ABSTRACT

Oftentimes smaller transmission systems will be designed and built with only essential telemetry in mind. While deliveries are not monitored in real time on SCADA, monthly consumption data is recorded and available. While this amount of telemetry is sufficient to accurately and appropriately monitor the pipeline, it may not provide enough data to produce a hydraulically accurate simulation model.

We set out to determine the feasibility of creating a Transient real time model of one such small transmission system where as much as 80% of the deliveries are not on SCADA. This ~75-mile-long system is mostly comprised of larger seasonal agricultural customers which can draw the system down and impact the few residential distribution systems that are on the mainline. The real time model can be used to analyze potential improvements and/or system expansion alternatives and their effect on pressure at the delivery border station.

We combined the use of a hydraulic simulator, load prediction software, and data analysis to develop a methodology to simulate the transient behavior for these non-SCADA points. Where SCADA was not available, historical data from similar type customers was analyzed to produce profiles that could be applied.

A Real Time Model (RTM) was built utilizing both actual SCADA data and simulated SCADA to accurately model the transmission system. This model demonstrates that despite a large gap in the available real-time SCADA data, where missing data could account for as much as 80% of the total load on the system, we can model the behavior of the system by calculating and accurately estimating flows and pressures.

In addition, users can easily convert the RTM into a transient predictive model where further feasibility and system improvements can be analyzed.

INTRODUCTION AND BACKGROUND

Designing and building an RTM for a transmission system is often a well-defined process wherein SCADA data is used to derive the transient behavior for the loads. However, this system only provides monthly consumption data rather than real time SCADA data at many of the large deliveries.

The system is an approximately 75-mile-long (~121 km), 4-inch-diameter (10 cm diameter) transmission system delivering natural gas to a large border station city (BSC). The system also delivers gas to several smaller townships, irrigation systems, and agricultural dehydrators. There are two (2) compressor stations along the system.

The system has seasonal loads that can vary considerably. During the spring and summer, the usage is lower since most of the draw on the system is limited to the townships and border stations. However, during the fall and winter, gas usage is significantly higher since this is peak harvesting season.

This increased usage is primarily the result of the agricultural dehydrators located throughout the system. The system has nine (9) dehydrators, seven (7) of which are used with Produce A while the remaining two (2) are used with Produce B. Typically, Produce A season runs from approximately October into June, while Produce B season runs approximately from July to early October.

The dehydrators will typically only run when the weather gets cooler and the produce needs the dehydrators to run to keep them warm and dry. This is important to note because the load drawn due to the dehydrators can account for 60 – 80% of the draw on the system on a given day.
In addition, there are times, typically in the winter, where the irrigation pumps along the system will run concurrent with the dehydrators. The result of these loads is that the highest demands on the system occur in the winter.

Figure 1: Average Annual Loads for a 6 Year Period

The graphic above illustrates this further, with flow rates peaking in the winter, and dipping much lower in the summer. This confirms that the combination of dehydrator and irrigation pump loads during winter is a critical time for the system.

DATA COLLECTION PROCESS

The process to begin collecting data for the model involved correlating SCADA tags for the system with tags that could bring the data into the RTM. A spreadsheet is established as the go-between to link the two systems.

Typically, an RTM requires many key pieces of data, including pressures, flow rates, and the gas properties at system receipts and deliveries. In addition, SCADA data correlating to the operation of regulators and compressor stations in the system must be utilized.

However, it became clear that much of the typical data needed to run an RTM was not available for this system.

Residential and Irrigation Customers

Some of the gaps in the information provided to the model are the many small deliveries along the transmission system. These deliveries are typically referred to as small deliveries since their loads are minor compared to the dehydrators, described earlier, and BSC. There are thirteen (13) small deliveries on the system.

Off-SCADA Dehydrators

A second and larger gap in information results from the lack of SCADA data, pressure, and flow rates at many of the system’s dehydrators. In fact, only five (5) of the nine (9) dehydrators report any SCADA measurements. Even with these 5, only the flow rates are useful, as the reported pressures are customer pressures, which reflect the discharge of the regulators and are not modeled. That is, the reported pressures have already been reduced for deliveries and do not correlate to the high-pressure transmission line.

DATA ANALYSIS AND ASSUMPTIONS

To determine the extent of this gap in information, we reviewed historical loads on the system for the year from July 2015 to July 2016.

We found that during the summer months approximately 20% of the loads on the system were being reported by SCADA, and during the fall and winter seasons, 60-80% of the loads were reported by SCADA. Therefore, when the dehydrators are running, the model will have 60-80% of the loads reported. However, throughout the remainder of the year (when the dehydrators are not used) only 20% of our system’s load will be accounted for by SCADA readings. In other words, NextGen will need to approximate loads ranging from 20 – 80% of the total system load.

To achieve this goal, it was necessary to derive accurate estimates based on historical data at both the residential and irrigation customers and the Off-SCADA dehydrators.

Small Deliveries using Loads Generator Data

The Loads Generator is already a tool used for modeling and analyzing the various small distribution systems branching off this transmission system. And, without any meaningful SCADA flow rates or pressures, utilizing historical consumption data and the Loads Generator data became the best option for modeling them in the RTM.

We collected monthly historical consumption volume for all core customers from approximately December 2011 to August 2016, as well as daily weather data for the same period. This data provides us the ability to utilize the Loads Generator to perform a regression analysis to determine approximate flow
rates. However, a couple of challenges remained.

As a transmission model, the core customers on the laterals of the system are represented as a single node. Therefore, the individual customer loads needed to be combined in a manner that allowed a regression to be run that accounted for all customers on a branch of the system.

This task was handled utilizing NextGen’s region selection tools and an additional distribution model used for their typical distribution analysis.

For example, in this transmission model, we have a node labeled “Old Town Distribution”, which represents the core customers in Old Town. Since the model was built with shapefiles, we can use Google Maps to verify exactly where Old Town is in the model. (NOTE: The image below is an example only and not the actual location of the system.)

Once Old Town has been located, it is a simple matter of zooming into the regulator for the lateral and using the select by boundary region tool to group all the core customers in this area. Then, with the Reports filtered to only the meters for the customers in this region, we could export those to Excel.

With this list in Excel, as well as the Loads Generator data, we could organize the customers based on the corresponding node in the transmission model. Then, any dehydrators that are also included in these regions were removed from the data set, as each dehydrator is individually specified in the transmission model.

These steps were repeated for each of the 13 nodes representing these residential and irrigation customers branching from the transmission system. Since the Loads Generator allows customers to be grouped based on three levels of categorization, we simply transferred our new groupings into the regression tool.

This provided us with the regression fit needed to create profiles for use in the simulator. NextGen offers many different types of profiles. We utilized the 365 Day Absolute profile for this model.

Therefore, for every day of the year, each of our small deliveries on the system will use the flow rate provided by this profile.

To create this profile, we utilized the regression with the weather data from December 2011 to August 2016. This provided us with an approximate load for every day through the data set. Then, the flow rate for each day was averaged, providing us the 365 Day Absolute profile.

For instance, using the Loads Generator and weather data, we derived a load for each delivery for April 16.

Performing this analysis for every day of the year for all 13 residential and irrigation customers’ nodes provided the profiles needed to estimate the system’s small deliveries.
Large Deliveries for Off-SCADA Dehydrators

Since four of the five dehydrators do not report pressures or flow rates to the SCADA system, we again needed to determine a reasonable approximation for the flow rates at those dehydrators at any given time by reviewing historical monthly consumption data.

Like the residential and irrigation deliveries, this analysis began with historical monthly consumption volumes from December 2011 to August 2016.

Off SCADA Dehydrators
- Dehydrator 1
- Dehydrator 2
- Dehydrator 3
- Dehydrator 4

Correlating Off-SCADA Dehydrators

The illustration above helped us to identify some correlations between the dehydrators, such as months in which they began to flow and ended.

We found that Dehydrator 2 closely followed Dehydrator 5 and that Dehydrator 1 followed Dehydrator 6. Dehydrator 3 and Dehydrator 4 begin flowing much sooner than the other dehydrators, so a reliable correlation with an On-SCADA dehydrator could not be reached.

Determining Flow Rates

Next, we considered the best method for determining the volume that each of the Off-SCADA dehydrators would flow. Since the Primary Regulator has both flows and pressures from SCADA, we could utilize that as the known volume entering the northern half of the system.

Therefore, with the following information:
- Flow rates through the Primary Regulator supply our northern system.
- Deliveries from SCADA for BSC are known.
- Deliveries for half of the dehydrators are known.
- Our estimates for the small deliveries are reasonable.

We can deduce that the remaining, unallocated flow must be distributed amongst the four Off-SCADA dehydrators.

Prorate the Unallocated Flow

Now we simply needed to determine how we would distribute this unallocated flow. We again reviewed the historical monthly consumption data to approximate a percentage of the unallocated flow to be applied as a prorate for each of the four Off-SCADA dehydrators.

<table>
<thead>
<tr>
<th>Percent of Consumption</th>
<th>Dehydrator 1</th>
<th>Dehydrator 2</th>
<th>Dehydrator 3</th>
<th>Dehydrator 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun-12</td>
<td>0.0%</td>
<td>0.0%</td>
<td>100.0%</td>
<td>0.0%</td>
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<tr>
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<td>0.0%</td>
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<tr>
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</tr>
<tr>
<td>Oct-12</td>
<td>71.5%</td>
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<td>7.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Nov-12</td>
<td>82.7%</td>
<td>17.3%</td>
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<tr>
<td>Dec-12</td>
<td>100.0%</td>
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<tr>
<td>Jan-13</td>
<td>100.0%</td>
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</tr>
</tbody>
</table>

The percentages shown in the table above represent the percentage of gas consumption across only these four dehydrators for the specified month (rounded). After reviewing the table, it appeared that the 2014 and 2015 seasons were more like each other than the 2012 and 2013, which may indicate...
consumption habits have changed.

Therefore, the percentages above are used to estimate the prorates to be applied at each of the Off-SCADA dehydrators against the unallocated flow rate found between the Primary Regulator station and our known delivery points.

AutoTuning the Model

Utilizing NextGen’s built-in automatic tuning feature, we enabled it to run alongside the RTM and tune the system as it ran. Tuning adjusts pipe efficiencies to better match pressures at known pressure locations e.g., BSC which reports known SCADA pressures to the model.

CONNECTING TO THE SCADA DATA

Connecting to SCADA to run an RTM is simple. After the spreadsheet described above was set as an established format, the software is configured to accept data from the SCADA Data Source.

However, any data manipulation that needs to occur after it has been collected from SCADA must be handled through other means e.g., using flow rates, compression ratios, and other data to determine if a compressor is on or off. In fact, this additional process is how we implemented the flow rates and prorates that were applied to the Off-SCADA dehydrators.

Here we utilize VB Scripting. We can manipulate and analyze all the data the software receives from an external source through a VB Script. This includes evaluating the difference between the flow rate passing through the Primary Regulator and the known deliveries to determine the unallocated flow to distribute to the Off-SCADA dehydrators.

```
' AutoTune
' Enabling AutoTuning in the RTM

' Connecting to SCADA Data

' Configure the software to accept data from the SCADA Data Source.

' Data manipulation and analysis through VB Script.
```

RTM ACCURACY

Using the estimates and assumptions described above, the simulation has been accurate when comparing RTM calculated data to actual field data.

Analyzing the flow rate deviation at the Primary Regulator shows simulation flow (dark red line) tracking very closely to the actual reported flow rate (light blue line). The flow rate deviation at the Primary Regulator is small at low flow rates but increases somewhat when peak loads start up.

The pressure deviation at BSC was an average of 5.6 psi (38.6106 kPa), or about 1.2%. The reason for this discrepancy may be that the prorates have changed somewhat from previous years. That is, the loads at Off-SCADA dehydrators may have changed.

```
Figure 9: VB Script for Dehydrator Flow Difference

For example, Dehydrator 2 is providing the total “Flow Difference” between the Primary Regulator and the known deliveries to the InFlow Set Point field and the Prorate we determined above is set to the InFlow Factor field.

This means that, even without opening the VB Script and reviewing the data within, you can see what the total flow difference is as well as the current prorate being applied, as shown in the Reports image below.

```

Figure 10: Flow Difference within the Program’s Interface

Figure 11: Simulation Flow vs. SCADA Field Flow

Figure 12: RTM vs. Field Pressure Deviation at BSC
CONCLUSIONS

An OnLine solution for the system using simulation is accurate despite the large gap in available SCADA data, where missing data could account for as much as 80% of the total load on the system. By using monthly consumption data, we can analyze and estimate with precision the various flow rates throughout the system.

However, to ensure these estimates remain accurate, it is also important to review monthly consumption data, perhaps on an annual basis to verify or adjust the prorates being applied to the dehydrators in the event their relationships change.

With that said, these results open new options when reviewing the current condition of the pipeline. In fact, the ability to convert an RTM and the data relationships into a predictive model with only a few clicks of the mouse can further expand and enhance its applications for this hydraulic model.

For instance, users can evaluate system expansions and upgrade alternatives that will allow more dehydrators to be added while keeping BSC above a minimum pressure during a peak heating day. In addition, this could include other alternatives such as:

- Adding Looped Lines
- Adding compression or changing the current HP operations
- Upgrading the pipe and moving or removing the Primary Regulator

Furthermore, this technology and approach can be used on significantly larger portions of the pipeline.

Once implemented on larger systems, the increased functionality and reliability of the models becomes even more apparent as problems to solve become simpler and those solutions become more accurate.

AUTHOR BIOGRAPHY

Alisa Bullard works for the New Mexico Gas Company in Albuquerque, New Mexico. She has held numerous engineering positions through her tenure with the company with her most recent position focused on transmission hydraulic modeling. Alisa graduated from the University of New Mexico with a degree in Mechanical Engineering.

Samon Kashani works as a Software Engineer for Gregg Engineering Inc. headquartered in Sugar Land, Texas. Samon works primarily on new software development for Gregg Engineering’s NextGen Software Simulation Suite. He has also assisted on various implementation projects, such as leak detection studies and Trainer implementations. Samon graduated from The University of Texas at Austin where he received his Bachelor of Science in Mechanical Engineering. Samon has also received a Master of Business Administration from Prairie View A&M University.
FIGURES

Figure 1 - Average Annual Loads for a 6 Year Period

Figure 2 - Historical Loads from 2015 to 2016
Figure 3 - Model overlaid on Google Maps to Locate Old Town

Figure 4 - NextGen Reports Filtered to Customers to Export
Implementing a Real Time System where a Majority of Deliveries are not on SCADA

Figure 5 - Loads Generator with Grouped Customers

Figure 6 - Derived Load for April 16 for Multiple Years
All Dehydrator Consumption

Figure 7 - Loads of All Dehydrators

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<tr>
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Figure 8 - Historic Gas Consumption for Off-SCADA Dehydrators as a Percentage
Implementing a Real Time System where a Majority of Deliveries are not on SCADA

Figure 9 - VB Script for Dehydrator Flow Difference

```vbscript
' Dehydrator Flow Difference
' It has also shown that Dehy 2 typically runs in the same month as Dehy 3
' so if Dehy 2 is on, then Dehy 2 will be too
If Abs(Dehy2InFlow > 0.0) Then
    ' We need to Add a tag for the Set Point we are putting our Flows into
    Dehy2InFlow = VBAddData("Dehy - 2", "Inflow Set Point", 0)
    ' Copy the commodities to the Inflow Factor in NextGen
    Dehy2InFlowFactor = VBAddData("Dehy - 2", "Inflow Factor", Dehy2InFlowFactor)
    ' Prorate the remainder
    Dehy2InFlow = -abs(FlowDifference)
    VBLogMsg(LogFileName, "Dehy2InFlow Delivery " + FloatToStr(Dehy2InFlow))
End If
```

Figure 10 - Flow Difference within the Program’s Interface

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<thead>
<tr>
<th>Name</th>
<th>Inflow Set Point (M3/hr)</th>
<th>Inflow Factor</th>
<th>Inflow (M3/hr)</th>
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Figure 11 - Simulation Flow vs. SCADA Field Flow

Figure 12 - RTM vs. Field Pressure Deviation at BSC