

Best Practices for Controller Tuning

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Summary

Controller tuning can be accomplished quickly and accurately using proven techniques. While many engineers and technicians resort to “tune by feel”, most will admit that this approach yields inconsistent results. While some might claim that controller tuning is “part art, part science”, use of these best practices can ensure that it is 98% science.

Overview

Why Controller Tuning is Important

The control system acts as the nervous system for the plant. It provides sensing, analysis, and control of the physical process. When a control system is at properly tuned, the process variability is reduced, efficiency is maximized, energy costs are minimized, and production rates can be increased.

Controller Tuning

Controller tuning refers to the selection of tuning parameters to ensure the best response of the controller. Choose tuning that is too slow, and the response will be sluggish...the controller will not handle upsets, and it will take too long to reach setpoint. Choose tuning that is too aggressive, and the loop will overshoot or become unstable.

In this paper, we'll address best practices for many aspects of controller tuning, focusing primarily on the PID controller, which accounts for over 98% of industrial control applications.

Using the best practices saves you time. I know many people who can now confidently tune over 20 control loops per day. Using best practices saves money for your company, and helps the control system to deliver its best value.

The Best Practices

Using the “Best Practices for Controller Tuning” can help you to deliver value to your business quickly and accurately, without a lot of guesswork. The 6 best practices are:

1. Check the Equipment
2. Model the Process Dynamics
3. Define Process Needs
4. Choose the Right Tuning
5. Simulate before Download
6. Monitor the Results

Best Practice #1 – Check the Equipment

Don't Tune the Loop!

You might think it is strange that the first best practice of controller tuning is “Don't Tune the Loop”! But this is critically important. When the control equipment has a problem, you should fix the equipment first.

Control valves may have problems with stiction or hysteresis. They may be too large or too small. They may open too slowly. Instrumentation may have problems with electrical noise, process noise, calibration, or ranging.

Many of these problems can be resolved while the process is running. For example, stiction problems can often be fixed by releasing the torque on the valve packing. Take the time to ensure that the equipment is in good condition before tuning the control loop.

Trying to tune a loop while it has an equipment problem is usually a waste of time. Don't waste your time. Fix the equipment first.

Diagnosing Equipment Issues

There are many simple tests to help determine the health of equipment. In fact, many of these diagnostics can be completed automatically, as shown in Figure 1.

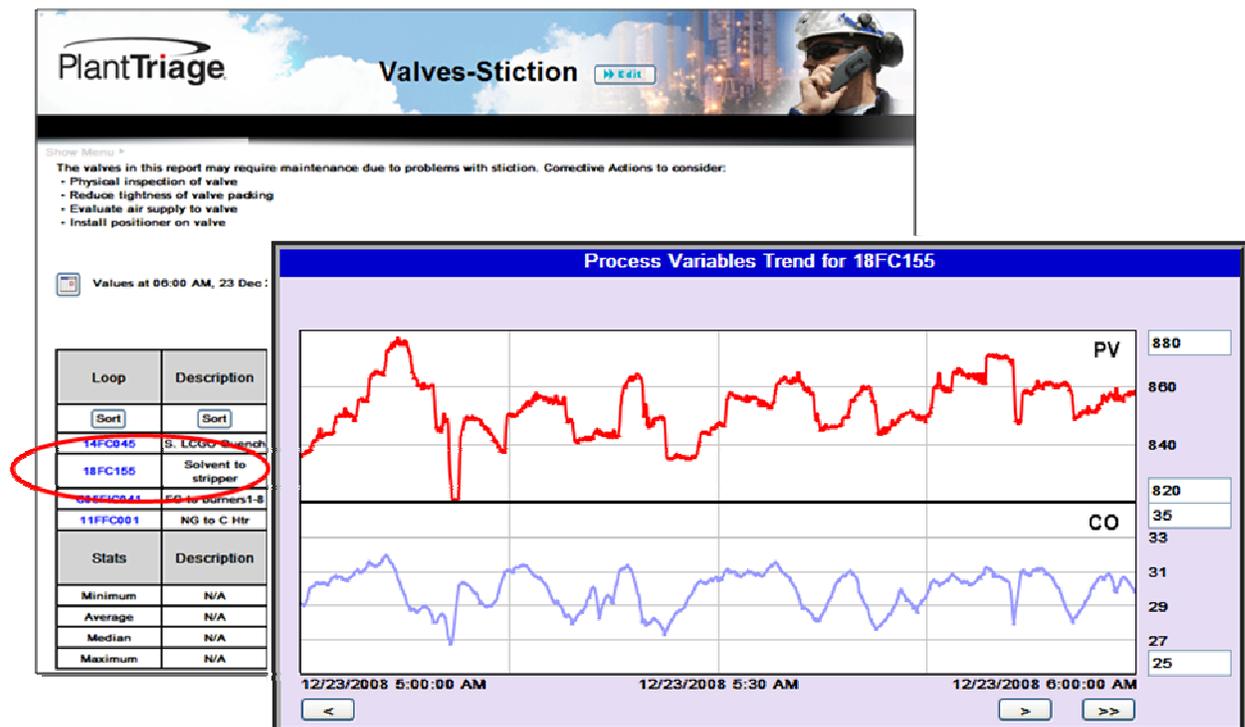


Figure 1. Automated diagnostics can identify equipment problems. Valve Stiction can be found by looking for the pattern: PV=Square/Step Wave, CO=Sawtooth

Best Practice #2 – Model the Process Dynamics

Models Are Important

All successful controller tuning methods develop some type of process model. Don't fool yourself into thinking you can get good tuning without a model. Your trial-and-error methods might eventually find some tuning that "works", but you will never be confident that you have the best tuning unless you start with a good process model.

Choose a Practical Method

There are many methods to develop process models. Most control engineers, however, can only name one: Ziegler-Nichols. With this method, you keep the loop in AUTO, and keep increasing the controller gain until the loop goes into sustained oscillation, as shown in Figure 2. Unfortunately, this method is not very practical for most plants. In fact, I know some control engineers who have been thrown out of the control room for trying this!

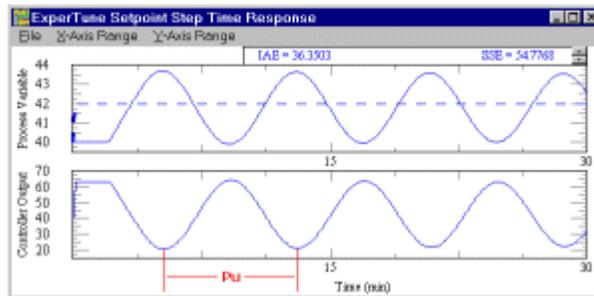


Figure 2. The Ziegler-Nichols method is not recommended

Simple bump test methods provide good data for process dynamics. These can be accomplished in open-loop (MANUAL) or closed-loop (AUTO). A closed-loop bump test is shown in Figure 3.

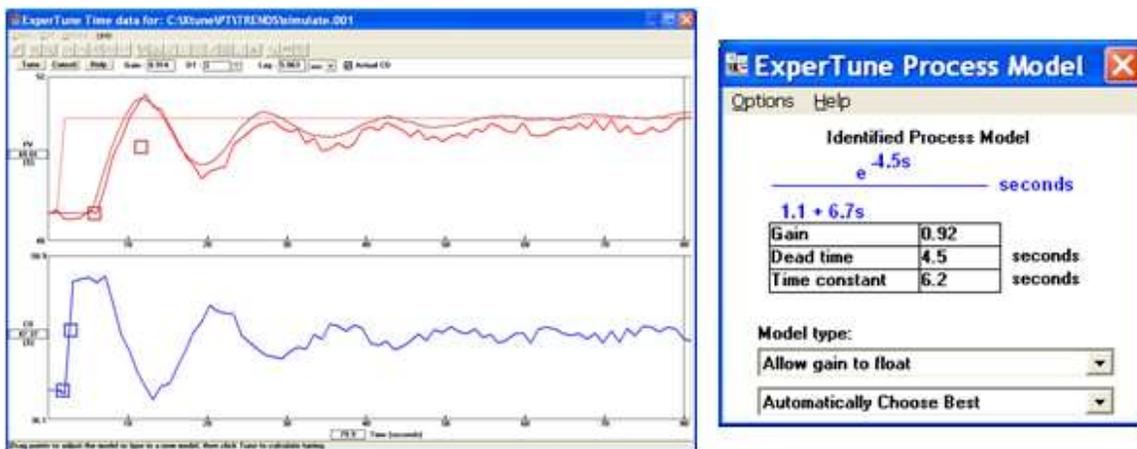


Figure 3. Developing a Model From Closed-Loop Data

Get a Good Bump Test

When making bump tests, keep in mind the following guidelines:

- Always coordinate your bump tests with the operator.
- The bump should be at least 3 times larger than the process noise.
- Get a good baseline and a good final condition.
- Do not use data from a disturbance or upset as your bump test.
- Bump tests should be done in the normal range of operation for that controller.

Special Bump Methods

For some control loops, traditional bump tests are not practical. For example, level controls will rarely stabilize in MANUAL. For slow-responding loops, it may take hours to achieve steady-state. A few special bump test methods are worth noting:

1. For level loops, do closed-loop bumps with a P-Only.
2. For slow loops, use pulse methods, like the “Fast Plant Test” shown in Figure 4.

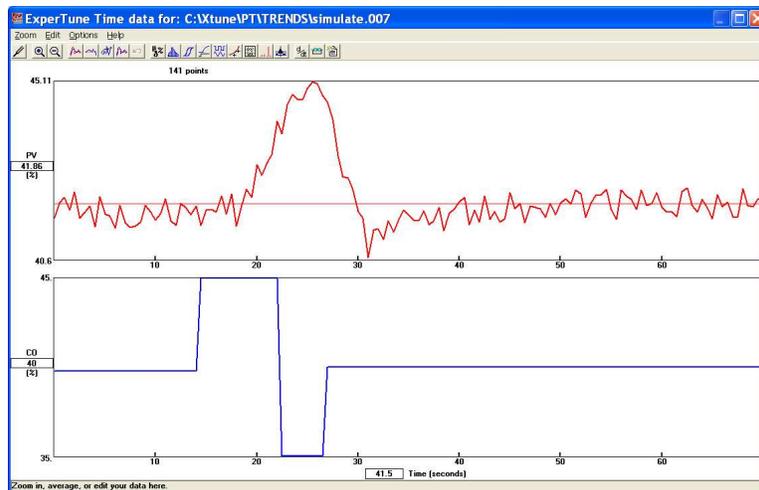


Figure 4. The Fast Plant Test can model the dynamics of slow loops

Use Software for Modeling

The best practice for process modeling is to use software to fit the models. Sure, you can do the bumps, fit the curves, and do the math by hand. In fact, when I teach courses on loop tuning, we do exercises, where the students fit and calculate models. Even in this ideal classroom setting, many people make simple math errors that would be disastrous in a real-world scenario.

Make sure to use software that can model the behavior of the real-world loops, such as level (integrating), flow (first-order), and temperature (usually second-order).

Use Active Model Capture to Tune 20 Loops per Day

The use of Active Model Capture Technology (AMCT) speeds up the tuning process, because it eliminates the most time-consuming part of the work: the modeling.

Here's how it works:

1. During normal operation, the operator changes setpoint or control output.
2. The AMCT software automatically identifies this as a possible bump test.
3. A process model is automatically developed, and qualified.
4. AMCT automatically shows you the model, the suggested tuning, and the simulation of results.
5. You accept and download the tuning.

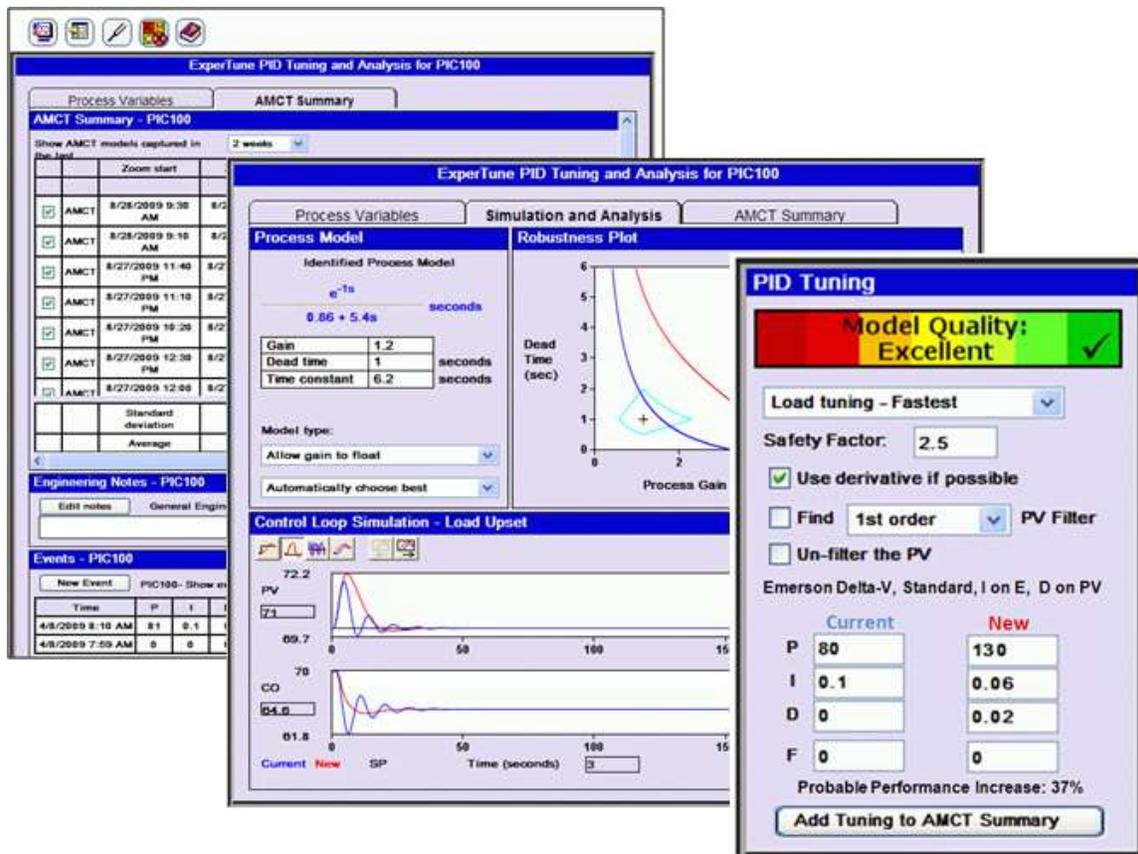


Figure 5. PlantTriage Active Model Capture speeds up the tuning process

The AMCT approach speeds up the tuning process. This is especially true for slow-responding loops. As long as the operator is making process changes, process models will be determined. Since models are already built and qualified, most people find that they can tune more than 20 loops per day.

Best Practice #3 – Define Process Needs

What Does the Process Require?

If you blindly follow tuning rules, you will miss out on one of the most important aspects of controller tuning: Controller tuning should be based on the needs of the process.

Every control loop has different tuning requirements. For example, level control of a surge tank should be slow, even sluggish. This is because the purpose of a surge tank is to absorb upsets. Fast tuning would completely defeat this purpose. Use a tuning method based on available surge, as shown in Figure 6.

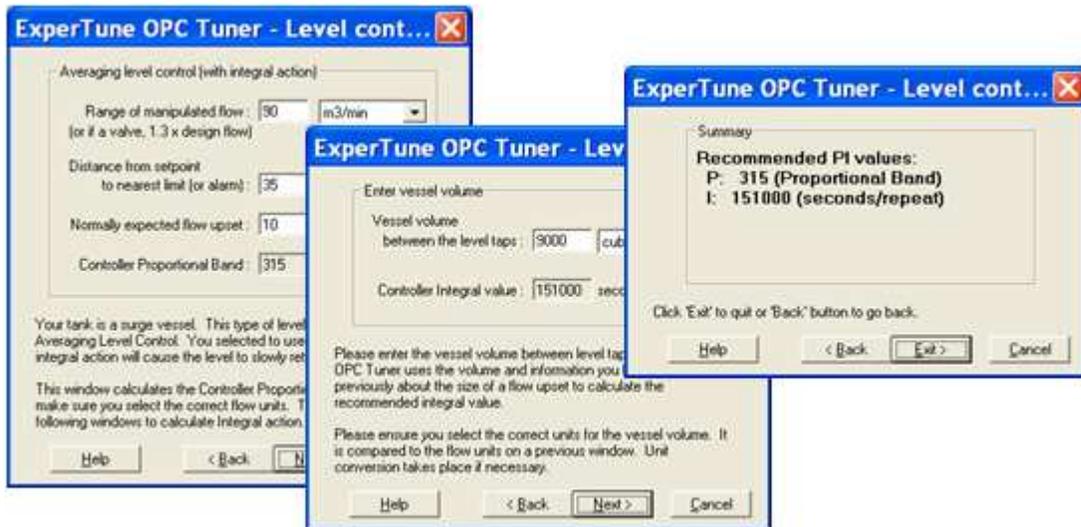


Figure 6. Tuning a surge tank based on available surge capacity

However, level control of a boiler drum should be fast, and respond quickly to upsets.

Table 1 shows some of the criteria that may be used to define the process needs for each control loop.

Table 1. Process Requirements

Requirement	Typical Scenario
No Overshoot	Processes with safety limits for temperature. Tank Levels.
Fast Response	Header pressure. Exothermic reactors. Most flow loops.
Robust	Wide range of operating conditions.
Specific Response Time	When coordinating loops, such as Cascade, Ratio, or Feedforward.
Minimize Movement	Large, expensive, or sensitive actuators.
Surge Balancing	Surge Tanks

Best Practice #4 – Choose the Right Tuning

Based on the process requirements, you are now ready to select the tuning you want.

Choose Tuning for Your Controller

All controllers are not created equal. In fact, just about every industrial control manufacturer has their own formulation of the PID equations. In many cases, DCS vendors even use several different equations on a single type of controller, as shown in Figure 7.. They may use standard, parallel, ideal, or some other algorithm.

Good tuning parameters should be based upon the exact controller algorithm in use. Make sure that you are using the right units for controller gain, integral, derivative, and filter. It makes sense to choose tuning software that automatically finds tuning parameters for your controller.

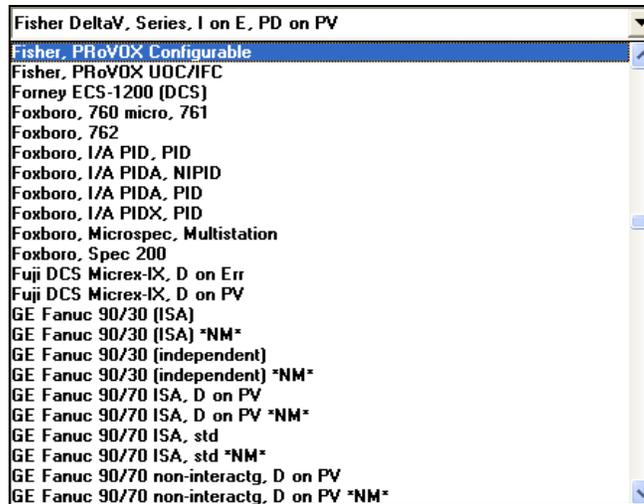


Figure 7. Some of the many control algorithms in use

Choose Tuning to Match the Process Requirements

As you choose your tuning, make sure that it matches the process requirements that you have defined.

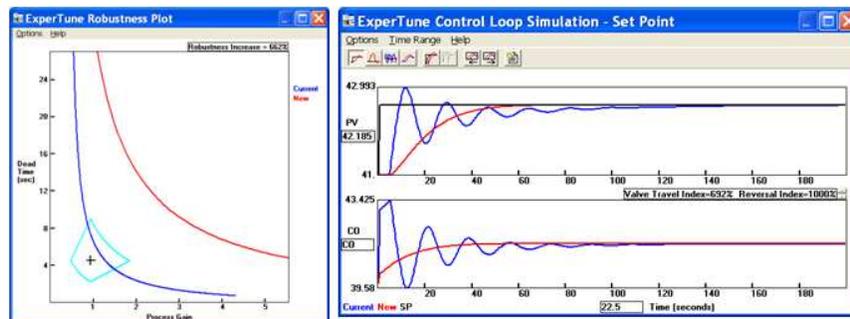


Figure 8. Customize the tuning to meet process requirements

Keep in mind that there is a range of tuning parameters that “will work”. That is, the loop will be stable. However, you want to select the set of parameters that meet all of your process requirements, including speed of response and overshoot.

Derivative Only When Necessary

Most industrial control loops can be handled with P-I control alone. Derivative action should **only** be applied to loops when all of these conditions are true:

- There is little or no noise
- Fast-responding control is critical
- P-I alone is not good enough
- There is some (small) filtering of the PV. (Note: some controllers have built-in derivative filters)

Choose a Filter

I often refer to filter as “the fourth PID parameter”. Choosing the right filter helps to ensure the overall performance of the control loop.

If the filter is not used, or if it is too small, then the controller will be responding to noise. This causes the valve to move unnecessarily, and actual induces process upset.

If a filter is too large, then it will slow the performance of the controller. You want the controller to respond quickly to upsets, so be sure to match the filter selection to the process dynamics, so that it does not over-shadow actual process response.

Choose a filter for the loop based upon the dominant process dynamics. The filter should be at least 3X the sampling time, and no more than 1/3 of the process dead time.

Most control systems support simple first-order filters. Some, however, may allow you to select a more sophisticated filter, such as the ones shown in Figure 9.



Figure 9. Selecting the filter type that you wish to apply.

Best Practice #5 – Simulate Before Download

Know What to Expect

A friend of mine once spent an afternoon shoveling molten peanut butter because he failed to simulate! He was tuning a tank level, and did not simulate the new level control parameters before he put them in the controller. The tank overflowed hot peanut butter all over the floor, and the operators simply stated their mantra, “You made the mess, you clean it up!”

Keep in mind that you will want to simulate the controller tuning under a variety of scenarios, including:

- How does it respond to a setpoint change?
- How does it respond to load upsets?
- What is the effect of process noise?

Figure 10 shows a variety of simulations, showing the behavior of the old (blue) and new (red) tuning.

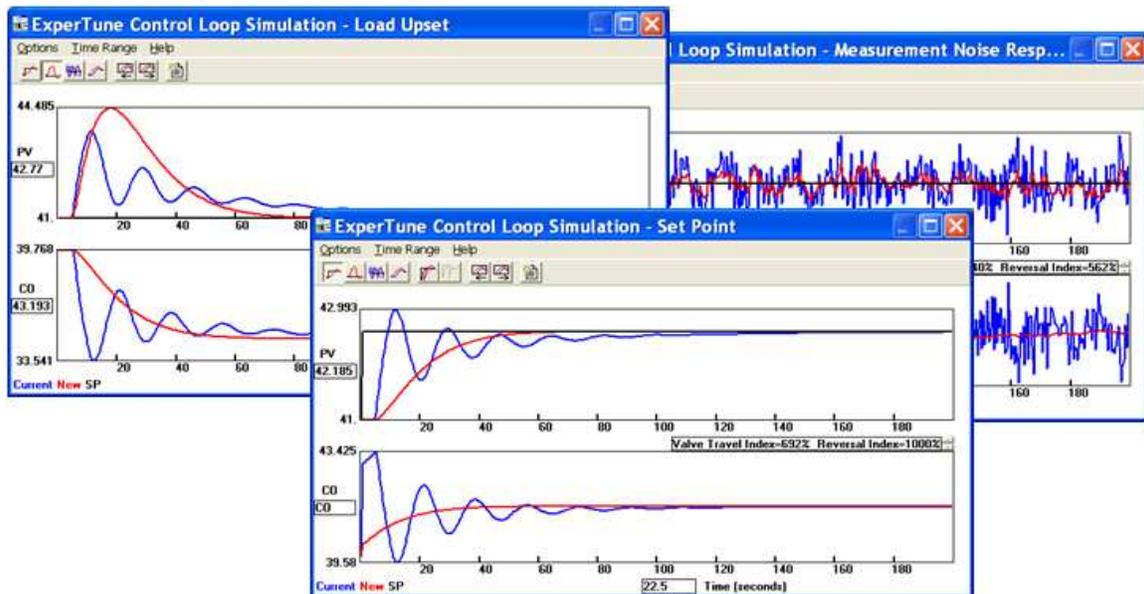


Figure 10. Simulated tuning response to load upset, noise, and setpoint change

As a best practice, you should always simulate the control response before downloading parameters to the controller. This only takes a minute, and it is well worth it.

Best Practice #6 – Monitor the Results

Know When to Tune

How will you know when to tune the loop again? Control loops may require new tuning when:

- The process changes.
- The instrument changes.
- The valve changes.
- Raw materials change.
- Seasons change.
- Operating procedures change.

All of these have an impact on control performance. You may not know that any of these have occurred, so you need a better way to know if tuning is needed. Don't rely on the operator alone...operators often ignore "small" problems, and might even just put the loop in MANUAL.

To know when to tune the loop again, you need to continuously monitor control performance.

Monitoring Control Loop Performance

As the process changes, control performance will change. The best practice is to continuously monitor key aspects of control performance, which may include the following:

- % Time in normal mode
- % Time Valve is at Limits
- Variability
- Significant Oscillations
- Integral Absolute Error
- Many Others...



Each assessment can be baselined and tracked against thresholds for action. In small plants, these evaluations can be handled manually. In larger plants, with more than 100 control loops, control loop monitoring software should be used.

ExperTune's PlantTriage control loop performance monitoring software automatically performs these evaluations and notifies you of the results. Figure 11 shows an example dashboard, with graphical controls to highlight control loop performance issues.

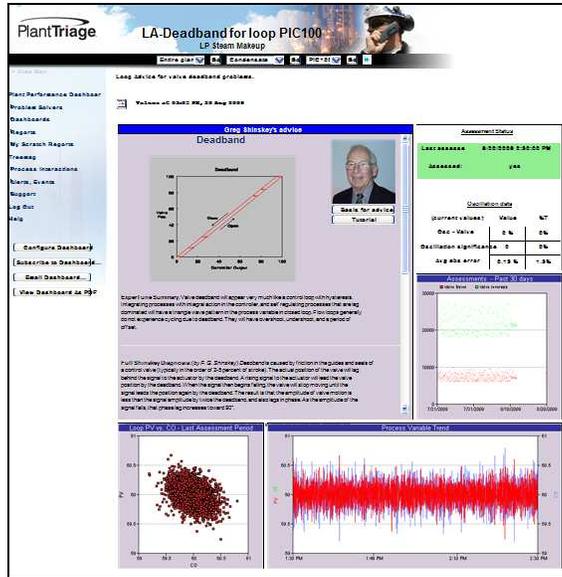


Figure 11. PlantTriage dashboard provides details and advice

Automated Diagnostics

Control loop performance monitoring also includes diagnostics of equipment and control problems. These diagnostics are often able to pinpoint specific issues before the operator has noticed. Figure 12 shows an example of some maintenance-related diagnostics that can be performed automatically.



Figure 12. Maintenance-related diagnostics

Each of these “problem-solvers” is a report that automatically diagnoses, highlights and prioritizes specific control loop issues. The problem-solvers also provide advice for solving the problems.

By automating the diagnostic process, you will find and solve problems much faster than in the past. The best practice for automated diagnostics is to have these reports automatically delivered to the responsible person.

Summary

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Recommendations

1. Get Started Today. These are simple, easy, and effective techniques.
2. Use Modern Tools. No modern plant should be without control loop monitoring and tuning software tools.
3. Training. Today’s technicians and engineers are knowledge workers. The world has changed. Train your plant personnel on the latest best practices.

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About the Author

George Buckbee is V.P. of Marketing and Product Development at ExperTune. George has over 20 years of practical experience improving process performance in a wide array of process industries. An experienced manager and instructor, George holds a B.S. in Chemical Engineering from Washington University, and an M.S. in Chemical Engineering from the University of California.

About PlantTriage®

PlantTriage is Control Loop Performance Monitoring software that optimizes your entire process control system, including instrumentation, controllers, and control valves. Using advanced techniques, such as Active Model Capture Technology, PlantTriage can identify, diagnose, and prioritize improvements to your process.