The Southern California Gas Company (SoCalGas) bases pricing policies on the Weighted Average Cost of Gas (WACOG) from anticipated monthly spot market purchases. The purpose of this application was to find the least cost spot gas offered each month subject to the constraints of price, capacity and volume needs under varying business conditions. To meet this goal, the users requested complete flexibility in specifying every potential constraint when solving for the optimal gas purchasing strategy. The system uses SAS/OR® and SAS/AF® software to solve for spot gas under various scenarios. The scenarios may be represented as a linear programming problem, where some of the conditions are relatively simple while other constraints are more subtle. This paper describes how the model is able to translate user information about marketplace conditions into a sparse data matrix, generated in the data step and solved by PROC LP.

1 Introduction

The business function of this system is planning for gas purchases in the upcoming month. The key output of this function is the posted WACOG, or the weighted average cost of gas. This determines the price at which customers can purchase gas from SoCalGas. If this price is too high, purchases will be low (as customers purchase from alternate sources), costs will exceed purchases, and pipeline capacity will go unused. If the price is too low, sales may be oversubscribed, customers curtailed, and revenue lost. Looming over these profit and loss considerations is the prospect of regulatory review and the dreaded fear of having some purchases labeled as unsound, the costs disallowed. The final decision on the WACOG to be posted is made at the highest levels within the Gas Supply department.

Pipeline capacity is separated into volumes purchased by SoCalGas for resale and transportation volumes purchased by our customers for their own use. The total volume to be purchased for Company use is based on forecasted demand. The key decisions addressed by this application are how SoCalGas volumes are to be split among various categories of gas, and where that gas is purchased and how the gas is to be routed.

Every month, suppliers offer spot gas contract bids to SoCalGas for the following month. A bid is characterized by a price, a volume and a delivery location, or locations. Spot gas comes in two forms: firm and discretionary. Once a firm gas contract is signed, the supplier is obligated to deliver and the company to purchase the contract volumes. There is no flexibility in this, but typically a price premium reflects the greater security of the supply. Discretionary volumes set an agreed price, and maximum volume, but carry no legal obligation on the supplier to deliver or the gas company to purchase. In the model, this "flakiness" in discretionary contracts is captured by a performance factor (set by the users) that reflects the best guess as to what percentage of discretionary volumes will actually materialize.

Gas may also come from a minority supplier of gas, known affectionately as WMBEs; Women and Minority Business Enterprises. Management has set broad guidelines on purchases from WMBEs. These guidelines take the form of percentage targets, or the rule that if all else is equal, purchases should be taken from a WMBE.

Gas may be purchased on the El Paso, PG&E, or Transwestern pipeline systems. The networks of these pipeline companies have been greatly simplified to reflect the fact that this is a high level planning tool. The model represents the network as a backbone transmission system, attached to several major gas supply basins and delivery points. The focus is on capturing the key bottleneck points that exist on the networks. The networks differ in shrinkage (amount of gas lost during transportation), and the transportation rate charged. See Figure 1 for a diagram of the network structure.

The analysis that is done reflects different combinations of conditions that are expected to prevail in the upcoming month. These conditions are the relative prices of firm and discretionary gas, the possibility of additional capacity becoming available due to utilization of transportation capacity by SoCalGas customers, differing availability of capacity at delivery points or on transmission lines, and utilization of PG&E routing capacity. The analysis takes the form of scenarios that are developed, and then summarized in reports showing volumes purchased from various sources, along with the prevailing WACOG.

2 The User Interface

The analyst begins using the Gas Acquisition Scenarios Model by typing GASACQ at the DOS prompt. The AUTOEXEC.SAS file sets up all of the libraries and filenames, executes several set-up macros, and gives the AF command to display the main menu, shown below.

<table>
<thead>
<tr>
<th>Select An Option Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Edit Delivery Point and Transmission Line Constraints and Network Assumptions</td>
</tr>
<tr>
<td>2. View and Edit the Bid List</td>
</tr>
<tr>
<td>3. View and Report Configuration</td>
</tr>
<tr>
<td>4. Enter Other Gas Purchases</td>
</tr>
<tr>
<td>5. Run Scenarios</td>
</tr>
<tr>
<td>6. Exit to DOS</td>
</tr>
</tbody>
</table>

By selecting menu options, the user is able to perform a number of tasks. The first four menu items allow the user to set up the data which will be used in the optimization process. Option 1 allows the user to specify constraints for the maximum volumes at individual delivery points and along transmission lines. In addition, the user may change the settings for information specific to each pipeline network - the amount of shrinkage, the conversion factor for changing from MMbtu to MCF, the inter-utility charge, and the total pipeline capacity. Option 2 allows the user to read each month's contract offers into a SAS file and to sort and edit this file. Option 3 provides a summary of user defined options prior to running the model. Option 4 allows the user to input the long-term volumes which will be
Figure 1 - Pipeline Network Structure

Optimization Parameters Screen

Scenario Name: 
Target Month: 
Transportation Volumes: _______ MMcf/d
Allocate Transportation Failure (Y/N): (Default is No)
Use Analyst Defined Constraints (Y/N): (Default is Yes)
El Paso/P.G. & E. P.F. Volume: _______ MMcf/d
P.G. & E. Non Core Delivered Price: _______ $/MMbtu
P.G. & E. Non Core Border Volume: _______ MMbtu/d

<table>
<thead>
<tr>
<th>Source</th>
<th>Volume</th>
<th>Price</th>
<th>Yr/Month</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>El Paso</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transwestern</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. G. &amp; E.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL SYSTEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2
sharing the pipeline capacity with the short-term purchases in order to produce summary reports. Option 5 is the heart of the application. This screen allows for nearly unrestricted specification of the model.

III The Optimize Parameters Screen

Figure 2 shows the "Optimize Parameters" screen of the Gas Acquisition Scenario Model. It is at this point that the user has the power to define the scenario. When the system was first conceived, it was thought that there would be a standard Scenario Model for each month which would solve for the least cost discretionary spot gas. The standard Scenario 2 would solve for a specified volume of least cost firm gas and then fill in the total requirements with least cost discretionary gas. Unfortunately, we quickly discovered that there were no standard scenarios. The users required an interface which would allow them to put together any combination of requirements and constraints in order to reflect the unique marketplace each month.

The goal of the system is to solve for specified volumes of least cost gas (disccretionary and/or firm), subject to the constraints of delivery point, transmission line, and network capacity, transportation failure, long-term purchases, and other business conditions.

The Optimize Parameters screen allows the user to specify any condition or combination of conditions which reflect actual or expected business conditions. The user provides a unique name for each scenario. The system assumes that gas is being purchased for the month following the current date, so that information is provided automatically by calling the month and year values of the ASYS-DATE variable. If for some reason the user is working on information from another month, the default date may be over-written.

The user may specify the total amount of transportation volume which has been allotted to SoCalGas customers for the coming month. If this space is filled, the model will solve for an additional 10% and 20% of the transportation volumes after solving for the initial spot gas requirements. This allows the analysts to anticipate spot gas costs under conditions of under-utilization of the transportation allocations.

If the model is asked to solve for 10% and 20% transportation failure, there are two possible approaches. The simple approach is to solve for the least cost discretionary gas available on the bid list after filling total spot gas requirements. The other approach is to select discretionary gas to fill in for transportation failures in proportion to anticipated transportation volumes for each pipeline network. This option will be explained in greater detail in Section V - Special Business Problems and Solutions.

The next parameter on the screen asks the user to choose between analyst defined constraints and physical capacity. In most cases the amount of capacity at the delivery points and along transmission lines is different than the physical capacity, and user defined constraints are the default. However, if the analyst chooses not to enter different capacity constraints, the model will use physical capacity.

The next three options on the menu allow the user to set up conditions relating to buying spot gas on the El Paso Network for routing on the PG&E Network or for buying spot gas directly from PG&E. These options will be covered in greater detail in Section V.

Finally, the "Optimization Parameters" screen presents the user with an extended table for specifying volumes and minimum and maximum prices. The user may specify the minimum flow along each pipeline network as well as total system-wide requirements. In addition, the user may specify that only discretionary gas offered above a minimum price will be included in the model. This is to prevent unrealistically low offers (which are not likely to be backed by actual supply) from defining the final WACOG. The user may specify the amount of firm gas desired from each pipeline and/or for total requirements. In some cases, there is a need to restrict the firm gas contracts to those below a specified maximum value. This maximum value is often set at the maximum likely to be sold off at the spot market, for the spot gas under a previous scenario which solved for firm gas only. The logic of this option is that SoCalGas is trying to pay no more for the security of the firm contracts than it would have paid for discretionary gas.

There were a number of challenges inherent in developing the Gas Acquisition Scenarios Model. In actual use, the model is both an operational and analytic tool. Its main goal is to provide alternative scenarios in order to evaluate the value and risk of posting a relatively higher or lower WACOG. In this context the model does not select actual spot gas contracts for negotiation. In another context, however, the model is the tool by which the analyst selects the actual firm gas contracts to be purchased for the following month. For this reason, the model must solve for firm volumes before solving for discretionary volumes or transportation failures. This means that the model must have the capability to readjust the total system requirements and to recompute the remaining capacity at delivery points and along transmission lines following a partial solution for firm gas.

Another challenge arises from the fact that the amount of increased capacity due to transportation failure expected on each of the pipeline networks is a function of the amount of capacity already used by long-term gas purchases and the Gas Acquisition Scenarios Model's prior solution for spot requirements. For these reasons, although the solution is likely to be sub-optimal, a full model which solves for firm gas, discretionary gas, 10% transportation failure, and 20% transportation failure must create a sparse data matrix, evaluate the solution, adjust constraints, and begin the process over again through four iterations of PROC LP. All of this matrix generation and data manipulation is transparent to the user. The specifications for all four linear programming problems are supplied only once when the user completes the Optimize Parameters Screen.

IV Standard Elements of the Sparse Data Matrix

In every scenario, the structural variables are defined as the volume selected on each contract at a specified delivery point and as the flows on the nineteen arcs of the pipeline networks. The contract volumes are designated as \( V_{\text{arc}}(\text{doc}, \text{bid}, \text{ctr}, \text{nt}, \text{pt}) \) where \( \text{doc} \) is a unique three-digit id number from node and \( \text{bid} \) is the to node on the network. There are several "generic" constraints which are used in almost every scenario.

The Objective Function

The objective function of the Gas Acquisition Scenario Model has the basic goal of minimizing total cost. There are two additional elements which must be considered in the objective function. The first consideration relates to SoCalGas' goal of purchasing gas from WMBE suppliers in cases when prices are equal to non-WMBE prices; that is, in cases of a tie in price and subject to all other constraints, the solution should select a WMBE offer. This goal is achieved by adding a "non-WMBE penalty" to the offer price of the gas which has no economic impact on the actual WACOG. Prices are recorded in the database with four decimal places. In the data step which organized the input, a new variable \( \text{PPRICE} \) (a "pseudoprice") is calculated as \( \text{PRICE} + 0.000001 \) if the supplier is not a WMBE and \( \text{PRICE} \) if the supplier is a WMBE.
The second modification to the objective function results from the inter-utility charge (IUC). If gas is routed on transmission line F0913, then the inter-utility surcharge is applied. Thus, the objective function can be characterized as follows:

\[
\text{Minimize } \sum_{i=1}^{n} \text{PRICE}_{\text{VOL}} + \text{IUC} \cdot \sum_{i=1}^{m} \text{FLOW}_{i}
\]  

(1)

\textbf{Contract Volume Constraint}

For each bid offered to SoCalGas, the maximum volume offered (VOLUME) is the upper limit on the amount of gas which may be selected from any single contract at all delivery points at which it is offered. Thus, the contract volume constraint may be characterized as:

\[
\sum_{i=1}^{n} \text{FLOW}_{i} \leq \text{VOLUME}_{\text{CONTRACT}}
\]  

(2)

\textbf{Transmission Node Balance Constraint}

The logic of this constraint is that the amount of gas flowing into the system at any given node must balance the flow out of that node. This constraint serves the function of providing the model with the layout of the network (direction of flow and interconnections) as well as linking the volume and flow decision variables. The general form of the transmission node balance constraint is:

\[
\sum_{i=1}^{m} \text{FLOW}_{i} = 0
\]  

(3)

\textbf{Delivery Point Constraint}

This constraint limits the amount of gas that can be taken from any delivery point to the total capacity of that delivery point. The values used for capacity are supplied by the user:

\[
\sum_{i=1}^{n} \text{FLOW}_{i} \leq \text{DELIVERY POINT CAPACITY}_{\text{DELIVERY POINT}}
\]  

(4)

\textbf{Transmission Line Constraint}

This constraint limits the amount of gas that can flow along any of the transmission lines on the networks. These capacities are also supplied by the user:

\[
\sum_{i=1}^{m} \text{FLOW}_{i} \leq \text{TRANSMISSION CAPACITY}_{\text{TRANSMISSION LINE}}
\]  

(5)

\textbf{Total Gas Requirements}

The total amount of gas needed to meet SoCalGas needs is defined as the sum of the gas flowing along the arcs ending at the border (F000, F009, F1209, and F1620) as well as any gas purchased directly at the California border (contracts with delivery points 20):

\[
\sum_{i=1}^{n} \text{FLOW}_{i} = \text{TOTAL REQUIREMENTS}
\]  

(6)

\textbf{Minimum Volumes on Each Network}

At times, it is necessary to guarantee a minimum volume on one or more of the pipeline networks. In this case, the minimum volume requirements are defined for El Paso and Transwestern by the flow on the transmission arcs terminating at the border.

\[
\text{F000} + \text{F009} \geq \text{EL PASO MINIMUM}
\]  

(7)

\[
\text{F1209} \geq \text{TRANSWESTERN MINIMUM}
\]  

(8)

For the P.G. & E. Network, this formulation is not adequate because gas purchased on the El Paso Network and routed through P.G. & E. would be counted as part of the flow on arc F0913. To guarantee the actual purchase of specified minimum volumes on the P.G. & E. Network, the minimum flow requirement sums over the gas purchased at Mallin and through the P.G. & E. Interconnect.

\[
\text{F1413} + \text{F1516} \geq \text{GE P.G. & E. MINIMUM}
\]  

(9)

\section*{V Special Problems and Solutions}

Although each scenario is a unique and complex challenge, there are several interesting problems encountered in trying to create a nearly generic matrix generator. Several of these special problems and their solutions are presented here.

\subsection*{Solving for Maximum Volumes of Firm Gas}

During some months, due to changes in demand, supply, or pricing volatility, it is desirable to purchase increased volumes of firm gas. Under the condition that SoCalGas will not pay a higher price for firm gas than the highest price paid for discretionary gas, the problem is to find out how much firm gas is available, subject to capacity constraints, below the maximum price of discretionary. In order to meet this need, the Optimize Parameters screen allows the user to specify a maximum price for firm gas but to specify no total amount. When the scenario is submitted, a macro variable is switched on that informs the model that the goal of the first LP is to maximize firm gas purchases subject to the constraints of maximum price and system capacity. Most of the other constraints remain the same as for other problems. Selecting only from firm volumes (FV), the objective function changes to:

\[
\text{Maximize } \sum_{i=1}^{m} \text{FLOW}_{i}
\]  

(10)

\subsection*{Routing El Paso Gas onto the P.G. & E. Network}

In some circumstances, it is necessary to increase pipeline capacity on the El Paso Network by routing some of the spot gas purchased along this pipeline onto the P.G. & E. Network. This use of a competitor's pipeline is referred to as El Paso/P.G. & E. P. F. Volumes. There are several issues which had to be addressed in order to solve the model with these requirements. Gas shipped via P.G. & E. is subject to an inter-utility charge and shrinkage in addition to the shrinkage already extracted by the El Paso Network. Another issue is to be addressed in transporting El Paso gas over the P.G. & E. Network is moving gas from the Permian Basin into the P.G. & E. Network without reducing transmission line capacity. To solve these problems, "pseudo-arcs" were modeled into the network diagram. Gas may flow along these arcs from Permian without cost to the rest of the El Paso capacity. The sum of the flow on the pseudo-arcs F000 and F009, grossed up to reflect the shrinkage charged by P.G. & E. is defined as the P.F. requirement:

\[
(F000 + F009) \cdot \text{SHRINK} = \text{PF VOLUME}
\]  

(11)

Finally, the transmission node balance must be adjusted to reflect the fact that less than 100% of the gas flowing into arc F0913 will flow out. The adjusted transmission node balancing equation for this transmission line is:

\[
(F000 + F009) \cdot \text{SHRINKAGE}_{(F0913)} = 0
\]  

(12)

\subsection*{Buying P.G. & E. Non-Core Delivered Volumes}

Another business condition which the model was required to address was the condition under which analyst wanted to assess the effect on the WACOG of buying gas directly from P.G. & E. at their Non-Core Delivered price. The difficulty of this option was no such gas is offered on the monthly bids from suppliers. To solve this problem, the Optimize Parameters screen allows the user to create a "pseudo bid" having the expected value of P.G. & E.'s non-core...
delivered price of gas. If the analyst supplies a non-core delivered price and volume, and specifies this amount as the minimum volume on the P. G. & E. Network (using the minimum price constraint when necessary), a bid with these characteristics will be added to the bid list and the model will include this condition.

Allocating Transportation Volumes Between Networks

As mentioned earlier, additional gas to fill in under-utilized transportation capacity may be selected on a simple least cost basis, or may be allocated proportionately among the pipeline networks. It is most sensible to allocate it proportionately to the transportation capacity on each network because that more accurately reflects the likelihood of actual capacity becoming available. In order to accomplish this goal, if the user selects the Allocate Transportation Failure option on the Optimize Parameters screen, a macro is invoked to calculate the proportion of transportation capacity allotted to each pipeline. From the total capacity of the Transwestern Pipeline, long-term purchases and the model’s solutions for firm and discretionary gas are subtracted. This is the total transportation capacity on that network. Ten percent of that amount is then substituted for the transmission line constraint on the only arc along the Transwestern Network which flows into the border (F1220). This produces the desired effect of filling in transportation capacity in a manner more likely to reflect the coming month’s business conditions.

VI Conclusion

The development effort required for this system was minimal as a result of using SAS/AF® and SAS/OR®. Approximately three workforce months of effort, including a parallel test run during a Scenario day, went into the system before full implementation. In the ensuing months, a number of significant enhancements were added. The model has since stabilized, and been used in its current form for the last six months. Despite significant turnover in the user group, the model has continued to be used, indicating that it has become an integral part of the gas acquisition process.

A number of very real and tangible benefits resulted from the use of this model. The key benefit is the reduced turnaround time for scenario development and evaluation. This has allowed Gas Acquisition to contact suppliers earlier, thus acquiring more low priced firm gas at preferable locations. More scenarios are evaluated every month, and the scenarios are more complex. The model has not only enhanced analytical capabilities, but directly contributed to bottom line performance.

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