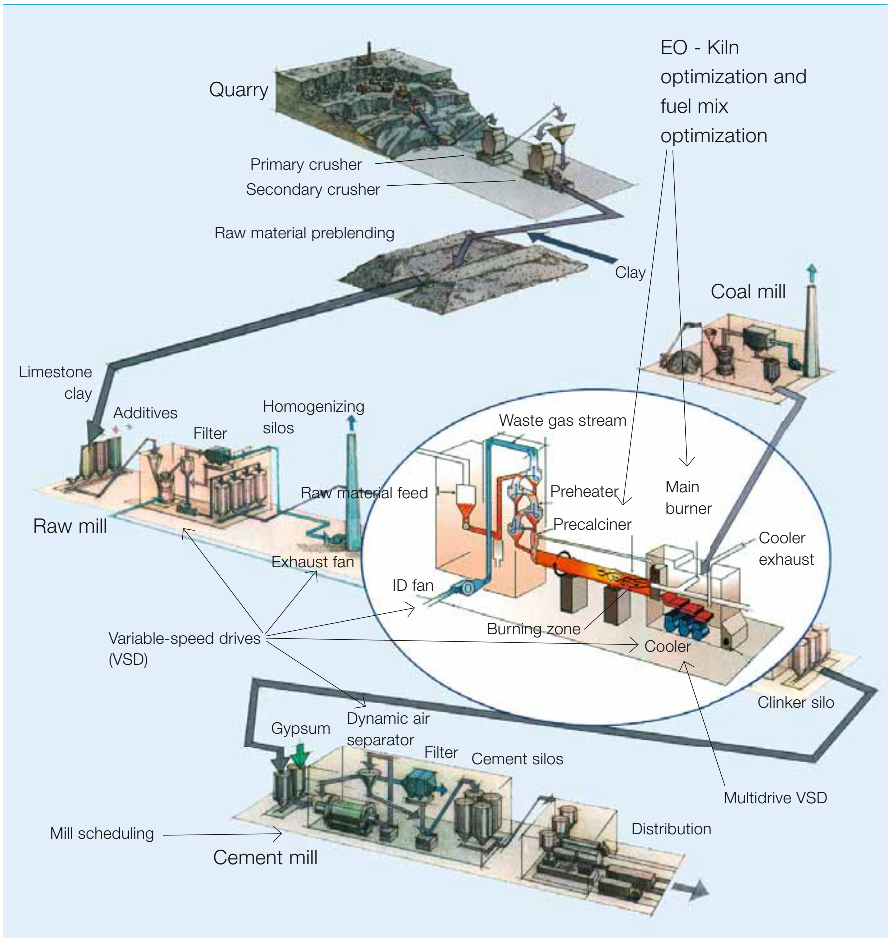
The building boom in China is unprecedented, particularly in Beijing and Shanghai. With more families migrating to the cities, the need for new buildings continues to grow. With construction comes the demand for cement. To satisfy this demand, China has become the world's largest cement producer, generating roughly half the total global output. To produce cement, large quantities of thermal and electrical energy are required, typically accounting for about 30 percent of the production costs. The cement industry in China consumes about 6 percent of the nation's total energy and is mainly derived from the combustion of fossil fuels. The recent increases in fossil fuel prices have pushed cement production costs up. Since the industry contributes significantly to global CO_2 emissions, these costs are not only economic, but also environmental. ABB offers technologies that help increase cement-plant efficiency, maintaining productivity levels and cement quality, while reducing CO_2 emissions and fuel consumption.

Productivity

The cement production process is complex, providing many opportunities for improvements to increase efficiency. ABB has a variety of products that can be installed to increase the fuel efficiency and the productivity of the cement manufacturing process 1. During production, large fans draw air through the kiln, precalciner, mills and filters to an exhaust stack and smaller fans. Many fans, in addition, push air into the grate cooler to reduce the temperature of the hot clinker leaving the kiln. All these airflows must be adjustable and controlled. Atmospheric conditions, process conditions and ventilation needs greatly affect the flow requirements. The method employed to control the airflow has a major effect on the running costs of the cement production plant. Controls can be retrofitted to manage the airflow. The least energy efficient method is to fit a damper with a fixed-speed motor, while the most energy efficient method is to fit a variable-speed drive (VSD) 2.

1 Schematic of the cement production process showing how ABB products can be installed to increase fuel efficiency and productivity



Replacing dampers and fixed-speed motors, ABB's variable-speed drives offer a huge potential for energy savings, especially in the cooler.

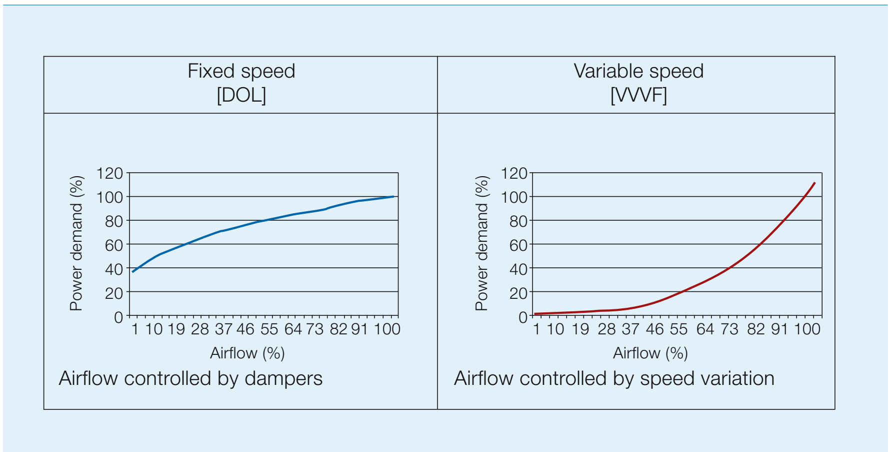
Variable-speed drives save energy

ABB's VSDs can provide power savings of as much as 70 percent when compared with a damper and fixed-speed motor (depending on the required air-flow rate). During nominal production, large fans usually drive airflows at 90 percent, which even at this high flow rate means that a VSD can provide a potential power savings of 20 percent 2. VSDs are usually installed in all-new plants today, but in older plants there is still big potential for energy savings by replacing dampers and fixed-speed motors with VSDs, especially in the cooler.

Multidrive solution for grate coolers

The cooling of one ton of clinker requires approximately 10 percent of the overall electrical energy required to produce it. It therefore makes good sense to carefully consider the choice of drive system used for the cooler. The ABB multidrive can be considered an optimized drive solution for the cooler 3. It offers all the benefits of variable-speed drives, while retaining the desirable features of a single drive without the economic disadvantages. Unlike a single drive, which requires its own rectifier, DC link and inverter, the multidrive system generates the required DC voltage in a central unit and feeds it into a common DC bus to which the single, independently operated inverters are connected. Since the individual inverters must not have the same power rating, a multidrive

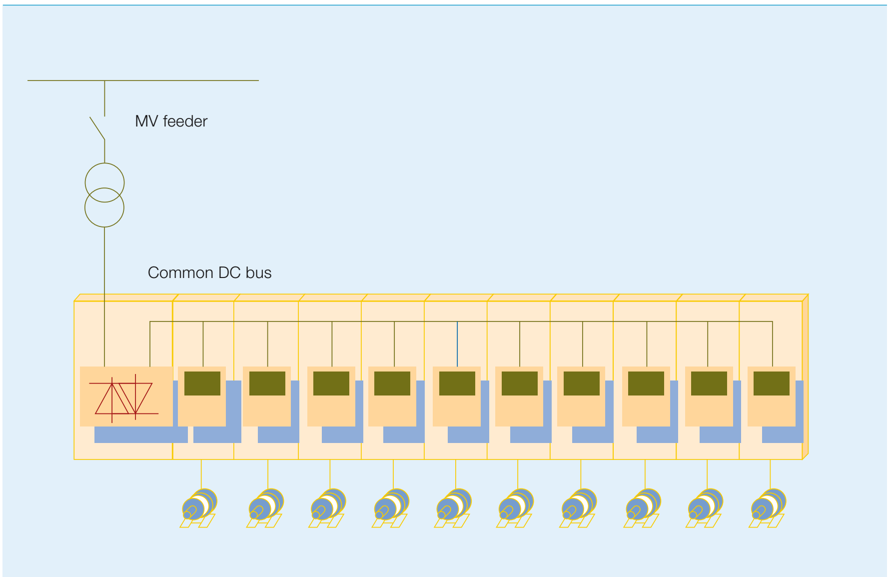
2 Comparison in power demand for an airflow controlled fan



package can consist of drives of very different sizes.

Some of the benefits include:
- Reduced cabling due to the single power entry for multiple drives
- Energy-saving motor-to-motor braking, which is required depending on the grate cooler type
- Reduced space requirement
- Elimination of the low-voltage distribution used for single drives or damper, and direct online motors in the case of a replacement
- Cost-effective reduction of harmonics using an active front-end supply unit or at least a 12-pulse line supply

3 Basic configuration of a multidrive system layout with active front-end supply



The ABB multidrive can be considered an energy-saving, optimized drive solution for the cooler.

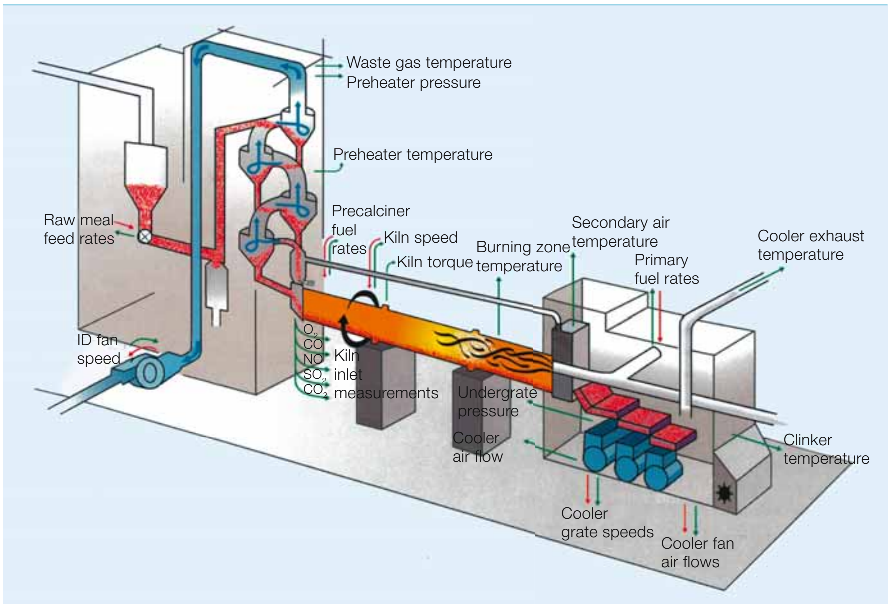
ABB Expert Optimizer saves energy

Cement manufacturing is a complex and energy-intensive process. A key stage in this process is the conversion of ground raw materials ($CaCO_3$, clay and/or shale) into clinker in the kiln. A typical operation uses kiln exhaust gases to preheat the raw materials before they enter the kiln. In the kiln's burning zone, the material is heated to about 1,500°C, where it partially melts and reacts to form clinker. Subsequent processing continues to convert the clinker to cement, with the addition of small amounts of gypsum ($CaSO_4$) and further grinding to produce a fine powder.

Conventionally, cement kilns are controlled by an experienced operator who constantly interprets the process conditions and makes frequent adjustments to control established standard set-points. This task is onerous enough, but is made even more difficult by the complex responses to these adjustments, time delays and the interactions between individual process variables. These difficulties force the operator to take a conservative approach to kiln operation, using process temperatures that are higher than the optimal, leading to unnecessarily high energy usage.

The ABB Expert Optimizer (EO) system was developed upon the solid foundations of its highly successful and highly regarded predecessor, the ABB LINKman optimization system. The system improves on conventional control methods by constantly monitoring the various input- and output-signals from the kiln and responds by initiating appropriate actions 4.

4 Kiln schematic showing input and output signals of an EO system



The burning zone temperatures (BZTs) are crucial to product quality, as they affect the proportion of free lime (unreacted CaO) in the finished product. Although this varies from one cement production plant to another, the basic principle is the same; namely, low BZTs will produce softer clinker with higher proportions of free lime content, and high BZTs will result in harder clinker with lower free lime levels 5. The higher the BZT, the higher the required clinker grinding capacity and therefore the greater the fuel consumption.

The BZT also affects the stability of the kiln's operation. A high BZT results in a more stable kiln, while a BZT that is too low can cause volatility, reducing productivity and even causing stoppages. An unstable kiln operation causes major thermal stress on refractory brickwork in the kiln, thus shortening refractory brick life and causing premature expenditure. Unnecessary kiln downtime causes increases in the energy requirements per unit of clinker produced, ie, a higher energy-base loading (or higher minimum energy requirement). This is especially true when considering the additional energy required to restart the kiln.

Proper, stable kiln operation can reduce energy consumption and maintenance costs, increase kiln output and improve overall product quality. However, maintaining an optimum BZT at a minimum level while preserving stability is difficult to sustain for three reasons:

- Variations in raw material feed composition
- Complexity of kiln operation
- Long-time delays between kiln operational changes (ie, setpoint changes and their effects)

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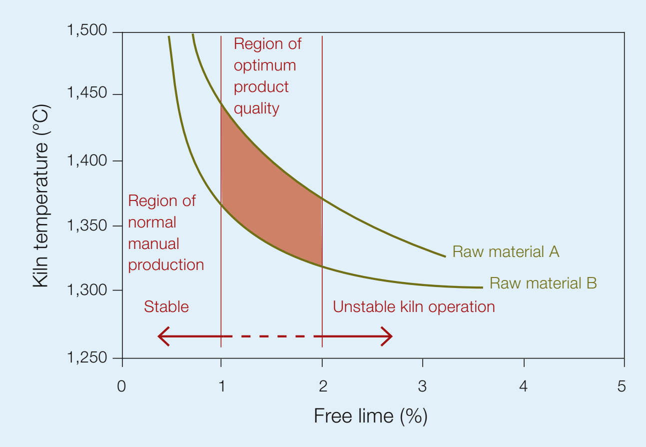
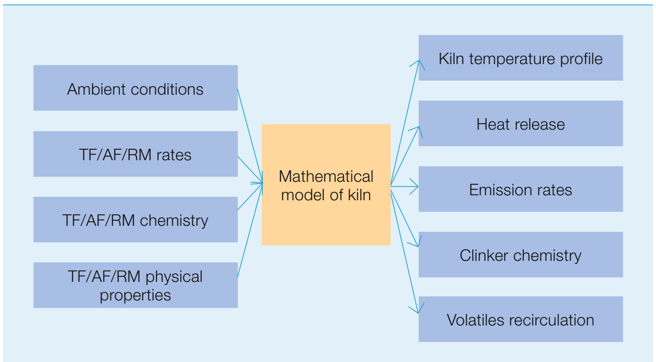
The EO advanced kiln control system, however, operates the kiln in an optimum manner, thereby ensuring a high-quality product, lower BZT and consequently, lower energy costs. The system achieves this by regularly making adjustments to the process every three to four minutes.

The EO is typically in control of kilns for more than 80 percent of its run time. Estimates based on measured free lime and nitrogen oxide (NO_x) levels made before and after EO installation suggest that fuel savings can, in some cases, approach 8 percent per kiln.

5 Burning zone temperature in function of free lime



6 Kiln model inputs and outputs



Kiln fuel mix optimization

The EO comprises rule-based control with modern tools like neural networks, fuzzy control and model predictive control (MPC)[1]. Enhancements that offer optimal fuel management will allow efficient use of alternative fuels so that the kiln can be operated economically. The main idea is to use the data gathered by the information management systems (equipment, process, market and laboratory) to calculate the lowest fuel mix costs that satisfy the process and business constraints **Factbox**.

The basic element of this algorithm is a dedicated mathematical kiln model developed in EO, which is used for model predictive control. The optimization algorithms are able to cope with both hard and soft constraints, which enhance the robustness and reliability of the optimization process **6**.

The implementation of this algorithm is such that the input data is updated at constant sampling times of about 15 to 30 minutes, computations are executed and the new fuel set-points are passed to EO strategy for implementation. Between sampling times, the standard EO strategy guarantees process stability and optimal performance. In particular, this strategy enforces:

- Economically optimal reactions to changing conditions in fuel, waste and raw meal quality
- Strict satisfaction of environmental, contractual and technical constraints

Electrical energy management

Cement production operation runs 24 hours a day, seven days a week,

Factbox A delicate balance

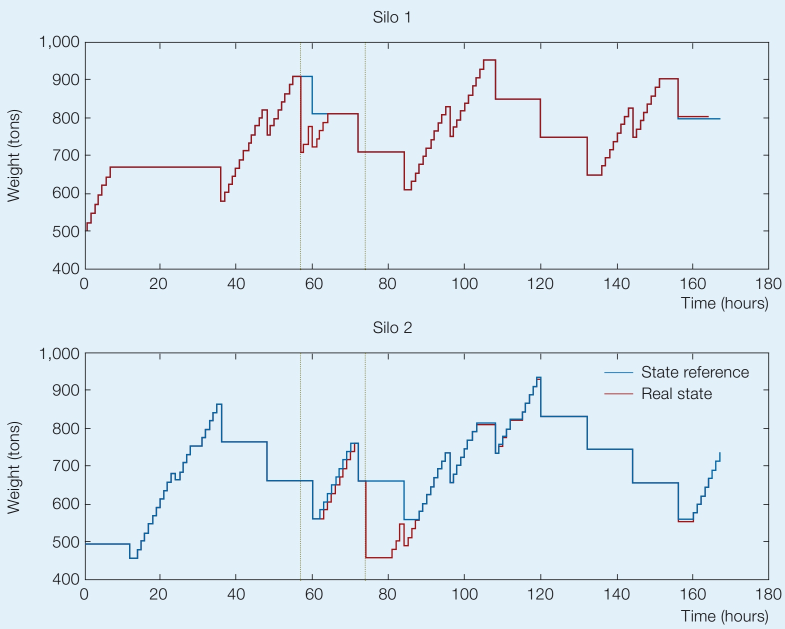
The process and business constraints to be satisfied are numerous. Among the most important are:

- Heat balance
- Excess oxygen level
- Clinker chemistry
- Concentration of volatiles
- Emission limits (SO_2, NO_2, etc)
- Maximum, minimum and speed of change constraints on actuators
- Operative constraints on fuel consumption
- Separate consideration of combustion process in precalciner and kiln, contracts (with customers or suppliers) to be satisfied at any cost

Footnote

[1] Neural networks are a system of programs and datasets that attempt to imitate the way a human brain works. They draw on large datasets of earlier examples, thereby weighing up inputs and their significance. Fuzzy control is a term that describes how concepts (inputs) that are fuzzy – ie, not simply true or false, but with degrees of truth – can be analyzed. Model predictive control is an advanced method of process control attempting to predict the output of a process with respect to changing inputs.

7 An example of the rescheduling capability of the EO: The solid line shows pre-computed reference levels for Silo 1 and Silo 2, while the cross line represents the actual silo levels as measured by online sensors.



At time t = 57 there is a deviation from the reference in Silo 1, caused by higher than forecasted dispatch and the algorithms react to correct the schedule.

with very limited spare capacity or redundancies installed. Thus, most of the equipment has to run around the clock or during daylight hours (due to constraints such as quarry operating times). It is difficult, therefore, to find opportunities to reduce electrical energy usage. The main area of flexibility is confined to the cement grinding area.

ABB's EO uses the data gathered by the information management systems to calculate the lowest fuel mix costs that satisfy the process and the business constraints.

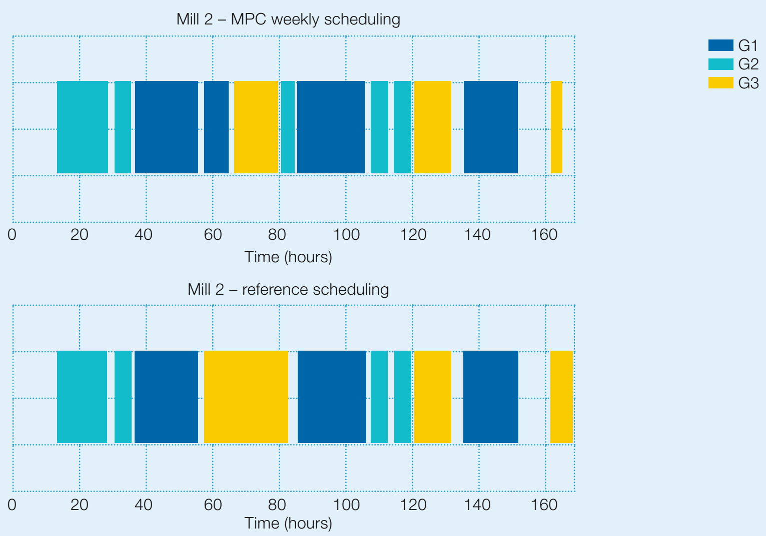
Currently, scheduling in the grinding area is performed manually, using heuristic rules and relying on operator experience. However, depending on the number of mills installed, cement grades produced and silos installed, manual scheduling, which takes account of various operating and contractual constraints, can be extremely complex. Too often, the operator's choice is far from optimal. The following solution describes an optimized scheduling based on MPC technology.

Using customer orders and energy price forecasts, the algorithm produces a reference schedule for the whole grinding plant's operations; ie, what type of product each mill will produce and when 8. Here the functional units represent the costs associated with the electricity consumption and the amount of low-grade cement produced (cement produced during the switch from one grade to another). Electricity cost reduction is achieved by scheduling production to periods when the electricity tariffs are lower, and ensuring that the contracted thresholds of maximum electrical power are not exceeded. Reductions of low-grade cement are obtained by minimizing the number of cement grade production changes.

By scheduling cement grinding to periods when electricity tariffs are lower, the costs of cement production can be reduced.

However, unplanned events such as component failures or unexpected product demands are frequent. MPC is able to react to such changes. In this phase, state variables are the silo levels, while the control variables are the commands to switch mills. The cost function is a weighted sum of

8 Algorithm response: The new control sequences (upper panel) are compared with the pre-computed control sequences (lower panel).



Note how the algorithm reacts immediately to the disturbance, committing at time (t = 58) to restart the production of grade 1 cement instead of changing to grade 3 production.

deviations from the values given by the MPC reference schedule. The typical sampling time is one hour.

ABB's EO can quickly react to differences between the predicted and actual levels of cement in the silos, rescheduling optimal production to meet demand.

In addition to physical constraints (silo capacity and mill availability), the grinding plant's operations must take account of time delays, which occur whenever a change of cement grade produced by a mill is made, so that the mill's throughput can be conveyed to a special silo. It must take account of changes in demand so that delivery time to customers is minimized. The optimization algorithm requires the sales forecasts for every type of cement grade. If the forecasted sales cannot be fulfilled, the algorithm will prioritize the cement grade produced. Furthermore, the optimization algorithm must evaluate the constraints on cement transport from the mills to the silos using, for example, available conveyor belts or bucket elevators. There may be three mills with only two independent transport routes. Multiple mills can simultaneously discharge the same cement grade using the same transport route to a single silo; however, when different mills are producing different cement grades, independent transport routes must be used to fill different silos.

ABB's EO can quickly react to changes in the forecasted levels of cement contained by the silos 7. Differences between the predicted silo levels and the actual silo levels, caused by higher dispatch, are detected by sensors in the silos. The algorithms react to correct the schedule and to reject the original ideal schedule. The algorithm immediately reschedules the mills to maximize efficiency, so that the supply of the correct grade cement continues to flow into the correct silo. A discrepancy between the forecast levels of cement in the silos and the actual levels has initiated the rescheduling of cement production by the mills, so that the planned change from grade 1 cement production to grade 3 cement production is postponed, optimizing the use of the mill 8.

More efficient and cost effective

Energy management can help reduce thermal and electrical energy demands and can be used to source less expensive energy. Today, proven technical solutions and reliable equipment are available to ensure successful energy use without jeopardizing the quality and productivity of a plant. These solutions provide positive effects on the environment, and since energy prices have been escalating recently, the returns on such investments can be made within increasingly reasonable time periods.

ABB's experience in the cement industry together with its board portfolio of products can help China reduce CO_2 emissions and increase energy efficiency.

ABB's experience in the cement industry together with its board portfolio of products can help China reduce emissions and increase energy efficiency so that the cement needed to build new offices and homes in the cities of China need not be such a drain on resources.

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