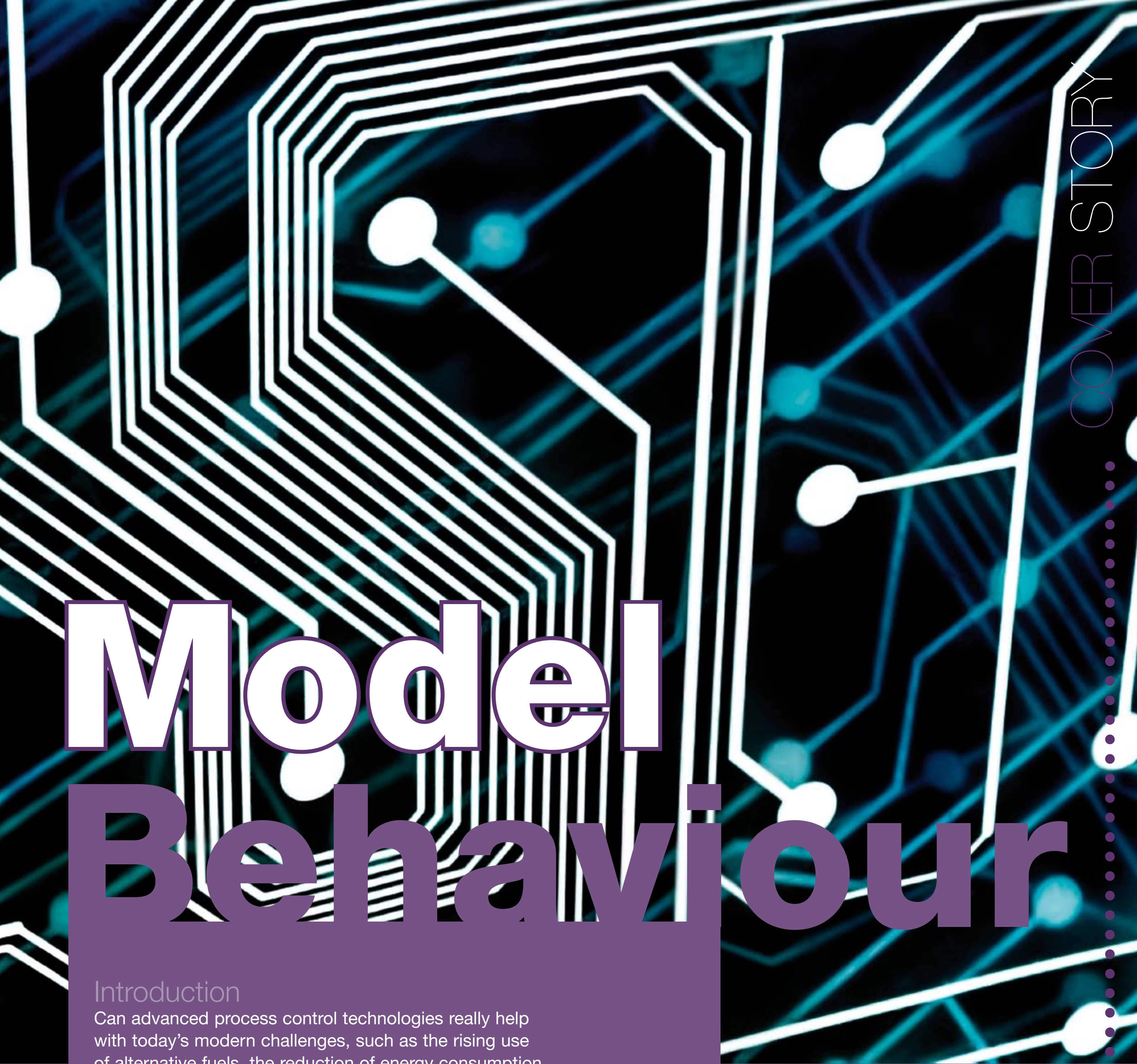

COVER STORY

Model Behaviour

Michelle Kiener and Dr Eduardo Gallestey, ABB Switzerland Ltd, look at three cement plants that have gained advantages through Expert Optimizer's advanced modelling techniques.

Introduction

Can advanced process control technologies really help with today's modern challenges, such as the rising use of alternative fuels, the reduction of energy consumption and the minimisation of process disruptions? The answer is a firm yes.

An example of this fact is the trajectory of benefits delivered by ABB's Expert Optimizer (formerly known as LINKman). Expert Optimizer (EO) has a long and successful history in the cement industry, providing intelligent control, and was ahead of its time in the use of artificial intelligence techniques, such as fuzzy logic and neural networks. It has now evolved again to utilise and tame the best of a new technology. This time, Model Predictive Control (MPC) is brought to users in the familiar EO environment. Moreover, EO has harnessed not only classical MPC, but also Mixed Logical Dynamic (MLD) as well.

In this article, the authors look at what MPC and MLD systems are and how they are being deployed in the cement industry. Three live applications, where these advanced techniques are bringing benefits to their users, are also discussed.

Figure 1. Holcim's Untervaz plant.

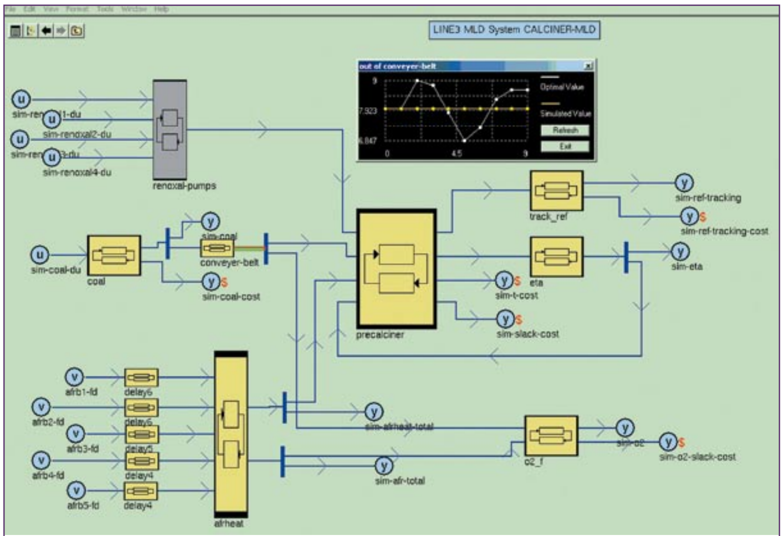

Figure 2. Precalciner MPC + MLD scheme in EO.

Key elements to success

Some argue that control algorithms based on mathematical models are unreliable and even superfluous. Sometimes shrouded in black boxes, occasionally controversial and contested, why would anyone trust their process, and therefore their bottom line, to a mathematical model? The answer is that not all models are created equal. Indeed, mathematical models, as a base for closed loop control applications, tend to attract controversy because the processes that are modelled are rapidly changing and not known in their full complexity, while their online measurements are scarce or unreliable. All of this can easily give modelling processes a bad name, especially when they are generated from 'data mining' algorithms using meaningless historical data.

However, when modelling technology is teamed with plant floor experience to fully exploit the available process knowledge, the results are quite different. ABB's engineers use a three step methodology to guarantee success. Firstly, models are created so that the energy and mass balances are correctly represented. Secondly, the models, or rather parts thereof, are adapted online to match the process conditions. This does not happen in an *ad hoc* manner, but with carefully tailored algorithms that use the available information to its maximum. Last but not least, these models are deployed in the transparent and graphically configurable environment of EO to allow for rapid commissioning and reconfiguration of changing plant structure. Now these models are in a position to bring an enormous amount of value to today's businesses.

MPC and MLD

Before going any further, a very short explanation of the modelling technology demonstrated in this article will be helpful.

MPC is a multivariable control technique. It is based on the 'receding horizon' principle where the controller uses a process model to predict process responses to actuator moves and thus is able to calculate those moves that are the best for the process evolution over a relevant period of time. The MPC controller then sends this set of independent variable moves to the corresponding regulatory (PID) controller to be implemented in the process as setpoints.

Notice, in particular, how a sequence of optimum actions are calculated, while incorporating the dynamics of the system. MPC technology can – unlike many other controller strategies – explicitly take account of lag and delay times in the model. Moreover, it can optimally handle process and actuator constraints.

As systems that use both logical and dynamic aspects need to be dealt with, the MLD framework establishes a link between both demands. MLD's best feature is its ability to model logical parts of processes, for example on/off switches, discrete mechanisms, combinational and sequential networks, along with a heuristic knowledge of a plant's operation. This makes it a powerful tool for modelling discrete-time hybrid systems.

MPC and MLD are well suited to working together and that makes them extremely powerful. The most obvious advantage of this blend is to combine the benefits of MPC's predictive and constraints handling features with MLD's ability to model the logical and continuous characteristics of the process. It follows, therefore, that MPC and MLD used together in EO, can establish an optimisation problem with explicit links between the discrete worlds of equipment availability and customer demands, and the continuous worlds of temperatures, pressures and concentrations usual in chemical processes.

In order to appreciate the full power that EO's use of MPC and MLD brings, the following three case studies, in which the modelling technology is successfully in use, are provided.

Alternative fuels at Lägerdorf

One man's waste is another man's alternative fuel. As is widely known, there are many benefits to be gained from the burning of alternative fuels, but their use is not always straightforward. Calorific and burnability variations can make them tricky to handle in the cement manufacturing process. Combine these variations with the rest of the process variables, and using alternative fuels, while maintaining product consistency and quality, can be demanding and challenging.

This was the starting point at Holcim's Lägerdorf plant. The management wanted to increase alternative fuel utilisation, get closer to the optimal calcination conditions, and reduce the risk of process disruption. The plant uses a large number of alternative fuel materials that have a high variability of calorific values, but are difficult to transport and dose. Further, material lab samples are often not representative and temperature measurements alone do not allow the identification of which component generated a change in the fuel mix properties.

These were the motivations for Holcim to seek a solution that would help improve the conditions at the plant. As part of a series of well thought through steps, such as changes in the precalciner geometry to increase the material residence times, Holcim decided to use Advanced Process Control to reach the ambitiously set goal of a coal-free precalciner.

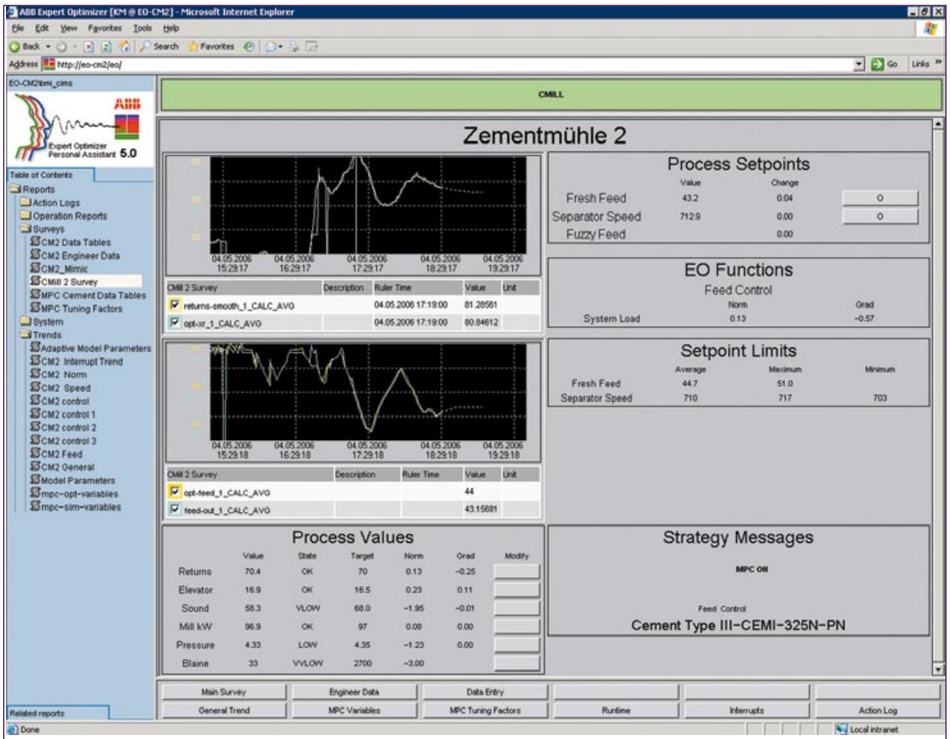

Figure 3. Mill start up shown in EO's personal assistant display.

Figure 4. Buzzi Unicem's Guidonia plant.

Solution

ABB installed their new model-based Precalciner Temperature (PCT) control solution as part of their EO solution. PCT was installed on the calciner at the plant in August 2006. The technologies used are MPC and MLD systems.

PCT has successfully overcome the plant's problems by applying an MPC+MLD scheme that includes a unique combination of adaptive first principle mathematical models. The controller detects the gap between what is measured and what is expected, to derive appropriate corrective actions. In order to mitigate disturbances in the process conditions, the system takes into account factors such as material transport delays, the system's thermal inertia, flame conditions and the combustion air supply etc. Additionally, accurate modelling of the calcination reaction as a function of the precalciner temperature plays a central role in the scheme. Peculiarities associated with the transport system have also been considered.

Thanks to the unique features of the MPC+MLD technique, PCT is able to anticipate the effects of events and take optimal corrective actions both in advance and afterwards. The resulting benefit is that process condition deviations have been reduced without any modifications to the plant hardware. Thanks to the PCT solution, occasional temperature excursions have been reduced substantially. Further, it has been possible to bring the average precalciner temperature towards optimal values and to reduce the variability of this important parameter by more than 50%. As a result of implementing this solution, the plant has reduced the risk of cyclone blockages and thus of costly disruptions in production.

Varied material sources at Untervaz

Holcim's Untervaz plant wanted to reduce raw mix quality variability in terms of alumina ratio (AR) and silica ratio (SR), reduce the associated material costs and increase the useful lifetime of the quarry. This would also allow them to have better process parameters in the kiln, getting closer to the clinker quality targets, increasing production and reducing the risk of process disruptions. The plant blends up to seven different material sources to create its raw mix. As usual, most of these materials have a high variability in chemical composition and are difficult to transport and dose. Furthermore, although a fully automatic laboratory is installed, material samples are often not representative and generate a measurement delay of up to 30 minutes. This mixture of constraints creates a difficult multivariable optimisation problem with delays that are difficult, if not impossible, to handle properly under manual control. These were the motivations for seeking a solution to help them improve the conditions at the plant.

Solution

In March 2007, ABB extended the plant's existing EO solutions for kiln and cement mills with their new model-based Raw Mix Preparation (RMP). RMP was installed to control the seven feeders of the raw mill.

RMP has successfully overcome the challenges that faced the plant by applying an MPC+MLD scheme that includes a unique combination of adaptive first principle mathematical models. The controller detects the gap between what is measured and what is expected, to adapt the model. In order to mitigate quality deviations, the system takes into account factors, including material, chemical and physical properties, transport delays, grinding, and conveyor belt system equipment. Additionally, accurate modelling of the blending process taking place in the mill plays a central role in the scheme.

Using the MPC+MLD technique, the strategy is able to anticipate the effects of events and take optimal corrective actions both in advance and afterwards. The documented benefits are that AR and SR variability in the raw mix has been reduced by almost 20% without any modifications to the plant hardware. The extension of the EO solution to include RMP ensures that raw mill and clinker quality targets are achieved. The degree of automation has been improved. Further, the operation of the blending bed has been significantly simplified because, with RMP, it is no longer necessary to start and end the blending bed with different programs.

Energy consumption at Guidonia

Buzzi Unicem wanted a solution for its Guidonia plant that would increase the productivity of its three cement mills, particularly with respect to product quality, startup time and specific energy consumption.

Long startup times and multiple process bottlenecks, such as elevator power, mill pressure, mill exit temperature and sound, made the problem additionally challenging. Furthermore, the signals are noisy and occasionally unreliable, and no direct measurement of the returns was available. Five to six cement types per mill had to be taken into account.

Solution

ABB installed the MPC-based EO on the three mills at the plant in December 2006. The aim of the controllers was to vary the fresh feed and separator speed in order to stabilise the system at maximum production within the process bottlenecks. The setpoints are chosen automatically in a way that ensures the product quality constraints are met at the maximum production rate. These setpoints are product-dependent and can be modified as quality results are made available by the laboratory.

The programme comprises models for mill load, elevator function, separator and returns dynamics. Time delays and lags are explicitly taken into account, while a combination of hard and soft constraints on these variables were imposed to achieve robustness and optimality. The model is self-adaptive, i.e. the parameters of the model are automatically updated to minimise model versus process mismatch. Here process knowledge is used explicitly to better exploit the information available.

Despite the large number of mills and cement types, the whole project was carried out in the record time of less than 2 months. The results were better grinding process parameters, operating more closely to the process constraints but never violating process bottlenecks, shorter startup times and the relief of operators for more demanding tasks. Analysis of the base line data shows that despite the demanding conditions the specific energy consumption has been reduced by 5% while meeting the constraints on product quality. EO run times are near 100%.

Conclusion

Deciding to commit to a new technology, especially one that is not familiar or comfortable, requires time, energy and courage. The authors hope that they have shown how the mathematical modelling techniques of MPC and MLD, when used wisely, transparently, and together with clear process knowledge, can bring enormous and ongoing benefits to the cement manufacturer. The modelling techniques used in EO are helping plants around the world to start using or increase their use of alternative fuels, maximise production, reduce energy consumption, and benefit from a host of other improvements as described in this article.