7 Methods to Improve Control Performance in Pulp and Paper

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Abstract

In today's highly automated production environment, the control system is critical to plant results. Yet most pulp and paper plants are failing to capture peak performance from their control systems. Surveys of control performance show that 30 to 50% of control loops have significant room for improvement.

This paper shows seven methods to measure and improve control performance. These methods have been proven in pulp and paper facilities globally. Case study examples are used to illustrate the techniques, and identify the bottom-line business results provided.

Control performance is defined as the overall performance of the control system, and its impact on the process. Traditional measures, such as "up-time" fail to capture the true process impact. A more modern approach is to look at real-time performance measures that tie more directly to cost, quality, environmental, and production goals.

These modern methods include ways to evaluate the performance of instrumentation, controllers, control valves, and the process itself. High-speed, high-resolution process data is now broadly available in most any paper mill. Performance monitoring techniques use this data to evaluate control performance in real-time. Diagnostic rules are applied to pinpoint specific issues and suggest corrective actions.

The seven methods presented in this paper can be re-applied at pulp and paper facilities globally. The link between these methods and business results are illustrated with case studies. The case study examples include bleach chemical reduction, energy savings, and root-cause problem-solving to eliminate basis weight swings.

Introduction

When you spend millions of dollars installing new equipment, management expects to see results. Yet, automation systems have been installed, maintained, and upgraded, often with little reporting of the business results. Control Performance Monitoring provides a way to measure, manage, improve, and report these results.

Over the past 10 years, Control Performance Monitoring has become a standard tool of the trade in some industries. The Pulp & Paper industry has adopted at a slower rate than have the Oil & Gas industries, for example. But substantial results in mills have led to an increasing rate of adoption.

The seven methods presented in this paper include:

1. Measure Control Performance
2. Apply Targeted Solutions

3. Reduce Variability
4. Get to the Root Cause
5. Follow Up
6. Document and Share Results
7. Make it a Habit

When these methods are applied, the results are dramatic. Specific case studies illustrate how these methods have worked to deliver business results.

Method 1: Measure Control Performance

Manufacturing guru Peter Drucker has said, "You can't manage what you can't control, and you can't control what you don't measure." So you must measure control performance if you want to improve it.

It is strange, then, that few plants are actually measuring control system performance. Ask the plant control engineer "How many of our control loops are in Manual?" and you will likely be met by a blank stare. The most important metrics for control system performance often go unmeasured.

The starting point for most process plants is finding key performance metrics for control systems. Table 1 below identifies some key performance metrics for control systems.

Metric	How Measured	How it Affects the Bottom Line
% of Time not in Normal Mode	% of time that control loops are in manual or other sub-optimal mode	Symptom of other underlying problems. Directly affects safety.
% of Time at Limit	% of time that valves are fully opened or fully closed.	Identifies production constraints.
Oscillation Significance	Affect of oscillation on process performance	Energy costs, variability, and quality.
Valve Travel	Amount of valve movement per hour.	Maintenance Costs.

Table 1. Measures of Control Performance

Why aren't these things measured? In the past, it was difficult to measure them. Custom databases and programming were required. Today, however, commercially-available software can monitor and report on these metrics using real-time information directly from the control system.

Document the Baseline

When starting to monitor control performance, it is very important to take time to document the current baseline for both the technical performance measures and the business-related metrics, such as production costs, energy per ton, and quality.

The technical measures are a good supplement, but only if they can be linked to the business metrics. For example, if you are trying to improve quality (reduce %rejects, for example), it may be a good idea to track a technical metric such as variability. You can make a strong case that reduced variability has a direct impact on reducing the amount of reject material.

Method 2: Apply Targeted Solutions

When most mills first start monitoring control performance, they find that there are many ways to make an immediate improvement. For many performance measures, there are targeted solutions that will immediately deliver improved business performance for the mill. Table 2 illustrates these performance measures, the actions required, and the resulting business value.

Measure	**Targeted Solution**	**Business Value**
%Time Valve at Limit	Change valve trim, or reduce restrictions, or increase pump capacity	Production increases, often for very minor investment in valve trim.
Excessive Valve Travel	Add a filter, remove derivative action.	Reduced process variability, improved reliability.
Harris Index, especially for flow loops.	Controller Tuning	Stability, fast response, and quality improvement.
Oscillation Significance and Oscillation Period.	Sort all loops by oscillation period. Resolve root cause by tuning or valve repair.	Most often, energy savings and process stability. Sometimes production increase.
Opportunity Gap	As variability is reduced, forces operators to push key setpoints closer to optimum target values.	Reduce Unit Cost and improve quality.
Noise Band, especially for consistency controls.	Filtering and tuning	Reduced quality variability. Reduced operating costs.

Table 2. Targeted Solutions

Method 3: Variability Reduction

In pulp and paper the end product, the paper itself, is actually an historical record of the process variability. This is quite unlike other industries, like oil refining, where process variability is averaged out by mixing fuel in a tank at the end of the process.

So it is important to pay attention to both short-term and long-term variability. Also, the variability may be periodic (cyclical) or more random in nature. Periodic variation can be tracked by performing Fourier Transform analysis on instrument signals. The analysis shows the strength and the period of oscillations.

Pulp and paper controls provide some unique opportunities. For example, consistency measurements are often quite noisy, when compared with other controls, such as temperature. When a controller is fed the noisy signal directly, it will start moving the valve in response to the noise. Not only does this cause the valve to wear faster, but it also induces variability into the process.

The variability spreads downstream, affecting refining, cleaners, and even basis weight variation. A simple solution, such as filtering the signal, or choosing tuning with little gain and no derivative action, can make a huge difference in stabilizing the operation.

CASE STUDY: One mill in Wisconsin reported a problem with a basis weight cycle, when starting up from a shutdown. The Basis weight was swinging on a 10-minute period. Using data from their control performance monitoring system, they discovered a similar swing in the mill water header pressure supply to that machine. Surprised by this, they investigated. They discovered that, during the recent shutdown, there had been an unauthorized tap into the mill water header, to supply a batching operation nearby. The batching system ran every 10 minutes, drawing water from the header, dropping header pressure, and inducing a response in many related controllers on the paper machine.

Method 4: Get to Root Cause

Automated Root Cause Analysis is one of the most exciting new technologies to arrive on the scene. Given the huge amounts of process data available, it is now possible to identify process correlations and likely root causes **without performing experiments**.

Massive Cross-Correlation Studies

One example of the new approach is the use of a massive cross-correlation study. Large amounts of existing historical process data are run through cross-correlation analysis. When comparing any two signals (process variables such as temperature, pressure, etc.), the analysis provides a correlation vector. The vector shows the strength of correlation between the signals at various time-shifts, which we can refer to as “leads” or “lags”.

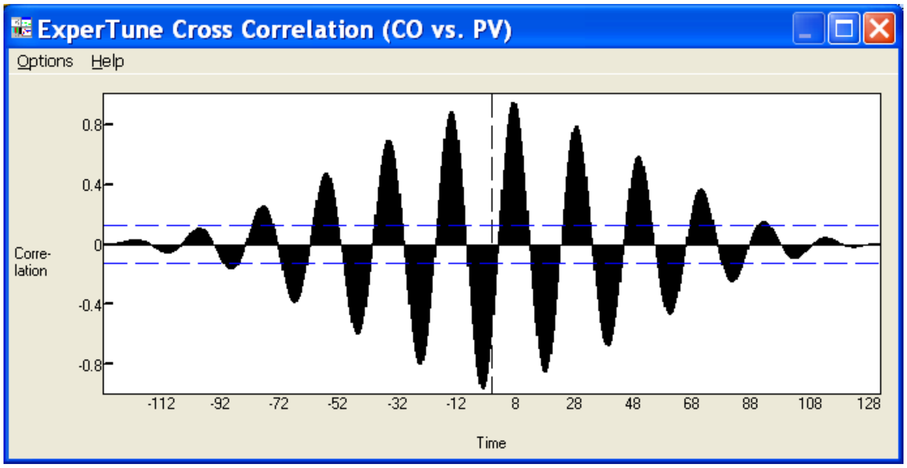

Figure 1. A Cross-Correlation Plot

The lead-lag analysis is critically important, because most process plants are relatively linear in nature: Raw Materials are physically transported through the plant, as they are transformed into finished products. This transportation delay results in data “lag”. In other words, an instantaneous change to the raw material might result in changes to finished product many hours later.

If we focus only on the strongest correlation in time, then the entire plot can be summarized in two values:

1. The peak correlation coefficient
2. The lead/lag time at that peak

The peak information can be displayed in an “Interaction Hot Spots” display, as shown in **Figure 2**. Strong correlations are shown in red, while weak correlations are green. Hovering over a particular grid location will display the strength and the lead/lag of the correlation.

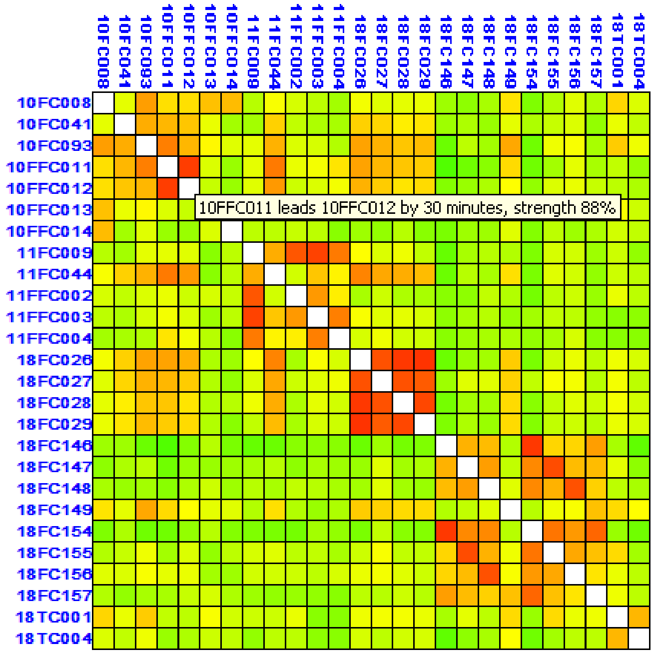

Figure 2. Interaction Hot Spots identifies correlation strength and Lead/Lag

Can You Avoid a DOE?

The information contained in the Interaction Hot Spots is very similar to the results of a Designed Experiment (DOE):

- The magnitude of the interaction is made clear.
- The groupings between variables is made clear.
- The lead/lag time factor is made clear.

So, we have achieved many of the results of a DOE, using normally-occurring process data, **without performing any experiments**. These results can, in fact, be improved by intentionally exciting the process, through the use of setpoint changes or other intentional process changes.

Automated Root-Cause Analysis

Process plants are complex places, with many direct and indirect interactions between areas of the plant. The Interaction Hot Spots, shown above, is a good tool for casting a wide net across the plant, and determining which items are related.

Suppose, however, that you need to resolve a specific problem. Perhaps a quality attribute is out-of-control, and product is being rejected or recycled. Or energy costs per ton are varying from day to day. Automated Root Cause Analysis can pinpoint the source of many of these problems.

Automated Root Cause Analysis uses correlation data in the form of a "Process Interaction Map", as shown in Figure 3.

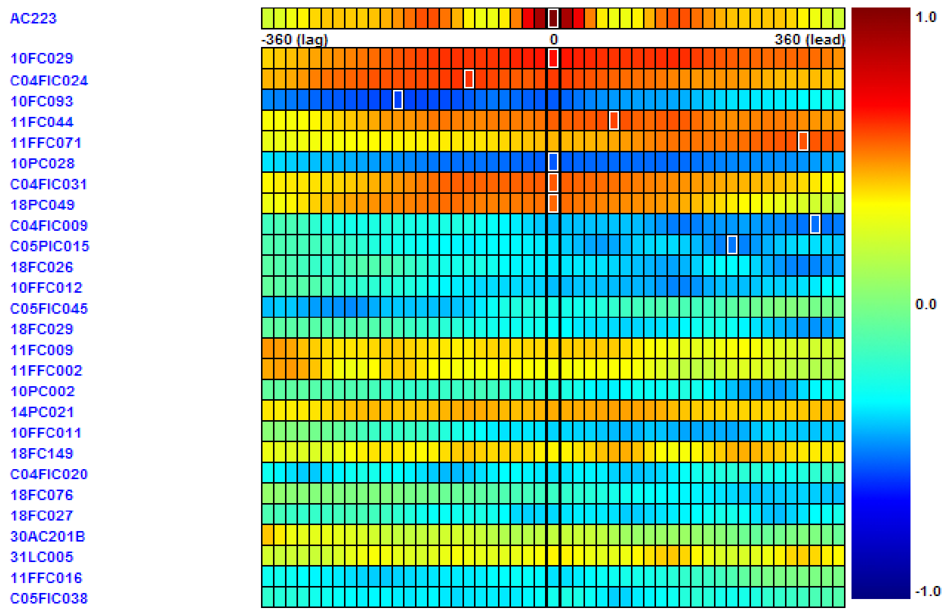

Figure 3. A Process Interaction Map

A Process Interaction Map shows both the strength and lead/lag of **all factors that are influencing the key variable**. Lead/lag is shown on the horizontal display, and strength of correlation is shown with color. Both positive (red) and negative (blue) correlations are significant.

The Automated Root Cause Analysis finds the root cause by looking for strong correlations with the longest time lead. This is most likely to be the original source of variation, furthest upstream in the plant facility.

Automated Root Cause is a Proven Technique

The automated root cause technology has been proven in many process plants world-wide:

- A Plastics Plant in Alabama saved $1MM+ after identifying a Cooling Tower cycle that drove process temperature and pressure swings.
- A Chemical plant in Texas found the root cause of distillation column upsets, and immediately captured energy savings of 7,000 pounds per hour.
- A Paper Plant in Wisconsin identified the root cause of paper machine basis weight quality problems in an unlikely upstream location.

Method 5: Follow Up

When a mill starts using control performance monitoring, they will generate a list of many corrections to be made. Controllers will need to be tuned, valves repaired or upgraded, instrument issues resolved, and process operating procedures changed. It will not be possible to address all of them at once.

Valves may require repairs or replacements during the next shutdown. Instrument ports may need to be cleaned out. Process changes might require more extensive follow-up, including design and safety reviews.

So it is absolutely critical to success that someone follow up on all the required improvements. A simple spreadsheet, or integrated to-do-list tracking may be good enough to support the work. However, the person assigned must be diligent, and make sure that all required actions are completed.

Method 6: Document and Share the Results

This is probably the most important of these 7 methods. If you do great things, and nobody knows what was done, you have lost.

Networking is a critical part of this. I'm not talking about computer networks, but people. Make sure you have credibility with a wide array of people. Think outside your normal workday routine. Set up lunch meetings with some of these people:

- The Plant IT Manager
- Your Counterparts in Other Departments
- The Plant Financial Guru
- Instrument Techs
- Operations Managers
- Purchasing Agents

This will be a challenge at first. But you will find that this helps you to develop stronger relationships in the plant. These relationships will be helpful as you communicate your results.

When you get some good results, you will need to communicate them clearly, concisely, *and in business terms.* Remember the baselining discussion above? Go back to your baseline measurements, and show how your work had an influence on the bottom line.

When it comes to communicating, keep it simple. Don't write a 200-page report. Nobody will read it. Instead, send a short email with "Before and After" pictures, and just a little bit of back-up material. The subject line of the email should be something like: "$120,000 Savings on the De-Chlorinator". That email will be opened, read, and forwarded to others.

How much value can you bring? It certainly depends on your role. With some effort, a typical control engineer should be able to document between 6 and 10 times their annual salary in savings. This may come from any combination of the business results areas listed in the baseline section.

Documenting the Benefit

Ask control engineers to provide "Before and After" pictures, showing the technical impact of their work. Figure 5 shows the before and after together on the same trend. At first, it will be difficult to assign an economic value. Don't worry about assigning economic value to each individual improvement. Just be sure to get written (electronic) confirmation, showing the improvement.

Start to identify where you expect to see the economic improvements. For example, stabilizing fuel flows and temperature controls should result in energy cost reductions. Real-time analysis of control valves should result in maintenance cost reductions, and ultimately a drop in unplanned downtime.

Some results will be immediate, and others accrue over time. One way to see the benefit more clearly is to focus on one unit operation at a time. Look for a step change in unit performance (production, quality, etc.) around the time of the effort.

Note that it is not critical to know exactly which control loop led to the performance increase. This process is somewhat like "tuning up" your car…you resolve all the spark plug issues; it doesn't matter which one was the cause of fuel inefficiency. Also, try to avoid the engineer's tendency to document every last dollar of benefit. It is enough to get a first-order approximation of the benefit. This can help you to determine the value of re-applying the same approach elsewhere in your plant or across your company.

Results & Expectations

Typical improvements for process plants are shown in Table 3.

Benefit	**Typical Range**	**Conservative Range**
Energy Reduction	0.5% to 2%	0.5% to 1%
Production Increase	1 to 10%	1 to2%
Valve Maintenance Budget	10% to 50% reduction	10% to 20%
Quality Improvement	5% to 50% improvement	5% to 10%

Table 3. Typical Results of Control System Improvements

How much benefit can you expect to see from control system improvements? Of course, the full extent of the benefits depends on your starting point, and how much focus is put con control system improvement.

Method 7: Make it a Habit

Controls continually degrade. Instruments fail. Valves wear. Processes change. It is important to continually monitor the mill, to be able to respond quickly when new issues occur.

Many of the steps in control performance monitoring can be easily incorporated into existing work flows and processes. Maintenance teams, for example, can look at valve performance reports when planning for an upcoming shutdown. This simply provides the right information at the right time.

To get the best results from control performance monitoring, the first 6 methods need to become a habit, a continuous improvement cycle that is reinforced by the rewards that are recognized in Method 6.

Summary and Conclusions

Control Performance Monitoring is has delivered substantial results in pulp and paper mills, which will lead to fast adoption. The seven methods presented in this paper can be re-applied at pulp and paper facilities globally. The link between these methods and business results are illustrated with case studies. The case study examples include bleach chemical reduction, energy savings, and root-cause problem-solving to eliminate basis weight swings.

Biography

George Buckbee, P.E. is a Fellow of ISA., author of several process control books, and is currently General Manager at ExperTune. An experienced instructor, George has over 25 years of practical experience improving process performance in a wide array of process industries, including Oil &Gas, Pulp & Paper, Pharmaceuticals, and Consumer Products. George holds a B.S. in Chemical Engineering from Washington University, and an M.S. in Chemical Engineering from the University of California, Santa Barbara.

Doug Nelson, P.Eng. is a principal at ProNamics Control in Vancouver. He has over 25 years of industrial process control experience and has authored papers on paper machine dryer control, loop performance monitoring systems, control valve selection and the uses of process simulation in optimization surveys.