Advanced process control for the cement industry
Why use advanced process control?

Advanced process control from FLSmidth ensures that cement plants perform better, resulting in increased stability and higher profitability.

Direct Benefits
• Up to 8% higher production
• Up to 6% lower fuel/energy consumption
• Up to 30% lower standard deviation of quality
• Payback of investment in less than a year (depending on specific applications)

Indirect Benefits
• Long-term stability
• Reduced equipment wear
• Minimized downtime
• Reduced maintenance costs

When a cement company wants to get the most out of its cement plant, Expert Control and Supervision (ECS) is the key.

FLSmidth’s ECS/ProcessExpert provides advanced process control and optimization for cement plants, so they can achieve maximum efficiency and higher profitability.

ECS/ProcessExpert stabilizes the plant, optimizes the production, manages and corrects process disruptions and minimizes wear on the plant’s equipment – all to ensure optimum plant performance. By improving equipment availability and utilization, the system helps reduce operational and maintenance costs.

Using a sophisticated toolbox and specialized application modules, ECS/ProcessExpert continuously performs complex analyses of a plant’s process conditions. This enables it to make adjustments to the process more frequently and reliably than a human operator can. Installed on a standard PC, the system has an easy-to-interpret graphical interface and advanced alarm and trend capabilities that are easy to use and manage – and it’s compatible with most other plant control systems.

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History
For 40 years, FLSmidth has been a pioneer in high-level expert control systems for cement applications. ECS/ProcessExpert is a development of ECS/FuzzyExpert, which was the first expert system engineering platform in the cement industry. It is based on the latest developments within proven technologies, such as Fuzzy Logic and Model-based Predictive Control. The control strategies in ECS/ProcessExpert are based on four decades of experience in cement control and optimization projects.

FLSmidth – the process knowledge experts
FLSmidth’s international team of process experts designs solutions specifically for cement applications. With more than 40 years of plant automation experience, FLSmidth has installed over 700 control systems and 450 laboratory systems – and understands the needs of today’s cement plants.

FLSmidth is a world leader in building and maintaining cement plants, and that first-hand experience plays an important role when developing innovative automation solutions that enhance the production capabilities of customers’ plants.
Kiln & cooler application

Control challenges
Controlling a cement kiln has always been a challenging task for cement plant operators. These days, a computer-based pyro control system is not merely nice to have, it is a practical necessity. Both the inherent complexity of the pyro process and the far-reaching consequences of off-spec clinker, faulty operating conditions and production shutdowns make an automated control system indispensable. Kiln process control is divided into three control strategies; normal, optimization and upset control:

Normal control
ECS/ProcessExpert initially operates in normal control mode, where the process is stabilized. Stabilization is a prerequisite for optimization control and is thus a key element of the overall control strategy. The normal control strategy stabilizes the preheater, kiln and cooler, using a range of calculated key performance indices. These indices include the Burning Zone Temperature Index, Kiln Operation Stability Index and the Kiln Heat Consumption Index.

Corrective actions made by ECS/ProcessExpert typically include a combination of changes to fuel injection, kiln feed and speed, as well as fan speeds. The result is stable temperature control in the calciner, stable filling degree in the kiln, stable cooler operation as well as consistent cinder quality.

Optimization control
Once the process has been stabilized, ECS/ProcessExpert will seek to optimize the process by operating as close as possible to the limits. In optimization control, free lime is kept closely on target, permitting an increase in the free lime target.

In addition, ECS/ProcessExpert also monitors the lime saturation factor (LSF) in the kiln feed and automatically adjusts the free lime target, to avoid over burning of cinder. ECS/ProcessExpert consequently ensures lower fuel consumption and minimizes the risk of off-spec cinder. The kiln and cooler can be further optimized using a multi-fuel add-on application (see page 6 for more information).

Upset and customized control
In the event of upset conditions such as fall of coating in the kiln, ECS/ProcessExpert reduces kiln feed and speed, while continuously monitoring kiln conditions to ensure smooth and fast recovery. A raw mill stoppage is another example of an upset condition handled by ECS/ProcessExpert, whereby gas pressure changes in the process are handled by changing the speed of the ID and EP fans. Other examples of upset conditions include high preheater exit CO, cooler bed build up and coal mill stoppage affecting the coal feed to the kiln.

ECS/ProcessExpert is easily customized to plant specific requirements, such as emissions control using ammonia injection.

Parameters controlled
- Kiln feed, speed and fuel
- Calciner fuel
- ID fan speed
- Cooler grate and fan speed

Parameters monitored
- Kiln inlet gas analyzer measurements
- Kiln temperatures and pressure
- Kiln torque
- Cooler pressure and temperatures

Benefits
- Production increased by up to 4%
- Reduced cyclone blockages and kiln ring formations
- Consistent quality with a reduction in standard deviation by up to 30%
- More stable operation

Calculate your own benefits online using the ECS/ProcessExpert benefit calculator at www.flsmidth.com/pxp
Multi-fuel application

Control challenges
With increased focus on cost reductions, many cement plants have started using alternative fuels for kiln and/or calciner firing. This has created more challenges for the operation of a kiln because of the different characteristics of different alternative fuels such as calorific value, moisture content and chemical composition. ECS/ProcessExpert ensures successful management of alternative fuels without compromising stability or quality.

Optimization control
The customizable multi-fuel application ensures the best possible mix of available fuels based on costs, heat value and chemistry implications. The application is designed to deliver a consistent total heat value at the lowest possible cost.

Benefits
• Better transition during loss of fuel, resulting in a stable kiln process
• Higher utilization of alternative fuels
• Any number of alternative fuels handled
• Better compliance with environmental restrictions
• Investment payback in less than one year

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Higher focus on cost reduction using alternative fuels causes disturbances in the pyro process, where operators need support from advanced process control systems.

This is achieved by a predictive technique to handle fuel feeder constants and dynamics, while minimizing combustion disturbances in the kiln.

The multi-fuel application is best implemented as an integrated add-on to a kiln and cooler application, but can also be installed as a stand-alone application.

The multi-fuel application may be integrated with an emission monitoring system such as ECS/StackGuide to incorporate emission data, ensuring that environmental limits are not exceeded.

Upset control
Burning alternative fuels may result in sudden drops of one or more fuels. ECS/ProcessExpert handles this condition by quickly compensating with other fuels, ensuring a continuous and stable process.

Parameters controlled
• Ratio between fuels

Parameters monitored
• Fuel costs
• Fuel feeder or environmental limitations
• Current feed rate of different fuels
• Chemical analysis of fuels
• NOx and burning zone temperatures
• Emissions data from optional emissions monitoring system (ECS/StackGuide)
Ball mill application

Ball mill grinding is a highly energy consuming process and the ECS/ProcessExpert Ball mill application is built to meet the increasing demand for maximum production with minimum power consumption while minimizing variations in quality.

Benefits
- Up to 6% increase in production
- Up to 4% reduction in ball mill specific power consumption
- Up to 30% reduction in quality variations
- Minimal product change-over time between recipes

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Control challenges
To obtain lowest possible power consumption, maximum production and lowest possible quality variation, a conventional control solution with PID loops is insufficient. Process delays (for example fineness analysis delay, material transportation) cannot be handled well by PID's. Furthermore, the process contains internal couplings. For example, the separator speed not only impacts the fineness, but also the mill filling level through the reject flow. Therefore, a change in one of the PID loops causes disturbance in the other PID loop. The two PID loops are consequently often in conflict to reach their own objective. This lack of coordinated action causes undesired disturbances and operation inefficiency. ECS/ProcessExpert aims to achieve the best possible grinding efficiency through an advanced Multi-Input Multi-Output (MIMO) control strategy using a Model-based Predictive Control (MPC) technique.

Normal control
In a conventional closed circuit grinding plant, separator speed and fresh feed are the main control parameters. The MPC controller frequently calculates new set points for the two parameters. The calculation is based on minimizing a so-called “cost-function” meaning minimum deviation from production targets and minimum changes of separator speed and fresh feed. The weight factors for targets are used to prioritize between objectives. The result is stable operation, reduced energy consumption and increased production.

Optimization control
The ball mill application automatically adjusts fresh feed, depending on clinker grindability, while ensuring the desired blaine or fineness. This ensures that the best throughput and quality is maintained for a given recipe.

Upset control
In the event of mill jamming, the application will ensure rapid action to achieve optimum recovery, by reducing the feed and monitoring the mill until normal conditions are restored. If a process measurement is declared invalid (for example due to hardware failure), the controller will automatically replace the measurements with second priority signals or estimated values in order to continue operations. This temporary measurement replacement can also be selected manually by the operator if a device is temporarily taken out for maintenance.

Automatic recipe handling
For cement grinding processes with different types of cement, efficient changeover between products is crucial in product optimization. ECS/ProcessExpert includes an efficient system for definition and configuration of cement recipes. The application enables the operator to change production by merely selecting a recipe number. The automatic procedure ensures minimum changeover time.

Parameters controlled
- Feed and fineness control by fresh feed and separator speed
- Feeder ratio control for quality
- Mill draft
- Water flow
- On-line process state estimation

Parameters monitored
- Product quality such as Blaine or online particle size analyzer, SO₃, LOI.
- Separator and fan speed
- Fresh and reject feed
- Mill Folaphone or elevator power
- Draft and temperature
- Feeder response to a given setpoint

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Control diagram:

- **Manipulated parameters**: Fresh feed, separator speed, elevator load, mill air, mill power.
- **Status measurements**: Blaine, (on-line) Particle sizing, SO₃, LOI.
- **Manipulated parameters (if available)**: Raw materials, product flow, separator speed, reject flow, elevator load, water inlet/outlet.
**Vertical roller mill application**

**Vertical roller mills** are increasingly being used in the cement industry due to their higher efficiency. Fully automatic control of the vertical mill will improve the operational capabilities and efficiency of the mill.

**Benefits**
- Up to 6% increase in production
- Up to 4% reduction in specific power consumption
- Up to 30% reduction in quality variations
- Tight control of vibrations to avoid mill shutdowns
- Minimal product change-over time between recipes
- Simplified mill start-up

**Calculate your own benefits** online using the ECS/ProcessExpert benefit calculator at www.flsmidth.com/pxp

**Control challenges**
Among the operational challenges of a vertical roller mill are the fast dynamics of the process. Compared to ball mills with dynamics changing in 15-20 minutes, vertical roller mills have dynamics changing in 2-4 minutes. The fast dynamics necessitate even closer attention to the process conditions and taking corrective action in time.

Other challenges include changes in the grindability of material and water injections causing mill vibrations which may result in mill shutdown.

**Optimization control**
An advanced mill controller continuously monitors and adjusts the mill to comply with the operational targets. When the mill reaches a stable level of operation and the targets are fulfilled, a high-level target optimization procedure calculates a new set of optimum targets.

The target optimization module continuously seeks to maximize the production within the allowed operational limits. This optimization ensures that the initial recipe targets are adjusted according to the given conditions of the process such as raw material grindability.

The typical manipulated setpoints of a vertical roller mill are separator speed, fresh feed and mill fan. However, the selection of process measurements, control variables and setpoints is customized to the given process configuration of the mill.

**Predictive process control**
Based on a mathematical multi-input multi-output model of the process, which describes delays and dynamics, future conditions of the process are predicted and optimum set points to reach the targets are planned and implemented. The planned setpoints are continuously updated due to the differences between the process variables predicted and measured.

The setpoint calculation is based on a so-called optimization cost function over the receding prediction horizon, which seeks to minimize deviation from production targets.

**Upset control**
In the event of mill vibrations, ECS/ProcessExpert immediately takes corrective action by reducing mill feed, resulting in optimum bed thickness. If a process measurement is declined invalid (for example due to hardware failure), the controller will automatically replace the measurements with second priority signals or estimated values, in order to continue operations.

This temporary measurement replacement can also be selected manually by the operator if a device is temporarily taken out for maintenance.

**Mill auto-start**
A novel part of the ECS/ProcessExpert control strategy for vertical roller mills is the auto-start function. A smooth and controlled start-up is essential for mills to rapidly achieve process stability and to minimize machinery wear. To accomplish this, the system transmits the start-up commands to the mill control system in the proper sequence, while manipulating and stabilizing key controlled variables, such as feed, separator speed and fan damper position. Once the mill is stabilized, the automatic start-up finishes and the normal strategy takes control of the mill.

The main benefits coming from this module are:
- Simplified and consistent mill start-up for operators
- Reduced mill start-up time

**Parameter summary**
- Feed and fineness control by fresh feed and separator speed
- Feeder ratio control for quality
- Mill draft
- Water flow
- On-line process state estimation

**Parameters monitored**
- Product quality such as Blaine or online particle size analyzer, SO_3, LOI.
- Separator and fan speed
- Fresh and reject feed
- Mill bed level thickness, power and differential pressure
- Draft and temperature
- Feeder response to a given setpoint

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Optimizing cement processes with cutting-edge technology

How does it work?
- **Measurement validation**: All the parameters are validated before being used inside the system.
- **KPIs**: Provides visualization of the process department status so operators can monitor the system and generate reports.
- **Online testing**: The controller behaviour can be tested in an on-line environment using the so-called “Monitor” function. The behaviour of all objects in the controller can be monitored at different levels of detail for easy troubleshooting of the controller.

For a realistic test of the controller, the designer will often use the built-in PLC communication drivers of ECS/ProcessExpert to perform real-time test with the current process values.

Easy integration with existing control systems
ECS/ProcessExpert has specific I/O drivers for communicating to PLC’s like:
- Rockwell Automation (PLC 5/ControlLogix)
- Siemens (S5/S7)
- Schneider

In addition, ECS/ProcessExpert supports industry standard OPC UA, enabling integration with most existing control systems.

Control system features
ECS/ProcessExpert has built-in control system features such as long-term historian with trending, alarm and event management as well as a sophisticated HMI for graphical process representation.

Custom design
- Process customized "abnormal situation management"
- Process customized operation objective
- Priority management of the objectives

Simulated testing
For control system designers in the cement industry, ECS/ProcessExpert can be seamlessly integrated with the real-time cement process simulator ECS/CEMulator. Using this simulator as a virtual plant, various process conditions can be triggered to test the controller behaviour, before the final implementation takes place. In fact, all new cement-oriented automation developments from FLSmidth are tested on the ECS/CEMulator for various difficult conditions, before the solution is ready for its first site test.

Measurement replacement
As another advantage of on-line estimation, if a process measurement is declared invalid (for example due to hardware failure), the controller will automatically replace the measurements with the estimated values in order to continue operations. This temporary measurement replacement can also be selected manually by the operator if a device is temporarily taken out for maintenance.

The technologies
- **MPC** (Model Predictive Control): A multi-input, multi-output controller that handles process dynamics and interactions. MPC performs optimization calculations to drive the measurements to predefined targets or ensure they remain within a set band limit.
- **Fuzzy logic**: Delivers rule-based, intelligent fuzzy control
- **Kalman filter**: A soft sensor that generates readings where signals are unavailable or unreliable
Eight steps to a successful process control solution

For equipment to operate reliably and efficiently, it needs to be implemented correctly. FLSmidth’s 8 step implementation model provides the professional support necessary to ensure the system meets all requirements and expectations.

The moment FLSmidth begins an advanced process control project, a dedicated project manager is assigned to coordinate all activities over the lifetime of the plant. As the main contact for the plant, the project manager is involved in the implementation process right from the start, providing the plant with a clear and detailed project plan that contains all the phases, key deadlines, project meetings and more.

Working with the FLSmidth 8 step model, the project manager will ensure the advanced process control system delivers reliable performance as quickly and as smoothly as possible. The model also ensures that the system is maintained correctly after implementation – so it continues to generate top performance for years to come.

Long-term support for long-term success
To ensure the lasting performance of the ECS/ProcessExpert control system, FLSmidth offers to continue to evaluate the system and its processes after commissioning is complete.

ECS/ProcessExpert continually gathers plant data and sends it to the processing centre at FLSmidth’s headquarters. A detailed KPI monitoring report is then generated, and if this indicates that the plant is not performing as efficiently as possible, FLSmidth in collaboration with the plant management can make adjustments remotely or onsite. However, if the plant prefers to do the data analysis in-house, FLSmidth will send all the necessary data directly to the plant.

FLSmidth’s 8 step implementation process
1. Project planning: An FLSmidth project manager prepares a comprehensive, start-to-finish strategy
2. Client process interviews: FLSmidth technicians visit the site to determine the plant’s control needs.
3. Application design and process strategy review: FLSmidth designs the right solution based on the site visit and interviews.
4. Primary system commissioning: Commissioning is completed and the system is implemented and monitored onsite.
5. Operator and super-user training: FLSmidth representatives train operators in the new system.
6. Remote monitoring and fine-tuning: As the final part of the commissioning phase, FLSmidth makes small adjustments to the system either remotely or onsite.
7. Follow-up visit: After commissioning is complete, FLSmidth visits the site and transitions to the service phase of the agreement.
8. Establishing long-term support: FLSmidth continues to monitor the system and analyze KPI data. FLSmidth continues to monitor the system and analyze KPI data, helping to support the system and ensure that the plant runs as efficiently as possible.

Customer services and support
FLSmidth offers a wide range of services to help customers ensure the long-term success of their ECS/ProcessExpert investment by boosting the system’s efficiency to improve performance, utilization and productivity.

With FLSmidth, great service and support doesn’t end when a plant’s automation system is fully commissioned. Even a highly reliable control system benefits from strong post commissioning support.

FLSmidth provides long-term support and remote assistance to help ensure efficient operations throughout the lifetime of the plant.

FLSmidth’s remote services
• 24-hour hotline: Telephone support for critical issues anytime.
• Remote troubleshooting: Online support for technical issues.
• Remote engineering: Specialist assistance for minor engineering issues.
• KPI monitoring: Data analysis and report generation provide an up-to-date overview of all plant processes.

FLSmidth provides the following services
• Remote engineering support: FLSmidth can often troubleshoot and make necessary adjustments from offsite. This approach can be used for cement plants that don’t want to invest in a system champion and want FLSmidth to maintain the advanced control applications. Evaluating a plant’s system remotely saves time and reduces travel costs associated with specialist visits.
• Training courses: To keep operators on top of processes and new technologies and knowledge, FLSmidth provides training courses for all plant staff. Courses are divided into introduction, user, specialist and expert levels – and special courses tailored to the unique requirements of engineering companies and technical centres can also be arranged.
• Service & migration agreement: When the plant has an emergency, it needs immediate assistance. With an FLSmidth service and migration agreement, the plant gets both remote and onsite help to ensure maximum system uptime and optimal plant performance at all times. This makes upgrades simple and smooth – and helps secure the plant’s long-term investments.

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