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Web Exclusive

True control system objective

How to turn control performance monitoring into performance improvement

Fast Forward

- Real purpose of a process control systems is to maximize plant profitability.
- To measure a system, engineers should invoke metrics like integrated error.
- Focus improvement effectively—identify, quantify, and prioritize problems.

By George Buckbee and Lew Gordon

It is a question often not asked: What is the purpose of the control system in my plant, anyway?

At first glance, the answer seems so obvious it is hardly worth the effort to think about. Modern plants are simply too large, complicated, and dangerous to operate without process controls. Without process controls, no product would be going out the door, and no revenue will be coming in.

But this answer justifies control systems by what would happen in their absence, and sets too low a bar for judging their performance. It is more useful and constructive to justify controls by what they contribute to a plant's operations.

Plant engineers answer this question in technical terms. Process control systems:

- Maintain stability at desired conditions
- Restore process conditions when they are upset by disturbances
- Move the process to new operating conditions by responding to set point changes

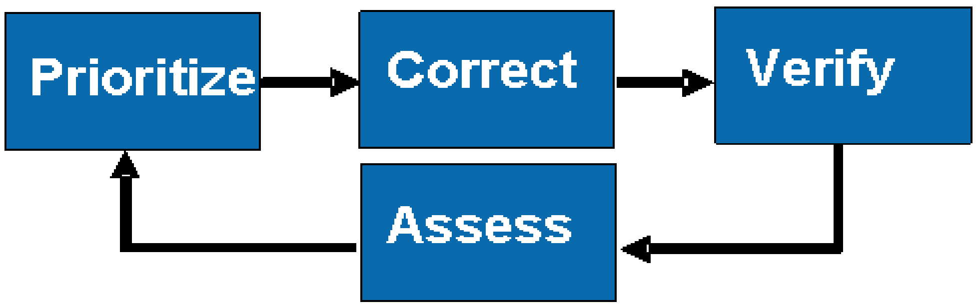
To measure this contribution, control engineers use control-related metrics, such as integrated error, load rejection, and control system robustness.

However, it is more useful and meaningful to answer this question in economic terms. The real purpose of a process control systems is to maximize plant profitability by helping to gain the most profit from a combination of process equipment, feed materials, and energy input. In this context, the control system is a tool to maximize production and yield, while minimizing energy consumption and maintenance costs per unit of product. Its performance can and should be measured by its contribution to increased production rates, higher yield, energy savings, maintenance cost savings, and longer equipment run times. A poorly performing control system that is not enabling operation at optimum conditions is simply not doing its job.

Path to profit

It is not enough to know the performance of your control system could be better. To focus improvement efforts effectively, you must identify, quantify, and prioritize problems. You should also then be able to track and confirm the benefits of any type of corrective action.

Tracking and confirmation provides the justification for moving on to other issues. More importantly, it provides the evidence necessary to maintain enthusiasm and management support, including budgetary support.



A flexible and capable control loop performance monitoring package is the best support for this process. This software resides on a server connected on the plant control system data network. It collects process and controller data in real time and generates a history of control performance metrics. A full-featured package can develop diagnostics and recommendations and provide integrated tools for loop tuning and valve analysis.

Start from beginning

The first requirement of a control system is to report for duty. The control loop service factor is the first performance metric that should undergo improvement. For a controller to be "in service":

- The communications network between the process and the control function must be in good working order; the system must not mark the data received as "bad."
- The PV value must be within its calibrated range.
- The controller output, either to an actuator or to another control function, must not be at its operating limit.
- The controller should be in a controlling, automatic state.

These basic issues should be the first ones addressed in a performance improvement effort.

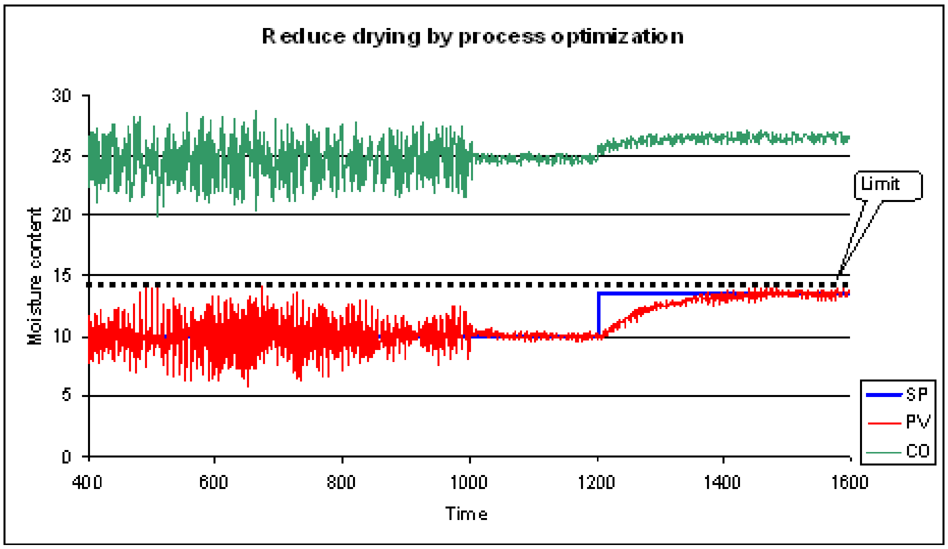
- Network communication errors can point to failed and/or missing field devices.
- Off scale measurements can point to field devices in need of re-calibration.
- Outputs normally at, or near, output limits can point to improperly sized valves.
- Controllers end up in manual position for quite a few reasons, including damaged actuators, poorly tuned controllers, and inadequate control strategy designs. The important thing is to find out why the loop remains in manual.

All of these problems are actually opportunities in disguise: Stepping stones to better control system performance and higher plant profitability.

Instability is the enemy

Products must meet quality specifications and production rate targets. There must not be any violation of emissions limits. You also have to respect the equipment operating limits. Typically, the highest energy efficiency and yield occurs when a plant is simultaneously operating against more than one of these constraints. Any plant performance condition other than optimum is worse.

Variation is the mortal enemy of operating condition optimization. Whether variation appears as random noise, steady cycling, or poor load rejection, the consequence is the same: To avoid violating operating limits, set points must move a proportional distance to the safe side of optimum operation. This margin is costly. For the best economic performance, the move should be minimal.



The dotted line defines the maximum allowable moisture content. To avoid violating this limit, the set point must be lower so the typical variation in moisture content does not violate this limit. On average, the product is over-dried. Higher energy consumption and solids give-away are the price paid for poor control.

When control improves and variation reduces, the set point can move closer to the limit without violating the product specification. The energy savings alone can be impressive. In a drying process example, a steam reduction of only $120/hr adds up to a significant yearly savings.

$120/hr x 24 h/d x 350 d/y = $1,008,000 $/yr

This concept is no less applicable to batch processes, which are often moving from one operating condition to another. In this case, it is the performance across the batch that should be stable and optimized. Transitions should be as rapid as the product quality allows, for maximum production rate. Measured variables should repeatedly follow an optimum trajectory for maximum energy efficiency, yield, and equipment life.

Find the real problem

The list of meaningful indicators and symptoms of poor control performance is long and varied. Chief among them are measures of variability and error, such as standard deviations, variance, average error, absolute error, integrated error, set point crossings, and the like.

But a control loop performance monitoring package can also quantify the performance of a control system in more subtle ways. Some of these metrics include:

- *Controller output changes in manual*: Large values indicate a control system that a user cannot trust in automatic. The operator has to provide control.
- *Mode changes*: Similarly, large numbers of transfers indicate controllers that cannot handle upsets and/or set point changes. In both cases, tuning and/or strategy changes may be required.
- *Measures of oscillation*: Control loop performance monitoring can use Fourier analysis to spot sustained periodic components in a PV signal. By referencing other information, such as current tuning constants, the packages can diagnose the root cause of the cycle.
- *Totalized valve reversals and valve travel*: High and low values indicate which actuators need maintenance and which do not. This insight can shorten turnarounds and avoid unplanned shutdowns.
- *Process model parameters*: By observing the process response to normal operator actions, control loop performance monitoring can parameterize the process model in terms of dead time, capacity lag times, and steady state gains. This can demonstrate a need for re-tuning, adaptive tuning, and/or non-linear characterization.

All of this information can be of critical importance in diagnosing the root causes of poor controller performance. Confirmation can come from direct analysis of a loop's data history.

The following are some common problems users can encounter:

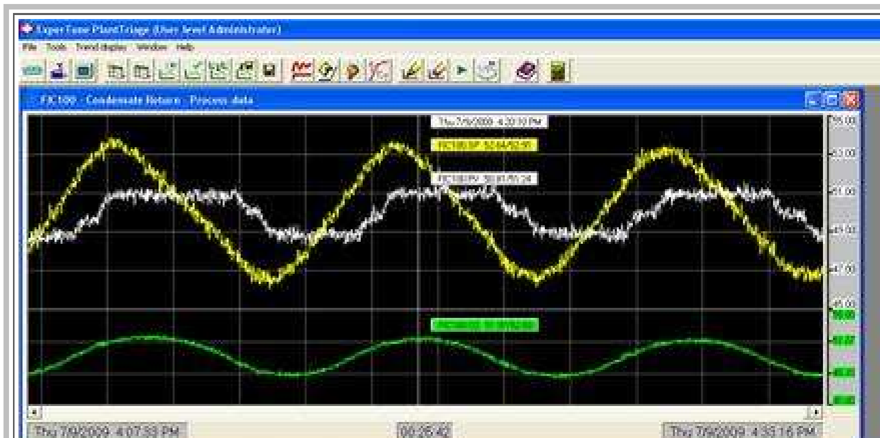
Resolving oscillation issues: Sustained oscillation in automatic is the most dramatic example of poor control. When this occurs, there can be myriad reasons, including damaged actuators, improperly tuned controllers, variable loop gains, interacting loops, and inadequate control strategy designs.

Expanding oscillations are so unacceptable to normal operations that you should never tolerate controllers tuned with gains high enough to cause expanding oscillations. The user needs to immediately correct them (or placed in manual permanently). More often, the problem is variable oscillations, which are oscillations that appear and disappear with changes in feed rate and/or operating point.

This is always a strong clue that some other gain in the loop is variable. Two likely possibilities are:

- Variable valve gain. The relation between valve position and flow is often non-linear, so valve gain changes with operating point. A non-linear compensator is often the solution.
- Variable process gain. Process gains often vary with throughput and/or other operating conditions. Examples include pH loops, and level control in oddly-shaped tanks. Programmed or adaptive tuning is often the solution.

Resolving valve issues: Constant amplitude oscillations are often the consequence of the physical condition of the final actuator.



The chart above shows a trend of a loop in oscillation. The

white trend is the PV. The green trend is the CO. This cycle is neither expanding nor decaying. Therefore, tuning is not the issue, and attempts to kill the oscillation by de-tuning the controller will fail. The clue is the distorted shape of the PV trend, in comparison to the sinusoidal CO trend. The flat sections at the top and bottoms of the cycles indicate periods when the PV is not changing even though the signal to the valve is changing. This is a classic indication of hysteresis and/or stiction in the valve mechanism. A PV vs. CO plot of these data points can confirm this diagnosis.

After finding the trends and doing a PV vs. CO plot to confirm, where an open pattern of the PV/CO data pairs would show the hysteresis in the actuator. Physical maintenance of the actuator is often the solution. Sometimes, adding a slight amount of derivative action to a flow controller can overcome stiction.

Dealing with constraints: Controllers often run into constrained conditions. If the condition is temporary, or cyclical, a loop will often cycle against this constraint, adding to process instability. If the condition persists, then there is a permanent constraint on the process, and a loss of control for this variable.

Proper valve sizing, or controller configuration with signals for initialization and tracking is often the solution. This may involve integration with other control functions using selector and/or logic schemes for programmed auto/manual transfer.

Untangling process interactions: A typical process unit has quite a few control loops. It is a rare loop whose PV does not also feel the affect of influences besides its own output. Similarly, a controller output typically affects multiple measurements.

In this environment, oscillations in one loop often also appear in other loops as well, through one-way or reciprocal interactions. Similarly, when there are disturbances in uncontrolled variables, they also appear as variations in whatever PVs they affect. These are the sources of many unexplained oscillations.

Control loop performance monitoring software can help by identifying which loops are oscillating at similar frequencies. This can identify the loop that may be the source of the problem.

Another control loop performance monitoring tool for solving interaction problems is the process interaction map. This tool illustrates the degree of interaction, and the relative time-shift of the interaction. You can pinpoint the root cause as a strong influence (strong color) on the leading side of the diagram.

When you uncover these interactions, modifications to the control system, such as feed-forward or decoupling controls, are often the solution.

No matter what the issue, the most fundamental problem, however, is often not in the technology of the control systems. The biggest obstacle to control system performance improvement is human nature. Performance problems can exist for years without anyone addressing them. Users end up labeling these problems as normal, and it is only human nature to accept them as they are rather than risk the uncertain consequences of change.

However, with sufficient will and perseverance, the payoff can be significant. Profitable opportunities to improve control system performance are at almost every turn in a production plant. Typically, there is no shortage of “low hanging fruit” that will yield large economic benefits for relatively small investments of time and effort.

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