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Understanding Strantrol® Control Theory

PID, TBP, SloLogic and Lag Time

Tips, Tricks and Traps

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Tips, Tricks and Traps is designed to present more specific and detailed information on Stranco products and services.

Inside this issue:

Understanding PID – A Layman's Description

PID stands for proportional, integral, and derivative (also called sensitivity, reset, and rate). It is the classic process control scheme for batch and once-thru applications.

On/off control works well enough in most recirculated systems. But on/off control fails in once-thru applications where "off" will almost never be appropriate and "on" will almost always be too much or too little. Unlike on/off control, PID control allows *continuous* feed, modulated in response to need.

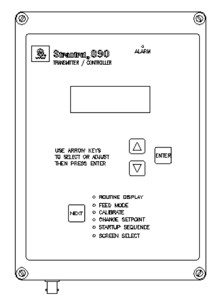
(For simplicity, this discussion assumes an application that is "feed up" in which chem feed causes the sensor signal to increase such as with chlorine and ORP, or caustic an pH. The opposite is a "feed down" application where chem feed causes the sensor signal to decrease such as with dechlor and ORP, or acid and pH.)

P (Proportional) – *P is a fixed response to change, and ignores setpoint.* So, as the sensor signal falls below setpoint, chem feed is increased. If the signal reacts by coming closer to setpoint, chem feed is decreased, if the signal reacts by falling further away from setpoint, chem feed is increased further.

I (Integral) – *I compares setpoint to sensor reading.* Load changes may vary so much that a fixed rate of increase "P" isn't enough. For example, a 10 mV offset which ordinarily calls for a 10% output increase may not keep up when load is too great. The 10% output increase might only keep the sensor within a 10 mV error. To correct the error and return to setpoint, more output is needed. "I" checks on this error at intervals of time, and resets the output up or down to correct the error "P" did not correct.

D (Derivative) – *Pays attention to the speed or rate of change of the mV reading.* When D is employed, fast changes in offset result in fast changes in output. But fast changes are more typical of pressure and flow control than ORP or pH. D is of less value on slow changing processes.

In most Strantrol applica-



STRANTROL 890

tions, P is sufficient. Tuning I and D takes training and experience. P is easier to service than PI, and PI is easier to service than PID. For once-thru systems – especially where step changes in load occur – neither P nor PI work as well as PID. However, for many ORP and pH applications, TBP (time based proportional) or SloLogic are better choices than PID.

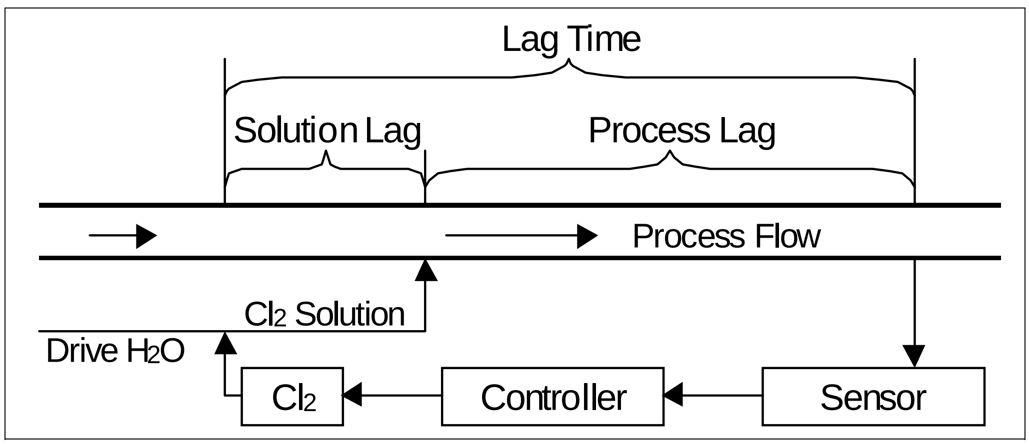
NOTE: PID and SloLogic are *control methods,* **not** *output signals,* the output signal for both PID and SloLogic can be either 4-20 mA or 0-100 strokes-per-minute. Use the latter to pace a solenoid actuated pump.

What is Lag Time?

In most control loops in water treatment, a sensor sees a change in the water and sends that information through a controller to a chemical feeder which responds by adjusting the amount of chemical injection. As the feeder responds, the water chemistry is changed, the sensor sees the change and then sends new information to the feeder, this process continues more of less continuously in most so-called "feed-back" control loops. The time between the moment when the water flows past the chemical feeder and then when it flows past the sensor is called the "process lag time."

In addition to the process lag, there is what is sometimes called a "solution lag." Gas chlorinators eject chlorine into water lines. Where chlorinators are located at a distance from the point of chlorine injection to the process, these water lines (also called solution lines, hence the name "solution lag") add to the time it takes for the sensor to see a change in feeder output.

SloLogic considers both process lag and solution lag together as "total lag," or lag time.



SloLogic™ - An Engineer's Brief Description

SloLogic calculates the dosage rates and the flow. Then it adjusts the output to maintain this dosage rate for the duration of the calculated lag time.

Why SloLogic?

Before microprocessors, analog instruments used PID control. PID takes its name from its basis in calculus: "Proportional-Integral-Derivative." The latter two are also referred to as "reset" and "rate." PID was developed originally to control pressure, flow, and temperature in fast-acting processes. In these, changes in control output are noticed by sensors in seconds, a condition called a short "lag time."
When lag times are in minutes, however, PID usually results in unsatisfactory control accuracy. To counter this problem, engineers working before microprocessors combined the output of the PID controller with a flow signal letting both PID and flow share in adjusting output. However, this too proved less than ideal in practice. Given systems designed for shared control between flow pacing and PID, most operators abandoned one or the other if not both.
Working to better control wastewater disinfection, and application where lag times are slow and varying, Stranco researchers developed a new control algorithm. Their goal was to cure the shortcomings of PID in long lag time applications. By using the power of the 1990's microprocessor and by taking a fresh approach to the problem, they not only solved the dilemma of long lag time control, but also made SloLogic work far better than PID for short lag times.

SloLogic™ - An Engineer's Brief Description (cont'd)

SloLogic With Short Lag Times

Here's an example of how SloLogic works in a short lag time application, assume a lag time of 10 seconds. SloLogic will make no changes to output except at 10 second intervals, then the nature of the output adjustment will be based on three factors. The first factor is the average offset from setpoint during the full 10 seconds. In other words, if the average offset is minor and low, this factor would tell the processor to increase output to a minor extent to get back up to the target.

So far, simple. And it's unlike PID mostly in that the changes are only allowed every 10 seconds, not in between.

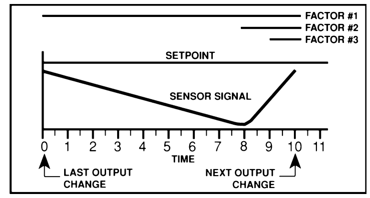
The second factor is the average offset from setpoint over the 2 seconds before the next change. This factor ignores the first 8 seconds altogether. Factor three averages the offset only in the last 1 second. Then the SloLogic processor averages the verdict of all three factors, determines how much to change output and in which direction, and then executes the change on the 10 second interval.

In the figure at the right, PID would have increased output as the process fell below setpoint (probably leading to the overshoot that is about to happen). Worse, because the sensor sees a value below setpoint at the end of 10 seconds, PID would still be calling for more, increasing the overshoot.

But an experienced operator would start <u>reducing</u> output after about 8 or 9 seconds, or just <u>after</u> he or she saw the "knuckle" in the curve of the process variable, SloLogic acts like the person, not PID.

Keep in mind SloLogic holds the prior output until the 10 seconds are up. To do otherwise would be to act before seeing the effect of its last adjustment. In the example graphed above, SloLogic, acting like the experienced operator and seeing the overshoot coming, would <u>decrease</u> the output at its next chance.

The experienced operator gives more weight to the end of the lag time interval than to the beginning or the middle. Similarly, in SloLogic the last 10% of the time interval contributes 53% of the output decision. The next to the last tenth of the lag time interval contributes 20%.



SloLogic for longer and Varying Lag Times

For longer lag times, SloLogic needs the input of a flow signal (4-20 mA). From this signal, SloLogic computes the lag time. This function is crucial when lag times vary, as they usually do in longer lag time applications, such as wastewater.

If SloLogic calculates lag time to be 10 minutes, then it will allow output changes only every 10 minutes. Factor one would look at the full 10 minutes, factor two the last 2 minutes, and factor three only the last minute.

If flow rate doubled, SloLogic would assume a 5 minute lag time and allow change only every 5 minutes. SloLogic would also adjust the times for factors one, two and three to the same 10:2:1 proportions.

The keys to SloLogic's success are:

1. The duration of factors two and three
2. The "don't touch" interval between changes, and
3. The instant variation of that interval proportional to flow.

The result is a process variable closer to setpoint – and closer much more of the time – than with manual control, flowpacing, PID, or even flowpacing plus PID.

PID Control Theory - When to use PID versus SloLogic

1. *When lag time is less than 1 minute.* Lag time is defined as the response time from a chlorinator change to the sensor reaction.

-and-

2. *When end-user has a technician that is familiar with PID routines.* This is because PID is a very time consuming and tedious routine.

-and-

3. *When flow is constant.* PID is defined as a single variable control routine. This means one input and one output based on the input. If flow is not constant, then there are 2 input variables that affect the mV signal; disinfection levels and flow.

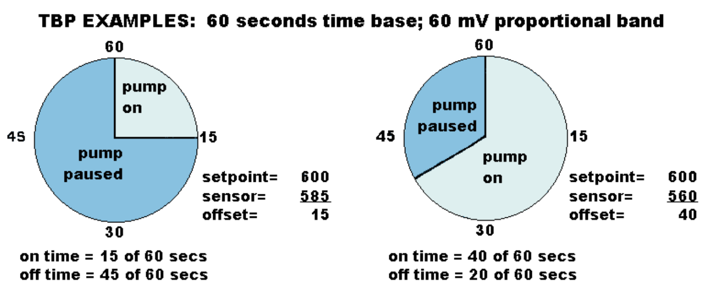
Understanding TBP™ (Time Based Proportional)

Stranco invented TBP (Time Based Proportional) so that simple, low cost on/off solenoid actuated metering pumps or valves could mimic the effectiveness of more complex and costly true proportional systems using 4-20 mA or 0-100 strokes-per-minute inputs. In practice, TBP not only achieves this goal, but can successfully be employed in many applications previously thought to require PID. This results in lower initial cost, quicker start-up, far simpler operator training, and less service. Everybody wins.

In short, here's how it works. (As with the PID description, a "feed up" example is used.) if the sensor signal falls below setpoint just a little bit, TBP turns on the feeder for a few seconds, and then pauses the feeder for a few seconds. If the sensor signal is unchanged, TBP repeats itself.
If the sensor reacts by returning to setpoint, TBP leaves the feeder off. If the sensor signal falls further from setpoint, TBP turns the feeder on again but leaves it on longer this time, then TBP pauses the feeder for a shorter time than before.

In more depth, TBP assumes a "time base" of, for example, 60 seconds. It also assumes a "proportional band" of, for example, 60 mV. In the example, each mV offset from setpoint would cause the feeder to be on for one second. So if the setpoint is 600 mV and the sensor sees 585 mV, the 15 mV offset would result in the feeder coming on for 15 seconds, then pausing for 45.

If the sensor signal was 560 mV or below (an offset greater than the proportional band) the feeder would be on continuously until the signal returns to above 560 mV. The proportional band is set at 1.0 pH units in the 860 and 60 mV in the 870.



The Strantrol 890 offers more flexibility. The time base is adjustable from 20-300 seconds and ships with a factory default setting of 60 seconds. The proportional band is adjustable from 0-99 mV with a factory default of 20 mV.

For fast acting processes, less than 2 minute response time, both the time base and the proportional band should be shortened. Be careful that you employ a rapid enough stroke frequency on the solenoid actuated pump so that the pump is sure to stroke during the on time, conversely, slow acting processes, such as most recirculated systems, use a longer time base and a wider proportional band.

If in practice the sensor signal seems to oscillate, lengthen the proportional band or the time base. Conversely, if the sensor signal is above or below setpoint for long periods, shorten the time base or proportional band.

The 890 also offers an adjustment called "offset %" of 0-50% with a factory default of 0. At 0, TBP acts exactly as described above. In some applications, however, the result is a variation of the sensor signal from the setpoint to a lesser value, back to the setpoint, etc. it is usually preferable to center this variation on the setpoint. This can be done by increasing offset %. Setting offset % to 10-20% is usually sufficient.

In more depth, offset % shifts the proportional band upwards (or downwards in a feed down application). For example, imagine a setpoint of 600 mV and a proportional band of 60 mV. The control zone is this 540-600 mV. But if this control scheme fails to maintain 600 mV ± an acceptable error, and instead results in sensor signals that vary from, say, 590-600 mV, increase the offset %. An increase in the offset % of 10% would shift the control zone to 546-606 mV. We would now expect the sensor signal to vary from 596-606 mV or roughly centered on the 600 mV setpoint.

If you have any questions or comments regarding Strantrol Control drop us a line at stranco@usfilter.com or contact our Technical Support team at 1-800-882-6466. If we use your question, we'll send you a gift.

Stranco Products
PO Box 389
595 Industrial Drive
Bradley, IL 60915

Phone: 815-932-8154
Toll-Free: 800-882-6466
Fax: 815-939-9845
Email: stranco@usfilter.com
http://www.stranco.com
http://www.usfilter.com