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ADVANTICA

TRACKING GAS QUALITY

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ABSTRACT

Consumers Power Company's new Gas SCADA System includes a networked real-time transient model. The model uses real-time SCADA data, including gas composition, to calculate the equivalent state of the pipeline system. The calculations include compositional tracking, pressure limit analysis and linepack. Flow calculations are performed at the RTUs and use gas quality data provided as downloaded parameters calculated by the real-time model.

PURPOSE OF PAPER

Is a real-time model running in parallel with a SCADA system capable of providing the gas components of BTU, Specific Gravity, CO_2 and N_2 required to calculate flow using AGA-3, AGA-7 and AGA-8 in a timely manner? Is the model calculated gas composition sufficiently accurate for use in the RTU flow calculations? The discussion that follows addresses these questions and describes Consumers Power Company's (CPCo) experience with such a model.

BACKGROUND

Consumers Power Company is a combination electric and gas utility. As a gas utility, CPCo is one of the largest combined gas transmission/distribution companies in the United States and the nation's fifth largest local gas distribution company. CPCo acquires, stores and delivers natural gas to its distribution system and non-affiliated companies in the State of Michigan. CPCo's pipeline system covers approximately 1,675 miles of transmission pipeline, and includes 14 storage pools and 7 compressor stations.

Natural gas is received from many different supply sources, including 7 interconnects with interstate pipeline suppliers and 29 intrastate gas supply points. Gas is delivered to a broad range of affiliated and non-affiliated customers at over 110 locations throughout the system CPCo also has a number of storage service customers who store gas in the summer and withdraw it in the winter. A significant portion of current system load is due to gas transportation to end-users who purchase gas on the spot market. CPCo operates the transmission pipeline system from the Gas Control Center in Jackson, Michigan. The primary responsibility of Gas Control is to receive gas deliveries from each of the suppliers and use the network of pipelines, storage pools and compressor stations to balance the requirements of each customer. The Gas Control Center is staffed 24 hours a day, 365 days a year to monitor and facilitate this activity.

To keep pace with the rapidly changing gas industry CPCo, having realized the limitations of the existing SCADA System, engaged Westin Engineering in February 1989 to perform a requirements study to help define the specific requirements of a new Gas Energy Management (GEM) System. Following approval of the requirements study Westin was also retained to evaluate system software alternatives and hardware configurations, provide an engineer's cost estimate and develop an implementation and procurement strategy. After the formal bidding process a contract for the GEM System was awarded to Amocams/Modular, Inc in November 1990.

Unlike the previous SCADA System, the new GEM System takes advantage of intelligent RTUs to perform several routine gas applications such as:

- AGA-3 orifice flow rate and flow volume calculations
- AGA-8 supercompressibility calculations (gross characterization method)
- AGA-7 turbine meter flow volume calculations
- Meter run control

and several special applications such as:

- Odorant monitoring and control valve control

By having the flow calculations performed by the RTU the calculation can be repeated every second, thus providing much greater accuracy than was previously available when the flow calculation was performed at the host. Installing the special applications in the RTUs allows the control functions to maintain current setpoint operation, even if the telephone communications are interrupted from the host.

DISCUSSION

The most innovative feature of the GEM System may be the inclusion of a real-time transient model. The modeling function is based on a hydraulic simulation of the entire gas transmission pipeline system which analyzes trends in the pipeline system conditions and considers the current load and supply scenarios and equipment setpoint schedules. The fact that CPCo had sufficient instrumentation on the major segments of the transmission pipeline system was one of the key considerations in including the transient model function in the GEM System.

[Advantica, formerly] Stoner Associates Inc was selected to supply the modeling software based on their hydraulic engine that includes the basic algorithms for conservation of mass, conservation of energy, conservation of momentum, and thermodynamic properties consistent with the Benedict-Webb-Rubin-Starling Equation of State. The hydraulic engine executes in three modes:

- Statefinder (Real-Time)
- Look-Ahead
- Predictive

The Statefinder mode calculates the mathematical equivalent of the current pipeline operation using the most recent SCADA pressures, flows and status points to define the pipeline configuration. Special subroutines check for data quality, consistency and repeatability and make limited adjustments to align all the hydraulic variables. Successive iterations define the system as a function of time.

The look-ahead mode extends the classical SCADA functions of data gathering, sorting and alarming as a means of recognizing historical trends to a forward looking approach by providing the Gas Controller with a window into the future. The look-ahead mode takes the Statefinder result and extrapolates into the short term future for up to 24 hours using the current operating plan, equipment setpoint schedules and forecasted loads. This mode is executed automatically every hour.

The predictive mode is similar to the look-ahead except the user can test alternative operating strategies. He can also retrieve an archived Statefinder condition and analyze a completely different scenario from that of the current pipeline state. Except for initializing the predictor mode with a real system transient condition as opposed to a steady state condition the operation of this mode is similar to the standard transient models available today.

Calculating and tracing the gas quality or composition is a feature the Statefinder provides which is the main subject of this paper. Included in the SCADA data obtained from gas chromatographs interfaced to RTUs are the mole percentages of the following gas components at the gas supply locations:

C_1	methane
C_2	ethane
C_3	propane
$1C_4$	iso-propane
NC_4	n-propane
IC_5	iso-pentane
NC_5	n-pentane
$NEOC_5$	neo-pentane
C_6	hexane
CO_2	carbon dioxide
N_2	nitrogen

CPCo has several Daniels Chromatographs at key supply points, including storage fields, which continuously analyze the gas supply stream and forward the analysis to the RTU at the site. Once each hour the SCADA host polls the RTU for the latest analysis. The retrieved analysis is made available to the Statefinder at each calculation interval. Although SCADA pressures and flows are being updated to the Statefinder every 30 seconds the composition analysis is kept constant for an hour. The reason is primarily because the Daniels Chromatographs are usually sampling several gas streams at a particular site and often take up to an hour to complete the cycle. Therefore, SCADA only polls for gas supply compositions once an hour.

CPCo has 36 different gas supply streams, some of which are not monitored by an on-site chromatograph. These are typically local production sites for which a monthly sample analyzed in the laboratory is used. For interstate pipelines, laboratory samples are also currently used, but the intention is to connect into the interstate pipeline chromatograph data.

With the composition of all the gas supplies provided as part of the input to the Statefinder, the model calculates the resulting composition including the BTU and specific gravity throughout the pipeline system using the Benedict-Webb-Rubin-Starling Equation of State. At each Statefinder calculation time step the results of the model, i.e. pressures, flows and composition, are exported to the SCADA real-time database. Some exported pressures are displayed as if they are live data retrieved from the RTUs at locations where there are no pressure transducers. This data is also flagged on the display to indicate that it is model calculated data. This information provides a better picture of the pipeline pressure gradient than can be obtained with only real pressure transducers. The exported composition which consists of the calculated BTU, G, CO_2 and N_2 is stored in the SCADA database and downloaded to the appropriate RTU locations once each hour for inclusion in the gas flow calculations, AGA-3, AGA-7 and AGA-8.

CPCo has selected this method to populate the local RTUs with gas composition data because other conventional methods such as algorithms based on supply and delivery volumes are very difficult to maintain due to the frequent flow directional changes within the transmission system and are of questionable accuracy. Adding extensive levels of instrumentation using gravitometers and gas chromatographs throughout the transmission system is also cost prohibitive.

The look-ahead mode also has compositional tracking capability and can provide an early warning of potential gas quality problems at critical locations. Examples of this are areas where there are industrial heat treating facilities which are particularly sensitive to CO_2 concentration.

CONTROLS

Operationally there are some serious questions that must be addressed in utilizing this approach. First, what happens when the Statefinder model fails or becomes confused because of inaccurate SCADA data? This will invariably happen from time to time, although a very limited amount of down time has actually been observed. To safeguard the RTU flow calculations all four components in the host database, i.e. BTU, G, CO_2 and N_2, are subjected to high and low limit checks such that anytime a model exported value is outside the limit the SCADA will automatically substitute the last acceptable value and download it to the RTIJ. An alarm is also generated providing the Gas Controller with both the calculated value from the model which is out of limits and the substituted value which is being used. Exactly how close to set the limits is important since some tolerance should be allowed for normally expected changes in the gas composition, but setting too broad a range may allow errors to be propagated throughout the system. Experience should quickly lead to a comfortable tolerance level which can be unique for different areas of the transmission system.

Second, what happens when the gas composition data coming from the gas chromatograph is bad? Similar limits have been assigned to all eleven components associated with every gas supply stream. In addition there is an alarm to catch a failure within the Daniels Chromatograph which the instrument sends to the RTU. There is also an alarm generated when communications between the RTU and the chromatograph have failed. When either of these alarms occurs, a call is made to the technical service area to make repairs. In the time interval between detection and repair the last acceptable value received from the chromatograph is used for further analysis.

TEST ENVIRONMENT

As part of the preparation for the presentation of this methodology CPCo collected gas samples at several locations throughout the transmission system where flow reversals are common over the time period from November 30, 1994 to February 7, 1995. During that time the system throughput varied from 1,100MMcf/d to 2,700MMcf/d. The gas samples were time stamped and either sent to a laboratory for analysis using a gas chromatograph or analyzed on the spot with a portable gas chromatograph. The results were then compared with the BTU, G, CO_2 and N_2 obtained from the statefinder which were subsequently used within the RTU for flow calculation at the same time the sample was taken. Composition used for all flow calculations is archived in the SCADA historical subsystem along with other audit data and can be easily retrieved for up to thirteen months before it is transferred to optical disk storage.

There were 36 individual points of gas supply feeding the transmission system over this time period with a range of composition shown below in Table 1.

	BTU	GRAVITY	CO_2	N_2
MAX	1,091	0.792	5.860	24.932
MIN	941	0.574	0.000	0.290

Table 1 – Range of gas supply composition

Over the eleven weeks 48 samples from 13 different locations were gathered and analyzed. The overall deviations of the model calculated compositions to the laboratory analysis of the samples are shown below in Table 2.

	BTU	GRAVITY	CO_2	N_2
STD	5.897	0.005	0.353	0.286
AVG	3.848	-0.002	-0.134	0.079
MAX	18.663	0.009	0.730	1.340
MIN	-6.197	-0.010	-1.230	-0.210

Table 2 – Deviations of model compositions to gas sample compositions

CONCLUSION

Although the sample size of 48 is too small to support rigorous statistical analysis we, nevertheless, feel confident in concluding that the Statefinder is providing a good representation of composition throughout the transmission system. Further observations have been made to support this conclusion. Some gas supply points have poor quality, as can be seen in Table 1. When the gas flow at these points is interrupted for any reason a coincident change in the gas composition can be easily seen at nearby delivery points which are being supplied with gas composition from the Statefinder model via the SCADA to the RTU.

CPCo intends to continue refining this procedure and monitor more gas samples for further evaluation. As of this date, however, we believe the benefit of this approach has been demonstrated for a highly integrated system of pipeline loops and varying gas flow directions.