

Best Practices for Monitoring your PID Loops – The Key to Optimizing Control Assets

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Abstract- PID loops – also known as base layers or regulatory controls – form the foundation of any plant’s control layer. Keeping these thousands of control loops in good health has a direct impact on the plant’s bottom line: it reduces variability, improves quality and throughput, and decreases energy costs and raw material usage. This has been well proven and documented in many articles. In the last ten years, technology has evolved: control engineers can now keep track of control loop performance and link it to the root causes of variability. However, they lack industry-wide best practices and criteria for determining what can be considered as excellent, good, fair, or poor performance. To ensure that PID control loops continue to perform well and meet their objectives, control engineers need a combination of (a) an appropriate monitoring technology and (b) best practices for doing the maintenance of base layer controls. In this article, the authors propose a set of best practices and guidelines for measuring and monitoring the performance of base layer controls. Most plants have limited resources and operate with an increasing number of constraints. Therefore, the methodology is the key for success. Different aspects of the control loop health are taken into account.

I. INTRODUCTION

Although PID controllers are reliable workhorses in the process industry, they are often underrated. Since the 1980’s, computer control has evolved and the control algorithms used by control engineers have been increasingly complex. However, PID controllers still handle over 80% of the control loops in operating plants. Table 1 shows the savings associated with different process control categories (Brisk, 2004). The savings are expressed as a percentage of production costs.

Process control categories	Savings in production costs
Final control device performance and basic loop tuning	1.5%
Unit operations control	0.8%
Advanced control	1.4%
On-line optimization	0.5%

Table 1. Savings in production costs associated with different process control categories (Brisk, 2004)

Based on the authors’ experience, the main sources of loop problems include:

1. Valve performance issues
2. Inappropriate tuning parameters
3. Inappropriate control strategies

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4. Lack of resources
5. Lack of a proactive control loop optimization program
6. Inability to link PID benefits to process performance
7. Lack of process knowledge
8. Lack of monitoring technology
9. Lack of necessary skills to implement high performance PID loops
10. Changes in process dynamics – or equipment wear out

The purpose of this article is to provide an overview of the most common issues and best practices related to the sustainability of PID assets. Examples are used to illustrate the notions discussed.

II. THE IMPORTANCE OF USING A PID CONTROLLER

Plant efficiency and product quality depend on the PID loop performance, but tuning the controller is only the last step.

Good Tuning

There is a lot to be gained with the optimization of control loops. It has been estimated that 80% of process control loops cause more variability when they are run in automatic mode than when they are run in manual mode. About 30% of all loops oscillate due to non-linearities such as hysteresis, stiction, deadband, and non-linear process gain. Another 30% oscillate because of poor controller tuning.

When a loop is poorly optimized, an upset in the direction of inefficiency can cause product losses. Alternatively, a load can lead to the production of off-spec products. When a control loop is run optimally, variability is minimized. A better tuning keeps the process on spec and reduces the waste of often expensive ingredients.

One Size Does Not Fit All

Tuning objectives vary for different types of processes. For example, in a steam header, the pressure has to be maintained at the maximum allowable without large errors so that the safety valves will not open. The PID controller must be tuned tightly to ensure that the valve that controls the flow from the main header will move quickly to eliminate disturbance effects. On the other hand, in a mixing process, the PID controllers have to move all together, at the same speed, to ensure that the ratios remain constant.

The characteristics of a good control are difficult to obtain. Loop tuning involves a trade-off between robustness and speed of response. Robustness refers to the ability of the control loop to remain stable when the process (mainly dead time or process gain) changes.

III. MONITORING YOUR PID CONTROLLERS

When a control loop is analyzed, four aspects must be considered:

- Utilization: This is the first level of the analysis. If the controller is not used, there is probably a fundamental problem.
- Performance: A controller may be performing poorly even if it is in use.
- Diagnostic: If performance is not satisfactory, there can be several reasons: model plant mismatch, improper tuning, instrumentation issues, etc.
- Remediation: Once the reasons for unsatisfactory performance have been identified, it is important to prioritize actions and make changes to the controller or process, in order to improve performance without excessive costs or efforts.

Figure 1 shows how a typical PID application should be analyzed. The analysis process includes three steps: assessment, diagnostic, and remediation.

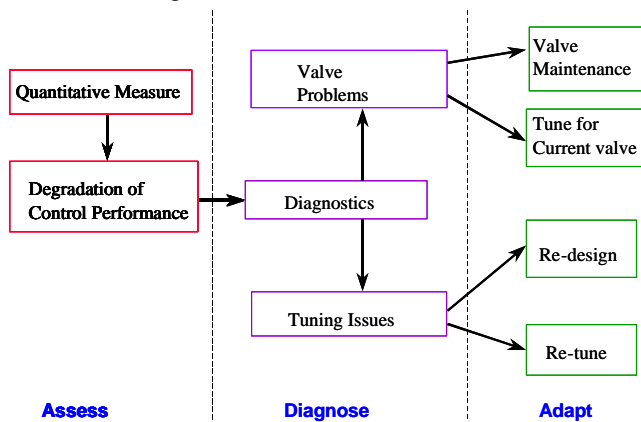


Figure 1. Assessment, diagnostic, and remediation of a typical PID application

The measurement of PID performance is not a trivial problem. The following section discusses the specific metrics that can help assess whether a controller is delivering satisfactory performance.

IV. PERFORMANCE MONITORING METRICS

Control performance monitoring tools allow to evaluate key indicators such as:

- % time in service
- % time in saturation
- Oscillation index

- Variability
- Integral of absolute error
- Stiction
- Settling time
- Operator activity

Three key aspects of PID performance are reviewed below: variability, actuator performance, and oscillations. Variability is an important measure as it is the basis on which PID applications are implemented. It is important to ensure that it is managed according to objectives.

Variability

Variability is often measured based on a historical baseline data set. Prior to commissioning, a historical baseline is selected. Then, variability (i.e., the standard deviation of key controlled variables) is compared to the baseline and improvements are noted.

A shortcoming of using absolute variability as a benchmark is its dependence on underlying process disturbances. With PID applications, variability can be compared at two points in time in a fair manner under the assumption that nothing else has changed (i.e., the disturbance magnitude and dynamics remain the same). This can lead to both false positives and false negatives. Variability may decrease because the overall process is more stable, and it may increase because process changes are made elsewhere.

A more accurate representation of closed loop performance can be made based on closed loop performance requirements (settling time, rise time, overshoot, IAE, ISE, etc.). These measures are invariant to the disturbance scale and are thus normalized. Some commercially available PID technologies directly incorporate such measures into their controller tuning stage.

$$\text{Relative Variability} = 100 * \frac{\sigma_{CV_{des}}^2}{\sigma_{CV_{ach}}^2}$$

The desired variability could be established based on historical benchmarking (post commissioning) or design considerations (closed loop response requirements), as discussed above. The relative variability can be calculated at the individual CV level and aggregated to the controller level.

Valve Performance

The valve is an important element of the control loop. Common valve problems include stiction, backlash, undersizing, and oversizing. Undersized or oversized valves are detected by monitoring valve opening. Stiction is the

worst enemy in process control. Fortunately, it can be measured using a continuous stream of data.

Stability

Oscillations are also detected using a continuous stream of data. Usually, the most oscillating loop is the cause of oscillations in a unit.

Table 2 proposes guidelines regarding the key metrics for any PID application. These metrics are used at the overall application level but they are related to the individual level. Variability is calculated based on design performance or desired variability. Model performance is calculated based on benchmarked model performance.

Effective utilization is based on (worst case):

- % time in service
- % time in saturation
- Operator activity

Variability is based on (one):

- Variability
- Integral of absolute error

Stability is based on (worst case):

- Oscillation index
- Stiction
- Settling time (should not change unless the process model changes)

Targets	Effective utilization	Variability	Stability
Daily	>50%	<150%	<40%
Weekly	>80%	<125%	<30%
Monthly	>90%	<125%	<20%
Quarterly	>90%	<110%	<20%
Yearly	>95%	<110%	<10%

Table 2. Recommended targets for performance metrics as a function of time (targets are expressed in terms of normalized values)

These targets take into account that there will be short-term variations in the different performance metrics because of operating point changes or disturbances. It is essential that the team that owns the PID application agrees upon these targets.

Each time one of the three characteristics is outside the expected bounds, a flag is raised in a report and personnel should be notified. That way, the workflow is automated and actions and decisions are taken based on rational performance measurements.

V. PERFORMANCE MONITORING – ROLES AND RESPONSIBILITIES

In most plants, base layer controls are supported by a group of people including process control engineers, operators, and managers. The instrument technician or process control engineer who has the appropriate PID training is the owner of the control loop; he is responsible for maintaining and troubleshooting the controller. He also works with the PID loops on a daily basis to address issues raised by the operators and to make sure that the controller is run adequately by the operators. The roles and responsibilities of the ownership team members are described below. Note that these roles and responsibilities can change from one organization to another, based on the organizational structure and resource availability.

Plant Manager

The plant manager should be concerned if (1) the base layer controller uptimes are not satisfactory and (2) process stability is not achieved by the controller.

Shift Supervisor

The shift supervisor should be concerned if the operators have to pay too much attention to one or more controllers and they need to take the controllers off. In other words, the shift supervisor is not concerned with the level of operator interactions, process stability, and controller uptimes.

Operator

The operator needs to know, based on a real-time interface, what the controller is doing at any given instant and why it is doing so. In more technical terms, the operator is concerned with (1) controller performance and (2) controller diagnostics.

Production Engineer

The production engineer must achieve the production targets that have been set by the planning/scheduling team and plant manager. Also, safety is a key priority for the production engineer. He should be concerned with the PID controller if it is engaging in behaviors that cause (1) unit-wide oscillations (i.e., instability) or (2) off-spec incidents resulting in the production of off-spec products. This information is usually provided by the operator or shift supervisor.

Process Engineer

The process engineer is involved in the design phase of the application. He makes sure that the key variables are

included and that the controller targets the “optimal” constraints. The process engineer may also get involved in troubleshooting if the underlying process behavior causes a problem with the controllers.

Technical or Process Control Manager

The technical or process control manager is concerned with (1) application uptimes and (2) benefits. Issues requiring additional resources will be brought to his attention as necessary. For example, if the process has undergone some changes recently and a full step test is required to update the plant models, the technical or process control manager will be notified.

Process Control Engineer

The process control engineer is concerned with all issues observed by the rest of the team. He is not only concerned with (1) controller uptimes, (2) controller performance, and (3) process stability, but he is also concerned with the “why” part. That is, he is interested in process variability relative to benchmarks, cycling in the controller, controller performance, operator interactions, tuning problems, and process changes that influence application behaviors.

Instrument & Electrical Technician

The instrument and electrical technician only gets involved if an issue (i.e., a sticky valve or a malfunctioning sensor or analyzer) raised by one of the other team members needs to be addressed in order to recover PID performance. Thus, he needs information on the diagnostics concerning the instruments or valves that have been flagged.

Table 3 shows a responsibility matrix for the different aspects of a PID application.

Role	Utilization	Benefits	Performance	Diagnostics
Operator	A	R	R	C
Shift Supervisor	R	R	C	C
Plant Manager	I	A	I	I
Production Engineer	I	R	C	C
Process Engineer	I	C	I	C
Technical Manager	R	R	I	I
Proc. Cont. Engineer	R	R	A	A
I&E Technician		I	C	R

Table 4. Responsibility matrix for maintaining PID loops (R = responsible, A = accountable, I = informative, and C = consultative)

Role	Utilization	Benefits	Performance	Diagnostics
Plant Manager	Monthly	Quarterly	Quarterly	Quarterly
Shift Supervisor	Daily	Monthly	Daily	Weekly
Operator	Minutes	Daily	Minutes	Daily
Production Engineer	Daily	Weekly	Daily	Weekly
Process Engineer	Monthly	Monthly	Monthly	Monthly
Technical Manager	Monthly	Quarterly	Monthly	Weekly
Proc. Cont. Engineer	Daily	Daily	Daily	Daily
I&E Tech.	Monthly	Monthly	Monthly	Weekly

Table 4. Performance monitoring timescales for PID monitoring metrics

VI. CONCLUSIONS

Maintaining and optimizing the performance of PID controllers is a challenge that involves different groups of individuals and work processes. The objective of this article was to describe the problem in an industrial context, and to discuss best practices for monitoring base layer or PID controllers. PID controllers have had a significant impact in the process industry. They can lead to substantial benefits (in the order of 1.5% of operating costs), including: improvement of the operability of individual process units, reduction of energy usage, increase of throughput, and improvement of quality. Appropriate steps need to be taken to monitor and continuously adapt PID performance to changing conditions. In particular, the right metrics and work processes must be used so that any significant performance degradation of the base layer control loops is detected, diagnosed, and remedied, in real time.

REFERENCES

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