Inferred On-Line Sensors May Improve Product Quality

Using Theoretical Process Modeling to Infer Real-Time Product Quality

Process Modeling

Process modeling has been employed successfully for decades in multiple industries that use continuous manufacturing processes. In fact, it is well-known that engineers use theoretical process models to do everything from design process production trains to determine key process quality performance indicators (KPIs). In the oil and gas industry, an example of such a KPI might be the composition of chemical splits at various stages in a separation column. In the specialty chemicals industry, a KPI might be the moisture content of an extruded plastic sheet; and in the pharmaceutical industry, it might be the predicted composition in a bioreactor. Since all chemical and biological processes may be modelled for steady-state and batch processes, engineers have spent years developing complex chemical and bio-chemical process models for these applications. And they've employed everything from old-school hand calculations to modern-day software programs to create them. Surprisingly, what is not as well-known is that process modeling may also be used for real-time process control.

KPI Measurement Lag

There are many industry process quality KPIs that cannot be measured in real-time or directly via an on-line sensor to a control system. These KPIs are therefore typically evaluated using samples taken to a quality control laboratory. However, the problem with sending samples to a lab is that it can take hours to get the results of the tests back. If the lab indicates that the samples tested out-of-range, then considerable rework must be done. This re-work may for example involve hours of isolating and diverting out-of-specification product from the process. Unfortunately, the further downstream in the manufacturer's process train that a sample is taken when the product is determined to be out of specification, the higher the resulting value in potential losses to the manufacturer's bottom line.

How can Process Modeling Help?

Now, if only there was an on-line sensor that could take the place of the laboratory measurement! While it is possible to use online sensors to measure samples, they often suffer from reliability issues. Another issue is that the types of measurements that must be done are so complex that using a physical on-line sensor is often not really a feasible option. This is where a process model can come to the rescue. Using a model, a process quality KPI can be calculated based on several measured process variables that are available in the control system. Granted, not all variables may be considered in the model, but this issue can be overcome using basic statistical process control principles.

How it Works

The model can be placed in expression logic in the control system, solving for the variable to be inferred. The result is stored in an analog signal that can be used as the input to a PID cascade loop that modulates a set-point downstream PID (or multiple downstream PIDs), and that acts as a closed-loop control logic for the inferred KPI. To account for variations not considered by the model, lab samples can be used to back-up the on-line sensor. The lab results are then fed back to the control system via a Laboratory Information System (LIMS) interface. Depending on the results of the lab sample, the setpoint for the KPI master PID loop can be adjusted according to standard short-term statistical process control (SPC) rules.

Benefits

In my work as a controls engineer, I've employed such a process control model to discover some additional benefits beyond the tighter process control of a KPI. One benefit of the process model is that it has helped me to discover issues with the laboratory measurement or sampling process. For example, on one occasion, there was a significant discrepancy between what was reported on-line by the inferred sensor and what was reported by the lab. I then discovered that although the lab instrument was malfunctioning, the on-line sensor was well within specification. In the early days before on-line sensors were available, operators would have spent hours in production doing re-work to fix this problem.

Is Model-Based Control Right for You?

In addition to its use in continuous manufacturing processes, model-based control can also be used in batch pharmaceutical processes to not only control virtual measurements but to help manufacturers achieve a "golden batch", or an optimal product batch that is of the highest quality at the lowest possible cost. In 2002, the FDA developed and published guidance for modeling pharmaceutical processes called the PAT (Process Analytical Technology). While not mandated, it is useful for any pharmaceutical manufacturer seeking to utilize a risk-based approach to ensure the consistency and quality of their products. In conclusion, I highly recommend that if you have a KPI that cannot be measured by an on-line sensor, use a process model to create a virtual sensor.

By Mark Durica, Controls Automation Manager