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Maximising the Heat Content of Sales Gas at Kailashtilla Gas Processing Plant

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Natural gas (NG) played an important role in different industrial and commercial sectors in Bangladesh. The natural gas received and transported by the major distribution companies must meet the quality standards on heat-content basis.
Three gas streams from different sources are combined at Kailashtilla Gas Processing (KGP) plant inlet and water content of the gas is reduced to increase heat content in the processing plant. In this work, simulation is carried out in HYSYS simulator based on the design data of the plant and validated the predicted data with the operating data of the plant. An SQP based optimization framework in HYSYS is developed for the maximizing the heat content of the sales gas whereas optimizing raw feed gas flow rates, methane composition of sales gas, total energy input of the process and Natural Gas Liquefied (NGL) gas temperature.

1. Introduction

In the 21st century, meeting demands for energy is the most important factor to achieve sustainable development of any nation. Natural Gas is the cleanest of all the fossil fuels. Natural gas accounts for almost 75% of commercial energy consumption of Bangladesh. The production of power, fertilizer, ceramic and other industries are based on the Natural gas. Since 2001, Bangladesh has been unable to meet the demand for natural gas required by the power, fertilizer and industrial sectors (The Daily Star, 2010).
Three gas streams from different sources are combined at KGP plant (Figure 1) inlet; then gas goes through several stages of processing, including the removal of entrained liquids and heavy carbon from the sales gas, followed by drying to reduce water vapor content. Most of the liquid is removed by simple separation methods at or near the wellhead. The plant consists of pressure reduction system, three flash separators, dehydration unit, adsorption tower and condensate fractionation column.
Natural Gas distribution companies monitor their hydrocarbon dew point temperature to avoid any potential liquid formation within the pipes and any corrosion-erosion problem in the equipment. Therefore, natural gas needs to be processed according to specified dew point temperature of the sales gas. Higher content of the higher hydrocarbon may lead to higher heat content of the sales gas. However, this comes at the cost of higher operating cost and off specification of the sales gas to the customers will result in penalties.

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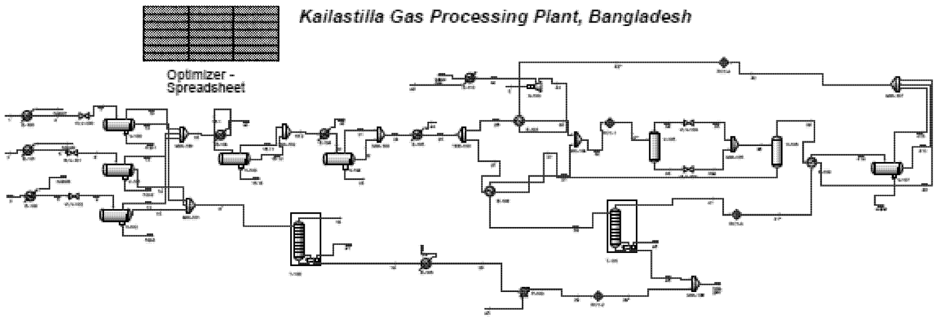

Figure 1: Kailashtila Natural Gas Processing Plant (KGP) in HYSYS interface

Like other chemical and petrochemical companies, KGP plant is also facing the challenges to improve the market shares (profitability) while meeting strict environmental constraints. Optimization can play an important role to combat these challenges (Edgar and Himmulbau, 1989). Three gas streams from different wellhead sources are mixed as a feedstock to the KGP plant. As a result, the feedstock compositions may vary continuously. The other key parameters such as three raw feed gas flow rates, methane composition of sales gas, and total energy input of the process and NGL temperature affect the overall heat content of sales gas. An optimum combination of above parameters will help to achieve the optimum operation.
In this work, simulation is carried out based using the design data of the plant and feedstock input in HYSYS simulator. Sharmin (1999) and Kamruzzaman (1999) simulated the KGP. In this work, Recycle logical operation block is introduced and other solution parameter is fixed for faster convergence of the column (known as demethanizer, ethanizer) and absorber unit. There is a good agreement found between the predicted data with the operating data of the plant. Afterwards, an SQP based optimization framework in HSYS is developed for the maximizing the profit of the operation where the heat content of the sales gas and NGL steam is added in the profit function whereas optimizing whereas raw feed gas flow rates, water content of sales gas for a given dew point temperature and pressure, total energy input of the process and NGL temperature.

2. Process Model Development in HYSYS Interface

HYSYS is powerful interactive and flexible process modelling software for simulation and optimization of chemical plants and oil refineries. (HYSYS, 2009). In this work, the fluid package Peng-Robinson equation and components (shown in Table 1) are selected in base case in the HYSYS interface. Water content and other physical properties of the natural gas are computed by HYSYS program. All unit operations are linked to each other by the material and energy streams. In general, the unit operations and streams are installed in HYSYS process flow diagram (PFD) from left to right and upwards. Logical operations such as recycle operators are added to simulate KGP plant model in HYSYS simulator. This helps to faster convergence in optimization. In this work, Molecular sieve operation is developed in HYSYS interface by combining heater and cooler. All the design parameters of the different equipments are supplied in the PFD interface from the design data of the KGP plant.

3. Optimization Problem Formulation

The optimization problem can be stated as:

Given: Three Raw Feed gas Flow rates, Methane composition of sales gas, total energy input of the process and Sales gas dew point temperature, product demand

Determine : Optimum design and operation variables

So as to maximize: The profit of the production (cost function is related to the heat content of the sales gas)

Subject to: equality and inequality constraints

Mathematically, optimization problem is formulated as follows:

Objective_Function $$\underset{F1,F2,F3}{OP}$$

s.t. $$x_L \le x \le x_U \, (inequality\_constraints)$$

$$1450 \le Well\_Gas\_Flowrates \; (F1, F2, F3) \le 1650 \, (Kgmole/h)$$

$$TOTAL\_ENERGY\_INPUT \le 4 \times 10^7 \text{ KJ/h}$$

$$SALES\_GAS\_DEWPOINT = 49^O c$$

An Objective function is formulated where objective function profit is related to the heat content of the sales gas. So, heating value/heat content of the gas increases when profit is maximized. The objective function is shown in bellow:

OBJECTIVE_FUNCTION OP (PROFIT \$/h)

$$OP = Sales\_Gas\_Flow \times Heatingvalue \times Cost\_Index\_A$$

$$-Total\_Raw\_Gas\_FLowrate \times Processing\_Energy \times CostindexB$$

$$Operating\_Cost(Amount\_Energy \times CostindexC)$$

Such OP depends on the different cost parameters (Tanvir and Mujtaba, 2006). Heating value of the gas is the summation of the individual component of the gas. Cost index A ands Cost index C is calculated assuming \$2/MJ and Cost index B is calculated by assuming \$0.2/Kmol. Optimization solver is user Mixed solver (SQP based optimizer).

4. Results and Discussion

Table 1 lists all Well head composition and flow rate of the Kailashtilla Gas processing plant. Detailed designed input parameters can be found in the (Kamruzzaman, 1999). The comparison between predicted data and actual plant data is presented in Table 2. A good agreement is found between them.

Table 1: Well head composition of the Kailashtilla- Gas processing plant

	Well 1	Well 2	Well 3
Flow rate	1542 (F_1)	1534 (F_2)	1542 (F_3)
Methane	0.9457	0.9413	0.9457
Ethane	0.0255	0.0274	0.0255
Propane	0.0085	0.0103	0.0086
i-Butane	0.0022	0.0027	0.0022
n-Butane	0.0023	0.0030	0.0023
i-Pentane	0.0014	0.0014	0.0014
n-Pentane	0.0009	0.0008	0.0009
n-Hexane	0.0018	0.0013	0.0018
n-Heptane	0.0035	0.0025	0.0035
Octane	0.0014	0.0026	0.0014
Nonane	0.0008	0.0011	0.0008
Decane	0.0004	0.0002	0.0004
C_{11}	0.0003	0.0001	0.0003
C_{12}	0.0003	0.000	0.0003
C_{13}	0.0003	0.0001	0.0003
C_{14}	0.0007	0.0001	0.0007
H_2O	0.0005	0.0006	0.0005
Nitrogen	0.0020	0.0039	0.0020
CO_2	0.0015	0.0006	0.0015

Table 2: Comparison of the plant data and simulated data

Sales Gas Composition			LPG Composition	
	Mole Fraction (plant data)	Mole Fraction (Simulated)	Mole Fraction (plant data)	Mole Fraction (Simulated)
Methane	0.9667	0.9660	0	0
Ethane	0.0264	0.0262	0.0059	0.0153
Propane	0.0026	0.003294	0.2927	0.2716
i-Butane	0.0002	0.0003	0.0942	0.0931
n-Butane	0.0002	0.0002	0.1054	0.104

Sales Gas Composition			LPG Composition	
	Mole Fraction (plant data)	Mole Fraction (Simulated)	Mole Fraction (plant data)	Mole Fraction (Simulated)
n-Pentane	0	0	0.0381	0.0362
i-Pentane	0	0	0.0611	0.0587
n-Hexane	0	0	0.0725	0.0746
n-Heptane	0	0	0.1411	0.1480
Octane	0	0	0.0803	0.08457
Nonane	0	0	0.0402	0.0424
Decane	0	0	0.0149	0.015755
C_{11}	0	0	0.0104	0.01104
C_{12}	0	0	0.0104	0.00947
C_{13}	0	0	0.0104	0.01105
C_{14}	0	0	0.0224	0.0236
H_2O	0	0	0	0
Nitrogen	0.0027	0.0026	0	0
CO_2	0.0012	0.0012	0	0

Table 3: Sensitivities of different cost parameter

Objective function	Cost Index A	Cost Index B	Cost Index C
500	$2\text{x}10^{-4}$	$2\ \text{x}10^{-2}$	$5\ \text{x}10^{-6}$
589	$\mathbf{2.2\ x10^{-4}}$	$2\ \text{x}10^{-2}$	$5\ \text{x}10^{-6}$
410	$\mathbf{1.8\ x10^{-4}}$	$2\ \text{x}10^{-2}$	$5\ \text{x}10^{-6}$
481	$2\text{x}10^{-4}$	$\mathbf{2.2\ x10^{-2}}$	$5\ \text{x}10^{-6}$
518	$2\text{x}10^{-4}$	$\mathbf{1.8\ x10^{-2}}$	$5\ \text{x}10^{-6}$
479	$2\text{x}10^{-4}$	$2\ \text{x}10^{-2}$	$\mathbf{5.5\ x10^{-6}}$
520	$2\text{x}10^{-4}$	$2\ \text{x}10^{-2}$	$\mathbf{4.55\ x10^{-6}}$

4.1 Sensitivity Analysis (Optimization Result)

By varying 10% of the cost index, the sensitivity of different objective faction/profit is studied in Table 3. The following observations are made from the results presented in Table 3:

- For increase in the price of the sales gas cost more profit will be achieved (Cost Index A).
- For increase in the heavy hydrocarbon and decrease in water content of the sales gas more profit will be achieved (Sales gas price formulation).
- For increase in the price of the processing cost of the raw materials lower profit will be achieved (Cost Index B).
- For increase in the recirculation rate of TEG and other energy input, increase the pumping cost whereas decreases the profit.
- For increase in the price of the energy cost/operating cost, lower profit will be achieved (Cost Index C).

5. Conclusions

In this work, the simulation of the KGP plant is conducted and validated with real plant data. The compositions gas obtained from the simulation is close to the operating data of the plant. Convergence problem of the absorber unit and distillation column problem is solved by using two HYSYS recycle block and fixing different solution parameter.
An attempt is made to study optimization of KGP within HYSYS process simulator to maximize the heat content of sales gas by adjusting within the limit water content and amount of heavy hydrocarbon. The sensitivity analysis of the cost parameters shows that the optimal design and operation are sensitive to some of the parameters.

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