Simulations – useful tools or toys?

Computer based process simulations are used since many years for the design of new plant equipment and also for training. But they are hardly used for the design of control schemes or for the tuning and testing of controllers. On the other hand it is not always possible or useful to perform all the necessary studies and tests on the process itself. Therefore we want to explore here if simulations could not come in handy in these cases.

The situation

Computer simulations are in routine use since more than thirty years. Amongst the first intensive users of these tools were the process designers. With them they can carry out their work much faster and easier and also study many more different situations and cases – although these simulations were and are in most cases still static and not dynamic.

Later on more and more dynamic simulators were developed, mainly for pre-start-up training of operators when new equipment or even an entire new plant was installed. Some of them are quite complex and also expensive, up to several million dollars. But they easily paid their money back because they allowed to start up the new equipment or plant more smoothly and to bring it much faster to its full capacity.

Here and there it also was tried to use such simulators for the development of new controls. But so far they have not become a standard tool for control engineers, although they could in principle offer quite similar benefits as for design and training, namely the possibility to look at more different scenarios and solutions or simply to save time. One reason is that until a few years back there were basically only two types of dynamic simulation tools around: Large packages that allowed very realistic models but were much too complex, expensive and difficult to be used in daily life. On the other end of the spectrum were numerous more or less academic tools that were very simple and easy to use but were lacking the needed coverage of real life situations like sticking valves etc. In the meantime several more compact and relatively cheap packages have arrived on the market. Let us therefore take a look here at three quite different but pretty typical cases to see is we could and should not use such tools today in the context of process control.

Three examples:

1) Distillation tower

Some time back the author has been called by an oil refinery to help develop several product quality controls for the distillation towers of their Delayed Coker Unit. It became clear quite fast that because of the process dynamics the standard PID-controller was not usable and that Model Based Predictive Control had to be applied. As the name implies, this technology is based on a mathematical description of the process behavior, it requires therefore quantitative knowledge of the static and dynamic effects, as represented e.g. by the process parameters.

Normally it is not a big problem to carry out the necessary tests on a distillation tower but here the situation was different: The unit used several drums to store the coke. Whenever one particular drum was full, the coke was routed into the next one and so on. These switches happened every few hours and caused a tremendous upset for the plant because the new drum had to be made oxygen-free with steam, heated up etc. The consequence of this situation was that the time span during which the plant was running smooth and steady was never long enough to conduct a meaningful test. This of course brought us into a severe dilemma because we definitely needed the process parameters.

In checking out the alternatives we found out that the refinery still had a quite well kept dynamic simulator in the training center that had been used for pre-startup training of the operators and that we potentially could use for our test work. Some checks ensured that the behavior was realistic enough and luckily this simulation gave us even the possibility to disable the coke switching procedure and therefore to study the behavior of the distillation towers in the needed length of time. At the end all the necessary test were done in the simulator, all the needed information was obtained in short time and the controls could be developed and tuned. In this case the simulator has helped to overcome an unusual problem and allowed us to finally make a significant improvement in the operation of the unit.

Unfortunately, in some other cases where training simulators existed they turned out to be not usable, the main common reason being that after the end of the pre-startup operator training there was no person assigned to keep them up-to date and therefore they did not represent a credible representation of the real process any more. A real pitty, because they were not only useless for control purposes but of course also for future training of new operators. So the key message is here: If such a simulator is built, then it should be properly maintained and also used actively for control development.

2. Liquid level control

The second example has to do with a much less complicated situation, in fact with a control task that is in principle quite easy and simple, but still gives a lot of problems that can have quite significant negative effects on other, downstream parts of the plant: It has to do with control of the liquid level in drums, towers etc.

In almost all cases the standard PI-controller is used for level control and normally the tuning is not calculated based on the process parameters with some suitable methods but simply found by trial and error. This implies that there are several tests with the controller necessary to find the proper settings. These tests are almost exclusively setpoint step-tests because this is the only test that can be applied under normal conditions: It is certainly not acceptable to create a disturbance in the plant just in order to tune a single, simple PI controller.

But these setpoint-tests do not give us the correct picture, because the setpoint of a level controller is practically never changed. The task of the controller is to deal with disturbances, a situation which, as said, typically cannot be tested during the tuning effort. We are thus tuning the controller for the wrong task.

On the other hand is it extremely easy and simple to simulate the dynamic effects of a level in a drum or basin: In the case of a vertical drum only the diameter and the distance between the measurement taps are needed in order to describe the situation sufficiently. If there is a suitable simulation tool such as Matlab, MatrixX etc. available, then the controller can be very quickly tested under the correct situation, and of course esp. in cases where tools such as TOPAS are available, not only different disturbances can be simulated: With such aids it is also possible to calculate the tuning swiftly and specifically for the prevailing situation. For example, we can also test very quickly if e.g. an so-called error-squared PID controller type could deliver better results in the case where smooth action on the manipulated flow is needed. And also for new designs it could be checked within a few minutes whether or not the dimensions of the vessel are sufficient for proper control without negative influences elsewhere.

3. Decision Feeforward – yes or no?

The third case has also to do with a quite widely found situation, a situation where we have to make a decision regarding the control scheme structure and are looking for extra information to support that decision. Let us take a simple example, a furnace: The key control objective here is to keep the product temperature as close as possible at the setpoint. If this furnace is subject to frequent changes in the product flow rate then it is certainly difficult if not impossible to avoid large fluctuations in the temperature just by use of feedback control. But of course we can use a disturbance compensator, a feedforward, to reduce the effect of disturbance and consequently these variations. We know that we need to be able to recognize the change in the disturbance variable and to react in time. We also know from theory that in the perfect case, where all process parameters used in the feedforward are100% correct and there is sufficient time to react, i.e. when the deadtime of the disturbance is longer than the deadtime of the manipulated variable, we even could achieve total compensation of the effect of the disturbance.

But what happens often is that the deadtime of the disturbance, the product flow in our example, is shorter than the deadtime of the manipulated variable, the fuel gas flow? The only thing we know is that even in the (academic) case where all other parameters were 100% exact, we never could compensate the disturbance in full, the feedforward will always act too late.

This leads to a simple but crucial question: Does in such a situation a feedforward make sense at all, can it still improve the performance of the temperature or not? After all, it costs extra effort to develop and to maintain it. The answer can be found by calculations but this is quite a tedious task. Much faster and more convincing even is to simulate the situation – once with feedback control alone and once with the (imperfect) feedforward. Such a comparison delivers the answer with ease and in very short time. We have to invest some effort though: We have to get at least a reasonable estimate of the process parameters in order to conduct a meaningful study. But once we have them, the simulation is done quite easily and fast. On the other hand, the effort to get the process parameters is – at least in the case of those for the manipulated variable - not wasted at all, even if we decide against the feedforward: They can be used to calculate the best suited tuning of the feedback controller.

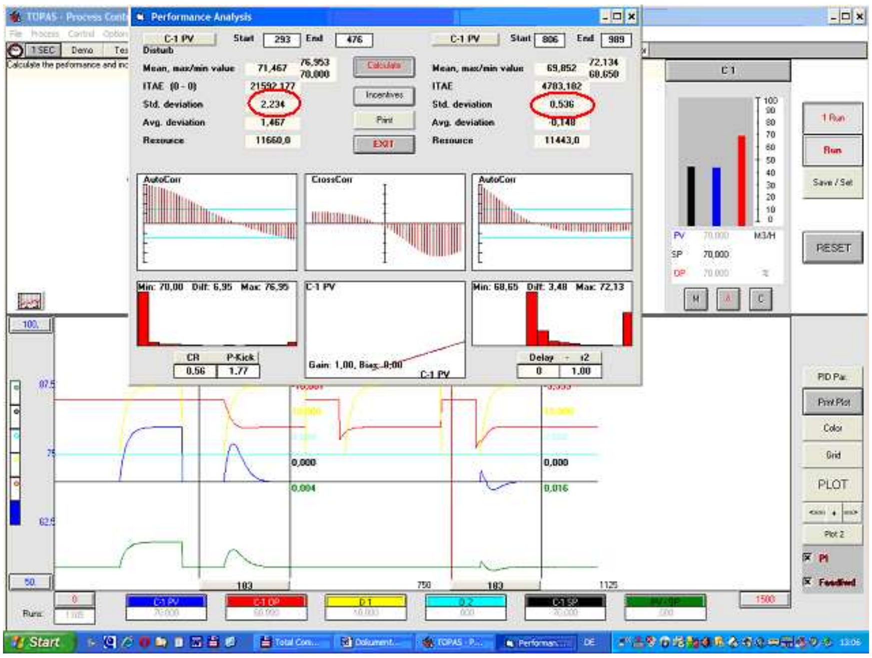

Figure 1
Comparison between simple feedback control and feedforward compensation

Conclusion

Computer simulations are indeed valuable tools, not just for the design of new equipment and for training and practicing, but they can give very valuable support in dealing with common daily control problems as well as special situations. However, they are not used as intensively as they could and should be, one reason being that the common perception still is that such simulations have to be always of extremely high fidelity in order to deliver meaningful results, which means complexity and that in turn would mean unacceptably high cost and of course difficulties in the use.

At least the two last examples have shown that this is not necessarily the case and that also even relatively simple simulation tools can make very valuable contributions in our strive for operations improvement: They can help to produce better control solutions, often with less disturbance of the process, and especially help to save us time. They key is, however, that these tools are sufficiently realistic, that means that they allow us to describe and study many real life situations and here especially disturbances and problems in an easy to handle way, provide all the needed control functionality, and allow also the easy transfer of the results into the DCS.

Hans H. Eder

ACT
hans.eder@act-control.com
www.act-control.com