OPTIMIZE LEVEL CONTROL PID TUNING USING MODERN SOFTWARE TOOLS

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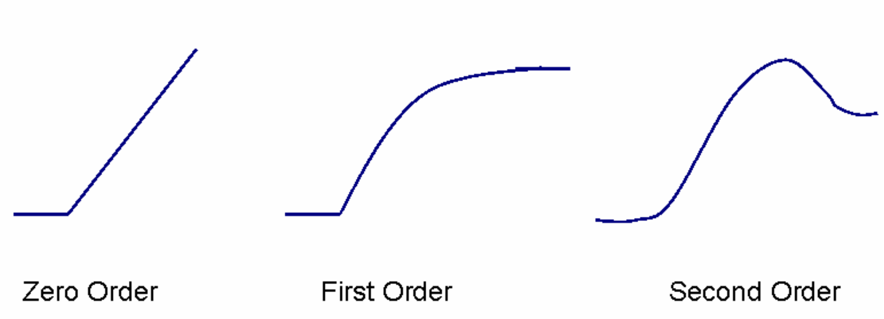
Introduction

Many level controllers (LCs) in chemical plants are not optimally tuned. Poor LC tuning can cause cycling in the output. Cycling can cause many downstream flows to oscillate. This in turn can cripple the performance of higher level advanced process control (APC) systems resulting in reduced profit margins and fail to deliver the expected payback. This paper shows a quick, simple and powerful method to effectively optimize LC tuning and improve the overall plant control quality.

Chemical Process Dynamics

Most chemical process dynamics can be well represented by the transfer functions shown in Figure 1.

Figure 1. Common Chemical Process Transfer Functions



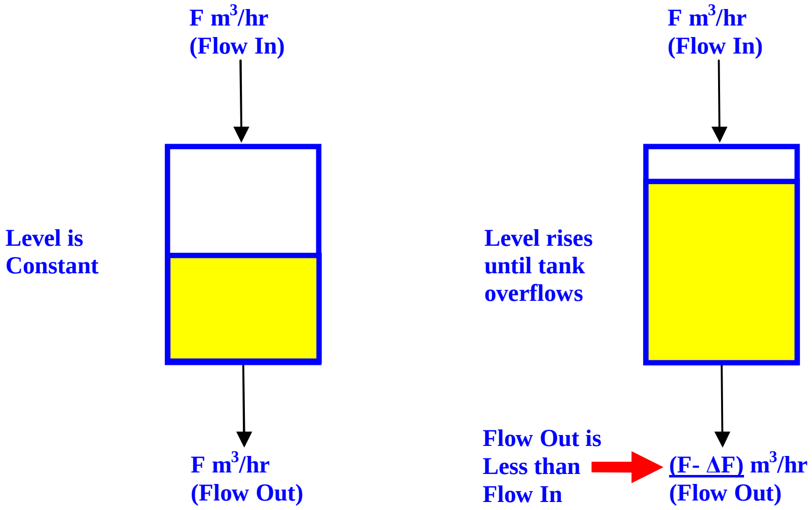
The zero order transfer function characterizes LCs. See Figure 1b for an illustration. If F m^3/hr are going into a tank and exactly F m^3/h are leaving the tank, then the level in the tank will be held constant. Now if the flow out from the tank is reduced by ΔF, then the level starts to rise at a steady rate (called Ramp Rate) and will continue to rise until the tank overflows. Let's say, after time Δt, the change in level is ΔL. The Ramp Rate is calculated as:

Ramp Rate = $\Delta L / \Delta t / \Delta F$

Note that the engineering units of Ramp Rate in this example will be: %level / minutes / m^3/h.

This is the zero order transfer function behavior, where there is no final new steady state like a first, second or higher order transfer functions. The zero order transfer function is also called an integrating type transfer function. At a first glance, the zero-order transfer function appears the simplest since it has only two parameters – process dead time and ramp rate. There are no time constants involved as in the case of non-zero order transfer functions. However, the zero-order transfer function interestingly, poses some unique challenges when it comes to determining optimal tuning parameters for the LC PID.

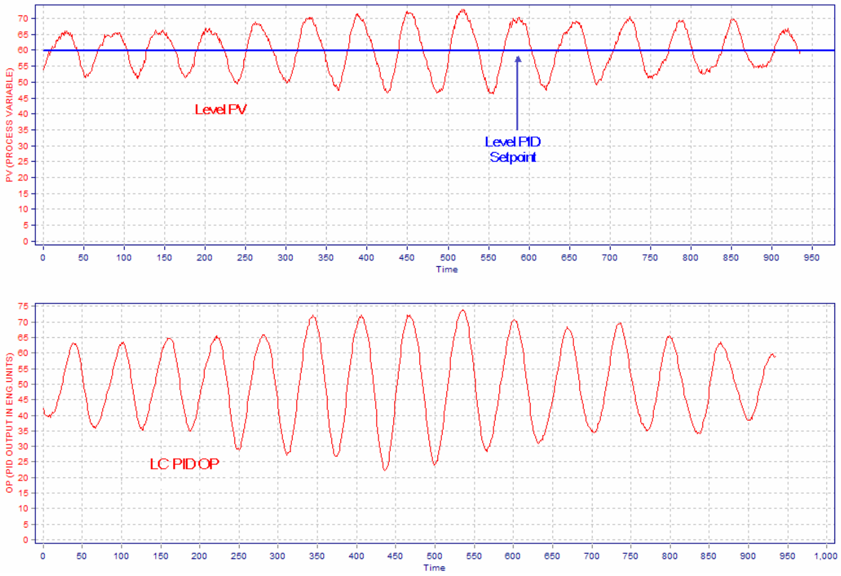
Figure 1b. Level in Tank Illustration



See Figure 2, showing a distillation column bottoms sump LC. The top window shows the LC setpoint (SP); the horizontal line at a fixed SP of 60. The cyclical trend in the top window is the actual level (PV). Notice that the level is cycling about + and – 5% from the LC's SP. The bottom trend shows the LC's output. The output directly manipulates the SP of the bottoms product flow controller (FC). If the LC's PV (sump level) increases, the LC's Output increases the FC's SP to take more liquid out of the sump and vice versa.

Level is the controlled variable (CV) and the bottoms FC is the manipulated variable (MV). The level (CV) range is 0 – 100% and the FC (MV) range is 0 – 200 t/hr.

Figure 2. Distillation Column Sump Level Control

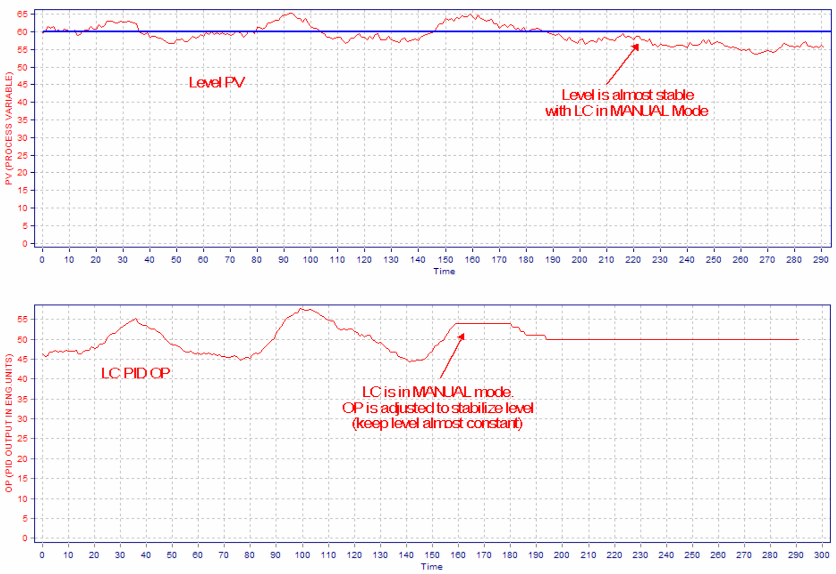


The LC's PID equation is: $OP = OP + P\,[\Delta E + E\,\Delta t/ I + D\,\Delta(\Delta PV)/\Delta t\,]$, where:
OP = PID controller Output
P = Proportional Gain, I = Integral Constant and D = Derivative Constant

E = Controller Error (PV – SP)
Δt = Scan Time of PID

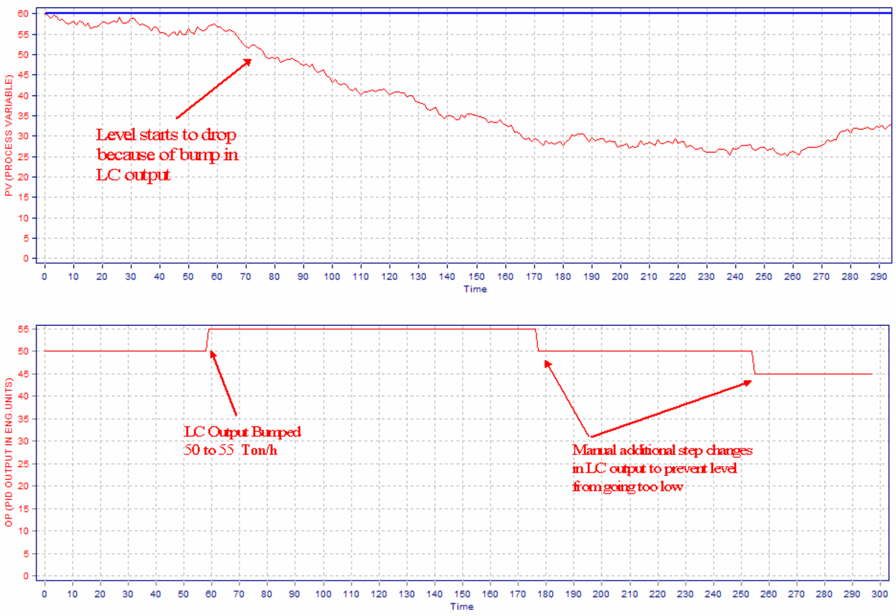
The LC's tuning causing the oscillations in Figure 2 is: P = 0.5, I = 3 minutes and D = 0. To scientifically calculate optimum PID parameters for the LC, first put the LC in Manual mode and set the LC's OP at approximately the average value to try and keep the level reasonably stable. See Figure 3.

Figure 3. Stabilizing the level with LC in Manual mode



Now bump the flow for at least 10 minutes or longer (if possible) to see a noticeable change in the level. Figure 4 shows a bump in the FC's SP by 5 ton/h. The level is allowed to drop all the way to about 30%. This is a rather large change and is shown here only for clarity of the illustration, but the level could have been allowed to drop to only 45% in a shorter time period without much loss of information.

Figure 4. Estimating the Ramp Rate of the Level – Flow Dynamics



The Ramp Rate is calculated as (57 – 33) /(160 – 60) / 5 = 0.048 %/(ton/h)/min. The process dead time can be seen by visual inspection of the data and this is approximately 2 minutes in this case. Now we can build a LC simulation in the Pitops software with the following additional configuration information:

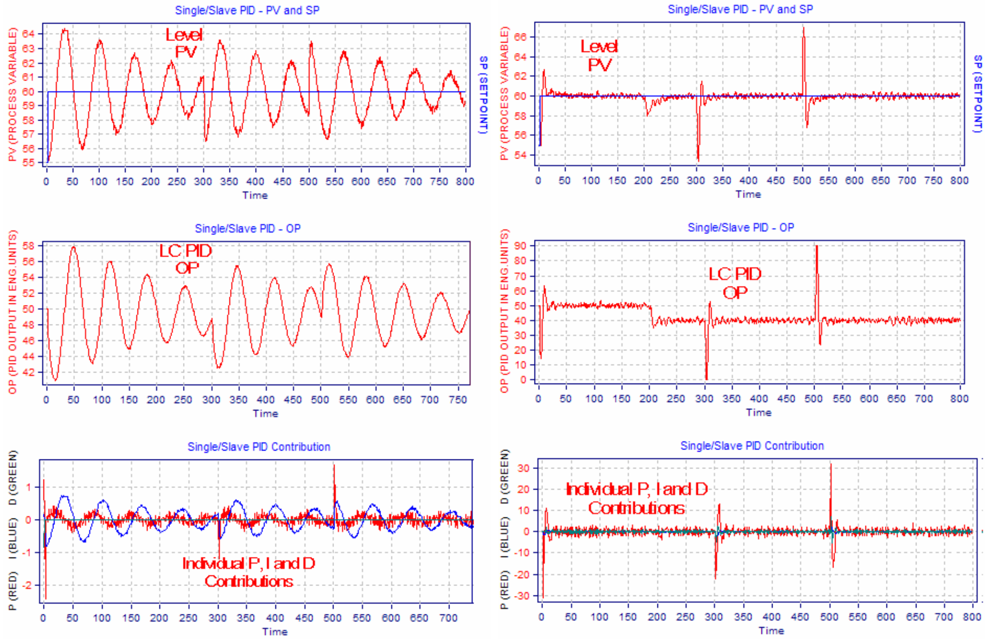
MV range = 0 – 200 ton/h (this is the range of the slave FC)
CV range = 0 – 100% (PV range of the LC to be tuned)

Optimum tuning from Pitops is P = 6.2, I = 22 and D = 0.25

Figure 5. Initial (Oscillatory) Tuning and Optimized (Crisp and Tight) Tuning

P = 0.5, I = 3, D= 0
(INITIAL)

P = 6.2, I = 22 and D = 0.25
(OPTIMIZED)



The final optimized tuning corresponds to the mathematical solution that minimizes the error for the following custom controller challenges:

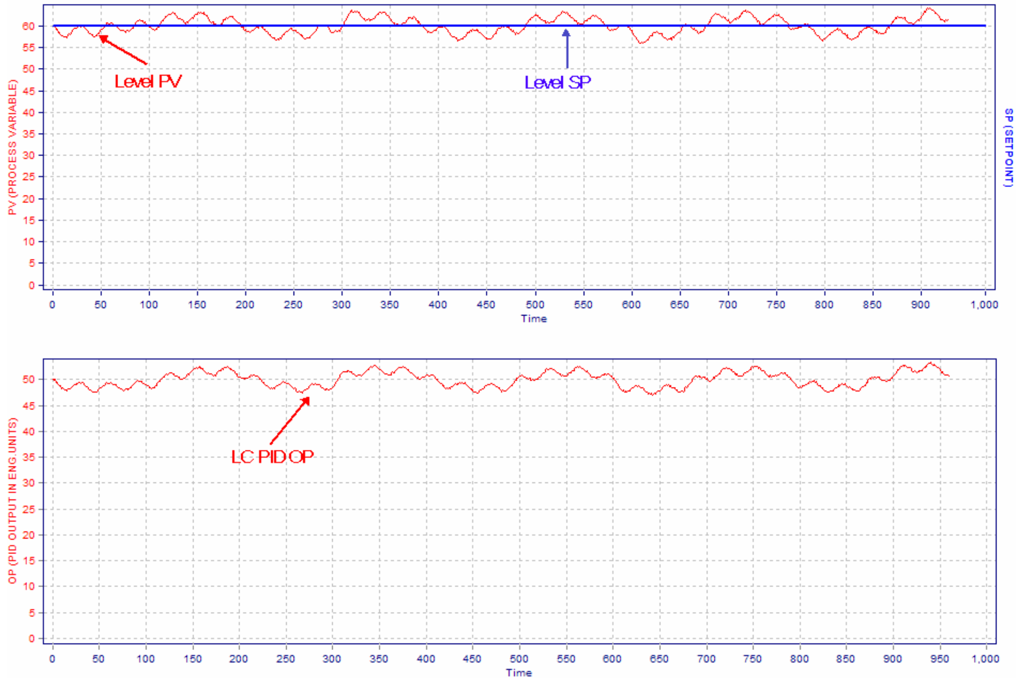
1. Setpoint change
2. Typical noise seen in the LC PV
3. Injection of a Ramp disturbance simulating a typical production rate change.
4. Injection of a Pulse disturbance simulating typical minor upsets.

The optimized tuning might be a little aggressive for the real process. The optimized tuning sets upper limits on the level of aggression and tuning tightness, beyond which incipient oscillations will start and might grow, making the controller possibly unstable.

To strike a balance between tight control and smoothness of downstream flow, the final tuning selected is: P = 2, I = 40, D = 0, gap gain = 0.5, gap high/low = 2. If the level is within 2% of the setpoint, the gap action detunes the controller action by 50% and to further smooth out the downstream flow changes.

The control action is shown in Figure 6. Now, as typical disturbance come, the control action is just about right – the level is controlled nicely without excessive oscillations or jerking around of the downstream flow. Note that the ripples seen are because of external oscillatory disturbances causing the level to cycle a little, and this could be because of upstream valve problems on interacting controllers or process issues which are often unavoidable.

Figure 6. Final Tuning for Smooth and Stable Control



The illustrations above were generated using Pitops^{TM} PID and Simcet^{TM} process control software from PiControl Solutions Company. The use of the software and the techniques allow fast and precise tuning of critical controllers and can reduce oscillations and improve control performance in any industrial process.

The software benefits tuning of all PID controllers encountered in the industry – FC, PC, TC, LC, AC (analyzer control), compressor surge control, motor control turbine control, power control, robotics and all related control problems.

PiControl can be contacted by sending an email to info@picontrolsolutions.com. Product information is available at www.picontrolsolutions.com.