Model Predictive Control for mining
Process optimization solution
Minerals and metals play a central role in the global economy and will continue to provide the materials the world needs.

THE WORLD IS SEEING INCREDIBLE CHANGES that require resource-intensive goods of all sorts. Overall population is growing and shifting to urban areas, the middle class is expanding and infrastructure development is increasing. With this growth comes a need for resources, meaning metals like iron, copper, aluminum and nickel will come with a much higher demand.

A new report from World Bank Group states that the production of minerals, such as lithium, graphite and cobalt, could increase by nearly 500% by 2050, in order to meet the growing demand for clean energy technologies. The report estimates that more than 3 billion tons of minerals and metals will be needed to deploy wind, solar and geothermal power, as well as energy storage, required for achieving a below 2°C future.

SOURCE: World Bank Group
Mineral processing challenges

Ore grades are declining and becoming more complex

Today’s process characteristics
Mineral processing plants are inherently complex, facing internal and external disturbances, many recirculating loads and multiple interactions. And the declining of the ore grades and continuous variability of raw material are pushing the limits of processing plants even more.

Process objectives
These process characteristics that miners are dealing with today provide opportunity to improve:

• Reduce cost per ton
• Lower plant costs
• Lower energy intensity
• Improve energy and water consumption
• Extend the life of existing ore bodies

How will you achieve these process objectives in such complex operations?
Although traditional optimization strategies provide adequate control in terms of plant safety, it rarely achieves optimal control of quality and economical, efficient operation.

Why? Mineral processing plants face inherent complexities that can’t be addressed through traditional technologies:

- Multiple constrains
- Time delay processes
- Multiple variables
- Key variables difficult to measure

Other potential technologies, such as expert systems, can address some of these challenges but with a price tag:

- **HIGH MAINTENANCE**
- **MODEL OPERATORS (INSTEAD OF PROCESSES)**
- **HARD TO COMPREHEND**

**MORE THAN 75%**

of mineral processing plants still use basic optimization strategies
Pavilion8
Model Predictive Control

Handling constraints, maximizing economics, and maintaining stable process

Pavilion8® Model Predictive Control (MPC) from Rockwell Automation reduces process variability and enhances stability over and above what is currently possible with more traditional control schemes. This is accomplished through our multi-variable, nonlinear, model predictive control capabilities.

Maximum profitability is realized by operating a process as close to its constraints as possible while maintaining an appropriate margin of safety.
Pavilion8 Model Predictive Control
ARCHITECTURE OVERVIEW

**Controller / optimizer:** Pavilion8 Model Predictive Control (MPC) optimizes the process making predictions about future plant outputs responding to changes in the process input variables and disturbances.

**The model:** In order to operate properly, we need an accurate model of the process. Pavilion8 MPC leverages best in class machine learning technologies to build robust models of the process incorporating and combining all available knowledge of the process, such as historical data, process equations, data from plant tests and operator knowledge.

**Virtual online analyzer:** The efficiency of the optimization tool is related to the richness and quality of the field data. However, in most of the process some measurements are unprecise, not present, or delayed (for example data from laboratory). In this instance, Pavilion8 MPC uses an innovative virtual online analyzer that’s able to estimate such variables closing the gap of this information gap.

**The console:** A powerful visualization tool allowing operators to visualize the process and model KPIs for better situational awareness of the system.
The controller matrix

The controller matrix shows dynamic relationships between process outputs and inputs. The system predicts future values of the outputs by movement of all the inputs including manipulated variables and disturbance variables.

**Controlled variables (CVs)**
Process variables to maintain at a target or within a range (can be considered outputs)

**Constrain variable (CCVs)**
The state is forbidden to penetrate or may have physical limitations

**Manipulated variables (MVs)**
A manipulated input is one that can be adjusted by the control system (or process operator)

**Disturbance variables (DVs)**
Disturbance variables - these are also called “load” variables and represent input variables that can cause the controlled variables to deviate

<table>
<thead>
<tr>
<th>Illustrative example of a flotation matrix model</th>
<th>MV1</th>
<th>MV2</th>
<th>MV3</th>
<th>MV4</th>
<th>MV5</th>
<th>DV1</th>
<th>DV2</th>
<th>DV3</th>
<th>DV4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector reagent flow ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depressor reagent flow ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tailings value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frother reagent flow ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P80 from grinding circuit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed flow from grinding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed density from grinding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **CV1**: Concentrate grade
- **CV2**: Metal recovery
- **CV3**: Froth depth
- **CV4**: Bubble speed of air hold up
- **CV5**: Bubble size distribution or surface area

Solutions to meet steel needs
PG 2

The connected steel plant
PG 5

Increase operational efficiency
PG 9

Knowledge driven operations
PG 14

Modernize and empower your workforce
PG 19

Design, build and upgrade with confidence
PG 22

The global mining market
PG 2

Model predictive control solutions
PG 5

Model predictive control in mining applications
PG 8

Model predictive control solutions
PG 5

Model predictive control in mining applications
PG 8
**Crusher circuits**

**PROCESS CHALLENGES**
- Balance between the individual crushers and the overall circuit goal
- Maintain circuit efficiency
- Ensure that crushers are choked
- Crusher capacity vs. feed
- Equipment wearing
- Power consumption

**RESULTS**
- Maximized crusher circuit throughput
- Process stability
- Optimum energy efficiency
- Decrease equipment wear
- Fewer trips over current, high-level silos
Comminution / grinding circuits

PROCESS CHALLENGES
- Complex behavior
- Process disturbances
- Relationship between variables is non-linear
- Energy waste due to overgrinding
- Requires operators with extensive experience
- Balance between throughput and downstream constraints such as optimum particle size

RESULTS
- Maximized throughput rate
- Decrease energy/ton
- Increased stability
- Reduction in particle size variation
- Delivers grinding circuit stability to achieve throughput and grind size targets

POTENTIAL GAINS:
Up to 10% increased throughput, 10% on reduced specific energy, with a P80 variability reduction of up to 50%
Flotation

PROCESS CHALLENGES

• Complex process that is not fully understood
• Still relies on operator control
• A small disturbance in one process variable propagates to the final process output

RESULTS

• Increased recovery
• Increased and stabilized cleaner grade
• Optimized reagent consumption

POTENTIAL GAINS:
Increased recovery of up to 3%, reduction of reagents of up to 3%
Thickeners

PROCESS CHALLENGES

• Water conservation
• Optimum reagents consumption
• Little control and local knowledge
• Not often integrated into control system
• Conventional control is inefficient (long residence time, large disturbances and non-linear behavior)

RESULTS

• Increased underflow density
• Decreased flocculant consumption
• Improved overflow clarity
• Better water utilization

POTENTIAL GAINS:

Increased water recovery of up to 3%, reduction of flocculant of around 2%
Material flow management

PROCESS CHALLENGES

• Inconsistent production rates
• Loss of production at shift change
• Conveyor system trips

RESULTS

• Maximizing ore flow
• Operate to maximum constraints
• Minimize equipment trips
• Extending equipment life
• Minimize interruptions during shift changes
• Energy conservation and maintaining the maximum throughput

POTENTIAL GAINS:

20% increased throughput
Material refining

PROCESS CHALLENGES
- Product under specified grade
- Change in feed characteristics
- Final product variability
- Temperature control

RESULTS
- Stabilization of the operation
- Improved quality
- Product consistency
- Energy savings
- Reduce emissions