Process Control Performance: Not as Good as you Think

By David B. Ender, President, Techmation, Inc.
Reprinted from Control Engineering September 1993

Twenty-five years ago, control systems were built around single loop pneumatic controllers, pneumatic transmitters, and control valves. These were hooked together with pneumatic tubing carrying 3-15 psi pneumatic signals that implemented control strategies at the speed of sound. Controllers were either proportional only (P) or proportional plus integral (PI). Derivative cascade, and feedforward were viewed as very advanced control strategies.

Controller tuning was considered more of an art than a science and the subject of active research at many universities. On a tour through a typical plant, one would find as many loops in manual as in auto, or drifting all over because the gain was turned way down to avoid troublesome oscillation (thereby also avoiding troublesome control.) In a word, control was poor.

Electronic analog controllers promised faster response, the possibility of more precise tuning, and a revolutionary improvement in control accuracy for a slight premium in price (usually about double). This triggered a long-lived debate as to which was better, analog or pneumatic instrumentation. The debate lasted nearly a decade and was never settled. It was finessed by the mid - '70s introduction of the micro computer based distributed control systems (DCSs).

In the early 1980s, after DCSs had been available for five or six years, Honeywell, Union Carbide, and others, to quantify the benefits of using DCSs rather than conventional analog instrumentation conducted some studies. One of the areas identified was better control.

Before and after comparisons of performance, when conventional instrumentation was replaced with digital systems, repeatedly revealed better control. Even when there was no overt change in control strategy - and when the old system was replaced loop for loop - reductions in variance in key process and product variables as high as 47% were reported!

The reasons identified for this phenomenon were straightforward;

- More loops were in auto
- The loops were tuned better
- Setpoints were adjusted with finer resolution and greater accuracy

Today's systems

Compared to older equipment, today's high technology control systems seem wonderful. But, let's take a closer look:

The operator's consoles - The color videos are very nice, and the touchscreens and track balls are state of the art. However, data sampling rates to the screen are still slow causing aliasing of true process response.

The latest microcomputers - Gordon Moore, founder and chair of Intel, formulated Moore's Law which quantifies the rapid advancement of computer technology: Every three years, computer technology doubles in power while its costs are reduced in half.

The software - It's improving. It's people intensive. But, it's not bug free.

Control valves - Better valve designs, anticavitation, and noise reducing trims are yielding high performance rotary valves with better seals and better packing designs.

Valve actuators - Spring and diaphragm valve actuators are still found operating at 3-15 psi, the most common control media. Excessive hysteresis, stick-slip, valve maintenance, and calibration are still major problems.

Field instrumentation - It's improving. Installation, calibration, and maintenance are still problems, though.

***Smart* transmitters** - These have only recently become available and their popularity is growing. Some designs contain on-board digital processors to massage the raw data readings, including; a moving window filter technique and a noise suppression deadband.

Closed-loop control - The transmitter dynamics change depending on the magnitude of the true signal change. This causes the feedback controller to introduce a resolution cycle similar to controlling the process with a valve with excessive stick-slip. Not too smart from a process control standpoint.

The control algorithms - PID is over 50 years old and is used in 95% of loops. Yet, after all this time, there is no standard for PID implementation in digital controllers. Hence, no two digital controllers on the market work the same.

***Advanced* digital systems** - Many do not provide enough functionality for even basic modification of the PID algorithm. For such basic control, as error squared for surge level tank control or PI-D and I-PD selection for modification of the setpoint response to the error, some manufacturers even limit the PID settings that can be entered. Because it's seldom applied effectively and less often tuned for minimum variance, feedforward is also not in wide use.

Process applications - There are not enough control engineers available to address all applications properly.

In summary, today's control systems provide major improvements in many areas, such as the human-machine interface, flexibility, ease of configuration, reliability, and communications with the process.

"*The bottom line is that the optimization of existing control systems would generate enough profits to eliminate the United States trade deficit*." - Bela Liptak

But, as with the changeover from pneumatic to analog, the development of the 4-20 mA standards, and the switch to digital instrumentation, there are still areas to debate.

Today, such debate centers around fieldbus standard. And, like the earlier debates, users want to know that whether the new digital fieldbus standards will really help process plants achieve better control.

Performance of today's systems

With the latest and greatest digital control systems presently installed in process plants, what follows are some first-hand observations of how the billions of dollars spent on DCSs has affected the quality of control.

In testing thousands of individual control loops, in hundreds of operating plants, the following summarizes what Techmation and others have found about how the typical process plant is operating.

- Today, more than 30% of the process controllers installed operate in manual.
- Today, more than 30% of the process controllers installed operate in manual. After presenting these data at a recent seminar, a participant challenged the findings. He was certain that his plant, and most others, could not possibly be running with such a high number of loops in manual. The following week he called to say the number should be closer to 50% and reported he had no idea that things were so bad.
- More than 30% of the loops actually increase variability over manual control due to poor tuning. At a recent control conference, a speaker from a major company stated that in a survey he conducted, 25% of the control loops in the DCSs in his companies' plants had the default parameters: Gain = 1.0, Integral = 0.1 repeat per minute.
- 30% percent of the loops have equipment problems. The equipment problems include oversized and undersized valves; excessive hysteresis, resolution, or stick-slip in the valves; and measurement problems.
- Measurement problems include; improper or no anti-aliasing filter settings in the transmitter, excessive filtering in smart transmitters, excessive noise on the measurement signal, and improper transmitter calibration, to name a few.

Recent findings indicate...

At a recent TAPPI (Technical Association of the Pulp and Paper Industry) meeting, a representative of a major valve manufacturer presented a paper where they tested 31 valves on a paper machine steam and condensate system. They found that 35.5% of the valves didn't have the correct travel set, another 35.5% had insufficient actuator thrust for smooth operation, 38.7% had improper bench set, 35.5% had excessive friction, 35.5% had I/P calibration problems, and 71% needed positioner calibration. No checks were made on sizing or installed characteristics.

Control engineers at the plant level will admit that they are so busy trying to solve *real problems* they do not have time for theory

Fifteen percent of the loops have design problems. One reason for this is a lack of process control design conditions at the time of initial engineering. All too often, we find control loops added to processes as an afterthought.

This causes improper installation procedures because that's all the room there was to install the equipment in the existing piping. Proper design includes a realistic expectation of control over a realistic control rangeability with some stated accuracy requirement.

Control rangeability is the ratio of the maximum control setpoint to the minimum control setpoint. Testing typically finds that less than 20% of control loops actually work well and reduce short term variability in automatic control. Variability impacts final product uniformity and plant efficiency. It also represents a poor utilization of the capital investment in the process control equipment. In short, the digital electronic control of modern process plants is typically not much better than was achieved with the pneumatic instrumentation of 25 years ago.

Who is responsible?

Consultants? Consultants are typically involved more in the design and construction and have only limited expertise in process control dynamics.
Vendors? Control system vendors' expertise is more in the control system and not in process control itself. They typically are more involved in installation, configuration, and commissioning. Typical tuning during commissioning is done to detune the system to make it stable at steady state. This type of tuning is not intended to provide minimum variance control.
User's? The Buck Stops Here!

Plant organization

Many engineers in process control took one or more control theory courses in their undergraduate program. The course was typically presented as an abstract math course by a professor who never worked as a controls engineer in industry. For control engineers working in the plants, once out of school, the material is quickly forgotten, and they practice process control on an ad-hoc basis without reference to the theory that governs the behavior of dynamic systems.

Control engineers at the plant level will admit that they are so busy trying to solve real problems they do not have time for theory. Control engineers in industry, in many cases, see process control as a problem of DCS configuration and plantwide systems integration. Even control engineers designing advanced control strategies typically assume the regulatory (feedback and feedforward) control systems work well and that the advanced control strategies will optimize the plant's performance.

In many cases, the advanced control strategies calculate optimum setpoints and demand continuous changes be made by the regulatory control system which is in manual, detuned for steady state operation, has equipment or design problems, or in some cases works well.

In many plants, the E/I technician have the direct mandate for loop tuning. The engineers cannot so much as touch a loop let alone tune it. E/I technicians' formal training typically varies from none at all, to a brief introduction to Ziegler-Nichols tuning rules.

In many plants, the E/I technician have the direct mandate for loop tuning. The engineers cannot so much as touch a loop let alone tune it

In practice, all technicians teach themselves to tune by the seat of the pants, sometimes referred to as trial and error or SWAG tuning. This typically involves "tweaking" the settings until the loop "looks" right. Operators know the process and feel that they can control the process and make product "in spite of" the control system. With experience and time, they learn how to stabilize the process, control upsets, and make fast changes manually to overcome the inherent problems in the control system. They are all for optimization, but resist any testing of the system which is running and making product.

The following are some observations by leaders in the field:

W.L. Bialkowski writes; "*The main barrier is not technological, but a deep seated lack of understanding by industry management of the true nature of process control and its potential to enhance competitiveness. This leads to an inability to provide the leadership necessary for bringing about the organization and cultural changes needed to meet the challenge.*"

Karl Astrom has written: "*The major obstacle to implementation of advanced control has been a lack of tools to determine the process dynamics*."

Bela Liptak writes; "*The bottom line is that the optimization of existing control systems would generate enough profits to eliminate the U.S. trade deficit*."

Reducing product variance

The issue that always comes up in discussions with management is one issue of proving the benefits of improved control. Management has invested greatly in the most modern control systems and assumed that the investments would lead to better control. Management has also shown a willingness to dedicate resources for improved control. Products like self-tuning controllers and resources dedicated to trial and error tuning by the technicians have not been proven to improve control, reduce variance, improve profits, and provide real tangible benefits.

Results of lessons learned

Techmation has developed tools and training programs to provide a systematic approach to process system analysis based on experience gained during the past 8 years in over 2,000 plant sites in 16 countries. Two such effort are a Fundamentals of Process Control training course for control engineers and E/I technicians and an Advanced Control System Analysis course for project, process, instrument and system engineers.

Developed as a systematic approach to process system analysis, the Techmation Protuner is a software tool for control system dynamic analysis. it enables optimization to be extended to all of the loops controlling the process.

Summary

Process plants around the world are feeling competitive pressure with escalating demand for lower cost, higher quality products at reasonable profit margins. Obtaining and optimizing the dynamic performance of control systems can make a measurable difference in plant operation and profits.