Maximization versus environmental compliance

Increase use of alternative fuels with no risk for quality and environment

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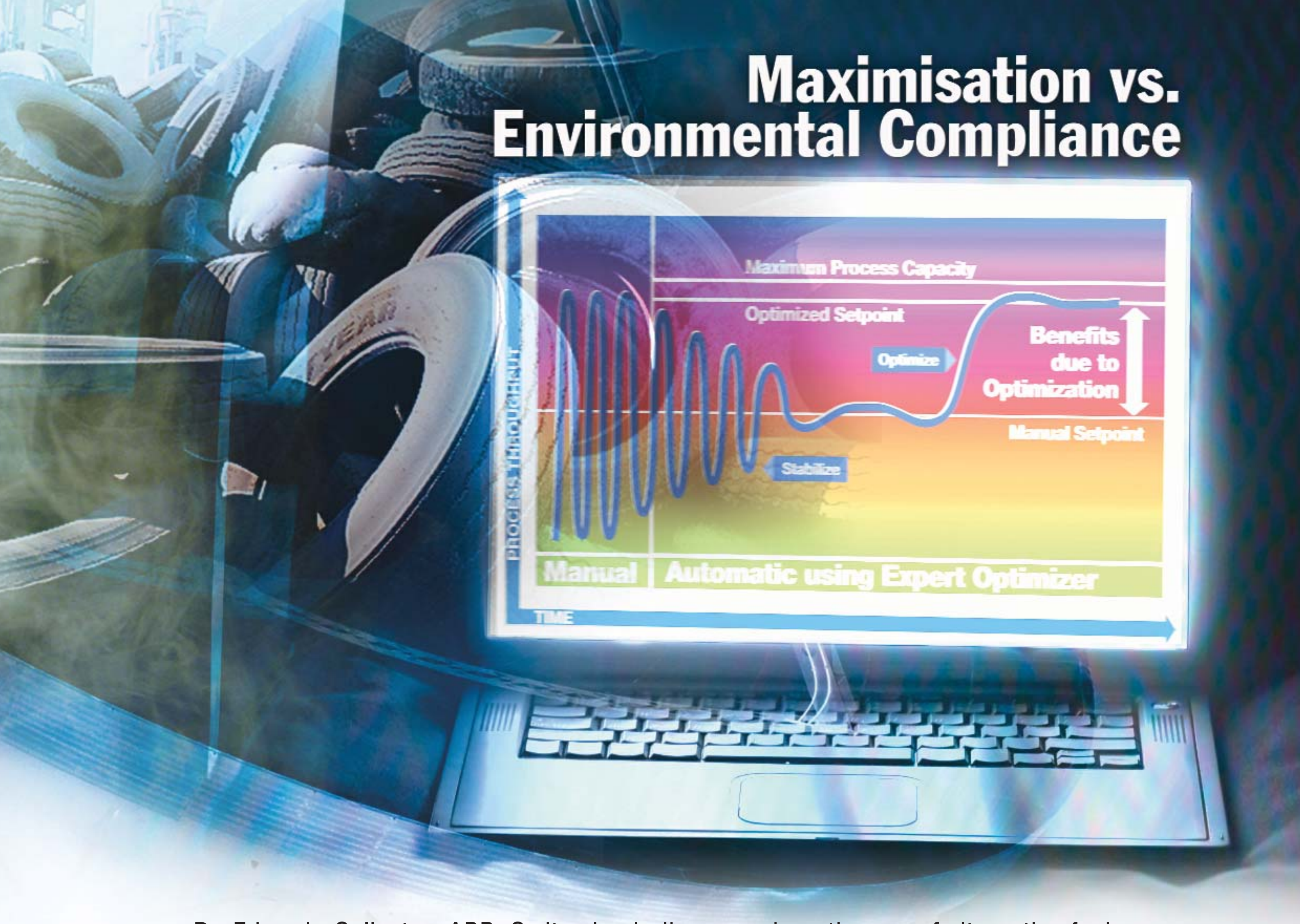
ABB



Maximisation vs. Environmental Compliance

Dr. Eduardo Gallestey, ABB, Switzerland, discusses how the use of alternative fuels can be maximised while ensuring compliance with process and environmental constraints.

Introduction

Whole tyres have been banned from landfill in the European Union since July 2003, and from July 2006, the landfilling of shredded tyres will also be banned. As tyres have a high energy value (similar to coal), sending them to landfill completes an unsustainable cycle of wasting material and energy resources.

The alternative

The use of tyres as an alternative fuel (AF) in cement manufacturing is growing alongside the use of, for example, solvents, plastics, petcoke and biomass. With approximately one-fifth of the cost of manufacturing cement accounted for by the cost of energy, AFs offer manufacturers a way to significantly reduce production costs and increase profitability. As a positive side effect, the potential of a resource is realised in a sustainable way. In such a win-win situation, why is there not greater use of AFs?

Highs and lows

Burning AFs requires expert control of the process to ensure optimal conditions for the manufacture of the product. To produce a quality product, stable manufacturing process conditions that avoid peaks and troughs are necessary. Environmental agencies specify stringent monitoring, control and reporting policies. Kilns must not become unstable through changes in calorific values of the fuels. It is in this context that advanced process control and optimisation systems are helping the modern cement industry in its quest for higher profitability.

Intelligent control

ABB's Expert Optimizer solution for AF control is built on years of LINKman experience using modern control techniques. The system ensures that best practice is

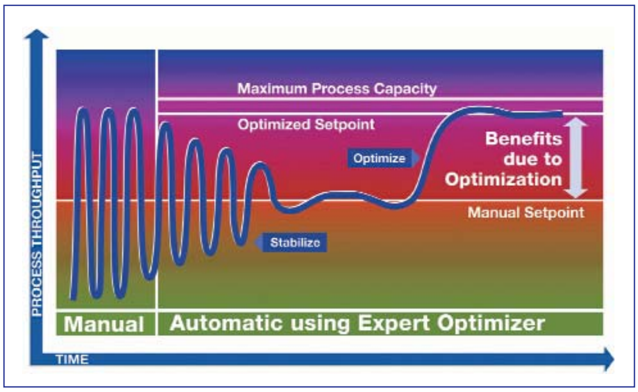


Figure 1. Illustration of the mechanism by which advanced process control produces benefits.

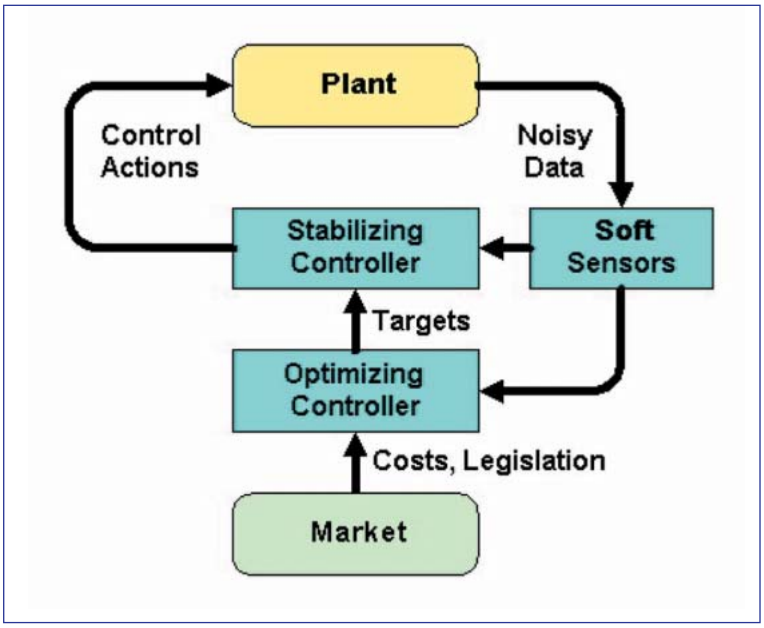


Figure 2. Control structure.

used at all times, avoiding shift-to-shift variations while reducing operating costs without destabilising the process. The effectiveness of ABB's solution to reduce NO_x emissions has been recognised by an environmental award presented by the British government. The solution uses a mix of the best properties of 'artificial intelligence' such as fuzzy logic, neural networks, and 'model based control'. This mix represents the method of choice for industrial practice for the design of robust advanced process control optimisation systems. These mathematical tools are complemented with process knowledge and project experience to generate plant 'autopilots', able to drive an installation at its best for long periods of time. These tools have been brought together into one single real-time software environment that allows for fast control strategy development and easy design of the human machine interfaces (HMIs).

The benefits of this system are obtained through the following mechanism:

- By enabling the consistent application of the best control policies, a strong reduction in variance of the key process parameters is achieved.
- This allows the process targets to be driven closer to the limits.
- This results in greater economical performance and better asset utilisation.

To control and optimise industrial equipment such as kilns, mills and furnaces, model based control can be used as control synthesis technology. Here, the equipment or plant under consideration should be represented as a system evolving according to continuous dynamics, discrete dynamics and logical rules. In addition, the success of the implementation relies heavily on the use of fuzzy control and neural networks. These technologies provide robust process indicators or so called 'soft sensors'. These process dependent rules, which are designed or 'trained' for each specific application, use all the available information to produce reliable signals of variables that are difficult or impossible to measure at high sampling rates. In particular, they detect faulty signals and adapt to the new situation automatically.

Control technology elements

Neuro-fuzzy techniques and model based control are well known paradigms for control design, while mixed logical dynamic systems represent a relatively new method created in the 1990s.

Neuro-fuzzy technology

One of the main strengths of control design technology is the integration of artificial intelligence tools for the development of the application. Indeed, fuzzy logic inference systems incorporate human knowledge to make and implement effective decisions during the process, while neural networks are used to understand relationships between key process variables. Moreover, they adapt themselves to cope with changing process conditions. The integration of these complementary control techniques, coupled with extensive process experience and expertise, allows the engineering of powerful robust solutions, thus providing substantial financial benefits to the factory for extended periods of time.

Neuro-fuzzy techniques, so called 'soft sensors', are applied when it is impossible or difficult to physically measure a process variable that is important for the control and optimisation of the process. Examples include predicting particle size average as a function of the mill state and history in mineral processing; the construction of free lime soft sensors for cement and lime kiln control; and assessing the temperature distribution of a kiln or furnaces in a continuous manner.

Soft sensors also provide a backup for critical process measurement devices. In case of failure of critical process measurements, they provide the control strategy with a usable estimate of the missing measurement, allowing the control and optimising system to continue to work to its objectives while the failed device is repaired.

Finally, it is possible to develop numerous neuro-fuzzy applications to predict the same magnitude using different process variables as inputs. This allows different neuro-fuzzy predictions to compete for the right to be used in the developed control and optimising strategy. It is a powerful tool and ensures that the best prediction is always used.

Forecasting the future

Model based control computes a sequence of future optimal control actions chosen according to a prediction of the (short to medium term) evolution of the system. Model based control is often used for control and optimisation of industrial processes. For example, in power generation, algorithms compute optimal setpoints for temperatures, pressures and fuel feed rates during the startups and shutdowns of large generating units. Similarly, it is one of the building blocks of today's state of the art process industry.

Managing operational constraints

Using mathematical models in a mixed logical dynamic (MLD) system is natural for several reasons. Firstly, it includes continuous and boolean states and inputs. Secondly, it contains the description of all logical relationships of the process. Moreover, it allows the inclusion of piecewise linear relationships in the modelling with the sake of approximation of non-linear relationships.

This approach to model generation greatly increases modelling possibilities. In particular, it allows for the representation of processes as diverse as turning on/off parts of the plant, different types of startup and shutdown procedures, as well as the introduction of complex operating constraints, such as switching between different operating conditions. Due to the integer variables, the scheme is formulated as a mixed integer linear or mixed integer quadratic program that can be solved efficiently. Although relatively new, MLD technology has been used successfully in a number of industrial applications.

Putting the pieces together

For control and optimisation of a given plant, ABB proposes a control scheme, which:

- Uses neuro-fuzzy techniques to filter and pre-process data and measurements creating reliable real-time signals.
- Uses neuro-fuzzy and/or model based control to stabilise the process on desired process targets.
- Uses MLD ideas to generate optimal reference trajectories. This part of the algorithm is driven by optimisation functionals related to economic performance.

The solution architecture is shown in Figure 2.

Kiln optimisation

ABB has developed state-of-the-art control strategies that aim to stabilise and optimise kiln operation. Traditionally, these were based on neural networks and fuzzy control. Its reference record indicates a strong and satisfactory performance. However, as there is a strong need for tools that offer optimal management of the alternative and traditional fuels involved in the kiln process, the system is being enhanced with an AF Optimisation Module based on the control design methodology described above.

The primary activity is to use the data gathered by the information management systems (equipment, process, market, laboratory) to calculate online the lowest cost fuel mix that satisfies the process and business constraints. These constraints, which are numerous, typically include:

- Heat balance.
- Excess oxygen level.
- Clinker chemistry.
- Volatiles concentration (SO_3,Cl_2).
- Emission limits (SO_x, NO_x, CO_x, 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.

The basic element is a dedicated kiln model in the MLD framework. The mathematical model can estimate cooler, flame, burning zone, back end and preheater temperatures, kiln energy requirements, emission and volatiles levels, etc. The model parameters are tuned using a combination of neural networks

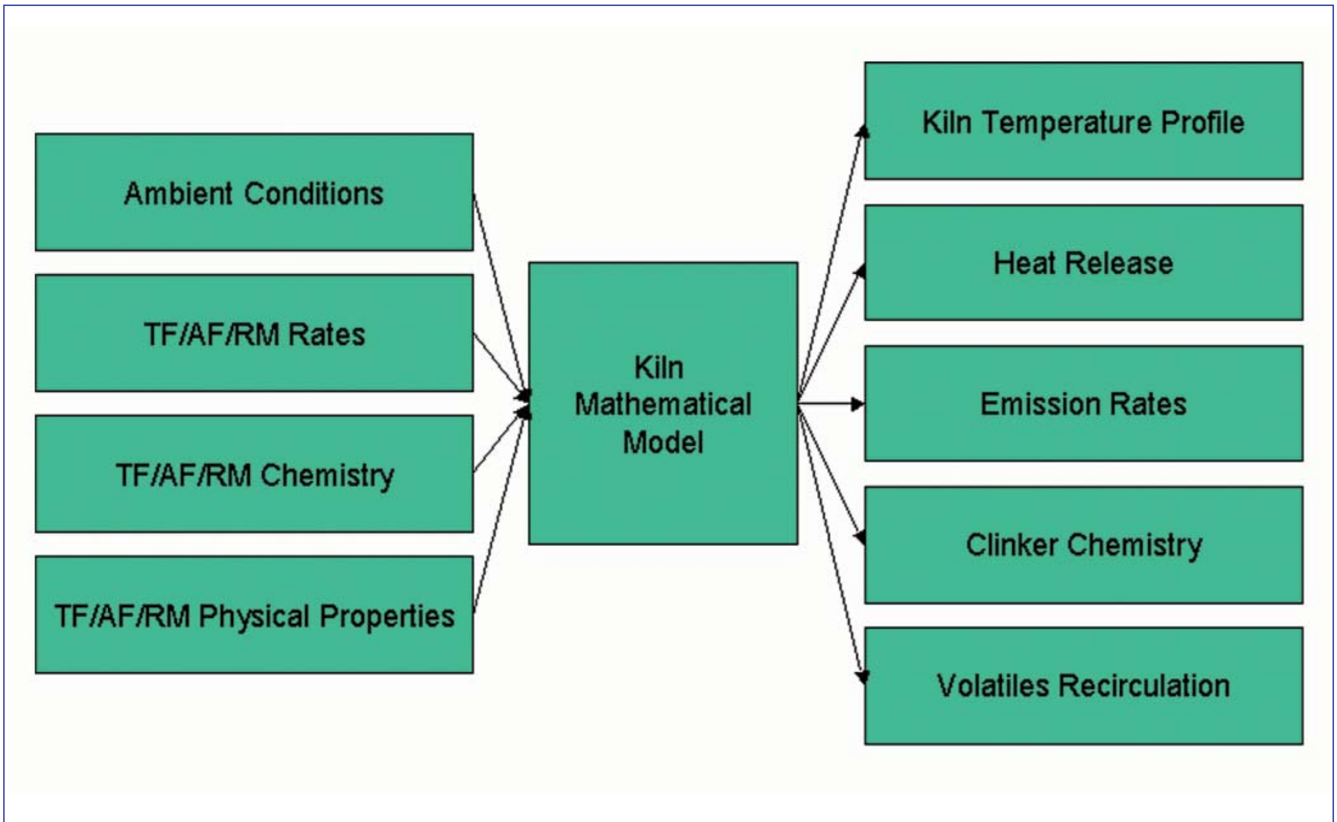


Figure 3. Kiln model inputs and outputs.

and Kalman filtering techniques. The optimisation algorithms are able to cope with hard and soft constraints, which enhances the robustness and reliability of the optimisation process.

The problem data is updated continuously during implementation. At constant sampling times, computations are executed and new process targets and fuel setpoints are generated. Between sampling times, the 'standard' strategy guarantees process stability, allowing economically optimal reactions to changing conditions in fuel, waste and raw meal quality, and strict satisfaction of environmental, contractual and technical constraints.

A pilot implementation is being tested at a Swiss cement plant. ABB expects improved annual plant operating profits of several thousands of dollars due to continuous optimal selection of operational parameters. These ideas are also being applied in the metallurgical industry, and systems for optimal control and scheduling of mineral ore refineries are being tested with promising results.

Conclusion

Efficient and flexible software architectures, together with more capable mathematical methods, offer the opportunity of achieving new levels of performance and environmental compliance. Intelligent devices communicate with one another, interchanging mission critical information, and make available quality information, process data, market boundary conditions, maintenance plans and others in a consistent and correct form. This enables plants operations to be coordinated and optimised. Real-time true optimisation is the result, leading to:

- Precise material balancing.
- Throughput as dictated by the market.
- Lower energy consumption.
- Better and more stable quality.
- Lower maintenance costs.

Advanced control methodology is the key to achieving these goals because it is the vital decision making element.

Appendix

By 2020 the OECD estimates that 45% more waste will be generated compared with 1995; in the UK alone, waste tyres are expected to increase by 50%. There is the potential to boost margins by cutting energy costs through the maximum use of AFs. Generally, cement companies are working towards yearly thermal substitution rate targets. Despite variations in the costs of AFs, if only 1% of thermal energy requirements are supplied by AFs, with current coal prices, this constitutes a US$63 000 annual saving for a typical cement plant. A more typical thermal energy replacement rate is 20%, which would mean an annual saving of US$1.2 million. Robust advanced process control and optimisation systems exist now that are ready to help the modern cement industry profit from the vast energy resources available in the form of AFs. This eliminates the need to choose between saving the planet and making a profit; the concepts are no longer mutually exclusive. ◆

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