Paper ID: IE-29

Flow Sheet Development and Simulation with Optimization of Industrial Scale Natural Gas Processing Plant by Using Aspen-Hysys

Md.Nurus Sakib[1], Noor Mohammad[2], Niloy Barua[3], Dr. Md Ruhul Amin [4],
[1], [2], [3] Department of Chemical Engineering, Bangladesh University of Engineering University, BUET
[4] Associate Professor, Department of Chemical Engineering, Bangladesh University of Engineering University, BUET
Email addresses: ruhulaminbuet@gmail.com, sakibaintsaint@gmail.com, noorche1002001@gmail.com, niloy.barua.pial@gmail.com

Abstract

Bangladesh has a gas field discovery success ratio 3.1:1 of which two of the gas fields are located in offshore area. Bibiyana gas field has been selected for the study of flow sheet development and simulation with optimization of industrial scale natural gas processing plant by using Aspen-Hysys as it is a world class gas reservoir. Flow sheet development and simulation of 150 MMSCFD natural gas producing Bibiyana gas plant was done by means of Aspen-Hysys. The steady state simulation was performed based on both the design and physical property data of the plant. The main purpose of optimization was cost minimization by regulating the process stream flows and heat duty and hence profit maximization. The objective function, Profit, was calculated from the difference of sales gas, LPG and condensate selling revenue and condenser or reboiler duty costs. Hysys Optimizer has been used to optimize the present process which resulted in more than 8.5% increase in profit with negligible change in optimized methane composition (around 99.46 %). In addition, LPG was also recovered with a production rate of around 1746 barrel/day.

Keywords: Natural Gas; Aspen-Hysys; Gas Processing; Separation; Simulation; Optimization.

1. Introduction

Natural Gas is among the top most used energy sources in the world. Since natural gas can be processed and distributed easily, the demand is growing rapidly [Rahman and Tamim, 2012]. Hence, fast and efficient gas processing and optimization are needed. Natural gas processing plants are used to purify the raw natural gas extracted from underground gas fields and brought up to the surface by gas wells.

Natural gas processing consists of separating all of the various hydrocarbons and fluids from the pure natural gas, to produce what is known as ‘pipeline quality’ dry natural gas. Many removal processes can be adopted, for example, amine base process for the removal of carbon di oxide [Kinigoma and Osharode, 2013] or by Benfield process [Chowdhury and Chowdhury, 2013]. Furthermore, Dehydration of Natural Gas which is another important step in gas processing. Deethanization and also depropanization can be enhanced by using dividing wall column [Long and Lee, 2012]. Nitrogen-removal processes using liquid solvents, adsorption, and cryogenic processing are currently available, but all of these methods require recompression of the methane product, which penalizes their economics. However, the Use of three column system requires less compression and higher methane recovery (around 98%) than other methods available [MacKenzie *et al.* 2012].

Analysis of industrial scale Natural Gas plant includes many complicated aspects which are mainly assessed by simulation programs. Aspen HYSYS is an easy-to-use process modeling environment that enables optimization of conceptual design and operations and removes process bottlenecks. Simulation of plant model and optimization of natural gas processing plant that reduces process loss and maximizes profit can be developed though Aspen-Hysys [Roy and Amin, 2011]. The role of Hysys is to provide a capable and accurate design. Aspen Hysys introduced the novel approach of steady state and dynamic simulations in the same platform. It has become the defacto standard in industry, and today enjoys universal acceptance [Amber *et al.* 2012]. Simulator response modeling relates key process variables to plant performance satisfying the remaining unknown information from the material balance equations [Bullin and Hall, 2000]. In a gas simulation process, the inlet conditions (Composition, pressure and temperature) affect the throughput and quality of products. However, to counter such problems, about 80 % of the bumps can be reduced by using Hysys [Ramzan *et al.*]. Owing to such performance, Hysys simulation has been used to optimize process condition for maximum profit.

2. Simulation of gas process unit

For the Bibiyana plant simulation, there are five major units which processes the raw natural gas. These are: **separation unit**, **dehydration unit**, **heat exchanger**, **de-ethanizer** and **final purification & CO_2 removal units**. The simulation process is based on Bibiyana gas production process and following are the description of units of the process:

2.1 Separation unit: Gas is drawn from three wells: Well-1, Well-2, Well-3 respectively in simulation of the processing plant. The feed Composition can be found in datasheet. Then the feed gas is passed through the pressure control valve to relief some pressure & then fed into 3 'three phase separators' (H-110A, H-110B, H-110C) to separate each valve out stream in heavy liquid, light liquid & vapor streams. Most of the liquids are separated at this separation unit. The 3 heavy liquid streams(mostly H_2O) is removed & the 3 light liquid streams are mixed together in a mixer & then entered into a distillation column(D-320) through an expansion valve, the bottom liquid product is liquefied petroleum gas(LPG) & is stored in a tank(F-210). The overhead product of D-320 is mixed with refined gas stream to prepare the very final product.

2.2 De-hydration unit & heat-exchanger unit: There are three vapor streams of the separators(H-110A, H-110B, H-110C) which are mixed in a mixer and passed through the dehydration unit for water removal. The dehydration unit consists of an absorption tower (D-310) where Tri Ethylene Glycol is used to absorb water. The overhead vapor product of (D-310) contains dehydrated hydrocarbons which is passed through two heat exchangers (E-230) & (E-250) so that temperature is decreased. The tube out of E-250 heat exchanger is then entered into a separator (H-140). Then expander (G-152) lowers streams temperature using Joule-Thomson principle of pressure relief & then three phase separator separates the remaining water in the mixed inlet more precisely. Heavy liquid is removed & light liquid (H-150 liq out) and vapor(H-150 vap out) is used for further processing.

On the other hand, bottom product of the absorption tower(D-310) is passed through an expansion valve (K-131) & a two phase separator(H-130) ,bottom product of which is used as a tube side inlet of heat exchanger (E-240). The tube side outlet is then entered into a column(D-330) whose bottom product is make-up Glycol solution & is entered into the shell side of the heat-exchanger(E-240) & heat-exchanger(E-230). Between the heat-exchangers a pump is used to increase the pressure. The shell outlet of E-230 is mixed with TEGlycol feed to use in the absorption tower (D-310)

2.3 De-ethanizer unit: The liquid stream of the three phase separator(H-150) is then used in the de-ethanizer which is a distillation column (D-340). Bottom product of the column(D-340) is LPG which is passed through the heat-exchanger(E-101) to prepare 'Final LPG' at low temperature. Stream(H-150 vap out) is mixed with the over-head vapor product of (D-340). Mixed stream out (M-231) is entered into the shell side of the heat exchanger (E-250) to increase the temperature.

2.4 Purification & CO_2 removal unit: Stream (M-251 shell out) is then undergone through CO_2 removal process. In this stage, we used principles of liquefaction to separate CO_2. Using cooler (E-100) we cooled shell out stream and this cool gas stream is passed to a separator (V-100) preceded by a valve (VLV-100). Then the final product stream enters compressor & then again thorough consecutive separations and thus CO_2 from natural gas has been decreased significantly (less than 0.03%). CO_2 can also be removed using absorption process where MEAmine solution is used to absorb CO_2.

3. Optimization of gas processing plant simulation

After performing the whole simulation process, profit optimization was done. Optimization was done by controlling two main prospect. One is the flow of the revenue earning stream and the other is the duty corresponding to cost of the process. The main purpose of optimization was cost minimization. The objective function, Profit, was calculated from the difference of sales gas, LPG and crude gasoline (a stream having many of the properties of gasoline) selling revenue and condenser or reboiler duty costs. . Some energy was also extracted from an expander (G152) that was included with the revenue too. In the process, the profit is a function of both cost of heat duty and the revenue of flow rates of products i.e. sales gas, LPG and crude gasoline. The objective function is given as :

$$\text{Profit} = \text{Total revenue} - \text{Total cost}$$

Several user defined variables were considered as primary variables; i.e.: outlet stream pressures of absorption, de-methanization and de –ethanizaion units, compressors and valves to name a few.

3.1 Optimization effect: This part illustrates on the optimization function and optimized condition of the final simulation. Here, the optimizer spread sheet (Fig 3.1) lists all the variables relating with price. This spread sheet was formed by opening the spreadsheet of Hysys Optimizer® tool. Then functions were listed in the functions tab of the tool. By means of Hysys Optimizer® which uses both static and dynamic simulation modeling tool, optimization is achieved. Hysys uses the dynamic analysis of a process system that provides understanding of process system which is not possible with steady state modeling. Following is the mathematical formulation:

Table3.1: Market Value of Products and utilities: (Prices estimated from the year book of Petrobangla and Bangladesh Energy Regulatory Commission)

Natural Gas	9.580 taka/m^3
LPG	56 taka/kg
Crude Gasoline	42470taka /m^3
Heating or Cooling Duty	0.737 taka/KWh

Revenue Calculation:
Sales gas volume = B1 Sales gas price per unit volume, B2=9.580 tk/m^3
LPG sales volume= B3 Sales LPG price per unit volume, B4 = 56 taka/kg
Crude Gasoline sales volume= B5 Crude Gasoline sales price per unit volume, B6= 42470 taka/m^3

Revenue, B7 = B1×B2+B3×B4+B5×B6

Cost Calculation:
Expander Duty = D1 , D320 Re-boiler Duty= D2 ,D330 Re-boiler Duty= D3, D330 Condenser Duty = D4
D340 Re-boiler Duty = D5 , D340 Condenser Duty = D6, L231 Pump Duty = D7, Cooling Duty = D8
Heating Duty = D9, E100 Heat Duty = D10, Compressor Duty = D11, E104 Duty = D12, Price per KWh, D13 = 0.737 $, Total Cost,

D14 = (D1+D2+D3+D4+D5+D6+D7+D8+D9+D10+D11+D12) × D13, Profit = B7-D13

Before Optimization

	A	B	C	D
1	SALES GAS	1.574e+005 m3/h	EXPANDER DUTY	1719 kW
2	SALES GAS PRICE	9.580	D330 REB DUTY	403.8 kW
3	LPG	6880 kg/h	D230 REB DUTY	418.6 kW
4	LPG PRICE	56.00	D340 REB DUTY	3.489e+004 kW
5	CRUDE GASOLINE	8.362 m3/h	D330 COND DUTY	20.43 kW
6	PRICE	4.247e+004	D340 COND DUTY	3.093e+004 kW
7	REVENUE	2.248e+006 m3/h	L231 PUMP DUTY	9.797 kW
8			COOLQ DUTY	2.450e+004 kW
9			HEAT Q DUTY	9111 kW
10			E100 HEAT DUTY	2.450e+004 kW
11			COMPRESSOR DU	1.217e+004 kW
12			E104 DUTY	444.1 kW
13			PRICE	0.7370
14			TOTAL COST	1.000e+005 kW
15				
16				
17			PROFIT	2.148e+006

After Optimization

	A	B	C	D
1	SALES GAS	1.745e+005 m3/h	EXPANDER DUTY	2014 kW
2	SALES GAS PRICE	9.580	D330 REB DUTY	403.8 kW
3	LPG	7134 kg/h	D230 REB DUTY	418.5 kW
4	LPG PRICE	56.00	D340 REB DUTY	3.457e+004 kW
5	CRUDE GASOLINE	8.362 m3/h	D330 COND DUTY	20.43 kW
6	PRICE	4.247e+004	D340 COND DUTY	3.032e+004 kW
7	REVENUE	2.426e+006 m3/h	L231 PUMP DUTY	9.797 kW
8			COOLQ DUTY	2.446e+004 kW
9			HEAT Q DUTY	-2.051 kW
10			E100 HEAT DUTY	2.446e+004 kW
11			COMPRESSOR DU	1.441e+004 kW
12			E104 DUTY	1277 kW
13			PRICE	0.7370
14			TOTAL COST	9.459e+004 kW
15				
16				
17			PROFIT	2.332e+006

Figure 3.1: Spread Sheet Values of the simulation after optimization

4. Results and discussions

After the optimization, both flow rates of LPG and Sales Gas were increased. Consequently, theoretical increase in revenue and total profit was about 8 percent as shown in the spread sheet of Figure 3.1. Following tables shows the before and after condition of the process which shows the variability in composition due to optimization. Comparing these tables shows the efficacy of optimization since the desired components compositions varies in a positive way. Even though the methane fraction lowered but the sales flow increased hence the revenue.

Table 4.1: Composition of significant components of sales gas before optimization*

Name of Components	Composition	Name of Components	Composition
Water(H_2O)	5.95E-06	Methane(CH_4)	0.995707
N_2	2.11E-03	Ethane	9.29E-04
CO_2	2.70E-04		

Table 4.2: Composition of significant components of LPG(Liquified Petroleum Gas)*

Name of Components	Composition in LPG	Name of Components	Composition in LPG
Propane	0.236602	n-Heptane	0.144678
i-Butane	0.154207		
n-Butane	0.15947		

Table 4.3: Optimized composition of significant components of sales gas

Name of Components	Composition	Name of Components	Composition
N_2	2.11E-03	Propane	2.61E-04
CO_2	5.41E-04	i-Butane	1.21E-04
Methane(CH_4)	0.994594	n-Butane	1.61E-04
Ethane	1.78E-03	i-Pentane	1.71E-04

Table 4.4: Optimized composition of significant components LPG(Liquified Petroleum Gas)

Name of Components	Composition in LPG	Name of Components	Composition in LPG
Propane	0.241527	n-Hexane	9.74E-02
i-Butane	0.153288	n-Heptane	0.143707
n-Butane	0.158469	n-Pentane	5.73E-02
i-Pentane	9.15E-02		

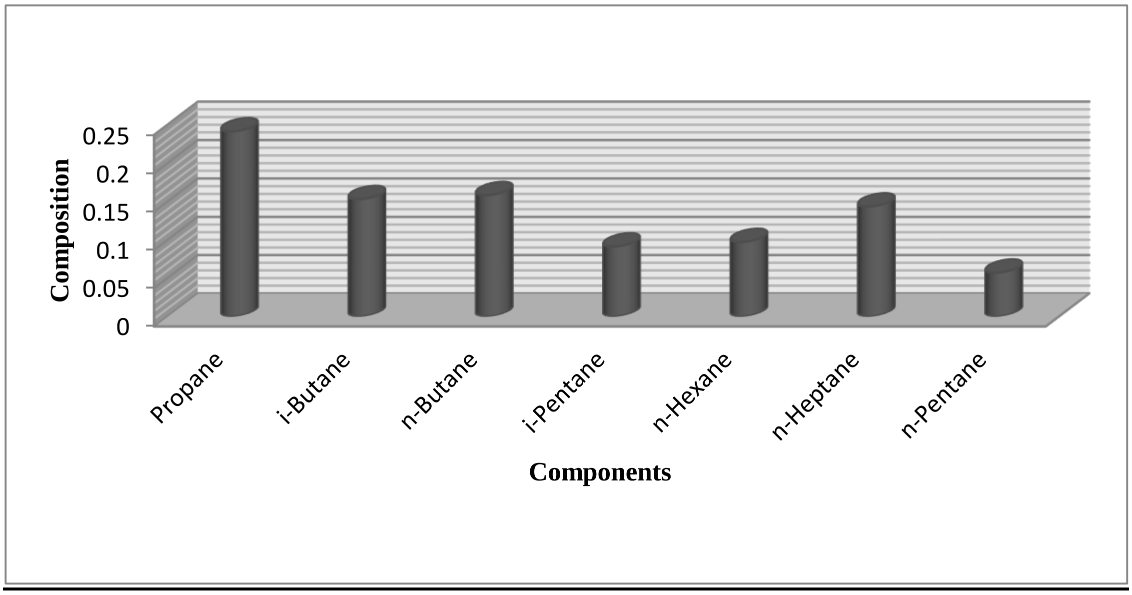

Figure 4.1: Graphical representation of LNG components

* Tablular Data were taken from Bibiyana Gas Fields of Bangladesh

5. Process flow diagram

Following is a depiction of part of the simulated process on Hysys.

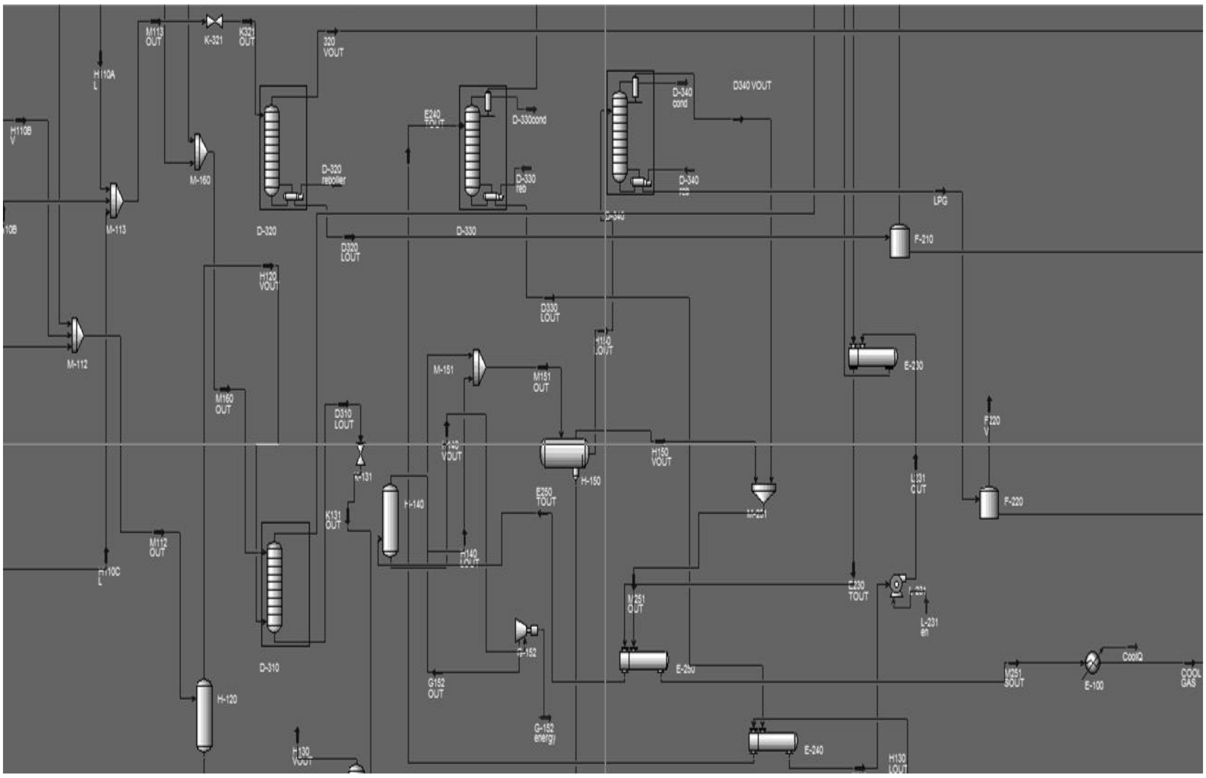

Figure 5.1: PFD of a part of the simulation process

6. Conclusion

At present time natural gas is a major source of energy. Most of the industries are run by energy using natural gas as their main source. Near about 95% of the natural gas is used as fuel gas. So, it is a major prospect to focus on and develop for the betterment of energy utilization. The model for natural gas processing plant is developed in this paper. Different process can be used to meet the specification required for processing of natural gas. Environmental constraints and the need to reduce cost require innovative processes. The process used here derived from earlier processes, but tend to offer significant reductions in investment and operating costs. In the longer term, new concepts such as gas permeation can be expected to play a growing role and the natural gas processing will keep changing. In this plan, the composition of sales gas is satisfactory. The percentage removals of unwanted elements are good enough to run the process. Furthermore, profit was maximized by means of optimization. Optimization provides a better process with higher benefits.

7. Acknowledgment

We are very thankful to BUET Chemical Engineering Forum (BCEF) for their support. The technical and administrative backup given by the Department of Chemical Engineering, BUET is highly appreciated.

Nomenclature

Symbol	Meaning
HC	Hydrocarbon
H	Two and three phase separator
E	Heat Exchanger
M	Mixer
LPG	Liquefied petroleum gas

References

[1] Amber, T., Chavan, T., Manali, K., Walke, S., M., " Simulation of Process Equipment by Using Hysys" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 .National Conference on Emerging Trends in Engineering & Technology (VNCET-30 Mar'12)

[2] Bullin, K.,A., Hall, K., R., " Optimization of Natural Gas Processing Plants Including Bussiness Aspects", Bryan Research and Engineering, Inc. Preceedings of the seventy ninth convention, 2000.

[3] Chowdhury N. B., Chowdhury N. B., "ChemCAD Simulation of Benfield Process to Remove CO_2 from Natural Gas and Inspection of Temperature Profile of Key Units", Advances in Mechanical Engineering and its Application (AMEA) Vol. 3,No. 2. 2013, ISSN 2167-6380

[4] Kinigoma, B., S., Osharode, D., I., "Optimization of Amine Base Process in the Removal of Carbon Dioxide from Natural Gas for LNG Production", Journal of Energy Technologies and Policy, ISSN 2224-3232, Vol. 3, No.3, 2013

[5] Long,N.,V.,D., Lee, M., " Improvement of the Deethenizing and Depropanizing Fractionation Steps in NGL Recovery Process Using Dividing Wall Column", JCEJ, Vol.45. No.4, April 2012

[6] MacKenzie, D., Cheta, I., Burns, D., "Removing Nitrogen", Gas Liquids Engineering, Canada, Hydrocarbon Engineering November 2002.

[7] Roy,S., Amin, R.,:"*Aspen-HYSYS Simulation of Natural Gas Processing Plant.* Journal of Chemical Engineering", IEB, 2011. Vol. ChE. 26(1): p. 4.

[8] Ramzan,N.m Naveed, S.m Muneeb, R., Tahir, F.,M., "Simulation of Natural Gas Processing Plant for Bump less Shift" NFC-IEFR Journal of Engineering and Scientific Research.

[9] Rahman M., Tamim M., Rahman L., "Analysis of Natural Gas Consumption by the Industrial Sector of Bangladesh", Journal of Chemical Engineering, IEB Vol. ChE. 27. No. 1, June 2012

[10] Vago, A., Rippel- Petho, D., Horvath, G., Toth, I., Olah, K. "Removal of Hydrogen Sulfide From Natural Gas, A Motor Vehicle Fuel", Hungarian Journal of Industrial Chemistry, Veszprem, Vol. 39(2) pp. 283-287 (2011)

[11] Haring, H.W. (2008) Industrial Gas Processing. Weinheim, Germany: WILEY-VCH Verlag Gmbh & CO. KGaA

[12] Kohl, A., & Nielsen, R. (1997) Gas Purification. 5TH Edition. Houston, Texas: Gulf Publishing Company

[13] "Gas Processes 2002", *Hydrocarbon Processing*, pages 84-86, May 2002 (schematic flow diagrams and descriptions of nitrogen rejection and nitrogen removal processes)