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Is it time to replace PID?

Applying model-predictive control at the single-loop level may yield the next big leap in performance gains.

By Don Morrison

For more than 70 years, proportional-integral-derivative (PID) control has reigned as the industrial standard, and for good reason: it's simple, fast, versatile, flexible, and such a sensible design that the underlying algorithm hasn't changed one bit in all these years.

Today, more than 99% of all single regulatory loops are configured for PID, and until recently, most engineers and instrumentation specialists considered the alternatives too complex and CPU-expensive for widespread use.

Several factors have created a perfect environment for PID replacement:

- The evolution of control systems from pneumatics to DCS to process knowledge systems
- The convergence of hardware and software technologies
- Wider industry acceptance of advanced control technologies

Now, a next-generation algorithm has appeared on the scene—one that enables model-predictive control at the single-loop level with comparable CPU and memory requirements.

Perhaps it's time to consider what was previously unthinkable—replacing PID.

PID in reality

It's not that PID is bad. However, it does have its weaknesses:

- PID controls have difficulty handling process delays, nonlinear processes, and noisy process signals. This leads to suboptimal control and increased tuning effort.
- PID is not as robust as alternatives, often delivering higher process variability.
- PID tuning is not easy to handle. Effective tuning requires experience, extensive training, and an investment in tuning software.
- PID transfers process signal noise directly to its controller output. This accelerates valve wear and increases energy usage.

These weaknesses add up over time, with the net impact being PID use may actually increase process variability, decrease production and product quality, and ultimately increase operating and maintenance costs.

Because of the widespread use of PID—and the technology's inherent weaknesses—regulatory controls remain one of the last frontiers for pushing performance further. Improvements at the regulatory control level can translate into significant benefits that compound upwards through the process. Single loop controls are the ultimate enablers of business agility and responsiveness. They contribute to operational and equipment safety and are the key means—either directly or indirectly—of implementing environmental control. Furthermore, multivariable control and site-wide optimization ultimately take place by leveraging single-loop controls.

Loop management pays

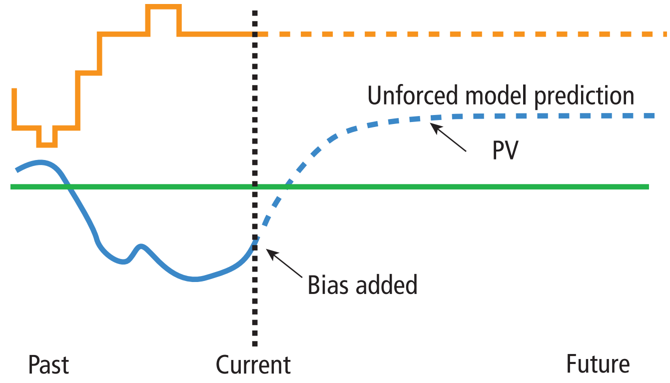
Industry surveys find that better regulatory control performance typically represents an opportunity of 1% to 4% of plant production. Results at individual plants support this:

- Better management of regulatory controls at specialty chemicals plant resulted in increased refrigerant production valued at $1.7 million per year.
- Adjustments to four regulatory controls on a hydrocracker 444 process resulted in 2.1% feed rate increase valued at $300,000 per year.
- Reduced variability of crude furnace pass temperatures allowed the use of higher crude temperatures during operation. An independent audit found the resulting product upgrade worth $200,000 per year.

The source of these returns becomes clear if you consider some of the key facts about the performance of PID-controlled loops, which make up nearly all plant control loops:

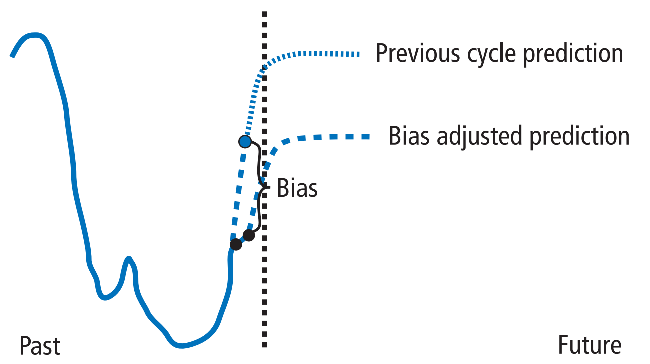
- Fifty percent of standard control loops display undesirable characteristics.
- Thirty-seven percent of plant control loops need retuning once per year or more.

Model predictive control—first



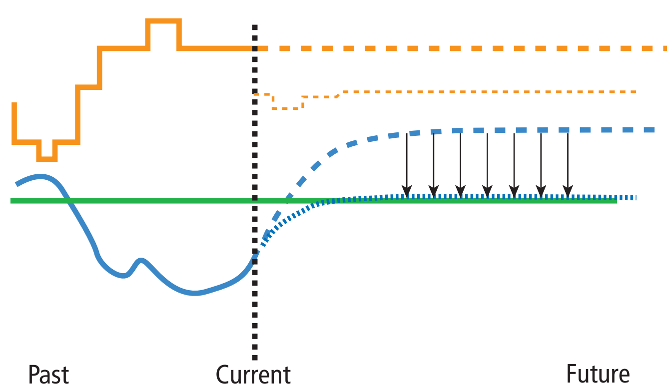
Using knowledge of past and present process behavior, MPC predicts where the process will go if no adjustments to control elements take place.

Model predictive control—next



MPC measures what it predicted would happen before and what actually transpired.

Model predictive control—finally



MPC algorithm calculates the necessary control element movement that will move the controlled variable to its setpoint.

A matter of perspective

Model predictive control works about the same as PID on loops where dead time is the dominating influence. On loops dominated by lags, PID is much better when load upsets occur. Model predictive is better on set point changes, assuming the software exactly knows the process model. However, in the process industries, it is usually the response to load upsets that is the more important.

—John Gerry, president of ExperTune and holder of ISA's Douglas H. Annin Award, for an outstanding achievement in the design or development of components of an automatic control system.

• Of the 37% retuned, only 22% perform better.

These numbers explain why tuning software, services, and valve maintenance is such a big business. However, they don't address the source of the problem—the PID technology itself. Changing the underlying technology can eliminate most of the PID-related control tuning software and services, while minimizing valve maintenance requirements.

Controlling the future

Hockey great Wayne Gretzky once said, "I skate to where the puck is going to be, not where it has been." Extrapolating this illustrates the value of replacing PID with model predictive control at the loop level. One can control the process based on where it is, where it has been, and where it's going.

A new, patented algorithm makes this type of single-input/single-output, model predictive control, possible at the regulatory control level. A solution built on this algorithm overcomes the weaknesses of PID, with memory and CPU requirements comparable to PID.

The PID algorithm is shortsighted. It has no "knowledge" of the system beyond its tuning constants. Only the *present* is of concern—where the process may go in the future isn't a consideration.

Model predictive control (MPC) looks at the system holistically. First, based on past and current behavior, it predicts where the system will go if no adjustments should happen. The second step in MPC problem resolution is to adjust the *bias* between what the algorithm predicted would happen at the last execution cycle and what really happened. Finally, the MPC algorithm calculates the necessary control element movement—current move and future *move plan* to bring the controlled variable to its objective.

Technology differentiation

This solution is an algorithm that provides a wall-to-wall package for PID replacement. The technology goes beyond PID and beyond typical model predictive control in many areas. The most notable, beyond the algorithm itself, are the tools included as part of the package.

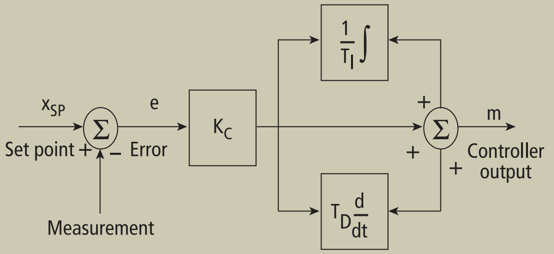
A full suite of tools is available to assist the user in applying the PID-replacement from start to finish. This MPC tool is for those who maintain the system on a day-to-day basis. It even provides a menu-driven interface that walks the control novice through the following tasks:

• On-the-fly conversion from PID

Definitions and terms

PID: Proportional-integral-derivative (PID) control is a combination of proportional, integral, and derivative control actions. It's the control method in which the controller output is proportional to the error, its time history, and the rate at which that error is changing. The error is the difference between the observed and desired values—set point—of the variable that is under control.

Signal noise: In process instrumentation is any unwanted component of a signal or variable. Think interference or electromagnetic obstruction. It includes any spurious variation in the electrical output that is not present in the input.



Single-loop control: All parts of a control system—the process, sensor(s), transmitter(s), the controller, and the final element—that put together to measure and/or control a process variable. The vast majority of controllers at work are single-loop controllers (versus multiple-loop controllers).

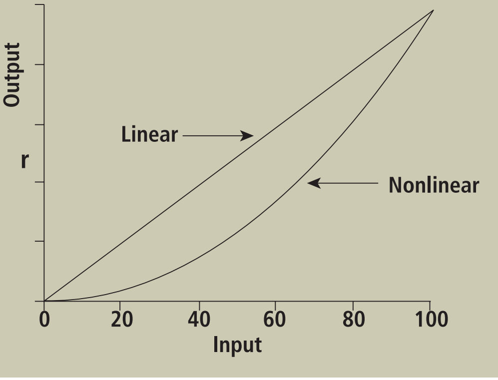
Hydrocracker: A chemical reactor in which large hydrocarbon molecules break apart in the presence of hydrogen into more useful, smaller hydrocarbons. An example of cracking is:

$$C_{15}H_{32} \longrightarrow 2C_2H_4 + C_3H_6 + C_8H_{18}$$

Ethene Propene Octane

Gain: In this context, the ratio of output signal magnitude to input signal magnitude. When gain is less than one, it is attenuation (ISA-26-1968).

Nonlinear process: Any process where the variable on the y-axis of a graph (output) does not directly relate to the variable on x-axis (input), such that the graph of their relationship is not a straight line.



- Control loop diagnostics, including loop performance and valve diagnostics
- *Wizard*-style tools for MPC development, testing, and deployment
- Once deployed, this MPC package continues to provide advantages including:
- Single handle for algorithm tuning, more or less aggressive
- *On-the-fly* switching between *tight* (setpoint) and *loose* (range or surge) control
- Optional configuration for economic optimization—maximize/minimize within a range
- Steady-state predictive alarming provides notification of a problem before it actually occurs
- Easy integration with sampled analyzers
- Gain scheduling for minor process nonlinearities

A replacement strategy

With the right PID replacement strategy, a plant can reap performance gains. These could include increased returns of $100,000 per year on critical loops because of tighter control and less oscillation, increased throughput of 1-4 % and increased plant efficiency of 3-5 %.

When investigating PID replacement at the loop level, consider using these questions to evaluate the available solutions:

- Are the CPU and memory requirements comparable to PID?
- Does it enable better, more flexible control performance?
- Does it reduce valve travel?
- Is it easier to tune?
- Does it enable the replacement of all loops with little impact on the controller?
- Does it provide tools that enable technicians to use the technology easily and quickly?
- Does it provide optimal control based on field-proven technology?
- Does it provide direct PID conversion that is transparent to the user?
- Does it provide upfront diagnosis of valve problems?
- Does it automatically identify a model via a regulatory control test?

When one can answer yes to these questions, an appropriate solution for replacing PID is close.

✍ Behind the byline

Don Morrison has a chemical engineering degree and experience in optimization engineering in the refining and petrochemical industry. He works as a manager at Honeywell Process Solutions. There are tens and hundreds of model predictive control software packages available in the automation marketplace.

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