Simulations for better control

by Hans Eder, ACT

Simulations are widely used to explore the behaviour of new equipment and for all kinds of training. Although suitable simulation tools can help to deliver better results and make work much faster, easier and more enjoyable, less use is made of simulation tools by control professionals in their daily work.

Concerning these tools, the emphasis is on the word 'suitable'. They must of course describe the dynamic behaviour of the equipment under study but should also provide the functions needed for developing control schemes and running controllers in a coherent, user-friendly way. This postulate guided us in the design of our package Topas, a simulator with a tightly integrated, comprehensive toolkit. A few real-life examples shows how such tools can help to achieve better control in a shorter time.

Example 1: Liquid level controller tuning

The objective of liquid level control is to keep the level within a certain range around the setpoint. If this controller only has to deal with setpoint changes then we would face a trivial task, since a loop consisting of an integrating process and a proportional controller can deliver the behaviour of a first order system in such a case – even without any offset from the setpoint, making this an ideal situation. So, we could just use a P-controller and tune it in minutes.

Unfortunately, for level controllers the setpoint never changes and when exposed to a disturbance, the P-only controller shows the old problem - the permanent offset. Therefore we need the I-controller – although this type is inherently unstable when used together with an integrating process. Therefore, tuning level control loops is not always trivial, especially when extra requirements are added. Often we have to master rapid, drastic changes in the flow into the vessel but are not supposed to make rapid and drastic changes to the flow out.

Different PID settings are needed when the controller is predominantly dealing with setpoint changes or with disturbances. This poses the next problem: In the plant we cannot trigger one disturbance after the other just for the sake of controller tuning. Thus we make setpoint changes, observe the response and correct our tuning. Yet, this is not the right operating scenario and thus the tuning can be quite a bit off.

This is where a suitable simulation tool can help. Most vessels can be described by just a few parameters: For a vertical drum e.g. only two data are needed to simulate the level behaviour - the drum diameter and the distance between the level measurements. Thus we can test and tune our controller settings easily with the simulation, trigger all kind of upsets in a very short time without disturbing the plant, and finally transfer the proven results to the real world.

Example 2: Decision on the use of a feed-forward

A process unit was struggling with frequent changes in the feed properties. To improve the performance it was decided to enhance the existing controls by a feed-forward. It would read the feed temperature and adjust the main manipulated variable, the fuel gas flow of the preheat furnace, in a proactive way and thus minimise the disturbance of the key controlled variable, the product temperature after the furnace.

A dynamic feed-forward scheme requires the process parameters for both mechanisms:

- The relationship between the manipulated variable and the controlled variable
- The relationship between the disturbance variable and the controlled variable.

These parameters were quickly found from tests but a first inspection confirmed our concerns from observations during these tests, namely an unusually slow, delayed reaction to changes in the fuel gas.

To make matters worse, a test with the inlet temperature showed the opposite picture. Very shortly after a change, the outlet temperature responded, i.e. it had a much shorter 'dead

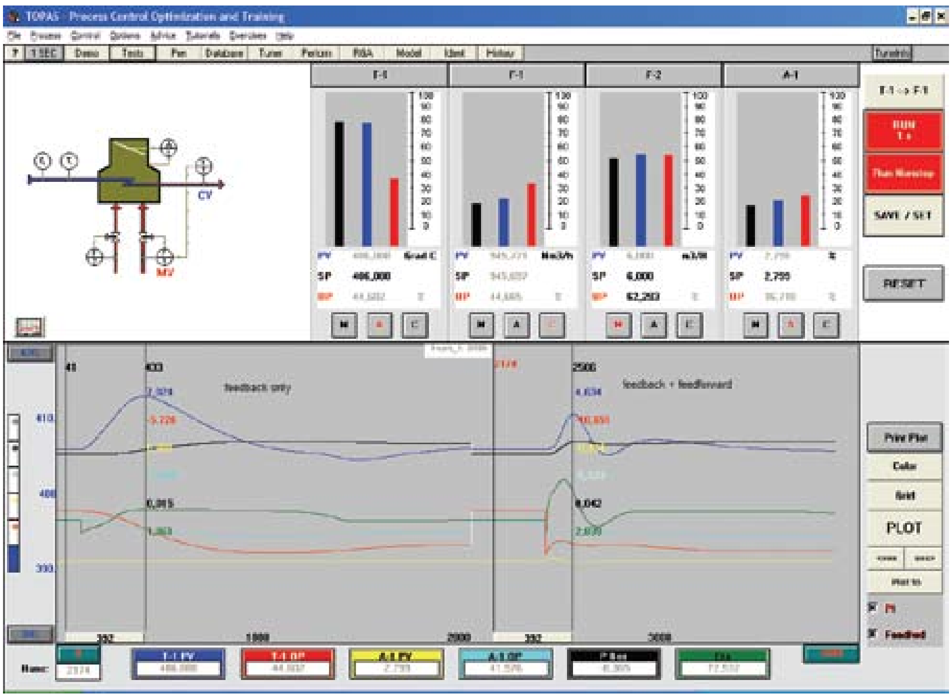

Fig. 1: Control performance without and with imperfect feed-forward (FFW1).

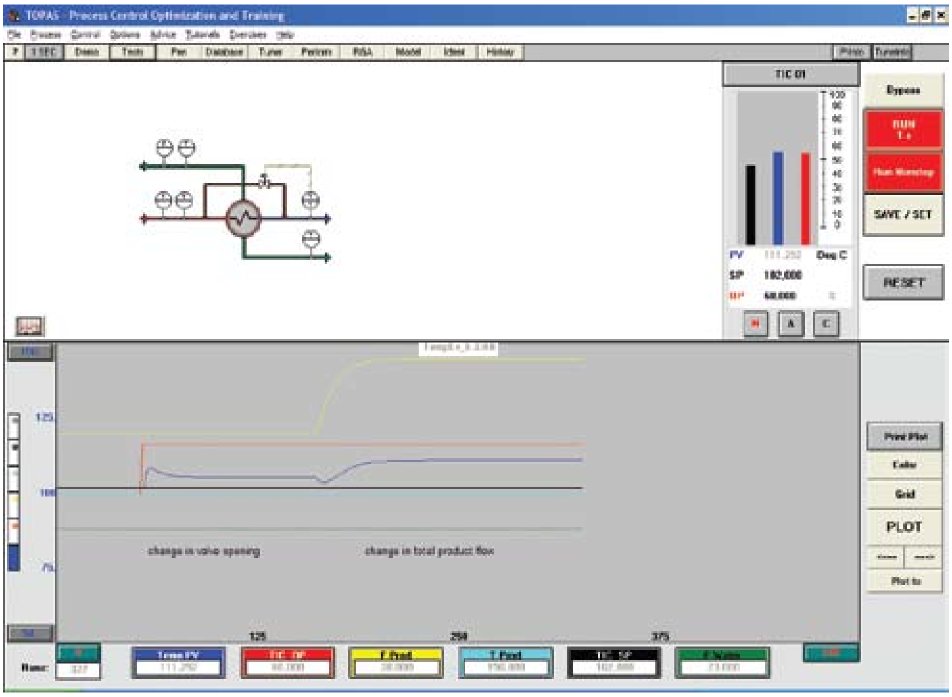

Fig. 2: Heat exchanger configuration (HEAT_EX).

time'. Thus, no matter how well the feed-forward was parameterised it could not carry out the compensation in time. In this case, would it make sense to use the feed-forward at all?

Since the process parameters were available, the situation was very quickly simulated. And the results showed immediately that even with the "imperfect " feed-forward the temperature performance was still significantly better than in the case with feedback control alone, as can be seen from Fig. 1 (the outlet temperature is the blue curve).

Example 3: Finding process parameters the heuristic way

In many cases, process parameters are needed and important. For PID tuning the preferred way is to obtain them first and then calculate the PID settings on that basis. And when we use a feed-forward then we need them in any case.

Normally, we would take the results of a plant test, open or closed loop, or gather meaningful operating data, export them from the DCS into a tool and estimate the process parameters there. But in some cases there is no easy way to export data from the DCS – a situation I have faced several times. But how can we get the process parameters now?

We need to become 'a bit heuristic'. The prerequisite is that we can test and get a good graphical representation, e.g. a screenshot from the result. We know the controller details in the DCS - measurement range, control interval, tuning etc. – and thus can simulate the controller. Next, we perform the same loop tests in the simulation and modify the process parameters by trial and error until we get a close-enough match to the original response. It is a tedious task, but less tedious and frustrating than tuning a PID, let a lone a feed-forward, by trial and error.

Example 4: Better understanding of the process behaviour

We had a problem with the temperature control of a heat exchanger - a cooler. Although seemingly an easy task, we could not get to the desired closed loop speed. The loop would go into oscillations. In the end we simulated the system as shown in Fig. 2 because we could not make more exploratory studies without upsetting production.

The simulation immediately revealed the problem: an open loop test with the valve in 'bypass' clearly showed an overshoot behaviour of the temperature. This was unexpected, but can be explained quite simply: When the valve is opened further, more hot product goes around the exchanger, thus the temperature increases rapidly. On the other hand, there is now less material going through the exchanger and thus, with slower dynamics, is cooled down more. Both effects together create the response. Furthermore, increasing the total product flow delivers an inverse response, as first more cooled material is pushed out the pipe to be later followed by the less cooled product.

So, the simulation clearly showed us that the dynamic behaviour of this simple system was by no means as trivial as assumed and that both effects, the overshoot and the inverse response, would never allow us a very tight tuning, no matter how much more time we invested.

One more opportunity: fine-tuning the PID for the special situations

There is one more case where simulations are quite helpful. When tuning a controller I always prefer to obtain the process parameters first. With our tools this is not such a big task and thus I have the best possible foundation for my work: sound, quantitative knowledge of the process behaviour. From this we can easily calculate the PID settings. Topas evaluates 25 different methods so we can be confident that we get the best tuning parameters for the situation.

Often there is still some testing and adjusting necessary, however, because no method we know of includes influences like noise of different strengths, sticking valves or speed (rate-of-change) clamps in the calculations. All of these can lead to significantly different tuning than in the "ideal" case. With the process parameters at hand, these influences can be easily simulated and the controller settings swiftly adjusted without any disturbance of the process.

Conclusion

These cases do not provide by any means an exhaustive list of situations where process control can gain substantial benefits from the use of simulations. Best suited are those simulations that already have the required tools and methods integrated for solving control tasks and challenges. They can save lots of time, effort and frustration, especially when the work with the real process cannot be carried out as needed. And since dynamic simulation packages are not that expensive any more, the use of simulations in process control will show value in a very short time.

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