Advanced process control for the minerals industry
Optimize efficiency using advanced process control

Low-grade, complex mineral deposits have resulted in the need for complicated large throughput processing plants delivering increased productivity, reliability and utilization, together with reducing operational costs.

Benefits
- Optimize the production at maximum and reduced capacity
- Improve energy efficiency
- Payback of investment in less than a year (depending on specific applications)
- Decrease process and quality variability
- Long-term stability and consistency of operation
- Minimized downtime
- Reduced maintenance costs
- Reduced equipment wear

Complex mineralogy has resulted in complicated process flow sheets designed to recover minerals as efficiently as possible. In addition, the remote location of many minerals-processing plants, continuously rising energy costs and fierce competition pose significant challenges to the modern mine, compounded by a global scarcity of qualified and experienced operational personnel. Maximized recovery, improved process stability and operational consistency is required.

Besides that, the complex dynamics and interactions among the process variables make the task of controlling a mining process a non-trivial activity, resulting in an unnecessary use of energy and resources.

Advanced process control is now widely accepted as a way to optimize mining operations and help to surpass the challenges described above. Existing advanced process-control technologies are consolidated and the combination of process control techniques has proven successful.

Advanced process control systems reduce process oscillations and lead the process to optimal points where a more stable operation is obtained, achieving better production throughput and quality.

A world leader in the minerals industry, FLSmidth offers automation solutions for every part of the minerals process flow sheet. Combining extensive process knowledge with proven automation solutions, FLSmidth is the preferred automation partner in the minerals industry- helping customers optimize their processes to the highest extent possible.
Why partner with FLSmidth?
Over a period exceeding 40 years, FLSmidth has been a pioneer in advanced process control systems for industrial applications.

FLSmidth combines the process and operational know-how coming from the design and supply of minerals plants with the knowledge of the available automation and process control techniques.

A well-proven methodology is used to assure the implementation success of advanced process control projects.

FLSmidth owns its own procedure and methodology to evaluate and measure the benefits and results of any advanced process control project.

ECS/ProcessExpert® System
FLSmidth’s ECS/ProcessExpert system is an advanced process control solution used to stabilize and then optimize key minerals processes, so they can achieve maximum efficiency and higher profitability. The system is supplied as a complete solution for custom modeling and control application.

The ECS/ProcessExpert system stabilizes the plant, balance equipment loads, manages and correct process disruptions and minimizes wear on the plant’s equipment – all to ensure optimum plant performance.

By improving circuit availability and utilization, the system helps reduce operational and maintenance costs.
Advanced process control for grinding circuits

An unstable grinding circuit operation and process can result in poor overall minerals plant performance.

The ECS/ProcessExpert system analyses a wide range of signals and actuates automatic adjustments to manage the equipment and process performance resulting in improved grinding efficiency.

Benefits
- Up to 6% increase in production
- Up to 6% reduction in grinding specific power consumption
- Up to 30% reduction in quality and process variability

The ESC/ProcessExpert solution also enables a minerals plant to develop a uniform operation strategy that outlines the best way to run the plant. Once this strategy has been established, training new operators becomes much easier.

Control challenges
Changes in process conditions in a typical minerals plant can result in variable flow through the circuit and delivery of material that is inconsistent with the required target particle size. This unstable performance can reduce the efficiency of the minerals liberation in the downstream processes resulting in loss of revenue.

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, material transportation) cannot be handled well by PID's affecting the process stability.

This lack of coordinated action causes undesired disturbances and operation inefficiency. The ECS/ProcessExpert system aims to achieve the best possible grinding efficiency through an advanced Multi Input Multi-Output Model-based Predictive Controller (MPC) used as a primary control technique in the control strategy.

When operators make adjustments – whether to the mill speed, pumps, water intake or fresh feed – they often choose conservative parameters due to the inability to analyze the multi input/multi output control requirements quickly enough on a constant basis.

An example of circuit measurements & actuators.
The ECS/ProcessExpert system monitors operational and process conditions and makes constant automatic adjustments necessary to stabilize the process flow, balance the load of the circuit and protect equipment, all while ensuring that the circuit delivers a product that matches the required quality.

The result is stable operation, reduced energy consumption and increased production.

Optimized automatic process control

The ECS/ProcessExpert solution improves the mill circuit grinding efficiency which in turn results in improved energy consumption and throughput. Improved circuit operation together with the increased equipment protection converts to less plant downtime, all of which enhances plant profitability.

A mill load target optimizer has been developed to automatically establish the mill weight target, manage mill critical impacts and adjust the mill load according to the process conditions.

The application automatically adjust the main operational variables such as fresh feed and mill speed while ensuring the desired process and quality values. This ensures that the best throughput and quality is achieved and maintained.

Stabilization of upset conditions

The upset control mode is designed to handle unexpected and sudden disturbances to the circuit. This upset control mode will bring the process back to normal operation as soon as the process disturbances disappear.

In the event of any disturbance the application will ensure rapid and bigger action on process actuators such as feed and speed of the mill to achieve optimum recovery, and the system monitors 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 secondary signals or estimated values in order to continue operation.

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

Parameters controlled
- Feed rate
- Mill water addition
- Mill speed
- Cyclone feed density
- Pump speeds
- Circulating loads

Parameters monitored
- Mill power consumption
- Load impacts
- Mill mass
- Sump levels
- Circuit flows
- Pump power
- Stream density
- Hydro-cyclone pressure
- Product quality
Impactmeter – Advanced instrumentation for grinding circuits

The impactmeter is an innovative example of how FLSmidth uses dedicated technology, process knowledge and practical experience to further enhance mill performance and extend the operational life of grinding mills.

Through specially designed acoustic sensors and proprietary software loaded, induced impacts generated inside SAG mills are monitored and interpreted so that undesirable impacts caused by steel balls striking the mill liners are eliminated.

Description
The impactmeter is a mill performance instrument that has been developed to monitor load generated impacts through the use of acoustic signals together with proprietary software.

Although the instrument provides output signals that can be tied to the mill control system to facilitate the mill reacting to the impactmeter information, the instrument does not actually control the mill and this remains the function of the mill control system. The instrument provides the operator with valuable information that may be used to improve mill performance.

Integration with advanced process control
Integration of the signals provided by the impactmeter to the ECS/ProcessExpert system allows the advanced process control system to make appropriate adjustments to mill operational conditions that improve ore reduction and energy efficiency.

At the same time the elimination of ball on liner impacts helps to prolong liner life, avoid media degradation and extend production between mill relining campaigns, further adding to mill availability and reduced operational costs.
Objectives
The main objectives of the impactmeter are:

- Equipment protection by prevention of undesirable impacts caused by the mill charge
- Increased energy efficiency resulting in higher production by maximum impact energy converted to ore reduction
- Reduced operational costs by increased liner system life and lower grinding media consumption

Acoustic sensors
Special acoustic sensors are installed onto an appropriate mounting at specified static locations in close proximity to the rotating mill shell. The sensors are enclosed in specially designed, environmentally secure enclosures, suitable for the extreme conditions existing in a milling operation.

Data acquisition module
The data acquisition module comprises a suitable industrial quality chassis with modular data acquisition cards to process the analog sound signals received from the field acoustic sensors, converting them to a digital signal. This system also provides the required power supplies and Ethernet connection with fiber optic media convertor (if needed) to send the information to the Processing Unit.

Processing unit/Operator station
Includes the computer required to visualize and graphically represent the impactmeter information. This unit includes the calculation engine that monitors the sound signals measured by the sensors to calculate the number of impacts. Also built in are communication protocols to integrate the impactmeter with other process control systems.
Advanced process control for flotation circuits

The advanced process control application for flotation circuits is designed to manage the material flow through the flotation circuit and the levels of pulp and froth.

The system monitors several signals originating in the plant control system and manipulates a series of key actuators to achieve maximum recovery and concentrate grade.

Benefits
- Improved recovery and/or grade control
- Decreased reagent consumption

The flotation application is designed to manage all variables and parameters typical in controlling pulp and froth levels with the objectives of maintaining stable operation while maximizing production and recovery. The system will manipulate key set-points in the main plant control system to achieve maximum recovery and concentrate quality.

Control challenges
The end goal of any flotation circuit is to increase the grade of mined ores while reducing loss. Typically, process and quality control on a flotation circuit is done by skilled operators looking at the froth surface and reviewing chemical assays. This feedback loop is slow and inconsistent as it relies on different operators.

Similar to the grinding circuit operation, a conventional control solution with PID loops is insufficient to handle the interactions between flotation tanks. Process delays cannot be handled well by PID’s opening the opportunity for advanced process control solutions to stabilize the operation, increase the reaction time along with the consistency of control actions.
Level control is a vital component of the solution. An effective level controller provides two important benefits to the overall operation of the separation – stabilization of interconnected units and minimized deviation from target. The main actuators of the advanced control loops are the set points of base level controllers.

A typical low level control solution to vessel levels is to have a PI(D) controller that measures a single vessel level and modulates a single valve (Single Input, Single Output). This method of controlling level is effective on single machines, but fails when multiple machines are connected together because each module will control its level at the expense of all machines further downstream.

Aeration rate affects the recovery of minerals in the concentrate. In addition, aeration rate is an effective control variable since flotation generally responds faster to changes in aeration than other variables, such as in froth depth. A properly tuned PID is normally adequate for airflow control. Advanced control strategies and operators could use the aeration rate as a control variable for grade/recovery control and circuit balancing.

A holistic approach to the flotation control problem by implementing a Multi Input, Multi Output control strategy will allow the entire circuit to absorb and dissipate disturbances in feed flow. This type of approach allows the circuit to filter feed disturbances and maintains the level of all machines closer to specification.

Optimized automatic process control
After the levels are stabilized and controllable, they can then be optimized in a manner that will produce the desired mass pull from each machine. Optimized level targets are necessary for improved efficiency of the separation.

The level optimization module implements a model predictive controller to adjust the targets used by the level controller to efficiently pull from the cell. It can also adjust the air injection rate to build more froth, ensuring efficient separation.

Upset control
Similar to the grinding circuit application, the upset control mode is designed to handle unexpected and sudden disturbances to the circuit, especially with the level control. This upset control mode will bring the process back to normal operation.

Parameters controlled
- Froth height
- Pulp level
- pH
- Flow rate of concentrate

Parameters monitored
- Tailing flow rate
- Aeration rate
- Lime addition rate
- Collector flow rate
- Frother flow rate
Froth vision - Advanced instrumentation for flotation circuits

The froth vision system is a proprietary advanced image processing solution designed specifically for analysis of froth characteristics in bubble flotation.

The system comprises all the necessary hardware and software to conduct froth image analysis and reports information relating to froth velocity, bubble size, froth color analysis, froth stability, and froth texture which is used to assist the control of the flotation process.

Description
The froth vision system aims to quantify the froth images and provide meaningful information of flotation condition, which can be used to control and optimize the flotation processes. The following features are extracted from froth images collected via cameras mounted above the flotation cells:
- Velocity
- Bubble size
- Color
- Stability
- Texture

The vision system consists of a server that gathers images from multiple cameras, processes them for information and displays the video stream online to screen(s). For large systems, an additional client PC is used to handle the task of display.

The froth vision system records a sequence of images from each camera and calculates relevant features. The calculated image features will be stored in the database, which can then be used for trending, alarming, etc.

The froth vision system is designed to run on a multiple processor server and interfaces to most common control systems via standard communication protocols (Modbus, OPC, etc.).

Integration with advanced process control
Large variations are often observed in the flotation process due to the variability in feed characteristics. Thus, manual control by operators looking at the cell surface periodically and taking actions does not maintain stable operating condition.

The information extracted from the froth vision system may be used to optimize flotation reagent additions and air control. The objective of combining the ECS/ProcessExpert...
solution and froth vision system is to improve the operation and control of flotation cells by taking advantage of image processing techniques.

**Competitive advantages**

- High Quality Cameras: High Speed GigE Cameras provide up to 110 frames per second with no data compression. IP cameras usually employed in competing products provide only 30 frames per second using data compression.
- Advanced LED Lights: Longer lasting, higher intensity, lower energy consumption than competitors Halogen lights. Provided more uniform illumination of viewing area.
- Each system is built using FLSmidth’s robust and proven ECS™ platform which enables alarming, trending, reporting and several communication protocols.
- The process-oriented operator station interface provides clear visualization of all data.
- The viewer application provides real time video for surveillance of multiple cameras at the same time with customizable options.
- Dirty lens detection and cleaning notification

**Camera**

Type: GigE high speed machine vision

CCD sensor

Format: Color

Effective resolution: 640 x 480 pixels

Frame rate: up to 110 uncompressed fps

Operating Temp.: up to 50 °C

Rating: IP67

Interface: Gigabit ethernet

**Lights**

Type: High intensity diffused LED ring light 1200 lumens

Rating: IP67
Optimizing minerals processes with cutting-edge technology

Designed by minerals process and automation experts specifically for minerals applications, the ECS/ProcessExpert system includes innovative tools and technologies that deliver flexible advanced process control strategies.

As a leader in the supply of minerals processing equipment and automation, FLSmidth continuously invests in research and development to provide plants with state-of-the-art technology.

The ECS/ProcessExpert software includes a suite of customisable technologies that allows plant operators to tailor functions to meet their unique requirements – and makes it possible for plants to design their own solutions.

How does it work?

- **Measurement validation**: All the parameters are validated before being used inside the system
- **KPI’s**: Provides visualization of the process department status so operators can monitor the system and generate reports
- **Online testing**: The controller behavior can be tested in an on-line environment using the so-called "Monitor" function. The behavior 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 the ECS/ProcessExpert software to perform real-time test with the current process values.

Each of the process control applications in the ECS/ProcessExpert software uses advanced techniques such as model predictive control and fuzzy logic rules. The system is designed for operation globally and is capable of handling a wide range of challenges, including adaption to plant upgrades and testing of new process control strategies.
Easy integration with existing control systems
The ECS/ProcessExpert solution has specific I/O drivers for communicating to the most recognized PLCs brands.

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

Control system features
The ECS/ProcessExpert software 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

The tools
- **Process input**: For input reading, validation, signal treatment and normalization
- **Process output**: For process control and trending
- **Control objectives**: For managing specific process conditions (for example, mill weight)
- **Priority management**: For prioritizing the handling of abnormal process conditions
- **Programming**: Enables an open development environment

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 project. 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.

The ECS/ProcessExpert system 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.
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 minerals plants that don’t want to invest in a system champion and wants 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 a minerals 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.

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, helping to support the system and ensure that the plant runs as efficiently as possible.