What Goes on Inside *Your* Controller?

By Harry Elliott

Even with all the built-in capability and reliability of today's digital controls, finding satisfactory control solutions may require some knowledge of the available options and inner workings of your controller. All of the comparably simple examples below are questions or applications I have encountered in recent weeks where a little understanding saved a lot of time. The alternatives to understanding a little about your controller are long trial and error searches for a workable control solution, or accepting control degradation. The solutions tend to be system dependent but the problems are seen with a variety of platforms. See also "Tuning and Control Loop Performance" by Gregory K. McMillan, ISA Monograph Series.

Why does the filter have an offset?

The positive displacement pump discharge pressure needed to be filtered before going to the PLC PID algorithm. Since no filter or lag function was available, a standard filter equation, Output(n) = Output(n-1) + (Input(n)-Output(n-1))*(Scan time/Filter time constant), was implemented at a specified scan time. It was observed that the output did not match the average of the input signal.

Anyone who has seen this before will recognize that an offset will exist proportional to the ratio of Scan time to filter time constant and inversely related to the number of bits used for the arithmetic. In this application, making the scan time larger provided an acceptable compromise between following the process without excessive lag and minimizing the error due to round-off in the arithmetic to a degree that was acceptable for control.

Does Your Output Change Immediately When You change Set Point? Should it?

Operators do not like to see the controller output jump. Thus many controllers are configured so a set point change enters only the integral portion of the PID algorithm. See Figure 1. No proportional or derivative control action occurs when the set point is changed. The process moves to the new set point at a rate determined by the reset time constant. What happens when a controller not having proportional action due to changes in the set point is the secondary controller in a cascade loop? The closed loop response becomes slow and the primary controller must have a wider proportional band and longer rest time for stable operation. Often, just changing an option on the secondary controller provides proportional action or even derivative action on the secondary controller significantly improving the cascade loop performance and permitting tighter tuning.

Does anyone know commonly accepted terms to describe the omission or inclusion of proportional and derivative action in a PID controller based on changes in set point?

Reset Wind-up

Anti-reset wind-up was a nice feature in pneumatic controllers. The reset was limited so the controller output would begin to change after reaching 3 or 15 PSIG before the process crossed set point. This reduced overshoot on recovery. The limiting was commonly based on the error and the proportional band. Within digital control algorithms, reset wind-up is handled differently by different products and even options within the same product.

When the control loop is controlling a throttling valve that functions much as a relief valve, the controller output should be zero until the pressure reaches set point. Then the valve should open and throttle, closing with normal P+I control action, and then remaining closed until the pressure again exceeds the set point. However, for a compressor anti-surge recycle valve, the recycle valve should begin to open before the flow through the compressor drops below the set point. Yet, it should not begin to open when the flow is twice the set point just because the flow dropped some. Thus different applications are best handled with different schemes for recovery from wind-up. Often an acceptable anti-reset wind-up option is provided within the PID block and need only be selected to suit the application.

External Reset, An Old Idea but still useful

Many pneumatic controllers had external reset. See Figure 2. The controller output or another signal from further down the chain was fed through a needle valve to the reset bellows. The reset time is adjusted using the needle valve position. The controller output is the sum of the pressure in the reset bellows and the proportional action based on error and proportional band. For selector controllers, the feedback to each of the controller reset bellows is the output of the low (or high) selector. A common application for demonstrating the usefulness of external reset is pipeline control with separate controllers for suction pressure, flow, and discharge pressure. The three outputs go to a low selector and the low selector output to a final control element. Most digital control algorithms do not use this external reset structure. However, when encountering selector controls that do not always perform as desired, the old pneumatic structure can usually be rapidly programmed within the structure of the digital controller by accessing the correct registers. The reset bellows is, mathematically, a lag function. One technique is to use a proportionally only controller and compute the manual reset value as if it were a reset bellows. One advantage of the digital world, the controller had continuous indication of which controller was selected simplifying analysis. One disadvantage was the need to configure anti-reset wind-up. Reset was limited to

$$\text{High limit} = 100 - \text{error}/(2*\text{PB}) \ \ \& \ \text{low limit} = \text{error}/(2*\text{PB}).$$

Another application for external reset is using the secondary variable as the external reset into a primary controller. When a flow controller located in the control room sends an output to a variable speed drive having a local manual control, using speed as the external reset into the flow controller will provide a reasonably smooth local to remote transition.

The flow controller will have a wide proportional band and a short reset time so special anti-reset wind-up limits usually are not needed.

Impulse Feedforward

The term impulse feedforward is no longer commonly used and does not appear in the ISA Dictionary of Measurement and Control. I encountered the term again as a boiler control system was being changed from pneumatic to digital. The feedforward added to the pneumatic controller output following a step disturbance was a pulse. The pulse was a step that decayed exponentially back to 0. (Think 0 in a functional sense not 0 PSI). The first impression is that the feedforward bumped the output and then the PID action had time to compensate. However, observe that even with zero error due to our fantastic feedforward, the impulse feedforward caused a <u>step</u> change in the controller output. The action through the external reset and reset bellows (typically the impulse decay time equals the controller reset time) results in a step change in output. Today, many digital PID algorithms have a feedforward input port and little if any special attention is required to implement feedforward unless a lead/lag or dead-time dynamic compensation is useful. The moral is to be careful when copying a control system from one control platform to another. Some loops may require understanding a little about the inner workings of both the old and the new controller.

Using the available tools to make the operators job easier

In almost any control room, the controls can be improved and require less operator attention with simple calculations and selection of options. The control improvements at the PID level provide the possibility that supervisory controls can be successful. Knowing how the controller options in the PLC, PC, DCS, or stand-alone controller function, and what is important to the operators in this application, makes the basis for sound decisions, and when to do a bit of special configuration to make the unit easier to operate.

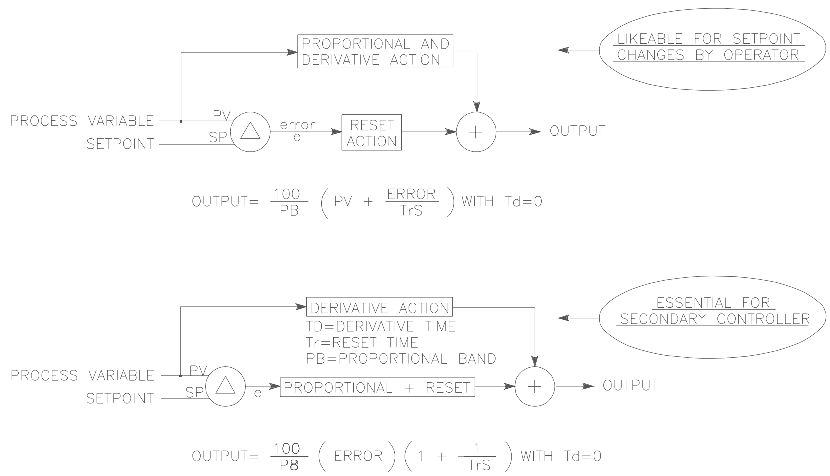
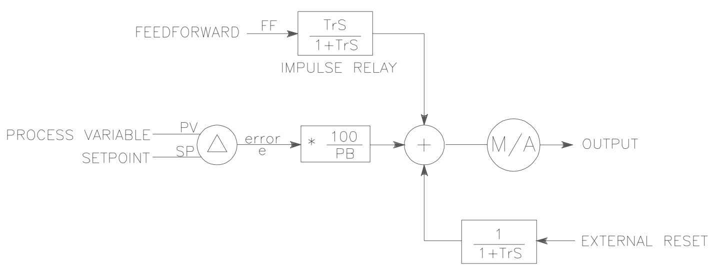


FIGURE 1: WHAT CHANGES WHEN THE SETPOINT CHANGES?



WHEN EXTERNAL RESET = OUTPUT, THEN

$$OUTPUT = \frac{100}{PB} e + \frac{TrS}{1+TrS} FF + \frac{OUTPUT}{1+TrS}$$

SOLVING FOR OUTPUT

$$OUTPUT = \frac{100}{PB}\left(\frac{1+TrS}{TrS}\right) + FF$$

FIGURE 2: TYPICAL PNEUMATIC CONTROLLER STRUCTURE WITH EXTERNAL RESET