

Mitigating Impact of “Off-Spec” Gas By Developing a Contingency Plan Based on a PipelineStudio® Simulation

Abstract

This paper explains the PipelineStudio simulation steps that were used by PGN in developing contingency plans for “off-spec” gas occurrence in distribution networks. It was triggered by occurrence of unplanned maintenance at the gas supplier’s processing plant and an obligation for PGN to maintain the delivered natural gas specification to conform to the customer’s requirement during supplier’s unplanned maintenance period. Otherwise, supply issues could result for customers due to a main equipment trip caused by the off-spec gas.

PGN developed a method to address these problems by altering the natural gas direction for supplying “on spec” gas to the customer. PGN developed a PipelineStudio simulation to evaluate this method with full consideration of the distribution networks. This paper also outlines how PGN constructed a contingency plan in dealing with any off-spec gas occurrence including important parameters for evaluation of the simulation model and the implementation processes.

Component	South Sumatra	West Java
CH ₄ , % mole	90	77
CH ₄ , % mole	4.5	10
CH ₄ , % mole	0.5	6
H ₂ O, lbs/mmScf	15	50
H ₂ S, ppmV	24	5
Heating Value, Btu/scf	1040	950
Specific Gravity	0.65	0.75

Table 1. Natural Gas Composition from South Sumatra and West Java

Keywords

Off-Spec Gas, PipelineStudio Simulation, Contingency Plan



Introduction

PGN is the biggest natural gas distribution company in Indonesia, with a total 807 MMScfd from multiple sources of gas. The Strategic Business Unit Distribution 1 (SBU 1) delivers gas into the JKT and West Java area amounting to a total distribution of 580 MMScfd in 2,433 km pipeline networks. SBU 1 has two main sources of gas with different gas quality, including West Java and South Sumatera sources, the later field with higher quality.

In light of this fact, the behavior of gas composition occasionally violates the specification limit. This has mostly been due to unplanned maintenance in the gas supplier’s processing plant and/or pipeline pigging by the transporter. The impact was an inability by customers to burn the off-spec gas and finally the main equipment was shut down caused by off-spec gas.

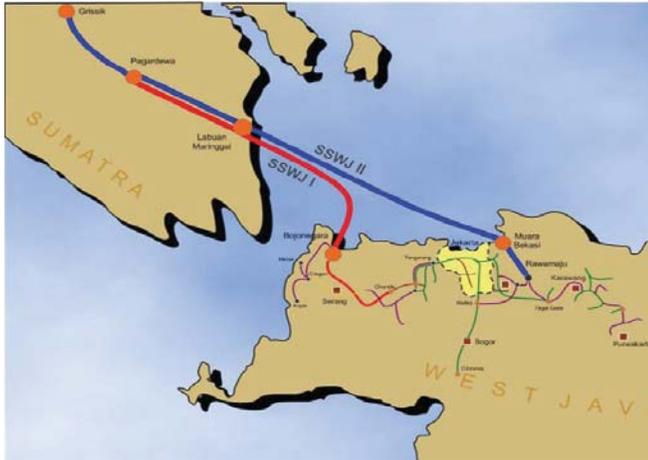


Table 2. Backbone Pipelines in the Examined Area

PGN also endured huge opportunity losses from an inability to sell the off-spec gas. Furthermore, the pipeline network was endangered by higher corrosion rates caused by CO₂, H₂O, and H₂S.

Therefore, there was an enquiry on securing gas sales to the customers by confirming the composition of the natural gas to the customer’s requirement during any off-spec gas period. This was conducted by altering the direction of the gas from South Sumatera to the area which the customer ought to get off-spec gas and at the same time a huge loss could be mitigated.

Off-spec Gas

PGN natural gas specification can be categorized as South Sumatera and West Java gas. Off-spec gas was mainly initiated by the increasing content of inert gas (CO₂, H₂O, N₂ and H₂S) above specification limit (supplier’s Gas Sales Agreement and/or customer specification).

The main concern of customer’s equipment was gas heating value. According to ISO 6976 (Calculation of calorific values, density, relative density and Wobbe index from composition), the heating value of a natural gas could be calculated from:

$$H = \frac{\tilde{H}^0}{Z_{mix}} \text{ where } \tilde{H}^0 = \sum_{j=1}^n y_i \tilde{H}_j^0$$

where \tilde{H}_j^0 is pure component heating value while y_i is mole fraction of the component. The mixture compressibility factor is given by:

$$\tilde{H}^0 = \sum_{j=1}^n y_i \tilde{H}_j^0$$

where the summation factors, b_j are specified for each component.

The pure component heating value (\tilde{H}^0), compressibility factor (Z) and summation factors (b) are specified in ISO 6976 for reference conditions of 0, 15 and 20°C and also for 60°F (all at 14.696 psia).

So, once the percentage of the inert component in the gas increased, the heating value of the gas dropped drastically until the natural gas becomes off-spec. In most cases this meant the customer’s equipment could not utilize the gas resulting in an unplanned shut down.

The Network under Consideration

The network under examination was the one area of PGN’s distribution network which was receiving lower quality West Java gas. The examined area is a complex interconnected distribution network with 4 backbone pipelines and 4 city gate stations. These four city gates regulate and act as the source of gas for four 16 inch principle pipelines to customers and each of the city gates has different heating values with more than a 12% difference. To appreciate the analysis undertaken, it is important to have an understanding of the main features of the network:

Pipelines	City Gate	Pressure (Barg)	Average GHV (Btu/scf)
Pipeline A to B	A	8	1050
Pipeline C to A	C	10	950
Pipeline D to B	D	12	1008
Pipeline E to D	E	14	1040

Table 2. Backbone Pipelines in the Examined Area

The difference of heating value for city gate C and D with city gate A and E was caused by different sources of gas. Both city gate C and D are connected with West Java transmission pipelines from West Java gas field while city gate E and A were supplied with higher quality gas from South Sumatera. City gate E is connected with South Sumatera transmission pipelines and city gate A is connected with JKT Area distribution networks. But, in normal operations, city gate A was usually closed.

The demand of Banten Timur area is approximately 80 MMScfd with approximately 400 customers. More than 98% distribution load is from supplying domestic light industrial/commercial customers with gas engines and boilers, while the rest is household customers.

An illustration of the Examined area configuration network can be seen in Figure 2 below.

Developing the Model in PipelineStudio

Up to the time any off-spec gas occurred, all simulation modeling of the examined area and SBU 1 distribution networks were evaluated using pressure as the parameter to ensure gas met customer requirements. The pressure based steady state models which had been used up to this point were principally focused on assessing capacity handling abilities in the event of peak demand conditions. However this steady-state model had not been connected with real time actual network conditions due to an under developed SCADA system.

Triggered by off-spec gas occurrence in examined area networks, it was finally realized that it would be essential to develop a gas quality profile based on the steady state model. Using the geometry of the steady-state pressure based model, a quality based model was developed. Large amounts of gas quality data from direct gas sampling was utilized to evaluate the gas quality profile.

To increase the acceptable level of confidence of the gas quality model the simulation results needed to be calibrated. As a result, the need to alter gas direction with different gas quality could be accurately simulated. This entailed considerable time and effort on altering the simulation model to track the gas quality and calibrating the simulation to mimic what exactly was happening in actual system. For the initial PipelineStudio simulation model, each of the gas supplying city gates were filled up with detailed compositional fluids from a representative gas producer or transporter, e.g. methane (C1), ethane (C2), Propane (C3), Isobutane (IC4), N-butane (NC4), Isopentane (IC5), N-pentane (NC5), Hexane (C6), Carbon Dioxide (CO2) and Nitrogen (N2). This compositional data was previously collected from online Gas Chromatography equipment or direct pipeline gas sampling. The simulation model was then turned to gas quality tracking by ticking Quality Tracking in Simulation Options. The Equation of State (EOS) was changed to BWRS (Benedict–Webb–Rubin–Starling) in order to accommodate compositional fluid simulation.

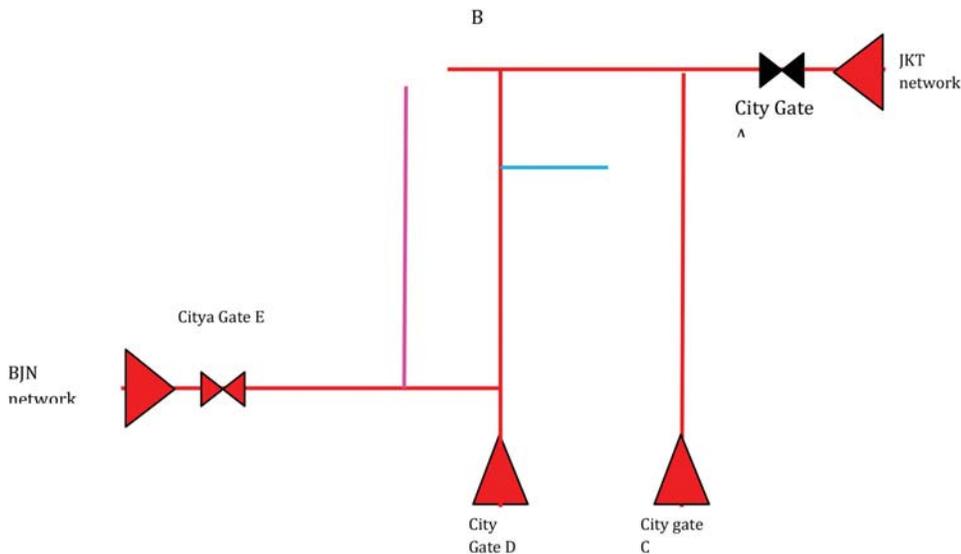


Figure 2. A Schematic of the Examined Area Distribution Network

Furthermore, to make visualization easier, the pipeline color was changed according to the heating value. This could be done by creating a range of simulated heating values in the pipeline network view properties.

The single biggest work function to be undertaken in the model development was the gas quality calibration. The model was calibrated using actual gas compositions that were obtained from direct gas sampling. Direct gas sampling was usually conducted on Tuesday with the intention for gas billing. By taking the average actual flows on Tuesday through examined area networks from previous weeks, it was possible to establish a significant level of confidence for flow parameters within the model. All calibration runs utilized hourly data at the time direct gas sampling was taken.

Calibrating the model consisted of taking flow data from the Gas Management Center (GMC) Daily Log Sheet and gas quality data from relevant gas composition from gas suppliers and running them in the model. The delivered volumes in the model were compared with actual flow data. Gas quality from simulation results were then compared with the relevant direct gas sampling.

The calibration network proved successful. Table 3 below shows gas heating values at the mixing area from direct gas sampling compared with modeled heating values at the same point:

Sampling Point	Simulated GHV (Btu/scf)	Direct Gas Sampling GHV (bTU/SCF)	Difference (%)
1	981.2357	996.9767	(1.67)
2	1081.2708	1067.7055	1.25
3	1007.7052	1002.4055	0.53
4	1030.9193	1031.5690	(0.06)
Average Difference			0.87

Table 3. Gas Qualities Model Calibration in Examined Areas

It can be seen that the simulation models match up with the actual gas field quality from direct gas sampling. A detailed review of the heating value at all sampling locations demonstrated that the model was functioning in a manner which reflected the network at ±1% differences in average compared with actual field sampling results of the heating value. The small value difference might be caused by the different methods of heating value calculation. In the

PipelineStudio model, the heating value calculation used ISO 6976 while the field heating value used GPA 2172. Notwithstanding the above heating value difference, the level of accuracy provided sufficient confidence for the modeling team to proceed with gas direction alterations to cope with any incoming off-spec gas.

The gas quality data used for calibration was for normal gas quality. Further work on the model was developed as an exercise to cope with any incoming off-spec gas. Any natural gas composition data from previous cases of off-spec occurrences were utilized in this exercise.

Component	Value
C1 (% mole)	76.68
C2 - C6+ (% mole)	4.85
CO2 (% mole)	11.37
Nitrogen (% mole)	7.08
GHV (Btu/scf)	896.84

Table 4. Particular Composition of Off-spec Gas

The above off-spec gas compositions were then filled up to the quality based simulation model and run into convergence. The PipelineStudio simulation resulted in several important findings. First was the coverage of off-spec gas distribution in the examined area networks as Shown in Figure 4 below, with red colored pipeline from City Gate C. It can be seen that most of the customers that receive gas from City Gate C (48 customers) endured significant losses due to off-spec gas and were forced to stop production because the gas could not be burned.

To solve these problems, City Gate A that was normally closed will be opened to supply on-spec gas from the JKT area to customers at the examined area. Further simulations were run to accommodate this scheme and in order to determine the on-spec gas distribution. The simulation results can be seen in Figure 5, as shown with a green colored pipeline (on spec gas with GHV 1054 Btu/scf) reaching the customer’s location and replacing a red colored pipeline (off-spec gas with GHV 898 Btu/scf) as shown in Figure 4.

It also can be seen that on spec gas flow from City Gate A could reach most of the customer’s locations in the examined area to replace the off-spec gas from City Gate C. So it was be concluded that it would be beneficial to open City Gate A as early as possible

to continue supplying the customers with on spec gas, resulting in a solution to overcome any off-spec gas issues in the future.

The other finding from the offline PipelineStudio simulation was the need to pay close attention to the pressure of the JKT area network above 11 Barg. This pressure needed to be maintained to provide enough pressure to reach the pressure requirement of power plant customers in the JKT distribution network.

Developing Contingency Plans

With a calibrated model running and several new discoveries made, attention was focused on developing a contingency plans to cope with any incoming off-spec gas in order to prevent customers suffering losses caused by offspec gas. In Figure 6 on the next page, the profile of incoming off-spec gas can be seen.

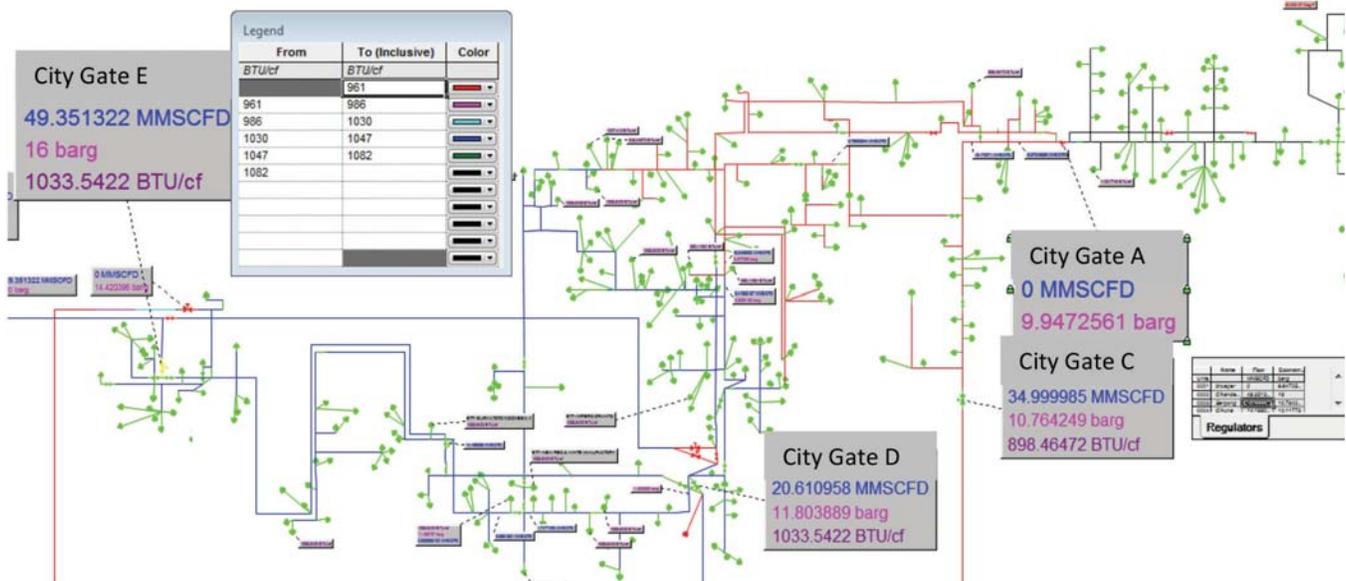


Figure 4. Simulation Model for Determining Off-spec Gas Distribution Coverage in Examined area

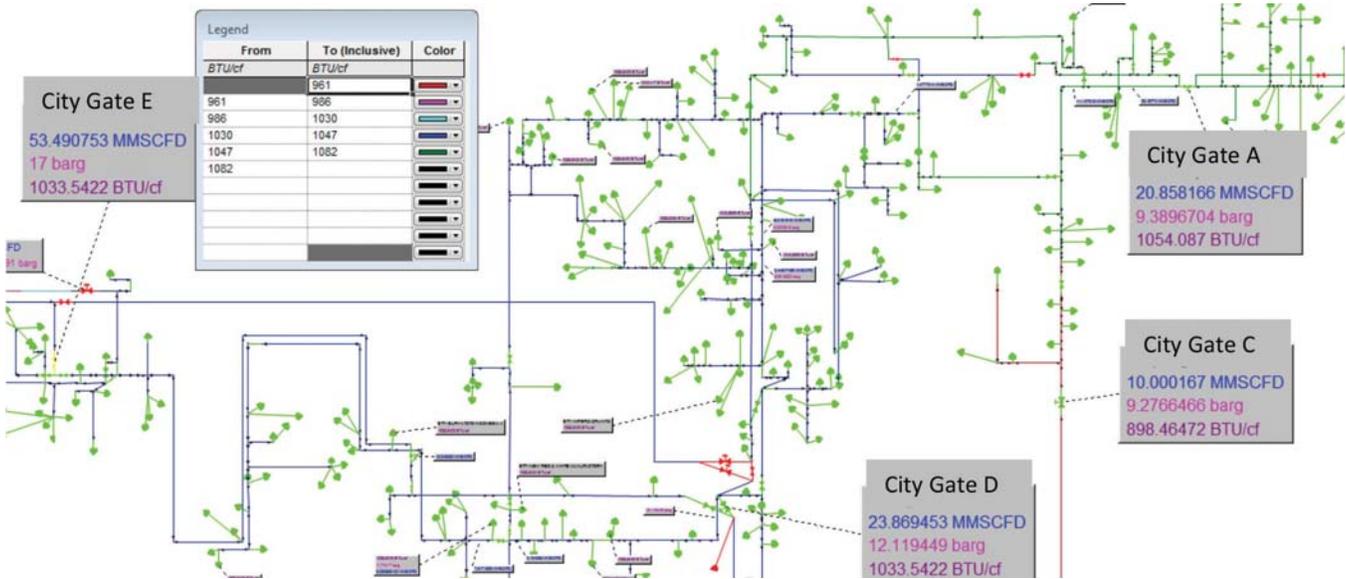


Figure 5. Simulation Model for On-Spec Gas Distribution Coverage in the Examined Area after City Gate A was Opened

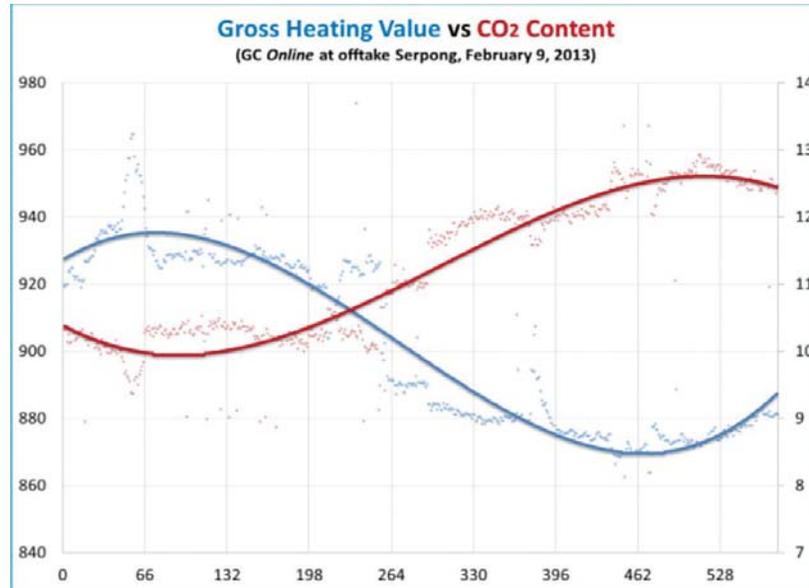


Figure 6. Gross Heating Value and CO₂ Content of Off-Spec Gas at City Gate C

First, as a result of a limited SCADA system, off-spec early warning equipment was installed with Gas Chromatography at City Gate C to detect if there is a trend of gas quality reduction below its set point (930 Btu/scf). Subsequently, this equipment will send an off-spec alarm by Short Message Service (SMS) to the GMC gas control team.

A further step is to communicate with gas suppliers whether is any failure has occurred in their gas purification system or other any other failure that has resulted in their gas being delivered off-spec.

If there is a confirmed situation that an off-spec gas period occurs for any significant time period (1 or 2 days), gas control will implement the contingency plan.

The gas control team starts with pressure evaluation of JKT area networks to decide whether it is possible to open the valve at City Gate A. If it is reasonable to open it, a request is made to the Operation & Maintenance team to open the valve at City Gate A as shown in the model.

While the valve at City Gate A is gradually opened, the GMC begins to adjust the outlet pressure of City Gate C by radio communication to the city gate operator. This is done to control the quantity of gas passing through city gate C in accordance with the simulation results. Turning down the outlet pressure at

city gate C, and transferring higher demand to city gate A, results in the discharge of on-spec gas.

Based on the PipelineStudio simulation, the optimum arrangement involved setting for city gate E outlet pressure to a minimum of 16 Barg; city gate D at 12 Barg; city gate C at 9.2 Barg; so that city gate A will balance the pressure between the examined area network and the JKT area network. After the off-spec gas is phased out, the examined area pipeline arrangement can then be returned to the normal operating conditions.

As a result of this work it was possible to identify an operating arrangement which allowed on-spec gas to be delivered to most of the customers in the examined area in an event any off-spec gas might occur. This ensures any off-spec gas occurrence will not result in large losses for PGN or our customers. In addition, this contingency plan was developed using PipelineStudio and fully implemented without any large investment by PGN, except for the installation of the off-spec gas early warning system equipment.

The developed contingency plan was then prepared, which described the full work flow arrangement and included relevant important parameters to consider during the implementation.

Further Studies

The accurate and robust nature of the PipelineStudio software has enabled PGN to model numerous pipeline capacity optimizations, gas quality prediction, survival time calculations and other usage parameters which have been successfully and cost-effectively carried out by PGN since the PipelineStudio simulation model was first developed.

The development of PipelineStudio gas quality model and off-spec gas contingency plan were a results of customer's complaint caused by off-spec gas at city gate C area. With certain requirements, the model has subsequently proved to be of considerable value in relation to other areas of the PGN business.

Using the quality tracking features in the transient model it was possible to develop a series of simulations which accurately reflected actual gross heating value of gas at various city gates. In the future, these simulations will be very interesting and become worthwhile exercise. As a result of the analysis it was possible to fully answer all the questions raised in relation to gas quality issue in examined area and other locations.

It is proposed to develop the model further and utilize the interactive transient functions within PipelineStudio software. With interactive capabilities, it should be possible to easily and quickly simulate and evaluate operation response to network difficulties. The further study to be undertaken will examine the examined area network when the SCADA system has already developed and connected as online system.

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