CADSIMulator

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New Dynamic Data Reconciliation Technology Provides Accurate Energy Accounting at Crofton Mill

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Catalyst's Crofton, BC Mill

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It is increasingly important for industry to monitor and control energy usage, not only to reduce costs, but also to reduce environmental impact. Mill information systems provide access to live and historical data that can be used for enhanced energy usage decision making.

However, mill steam flows are routinely found to be inaccurate due to instrument limitations. This problem hinders any evaluation or audit of the process, and can subsequently invalidate localized process decisions that are intended to reduce mill-wide energy consumption.

In 1997, Crofton began a pioneering effort to use steady-state Data Reconciliation (DR) to rationalize a balanced set of energy flows throughout the mill. Data reconciliation is the process of taking a set of measured values (with each measurement potentially inaccurate) and then determining a complete set of reconciled values.

The purpose of the original DR system was to determine the cost of steam produced by the recovery and power boilers so that it could be accounted as a cost to the paper machine users.

In May of 2006 Crofton replaced its data historian. This change provided an opportunity to update and repurpose the aging DR system.

CADSIM Plus, along

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(Data Reconciliation: continued from page 1)
with its Dynamic Data Reconciliation (DDR) option, was ultimately chosen as the best replacement technology.

CADSIM Plus offers a number of new and unique technologies that are changing the way that data reconciliation can be done. For example, the use of dynamic simulation in conjunction with DR and the method of allowing the change in a measured variable to be included with the objective function, are both proprietary, break-through DR technologies.

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Refining the model to add robustness under all situations took the most effort.

CADSIM Plus allows the user to add one or more measurements for each 'free' variable. More information (measurement redundancy) yields better results from DDR. It is also important to design the system with redundancy in each of several classes of variables: flows, temperatures and pressures. This is because (for example) an absolute pressure measurement can be used to reconcile other pressure measurements, but it may not have much effect on temperatures or flows.

The decision to use fully dynamic tracking was made to obtain more accurate, more frequent and more representative data reconciliation. Processes have physical time constants and dynamic events which can only be tracked if data reconciliation uses a dynamic base. The ability to be able to reconcile through major process upsets and major process changes is required for accurate results.

Dynamic DR also made it possible to run the reconciliation continuously.

Running the DDR continuously online has many advantages, one of which is that a shorter reconciliation time period is possible because a new set of results is usually fairly close to the last set of results, so convergence tends to be much faster. In addition, tracking dynamic changes such as area shutdowns and intermittent flows (e.g. sootblowing) is now possible. These would be ignored with purely steady-state reconciliation.

Another objective for the new system was to use the raw measurement data more wisely and to improve DDR accuracy.

A new feature of the CADSIM Plus DDR package allows the designer to decrease the weighting applied to a measurement on the fly. As the measurement moves away from a reasonable range, its weighting is reduced until it is eventually ignored when the weighting approaches zero. That improvement not only treats bad measurements as "outliers", but it also retains the raw data value so that faulty measurements are reported.

The CADSIM Plus logic building blocks were used to determine if a boiler or turbo Generator (TG) is down. The resulting system can be much smarter in determining unusual process states and therefore much more reliable.

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Two types of penalty functions steer the engine away from impossible solutions. One was implemented inside the CADSIM Plus engine to automatically handle mass or energy imbalance, and the other was put into the hands of the model developer.

Each time CADSIM Plus converges and subsequently writes data to the historian -- currently once every five minutes -- a log file is generated which reports the results of the simulation.

Every morning a Python script analyses the results of the previous 24 hours. The script then formats an e-mail which lists the most suspect measurements, which is then sent to a list of key process and support people.

The new CADSIM Plus DDR system has successfully met the goals that were set for the project. The system has a 99.7 % convergence/uptime rate and has received wide acceptance throughout the mill. A plant-wide energy display is available on the historian. The systems runs on-line on a single computer. A spare computer is available to do maintenance runs and as a backup.

An important use of the reconciled data has been energy budgeting and comparison of energy consumption to the budget. The historical data from the model is coupled with planned energy reductions to build an accurate forecast of energy use and demand. To date, this forecast has been very reliable.

Early on, data reconciliation proved its worth when it identified a natural gas metering issue. On investigation it was found that the natural gas supplier's billable flow meter was not accurate when a zero flow was reached. The issue was corrected and then the model was used to verify the amount of gas which was over-billed. The mill subsequently received a credit from the supplier.

The DDR system was used to evaluate the TG efficiency and to determine a fossil fuel price range which would yield economical power generation.

The energy information is used regularly by the mill's accountants to report on mill energy consumption to all levels of the organization. This information is also used by outside agencies such as Environment Canada to determine green house gas emissions.

The Role of Dynamic Simulation in Data Reconciliation

Simulation fits the results of basic conservation law calculations to the measurement data. These basic conservation law calculations are often referred to as “first principles” and involve material and energy balances that may include dynamic transient behaviour.

Using first principles to qualify the data has many advantages over any method that lacks this level of rigor. An example will illustrate why this is true.

Consider a hot water tank with a 10 minute retention time that suddenly gets a step change in one of the input flows that is 10 °C hotter than the other inlets to the tank. Measurements taken a minute later might indicate that the hot inlet has increased in flow, but the outlet temperature of the tank may have changed only a small amount.

If only steady-state mass and energy balances are used, the outlet temperature (which we will assume to be a reliable measurement) would tend to indicate that the inlet change in flow might not be correct, because tanks in steady-state simulation often have no holdup or accumulation. That would be a wrong conclusion.

However, if a dynamic simulation is used, then the time constant of the process could be included in the model and it therefore would be expected that the outlet temperature of the tank would have only increased a nominal amount over the given time period.

Measurements of individual variables that are in dynamic transition can cause completely wrong perceptions to be developed when doing DR, unless normal dynamic process response is also taken into account. Most processes seldom reach true steady-state, so reconciliation that assumes only steady-state operation can be problematic. This is especially important for on-line tracking.

Therefore, fitting the results of a robust dynamic process simulation to the measured plant data offers a better way of getting the most out of DR because it takes into account the first principles of mass balance, energy balance, process dynamics and process topology.

In addition, the use of a simulator allows filling in all the missing flows, temperatures and pressures for intermediate streams for which no measurements can be obtained, and any number of those values can then be saved in the process data historian.

The Role of Data Reconciliation in Measurement Correction

It can be frustrating when trying to make energy management decisions if process measurements from the plant cannot be trusted. Sometimes it is obvious that a measurement is not correct. For example, a measured negative flow, negative temperature or negative pressure of steam flowing to a heat exchanger is more likely to be erroneous than true.

However, experience alone does not always allow one to determine whether a measurement is correct. Calculated energy savings could be cast in some doubt if there are measurement errors.

There are many things that can contribute to measurement error. The accuracy of a measurement may depend on the type of sensor and how difficult it is to infer what the measured value should be from any given measurement method: there can be scaling errors (the measurement always reads some fractional amount of the true value); there can be offsets (the measurement is shifted high or low but the change in measurement is reasonably accurate); and there can be intermittent measurement noise.

Often with flow measurements, which vary with the square root of a pressure drop measurement, there are zero errors (when the flow should be zero, it reads some negative value or has some positive residual). Errors are often categorized as either random or gross errors.

Many permutations of the problems mentioned above are possible, and any of their contributions can also drift with time as sensors age or wear, or as unknown process variables influence the measurement.

Data reconciliation can help rationalize the measurements of a process in order to form a more consistent and accurate basis on which to base calculations and decisions. It does this by putting a best fit of a first-principles process model through the change in historical data measurements.

Other Uses for Dynamic Data Reconciliation:

- Report product life history from source to finish
- Track grade, species or batch campaigns
- Verify measurements like concentrations and consistencies
- Provide better data mining
- Calculate unmeasured variables
- Fill in intermediate or missing process stream information
- Give a solid basis for process optimization

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Tembec Implementing DDR System

By Joe Rankin & Larry Wasik

Tembec is currently implementing a CADSIM Plus dynamic data reconciliation (DDR) system to track pulp quality at their Specialty Cellulose mill in Temiscaming, QC. The mill has an annual capacity of 160,000 metric tonnes per year of specialty pulps.

Special cellulose pulps are produced in 11 batch digesters. These digesters empty into a blow tank with a storage retention time of anywhere from 30 to 130 minutes. After the blow tank, a Kappa number is tested to measure the degree of delignification.

If the mill wishes to make corrections to a particular digester operation as a result of a Kappa test, it is difficult for them to know which pulp coming from which digester has been Kappa tested because of the plug-flow retention.

That is where data reconciliation comes in. A CADSIM Plus dynamic simulation has been created to simulate the batch operation of the 11 digesters and the pulping process through screening.

The simulation tracks the pulp from each batch digester separately so that the contents of the blow tank are known. This allows the source of the discharge pulp to be identified by digester.

The DDR system is being implemented on-line with the discharge of the blow tank broken down by percentage from each of the 11 digesters being written back to the DCS historian. This work is on-going.

Did you know…

Controlling a ratio of two variables gives an easy way to provide a type of controller gain scheduling, which has good turndown, even to zero flow.

This can be an important strategy for making your models robust enough to handle the area shutdowns or quickly changing process behavior that may need to be tracked by on-line dynamic data reconciliation.

New DDR features planned for future releases of CADSIM Plus

- Support for cloning a simulation from an existing on-line tracking reconciliation simulation to:
  - Display current data for the full process with stream details
  - Run into the future
  - Form the basis for on-line optimization trials
  - Form the basis for 'what-if' scenarios starting from current operating parameters
- Ability to pre-condition and filter individual measurements
- Support for new reconciliation methods, including a separate process identification step
- Support for measurement sampling within the reconciliation period
- Tool to find the worst measurement while running the reconciliation
- Ability to halt at the end of the current reconciliation period