Data reconciliation adds control

Online process modeling plus statistical data reconciliation increases gas revenues.

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This article discusses an application of online process modeling technology combined with statistical data reconciliation methods in order to achieve tighter control of sales gas specifications and the best possible use of fields producing "out-of-spec" gas. The application is called Blending Management System (BMS) and is currently being implemented for a major gas producer in the Southern North Sea (SNS). These blending management systems are important because they allow operators to produce sub-quality gas reservoirs that could not be done in a standalone manner. The purpose of the BMS system is to allow one to maximize the flow rate of the bad gas while keeping the overall sales gas quality within desired specifications.

Case in point: If one can bring on a 100 MMscf/d reservoir, the potential economic impact over its field life can be US $1 billion. The major risk is, if the gas is not properly blended, penalties for selling or delivering "bad or off-spec" gas can be significant. For the above-noted operator, the penalty is in the range of $18.87 million per event. Entry of bad gas means part of the system must be shut down and blown down.

The primary challenge in building a reliable BMS is how to deal with failures and inaccuracies of field instrumentation. In a perfect world, when all necessary information is known precisely, calculating the maximum allowable flow rate from one off-spec gas producing field is just simple algebra. Unfortunately, the world is far from perfect or "simple."

Multiphase Solutions Inc. (MSi), a Houston-based provider of real-time model-based decision support systems for upstream operations, is designing the BMS utilizing proprietary "fit-for-purpose" online process modeling and statistical data reconciliation technologies. Together, these technologies are being used to reduce the uncertainties in field instrumentation, thereby pushing the BMS closer to routinely handling ideal-world scenarios.

The following sections provide a breakdown of the problem at hand, followed by a discussion of how online modeling technology addresses each of the smaller problems, giving one the ability to push the target energy content (Wobbe) down closer to the limit while maintaining, if not improving, the operational reliability.

Challenges

Inaccuracies in field instrumentation limit the operations from being too close to the operating limits. In this application, for instance, the key limit is the energy content of the sales gas.

The simple solution to dealing with uncertainty is to use a margin of safety in the target sales Wobbe, i.e., if the minimum allowable Wobbe is, say x, use $x+\Delta$ as the target Wobbe, where Δ is a small positive number. However, in doing so, one would be selling additional energy for free.

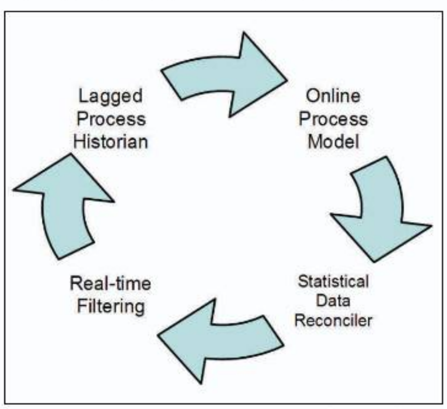

Figure 1. Four components make up the blending management system application. (All graphics courtesy of Multiphase Solutions Inc.)

In order to reduce these uncertainties, a real-time dynamic process model is used along with statistical data reconciliation. By using transient analyses of real-time data, it becomes possible to estimate the inaccuracies associated with all relevant field instruments.

Reducing uncertainty

BMS uses an online process model that estimates the sales gas Wobbe using the inlet flow rate measurements and gas chromatograph (GC) analyses. This estimate is then compared with field instrumentation that measures the sales gas Wobbe.

Since the field instruments for the sales gas Wobbe are the contractual measurement for determining penalties, the goal is to adjust the inlet measurements that feed the online process model so that the model-predicted sales gas Wobbe matches the field measurement.

This is where the statistical data reconciliation comes in. The reconciliation module compares flow rates and compositions predicted by the online model at the outlet of the model (sales points) to available field measurement at the same time. The difference between these quantities is reconciled by adjusting (biasing) the flow rates and compositions at the inlet to the plant. Figure 1 shows the cycle that the BMS components go through. Figure 2 shows the specific input/output between these components including the time lag effect (explained in the next section).

Lagging the model

Gas composition analyses are published in the process data database several minutes after the samples have been taken. Therefore, at any given time, the composition available in the database corresponds to a sample that was taken, say, n minutes ago. Moreover, multiple GCs are involved,

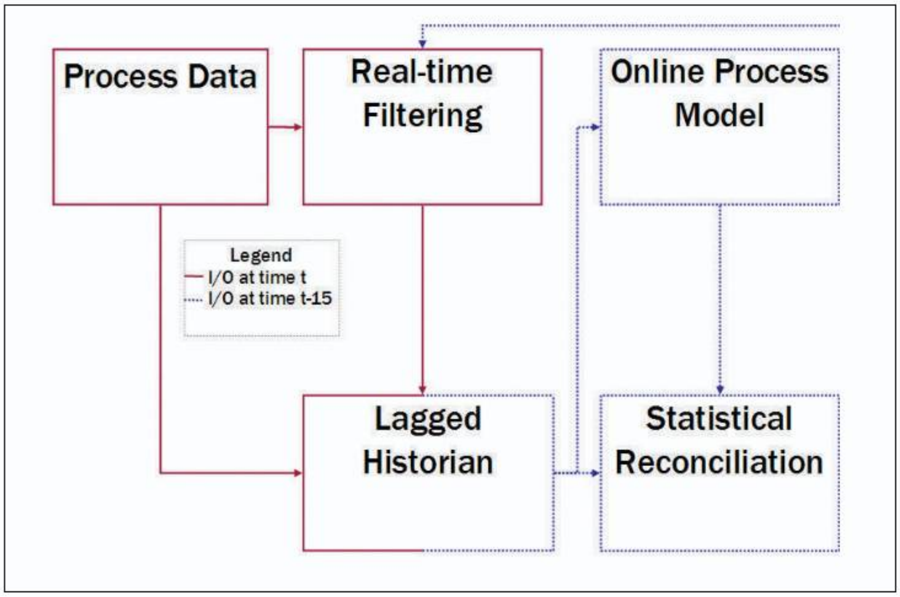

Figure 2. An input-output diagram shows the steps in the blending process.

and these all have different cycle times and are generally out of sync.

To overcome this problem, a module called the Lagged Process Historian (LPH) keeps track of process data for the last 15 minutes. When a new GC analysis result gets published, the LPH module back-corrects the measured composition of the corresponding stream for the last n minutes, where n is the cycle time for that GC.

This way, assuming all cycle times are less than 15 minutes, LPH is able to provide data for all the inlet streams, including flow rates and compositions that are consistent 15 minutes in the past. This data then feeds the online process model.

Real-time filtering (RTF)

While the statistical model eliminates inaccuracies in field instruments, it does little to handle communication losses, instrument down-time for maintenance, redundant instrument availability and data corruption. The real-time filtering module takes care of these situations.

The complete cycle

Data is first acquired from field instruments. This data is then filtered through the real-time filtering module. The first step in RTF is to throw out bad values. The status flag of the instrument, if available, and user-specified minima and maxima are all used to perform the first step. The outputs of this step, called bounded values, are adjusted using biases calculated using the data reconciliation module. These are the scaled values. Raw data, bounded data, scaled data and other flags are passed on to the Lagged Process Historian (LPH) which keeps a rolling history of 15 minutes. LPH outputs data for all measurements and filtered values that are consistent t-15 minutes ago. The t-15 data is then fed to the online process model which predicts the state of the entire process t-15 minutes ago. The statistical reconciliation module then compares the online model's predictions with t-15 measurements from LPH to adjust the biases in the inlet measurements. This cycle is repeated on a 15-second interval.

Once the biases are known for the inlets, the control model then back-calculates flow rate setpoint for the field producing off-spec gas by taking into account all the biases involved. Even though uncertainties are reduced by utilizing real-time modeling and data reconciliation, the control model still has advanced logic like adaptive gains for increasing and decreasing the flow rate setpoint, ladder logic for emergency shutdown of the off-spec field, and fast-response control for dealing with incoming spikes of off-spec gas.

Model requirements

The online model is a dynamic process model using rigorous heat, momentum, and mass balance and thermodynamic calculations. The entire cycle of computation as described above has to run sequentially every 15 seconds, and therefore the models have to be sufficiently fast. Currently, the entire cycle minus the process data acquisition has been benchmarked at utilizing 0.78 seconds to perform a 15-second update (~20 times real-time).

Results

Preliminary testing using field data indicates that the data reconciliation module is able to reduce the field instrument errors down to very low values. In reconciling molar flow rates, the net imbalance in field data was 1.25% (in – out/in) as compared to 0.037% with data reconciliation.

The BMS system is currently being tested offline using various simulated upset conditions and is scheduled to be field-tested in early second quarter of 2007.

The goal is to push the operating margin to minimum Wobbe limit plus 5 Wobbe units as against 12 Wobbe units in the existing BMS without a real-time model and data reconciliation.

Conclusions

The use of real-time models in combination with advanced filtering and data reconciliation algorithms allows operations to operate ever closer to operating limits while maintaining if not improving reliability. Such applications can be and are being used even further upstream where wellheads are controlled by model-based advanced control algorithms in closed-loop design.

Using mature real-time modeling technologies, upstream operations can "squeeze" the most out of their fields and facilities while ensuring maximum facility uptime. E&P