

# Cost Optimization of a Natural Gas Distribution Network



## Abstract

PGN, as the largest natural gas local distribution network in Indonesia, utilizes multi-supply point and transmission pipeline to deliver natural gas to the customer. With such a condition, supply combination needs to be calculated properly in order to achieve lower operational cost. Due to the complexity of the natural gas distribution network, which could contain considerable amounts of pipe sections, nodes, and loops, etc., a computer aided tool is needed to calculate the pressure setting at each city gate station for the desired minimum operational cost.

PipelineStudio® performs an important role as the simulation tool to calculate pressure setting for each supply point based on demand load characteristics. PGN natural gas distribution network was selected as the exemplary case. Supplies from transporter pipeline were minimized as low as possible, whilst supply from another city gate station was maximized. Maximum pipeline operating pressure and minimum pressure at the customers were also applied as a consideration. The results indicate that these efforts could reduce transported gas up to 38% and fuel usage up to 40% compared to the condition before the network was optimized.

## Introduction

As a part state-owned company, PGN's natural gas selling price is regulated by the government. Therefore, the key to achieve higher profit is increasing the efficiency of the existing network, in this case by lowering the operational cost. One particular cost that can be optimized is the transmission fee and fuel usage.

With an insufficient distribution pipeline capacity, the transmission pipeline is utilized to deliver natural gas from one to another distribution system pipeline. Natural gas from this transmission pipeline is fed into the system from a city gate station and integrates with other city gate stations to sustain multi-supply point natural gas distribution system.

The distribution system may consist of several interconnected pipeline networks operated at different pressure levels. A large city cluster system could contain over 300 pipe sections and 100 loops. Thus, the cost optimization of a natural gas distribution network is complex and requires computer-aided tools.

The aim of this paper is to introduce a method to develop cost-efficient distribution networks that utilize a transmission pipeline to support gas delivery because of its insufficient pipeline capacity. This procedure is adapted in a representative natural gas distribution network in order to show the applicability of the methods.

## Network Optimization

PGN Natural gas distribution networks are subdivided into different pressure regimes, as depicted in Figure 1.

The pressure regimes consists of four pressure stages: Extra High Pressure Pipeline Network (above 16 Barg), High Pressure Pipeline Network (between 4 and 16 Barg), Medium Pressure Pipeline Network (between 10 mBarg and 4 Barg), and Low Pressure Distribution Network (below 10 mBarg). The majority of industrial customers are supplied from the High Pressure Pipeline Network.

Simulation and analysis of interconnected different pressure regimes is done in order to predict the behavior of natural gas distribution network systems in accordance with different conditions. This may be used to help decisions regarding operation of the real system. Location and load of customer should be considered as an important factor in simulation. With high load during weekday then gradually decreasing on the weekend, city gate station pressure should be adjusted to keep the network operated in optimum condition.

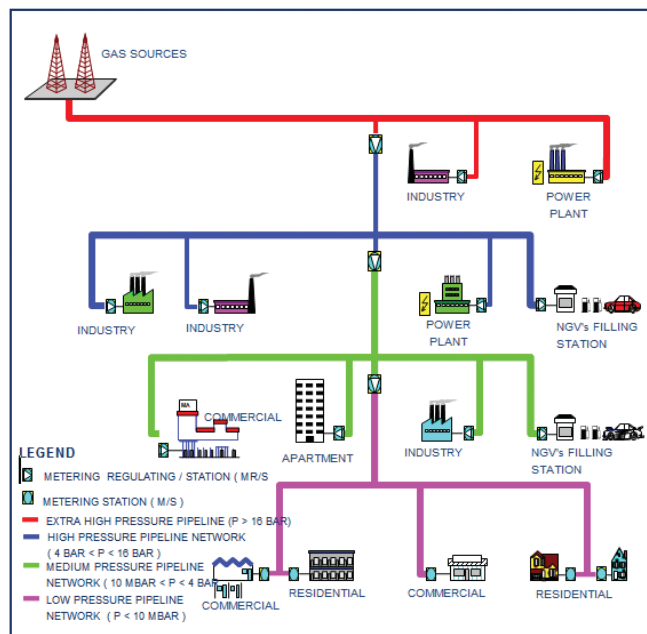


Figure 1. PGN Pressure Regime System

With multi-supply point system, the natural gas distribution network is optimized through minimizing gas supply from transmission pipeline, and maximizing supply from another city gate station as a supply alternative. These would reduce the transmission fee as well as fuel gas usage. Therefore, downstream pressure setting at each city gate station should be determined. Further restrictions become the boundary conditions in order to meet system safety, facility characteristics, and individual customer specifications.

Therefore, essential boundary conditions are:

- Minimum and maximum nodal pressure
- Maximum gas velocity on the pipeline
- Maximum volumetric flow rate of pressure regulator and metering system
- Commercial aspects

A computer-based optimization is performed to solve this extensive optimization task. PipelineStudio is utilized to calculate each city gate station pressure setting of existing networks under steady state calculation.

## Exemplary Results

Described methods above were tested to PGN natural gas distribution network. The costs (transmission fee and fuel gas) before and after optimization procedures were calculated and evaluated.

### Actual State Network

PGN West Java distribution network is subdivided into five major networks, with a total 2,433 km superimposed distribution pipelines serving 1,828 industrial and power plant customers and 55,133 residential customers.

The optimization subject was Distribution Network C as illustrated in Figure 2. The network has four (4) main supplies from city gate stations: two (2) sources are supplied from transmission pipeline whilst the others come from Distribution Network B and D.



Figure 2. Structure of Distribution Network C

The transmission pipeline is required because of insufficient pipeline capacity of Distribution Network B and D pipeline to fulfill Distribution Network C demand. Natural Gas from Distribution Network A is fed into the transmission pipeline then transported to Distribution Network C. City Gate 1 and City Gate 2 are utilized as receiving facilities from the transmission pipeline. City gate stations from Distribution Network D and B are City Gate 3 and City Gate 4. The supply scheme of the network is shown in Figure 3 on the next page.

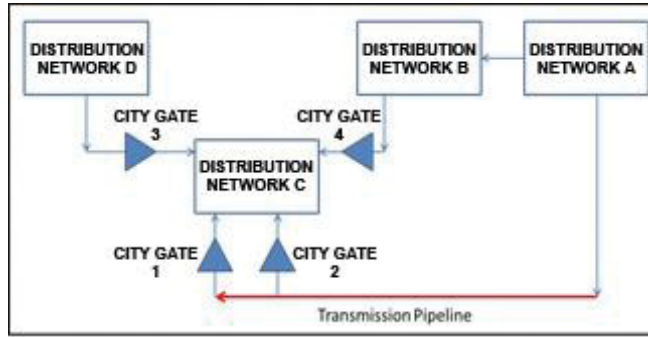


Figure 3. City C Main Natural Gas Sources

The Distribution Network C structure consists of 301.5 km of pipelines with diameter range varying from 4 inch to 24 inch. Each city gate station is fed at different operating pressure, which varies from 10 Barg to 16 Barg. 278 out of 554 network nodes are modeled as consumers. The pressure profile of the actual state network was calculated by gas flow simulation as illustrated in Figure 4.

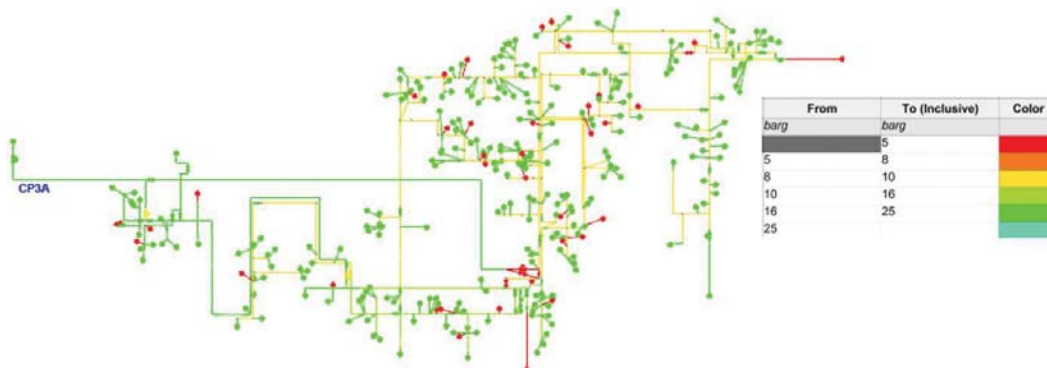


Figure 4. Distribution Network C Pressure Profile

### Developing the Model

Calculation was performed under steady state simulation model, calibrated to meet real condition as close as possible. Calibration process involved historical data of pressure and flow to establish significant level of confidence in the model. This consisted of taking flows from historical data and running them in the model. Model pressures were then compared with relevant historical data pressures and delivered volumes in the model were compared with actual flow data. The results of the calibration process were satisfactory, as shown in Table 1.

No.	Node Name	Actual State		Model Calculation		Model Accuracy
		Flow (MMSCFD)	Pressure (Barg)	Flow (MMSCFD)	Pressure (Barg)	
1	City Gate 1	12.9	11.2	12.9	11.2	100%
2	City Gate 2	37.8	10.2	37.8	10.2	100%
3	City Gate 3	31.4	16	33	16	95%
4	City Gate 4	12.9	11.2	12.9	11.2	100%

Table 1. Pressure and Flow Model Calibration in Distribution Network C

Calculated gas heating values were compared with actual sampling on field at the same node. The results are shown in Table 2.

No.	Sampling Point	Actual State	Model Calculation	Model Accuracy
1	Node 1	996.9767	981.2357	98.33%
2	Node 2	1067.7055	1081.2708	98.75%
3	Node 3	1002.4055	1007.7052	99.47%
4	Node 4	1031.5690	1030.9193	99.94%

Table 2. Heating Value Model Calibration in Distribution Network C

**Network Optimization**

The operating condition should be adjusted following any change in demand load. The characteristic of demand load as shown in Figure 5 on the next page will affect pressure setting on the city gate stations. City Gate 3 as the major supply for Distribution Network C was utilized as the controller of main grid pressure. As the demand load rise up, City Gate 3 downstream pressure would be adjusted into higher setting to keep the grid pressure in operational range, and vice versa. This idea was checked using steady state model to provide the exact value of City Gate 3 operational setting. Other city gate stations pressure setting was calculated to meet minimum flow required at each city gate and not adjusted as the function of demand load.

The simulation results indicated that City Gate 3 downstream pressure, as depicted in Figure 6, would vary between 15 to 16 Barg, depending on the demand load and other city gate stations supply availability. This calculation has been applied on field to expect lower transported gas as well as fuel gas. The results then examined from August 2012 just before the optimization, up until now.

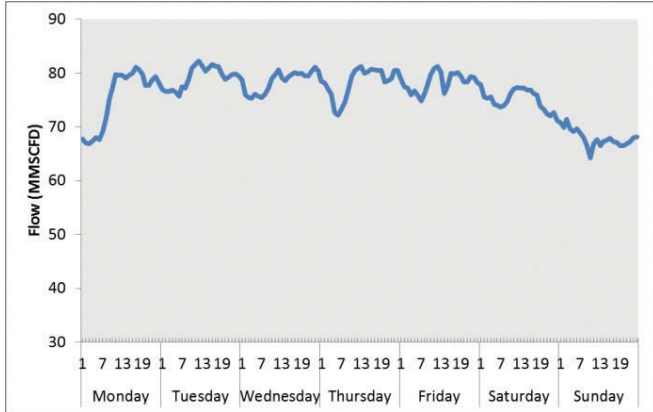


Figure 5. Distribution Network C Load Profile

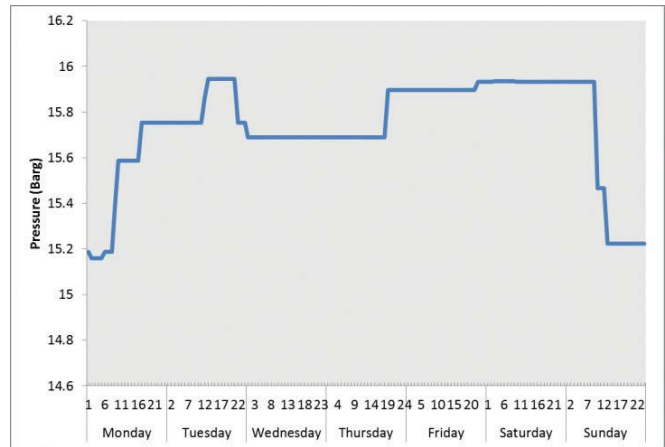


Figure 6. Application of Simulation Results on City Gate 3 Downstream Pressure Setting

The results of the reduction in transported gas and fuel gas which would reduce operational costs are depicted in Figure 7 and Figure 8.

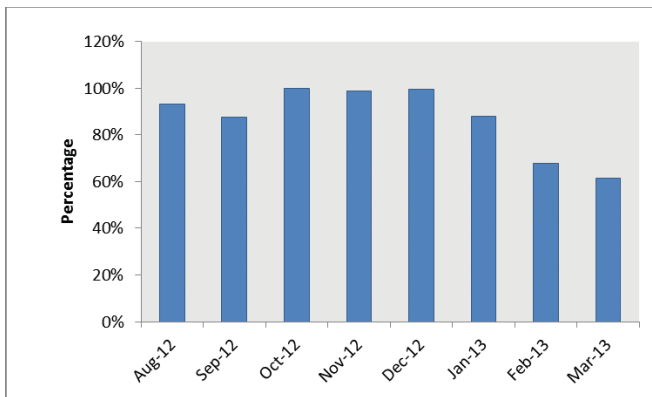


Figure 7. Amount of Reduction in Natural Gas Transported

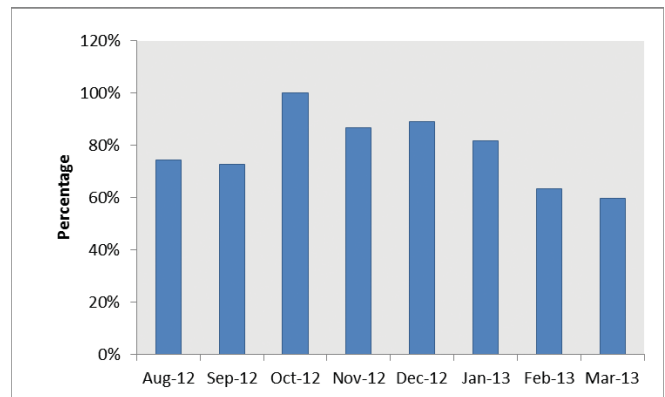


Figure 8. Amount of Reduction in Fuel Gas Usage

## Conclusions

PipelineStudio as a computer-aided tool delivered great results in calculating a complex natural gas distribution network. With considerable amount of pipe sections, nodes, and loops, calculation process could be done in a short time. Calibration process using historical data was also important to build an accurate model.

The exemplary results have proven the possibility of increasing natural gas distribution network efficiency by calculating pressure requirement of each city gate station for desired flow rate. Therefore, a method to optimize the network structure has been presented in this paper.

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