Case study: optimization of a critical level loop

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At a large paper manufacturer, a paper machine was experiencing high variability in paper quality because of cycling in the stock preparation. The stock preparation in a paper mill is a combination of the flows of stock mixed together in a mixing chest (Fig. 1).

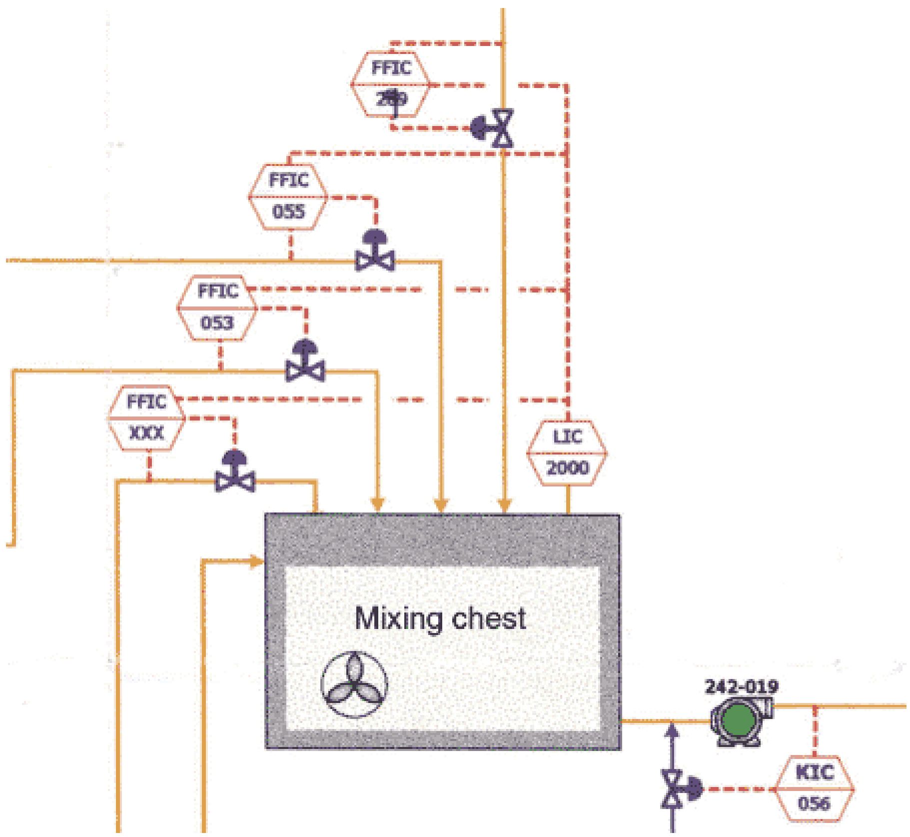

FIG 1: The mixing chest accepts a combination of flows of stock.

This mill has many grade changes in its paper, which means the speed of the machine and, hence, the demand for pulp can change often. Also, when operators change the grade, they try to reduce the level in the reservoir to make sure there is as small amount as possible of the older grade pulp in the chest.

The plant needed moderately aggressive tuning for regulation to handle the upsets from pulp demand. The process also needed good setpoint response with little overshoot to handle the change in the level just before and after grade changes.

Initially, plant personnel did not think it was possible to get good tuning for upsets and good setpoint response all at the same time. The plant controls its process with a Honeywell DCS that has a selection of algorithms available.

The mill had been using the A controller algorithm (usual structure for PID). When using this algorithm, plant operators had to choose between good setpoint response and good regulation. Perhaps by using C (PID structure where the controller is I only on a SP change but PID on a load change)they could get both. Trying what-if simulations with both controller algorithms on their process should provide the answer.

Any simulation requires a model of the plant and controller. Simulating the controller is as easy as picking it off a list as "Honeywell real, A" or "Honeywell real, C." The second step in simulating the loop is to get a good model of the process.

To model the loop, the modeling software needs both the level and the controller output data from a change done to the loop. For example, data from the level loop, shown in Fig. 2, was collected by ExperTune software. This data is then analyzed by the software, which finds the best process model. The model found from this the data that's shown in Fig. 3.

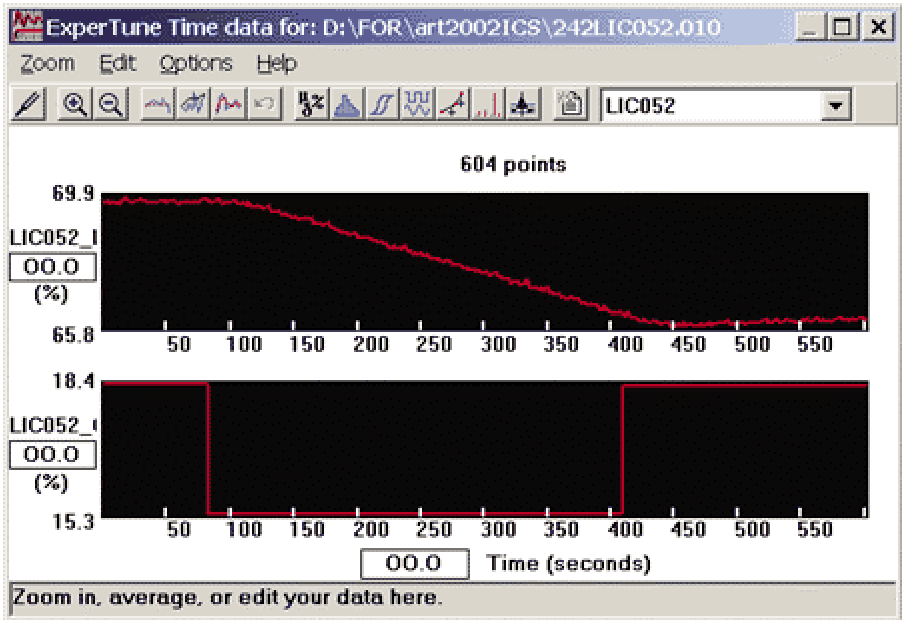

FIG. 2: Data from the level loop as collected by ExperTune analysis software.

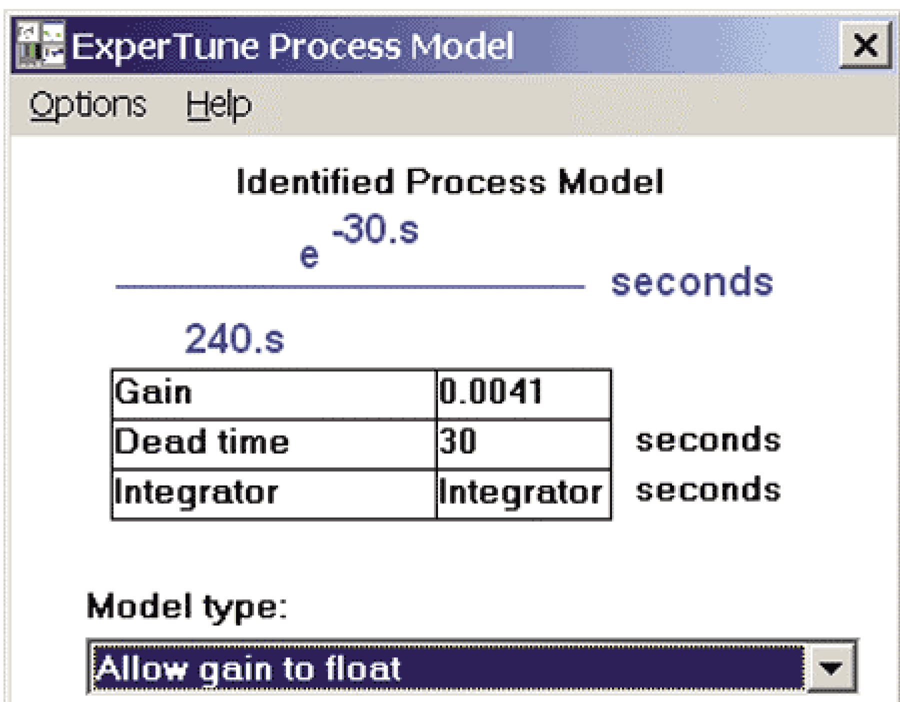

FIG. 3: From the data in Fig. 2, a model can be found.

Using this model with either the A or C controllers lets us simulate and try what-if analysis on this loop. Figure 4 shows simulated PV (level) and controller output response to a load upset. The blue line shows the response of the loop with the PI tuning as found in the controller. The green lines show the response using the tuning recommended by software.

This tuning was backed off from the software's optimal settings by a safety factor of three.

This load response simulates a decrease in the demand of pulp by the paper machine. The decrease in demand occurs at time 0 in the simulation, but the level starts to go up 30 seconds later, after the process deadtime has passed. After this time, the level increases since less pulp is being removed from the mixing chest. The controllers take corrective action to bring the level back, giving the resulting response in PV or level.

The blue line or "as found" tuning was overly aggressive, causing the controller output—and hence—the entire paper machine to cycle. The new tuning responds almost as fast and provides a smooth non-oscillatory controller output.

The load response of both the A and the C algorithms is identical to that shown in Fig. 4 since A and C algorithms respond the same to process upsets. But, what about setpoint changes? The plant's operators want no overshoot on a setpoint change.

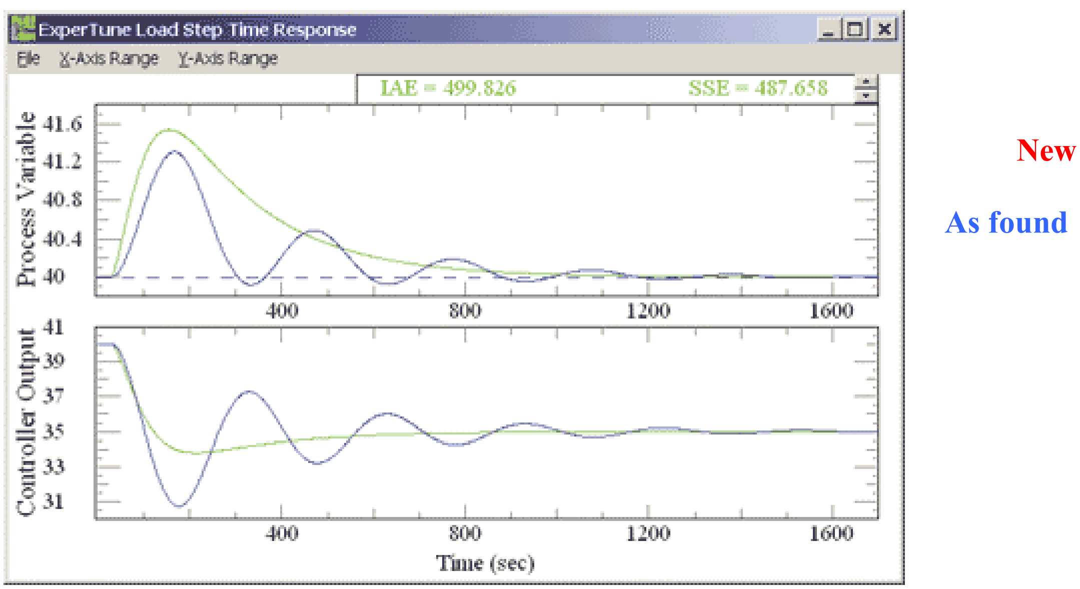

FIG. 4: Simulated PV (level) and controller response to a load upset.

Setpoint response using A or C algorithms

Figure 5 shows the simulated PV (level) and controller output response to a setpoint change. The setpoint change occurs at time 0 in the simulation. The setpoint is graphed as a dashed red line. The blue lines show the response using the as-is tuning with the A algorithm. We have already decided from the load simulation that we prefer the new tuning—at least for response to upsets. The new tuning using the A algorithm is shown in green.

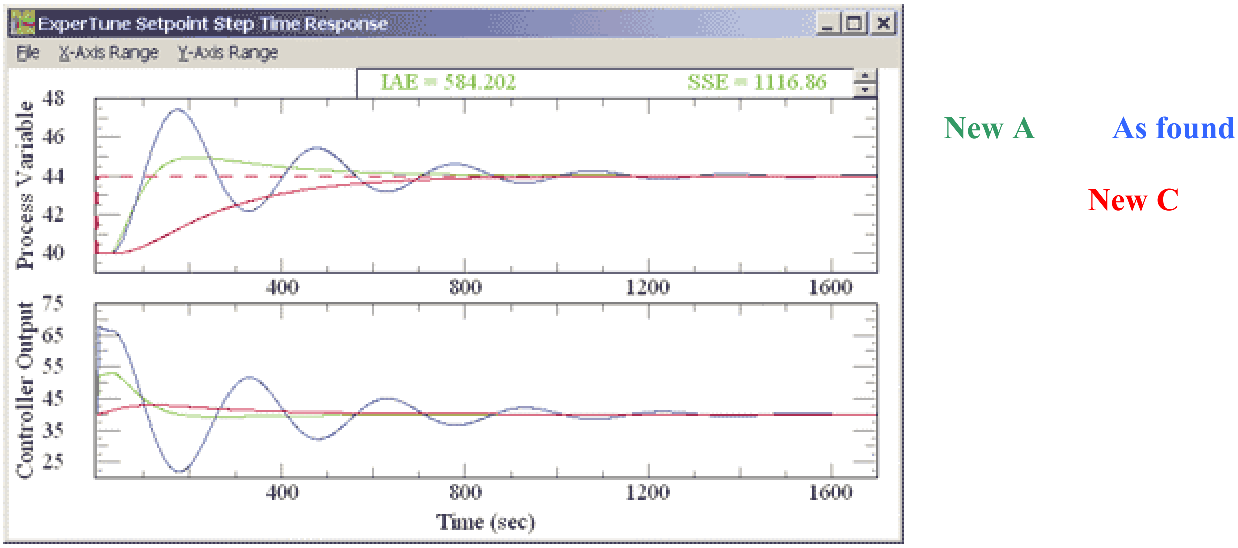

FIG. 5: Simulated PV (level) and controller output response to a setpoint change.

Since the plant did not want overshoot on setpoint changes, we tried simulating the setpoint response using the new tuning and C algorithm. The PV response in red is using the C algorithm. For the responses represented by both the red and green lines, the tuning was identical. The only difference was the choice of PID algorithm.

The C algorithm has the gain operating on the PV only and not the setpoint. Hence, when the setpoint occurs, its controller output (shown in red in the lower graph in Fig. 5) does not initially move. It slowly starts to move as a result of integral action in the controller.

Using the C algorithm gives the setpoint response the plant personnel like while still providing good response to load upsets. The A algorithm has the same response to load upsets, but overshoots (green line) to setpoint changes more than they want. C algorithm wins in this case. In other situations, plant engineers might want the quicker response of the A algorithm and can tolerate the overshoot.

Conclusions

Simulation can help you decide what controller algorithm and PID tuning to use in your plant. The what-if analysis allows you to try many different combinations, quickly, so you can find the optimal solution.

Acknowledgements

The analysis software used in this article was from ExperTune Inc, http://www.expertune.com/. Figures reproduced with permission of ExperTune and TOP Control.

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