Rockwell Automation

MINING **MPC FUNDAMENTALS**

Learn the basics of Model Predictive Control (MPC) – and how this technology works behind the scenes to optimize process performance.

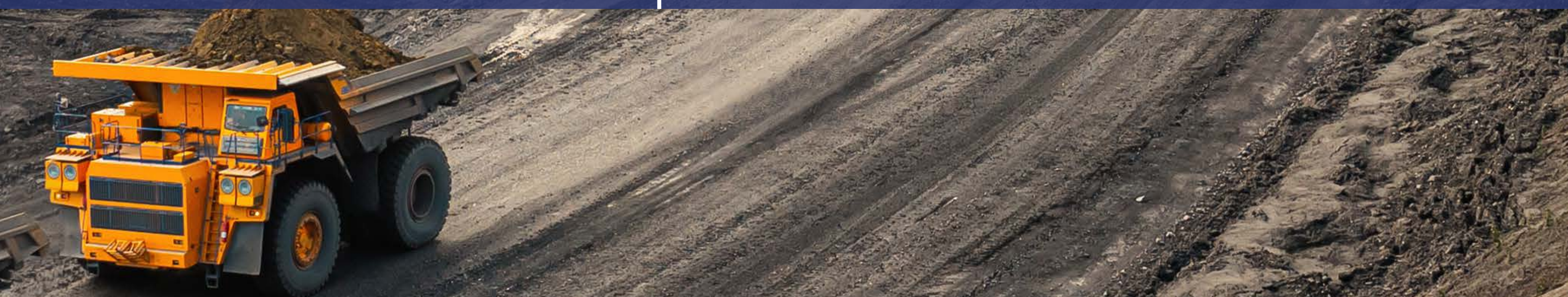
BEGIN

Taking control to the **next level**

Today's mines are challenged to meet increasing demand and to make the most of limited resources – against a backdrop of growing regulatory pressure. To achieve success, mines must maximize recovery, improve efficiency, decrease variability and minimize environmental impact across the mining value chain.

One solution that can help? Model Predictive Control (MPC), an advanced technology designed to optimize complex processes.

You have likely heard of MPC. But if you're like many mining professionals, you have questions regarding how the technology works – and the real production challenges it can help solve.



THE LIMITS OF BASIC CONTROL STRATEGIES

How does your mine manage processes across your operation today? Chances are, your systems rely heavily on regulatory control strategies based on Proportional-Integral-Derivative (PID) logic.

These control systems have automated mining processes for decades and rely on PID loops to regulate a single input and single output.

How? A setpoint or target is established and one variable is moved to achieve the desired target. PID loops are commonly used to control processing variables – like flow rate and temperature.

For example, you might use a PID loop to adjust pump speed and maintain a predetermined slurry flow rate at a discharge pump.

PID-loop control is appropriate for applications with fixed, one-to-one pairing between target and adjustment signals. And PID loops provide adequate control for plant safety.

But what if multiple variables impact the process and optimization is your goal? That's where regulatory control strategies fall short.

Intermittent feedback and adjustments

Maintaining a complex process with basic PID-loop control is challenging. To improve performance, an operator adjusts PID-loop setpoints and value positions through the DCS based on feedback from the system and lab results.

But:

- Processes can be interactive – moving one variable, changes two others.
- Lab feedback is infrequent.
- It can take minutes or hours before a change takes effect – and even longer to determine if the change achieved desired results.

UNDERSTANDING MULTIVARIABLE ENVIRONMENTS

What exactly is a multivariable environment?

Dynamic, multivariable environments are common in mining. But you encounter multivariable situations in your everyday life as well.

Think about it. What happens when you head off on a road trip?

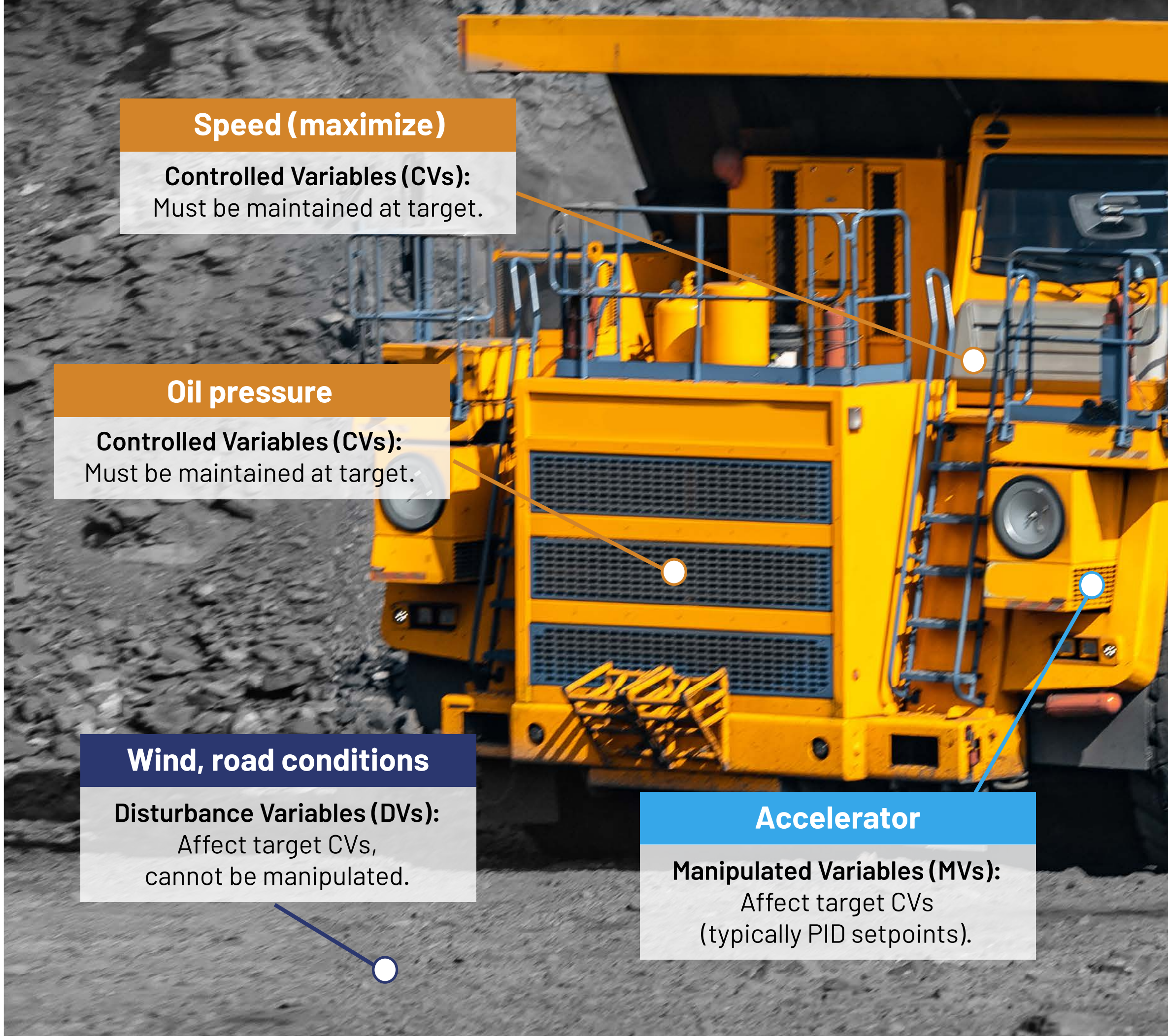
Your goal is to reach your destination efficiently and safely – and you intuitively control your vehicle's systems to achieve the best results.

You manipulate an important variable – the accelerator – to maximize the ideal target speed. And you also remain on high alert for any deviation from the target oil pressure.

But that's not all. You've learned to wait for the system to respond to your adjustments. And you are mindful of constraints – like the speed limit – and disturbances – like wind and road conditions.

Over time, you've learned how to optimize your driving experience. Similarly, MPC uses machine learning to enable process optimization in multivariable mining environments.

How MPC variables are defined.

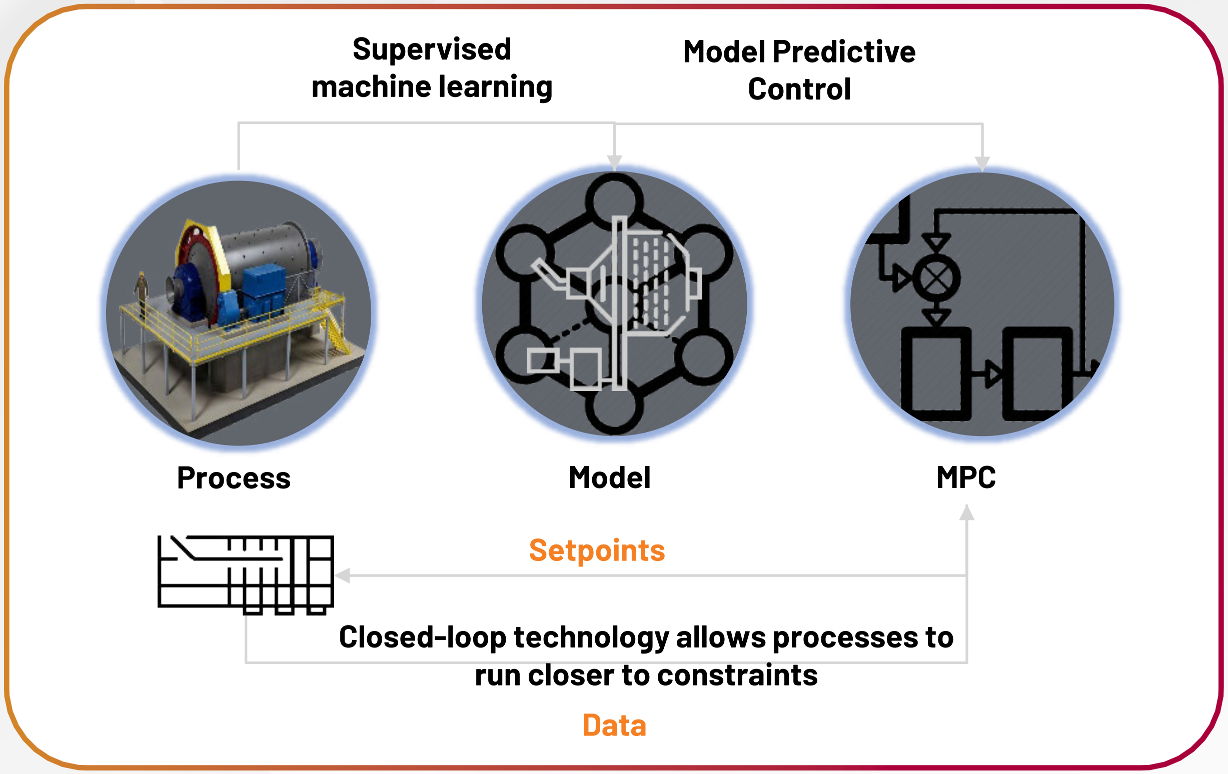


WHAT IS MODEL PREDICTIVE CONTROL?

MPC is an intelligence layer on top of an automation system. It uses dynamic, mathematical models of the process to **predict** variable behavior and **proactively control** it to improve process performance in real time.

MPC algorithms can coordinate interacting PID loops, handle complex or lagging responses dynamically, predictably manage disturbances – and push performance to process limits.

Put simply, MPC learns the impact one variable has on another and continuously prescribes the best action to take and then takes it. Operators no longer need to manage multiple loops and can start managing performance.



How it works: Through MPC, supervised machine learning assesses current and predicted operational data, compares the data to desired results, then computes online setpoint targets.

SO LET'S GO BACK TO YOUR DRIVING EXPERIENCE. **HOW COULD MPC OPTIMIZE YOUR JOURNEY?**

Here's a possible scenario. Using machine learning, MPC creates a dynamic model to predict exactly how an adjustment to the accelerator impacts your ideal speed. The system also considers a change in constraints – the speed limit – and unexpected disturbances, like hazardous road conditions or a vehicle unexpectedly stopping in front of you.

Then, MPC continuously adjusts your vehicle's accelerator to maximize speed and maintain safe operation.

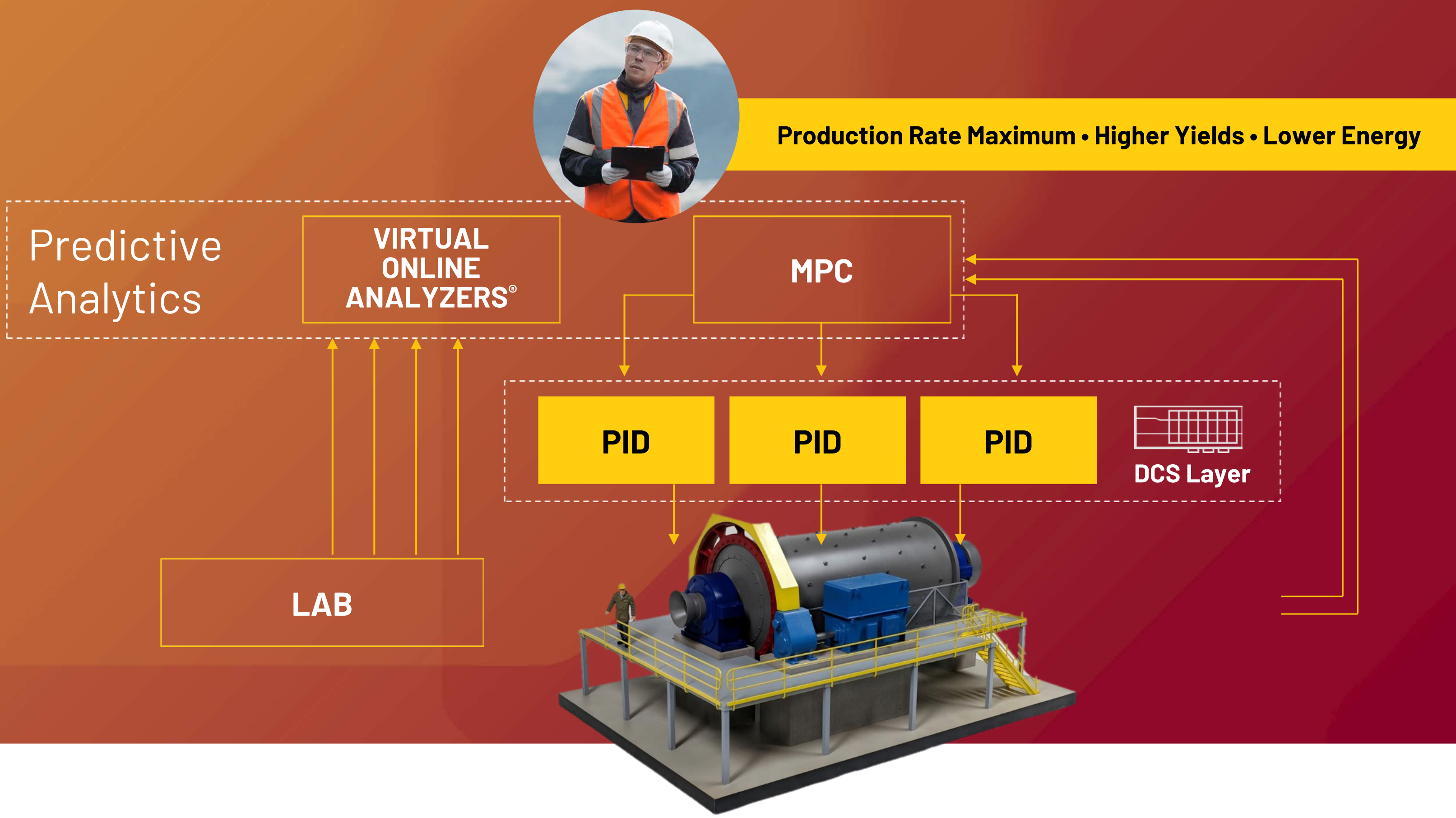
The result? A predictably efficient and pleasant journey.

You have probably realized that this scenario is not far-fetched. MPC is increasingly used in automated driving applications like adaptive cruise control and obstacle avoidance to help optimize vehicle performance and safety.

And these same MPC principles can be applied to mining applications throughout grinding circuits, flotation, mineral processing and more to:

- Reduce cost per ton
- Improve quality & consistency
- Lower energy intensity & usage
- Conserve water
- Meet regulatory requirements

MPC is all about interactions between variables, predictive values and proactive control.



Continuous feedback matters

An MPC solution requires a feedback loop. With the Pavilion8® MPC solution from Rockwell Automation, the Virtual Online Analyzer™ (VOA®) replaces sparse or infrequent feedback from the lab.

These inferential measurements provide continuous feedback of quality parameters that typically require lab sampling to measure and deliver feedback to the MPC controller, enabling continuous closed-loop control.

WHAT **MAKES MPC DIFFERENT?**

Now that we understand at a high level the difference between regulatory PID-control strategies and MPC, compare the two options using the chart below.

PID	MPC
SINGLE VARIABLE IN & SINGLE VARIABLE OUT Set target and control the process variable to the target. No awareness of how control changes impact other PID loops.	**MULTIVARIABLE IN & MULTIVARIABLE OUT** Control strategy based on a holistic approach. All key variables and their interdependencies are simultaneously considered.
FEEDBACK CONTROL The controller will take no action unless variable deviates from target.	**PREDICTIVE CONTROL** Dynamic models are developed through process step tests. Controller action is based on current and anticipated future variable deviations from target.
INDIRECT CONTROL OF LAB MEASUREMENTS Variables controlled through proxy (temperature, pressure, etc.).	**DIRECT CONTROL OF LAB MEASUREMENTS** Controller predictions of lab measurements are used for control and updated as lab results are available.
POOR ABILITY TO HANDLE PROCESS DELAYS During complex dynamic interactions.	**EXPLICIT DYNAMIC MODELS** Enables full understanding of process dynamics and interactions.
CONSTRAINTS Poor ability to handle constraints. Only internal awareness of loop limits on setpoints and outputs.	**CONSTRAINTS** Ability to predict and monitor future values of constraints.

A WORD ABOUT EXPERT SYSTEMS

Oftentimes, MPC and "expert systems" are confused. But while both systems drive toward closed-loop control, the strategies employed are vastly different.

Expert systems comprise strict "rules sets" designed to imitate the decision-making process of experts. They allow coding of operator control actions that can be automated as a type of "auto pilot" for a process. But only relationships between variables that are easily understood are coded and included in the rule base.

Highly structured expert systems are challenged by missing rules or gaps – or the opposite, rules explosion – and can take months or years to set up. Alternatively, MPC relies on machine learning and dynamic models that are continuously optimized based on real-time data.

The bottom line?

Unlike expert systems, MPC drives better performance by closing the control loop and improving processes dynamically.

CAN MPC OPTIMIZE YOUR MINING APPLICATIONS?

MPC uncovers multiple ways to close the control loop – and drive more autonomous optimization in complex industrial processes. But how do you determine which applications in your mine could benefit most from MPC?

Here are some questions that can help:

- When it comes to process control, what are your objectives? What must you improve?
- Where do you see your most significant variability or inefficiency?
- Do you see different performance between shifts?
- Are you achieving the "nameplate" performance of the equipment?
- Do you have processes where you are constantly balancing throughput and quality?
- How are you managing variability, inefficiency and other operational challenges today?
- Are you satisfied with the results?

If you are challenged to maintain material and energy balances, quality targets – or environmental and safety constraints – MPC could be an ideal response.

What kind of improvements can you expect?

While results vary by application, mines have reported a P80 variability reduction of up to 50% in comminution/grinding circuits and a 20% or more throughput improvement in material flow applications.

But that's only the beginning.

Learn more.

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