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Simulation and Optimization of Natural Gas Processing Plant

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Abstract

Natural gas (NG) is naturally generated gas mixture lying under the earth and collected from gas well directly. Natural gas emits little amount of pollutant when it burns and is buried around the world widely. Because of these properties, NG is receiving attention as low-carbon, eco-friendly alternative fuels. It is the major energy source of our country for both domestic and industrial operations. Natural Gas processing plant converts gas reservoir's raw natural gases to produce sales gas, which is highly demanded commodity in the market. Sales gas specification typically required processed gas with small amount of water to avoid pipelines corrosion, avoid hydrates formation in the gas and for their immediate industry consumption. The plant is equips with gas dehydration system facilities to absorb water from raw gas and most of the gas dehydration processes are using tri-ethylene glycol (TEG) process unit. This article presents a generalized methodology of a natural gas process plant simulation and optimization taking a typical gas process plant in Bangladesh as an example. In this study, a steady-state simulation of the process plant was performed using Aspen HYSYS. The work aims in achieving two main objectives, which are carrying out plant simulation model using Aspen HYSYS software and reasonable optimizing of gas dehydration system.

Keywords: *Natural gas plant, Simulation, Hysys, Process optimization, Separation.*

1. Introduction

The last 35 years have seen a remarkable growth in the contribution of gas to the world's total primary energy demand [1].The primary use of natural gas (NG) is as a fuel; it can also be a source of hydrocarbons for petrochemical feed stocks [2]. Its clean burning and ability to meet stringent environmental requirements have raised the demand for natural gas [3]. Much of the world's gas reserves are in offshore fields [4]. Natural gas is the gas obtained from natural underground reservoirs either as free gas or gas associated with crude oil. It generally contains large amounts of methane (CH_4) along with decreasing amounts of other hydrocarbons. Impurities such as H_2S, N_2, and CO_2 are often found with the gas. It also generally comes saturated with water vapor. The principal market for natural gas is achieved via transmission lines, which distribute it to different consuming centers, such as industrial, commercial and domestic. Field processing operations are thus enforced to treat the natural gas in order to meet the requirements and specifications set by the gas transmission companies. The main objective is to simply obtain the natural gas as a main product free from impurities [6]. There are quite a few treating processes available for removal of acid gases from natural gas, including Chemical solvents, Physical solvents, Adsorption Processes Hybrid solvents and Physical separation [5]. In addition, it should be recognized that field processing units are economically justified by the increased liquid product (NGL) recovery above that obtained by conventional separation. Different techniques are used for dehydration plant. Absorption (Glycol dehydration process) is one of the easy and vigorously used processes. In this process, a hygroscopic liquid is used to contact the wet gas to remove water vapor from it. Triethylene glycol (TEG) is the most common solvent used [6]. Process simulation has become an essential tool for operators and engineering firms in the oil & gas industry. Simulators can better support process design, debottlenecking and optimization when used to their full potential. Aspen HYSYS is the market-leading process modeling and simulation solution with a proven track record of providing substantial economic benefits throughout the process engineering lifecycle. It brings the power of process simulation and optimization to the engineering desktop, and delivers a unique combination of modeling technology and ease of use [7].

In order to reduce the operating costs of a plant, much effort is put to find the optimal design condition of the process though optimization studies. Optimization has many applications in chemical, mineral processing, oil and gas, petroleum, pharmaceuticals and related industries. Not surprisingly, it has attracted the interest and attention from many chemical engineers for several decades. Optimization of chemical and related processes requires a process modeling and optimization along with control characterizes the area of process systems engineering (PSE), important in chemical engineering with a wide range of applications. In this simulation work, use of Triethylene glycol (TEG) has been investigated for a variety of cases using a process simulation program HYSYS in steady state.

2. Effect of impurities found in natural gas

Field processing operations of natural gas, which is classified as a part of gas engineering, generally include the following:

1. Removal of water vapor, dehydration
2. Removal of acidic gases (H_2S and CO_2)
3. Separation of heavy hydrocarbons

The effect each of these impurities has on the gas industry, as end user, is briefly outlined.

Table 1. Effect of natural gas impurities [6]

Water vapor	H_2S and CO_2	Liquid Hydrocarbons
It is a common impurity. It is not objectionable as such ➢ Liquid water accelerates corrosion. ➢ Solid hydrates, made up of water and hydrocarbons, plug valves, fittings in pipelines, and so forth	Both gases are harmful specially H_2S which is toxic if burned. It gives SO_2 and SO_3 which are nuisance to consumers ➢ Both gases are corrosive in the presence of water. ➢ CO_2 contributes a lower heating value to gas	Their presence is undesirable in the gas used as fuel ➢ The liquid form is objectionable to burners designed for gas fuel ➢ For pipelines it is a serious problem to handle two-phase flow; liquid and gas

3. TEG process

Most natural gas producers use Triethylene glycol (TEG) to remove water from the natural gas stream in order to meet the pipeline quality standards. This process is required to prevent hydrates formation at low temperatures or corrosion problems due to the presence of carbon dioxide or hydrogen sulfide (regularly found in natural gas). Dehydration, or water vapor removal, is accomplished by reducing the inlet water dew point (temperature at which vapor begins to condense into a liquid) to the outlet dew point temperature which will contain a specified amount of water. Absorption of water vapor in the TEG is the common method. The wet gas is brought into contact with dry glycol in an absorber. Water vapor is absorbed in the glycol and consequently, its dew point reduces. The wet rich glycol then flows from the absorber to a regeneration system in which the entrained gas is separated and fractionated in a column and reboiler. The heating allows boiling off the absorbed water vapor and the water dry lean glycol is cooled (via heat exchange) and pumped back to the absorber [8].

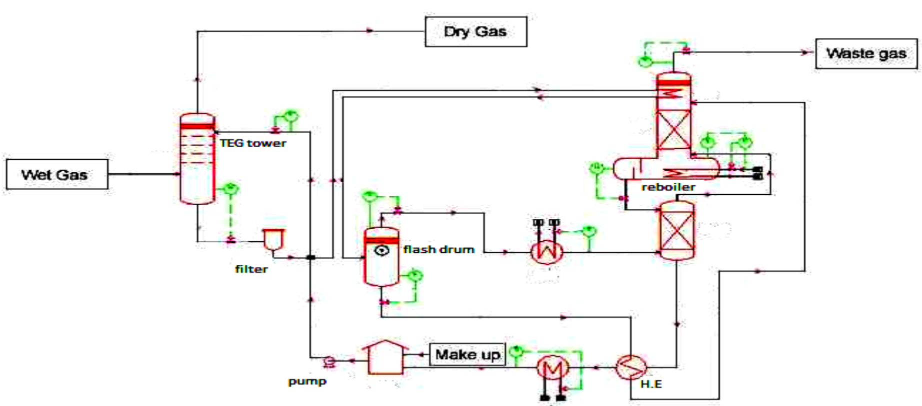

Fig. 1. Schematic diagram of a TEG dehydration type NG plant.

4. Simulation of gas processing plant

The simulation model is developed on Aspentech HYSYS 3.2.The type of fluid package selected is peng-robinson Package. TEG used as an aqueous absorbent to absorb water from gas streams. Before entering the contactor, the gas is passed through an inlet separator where entrained droplets of liquid are removed from the gas stream. Specification of feed gas is shown in figure 2.

Stream Name	well
Vapour / Phase Fraction	0.9949
Temperature [C]	86.67
Pressure [kPa]	2.925e+004
Molar Flow [kgmole/h]	1096
Mass Flow [kg/h]	1.873e+004
Std Ideal Liq Vol Flow [m3/h]	59.74
Molar Enthalpy [kJ/kgmole]	-7.925e+004
Molar Entropy [kJ/kgmole-C]	139.4
Heat Flow [kJ/h]	-8.683e+007
Liq Vol Flow @Std Cond [m3/h]	<empty>
Fluid Package	Basis-1

	Mole Fractions
Nitrogen	0.003674
CO2	0.004865
H2S	0.000000
Methane	0.947609
Ethane	0.025319
Propane	0.004269
i-Butane	0.001191
n-Butane	0.000596
i-Pentane	0.000298
n-Pentane	0.000199
n-Hexane	0.000796
n-Heptane	0.000497
n-Octane	0.000298
n-Nonane	0.000298
n-Decane	0.000895
TEGlycol	0.000000
H20	0.009193

Fig. 2. Conditions and compositions of raw gas coming from well.

In simulating the processing plant, natural gas with condensate and water is drawn from one well. The gas composition of this field is used. The industrial data are obtained for the simulation. Then the gas pressure is reduced and is passed through a water bath heater H-101 to heat the gas to prevent hydrate formation. Then the outlet streams of the heaters are passed through pressure reduction manifold VLV-101 to the inlet two phase separators (V-101) and then the TEG tower inlet scrubber. The pressure control valve (VLV-101) controls the pressure of the separator (V-101). The vapor phase (stream 8) from the separator goes to the T-101 scrubber and then is passed through the bottom of dehydration unit (TEG contactor) to dehydrate the gas. Lean TEGlycol enters from the top of the contactor (stream 33). The water is absorbed from gas by glycol and water free gas is then allowed to gas/glycol heat exchanger (E-202) to get heat from the hotter glycol. The gas then goes to fuel gas scrubber (V-104) for the final separation of gas-liquid before going to sales line. The rich glycol from T-101 contactor goes to the energy exchange pump (stream 17) and pressure dropped remarkably. Here VLV-100 denotes the pump as a pressure reduction device. Then the rich glycol goes to reflux condenser (E-206), then to glycol flash separator V-204 (another three phase separator) to remove condensate from gas. To be preheated the rich glycol (stream 24) enter into a Plate and Frame exchanger and then to the TEG reboiler through packed bed still column. The glycol heated here upto about 400 °F at almost atmospheric pressure. Water vaporized from glycol and from the top of the reboiler (stream 24) it goes out to V-206 via cooling system. The lean glycol circulates from the reboiler to E-201 (stream 28) for necessary cooling and then pumped by P-102 to TEG contactor via E-202 and E-205 where it's cooled to desire. The liquid consist condensate plus water from the bottom of V-101 goes to three phase separator V-102 and it's separated as water (stream API), condensate (stream 38) and gas (stream 36). Inlet of V-102 is the mixer of different stream of hydrocarbon liquid MIX-103. Fuel gas is collected from TEE-101 (stream 15), V-102 (stream 36) and V-204 (stream 21). Then it's gathered at MIX-105 and the buffered at V-103 for further distribution.

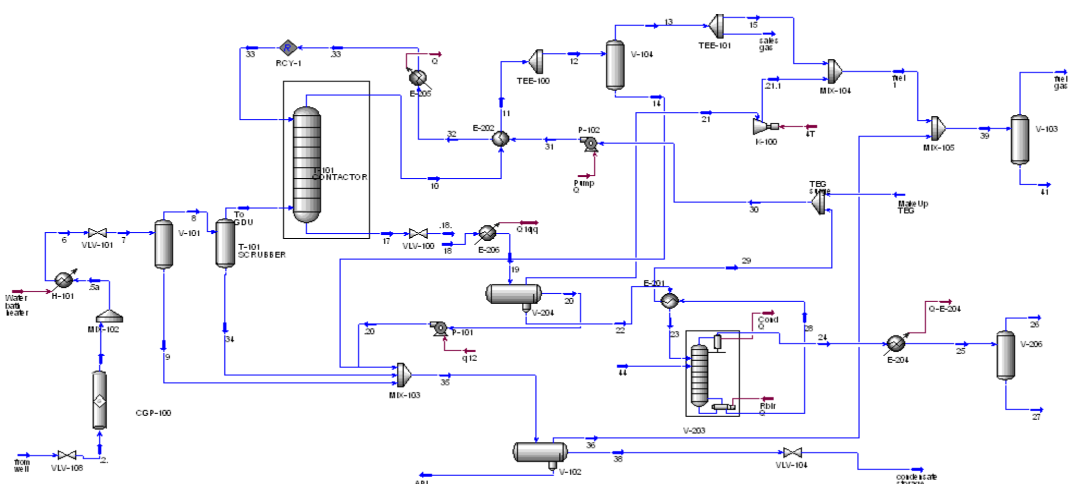

Fig. 3. Simulation model of natural gas processing plant.

5. Results and Discussions

The effect of process parameters have been studied in a typical gas processing plant in Bangladesh. Sweet natural gas is feed to the contactor designed for 20 MMSCFD and the operating pressure was 1010 Psig. Glycol circulation rates have been tested in different inlet gas temperatures and reboiler operating conditions.

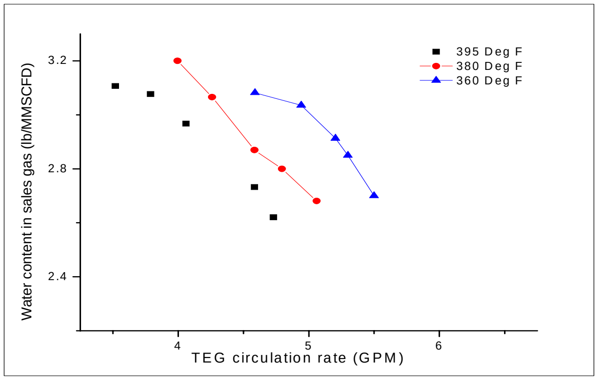

Fig. 4. Water content VS circulation rates and reboiler Temperature (Contactor Inlet Gas Temperature fixed at 90 ^{o}F)

The result clearly shows the optimum operating temperature of TEG reboiler. Lower dew points have been resulted TEG reboiler is operated at 395 ^{o}F. The optimum circulation rates under the operating conditions are also evident in the result. It is certain that under the design condition, lowest dew point refers the corresponding circulation rate somewhere between 4.5 to 5.5 GPM.

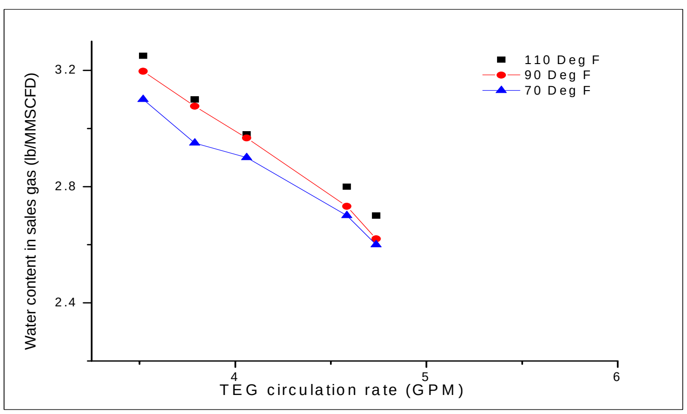

Fig. 5. Water content VS circulation rates for different inlet gas temperature. (Re-boiler Operating Temperature 395 ^{o}F)

Another graph has been plotted based on the inlet gas temperatures of the contactor. The results clearly show that lower inlet gas temperature to the contactor requires less amount of TEG circulation. However it will be clearer if there were another graph representing the experimental results under 70 ^{o}F but due to the raw gas temperature, composition and hydrate formation, the results are limited to the value of 70 ^{o}F. Flow direction and settling time are directly related to the water content in the wet gas from the high pressure two-phase separator (V-101). The following graph contains results on two different equilibrium conditions. Initially the high pressure separation was designed to handle 20 MMSCFD of sweet natural gas with and operating pressure of 1010 psig. Later a contactor (T-101) inlet scrubber has been installed to increase the settling time (time in V-101 plus time in inlet scrubber) and flow direction of the inlet fluid. The results confirm that initially HP separator outlet gas stream's water content and after inlet scrubber water content came down as well as in the sales gas water content (lb/MMSCF) decreased. As the inlet water content decreases due to the equilibrium condition, lower dew points have been observed in same TEG circulation rates.

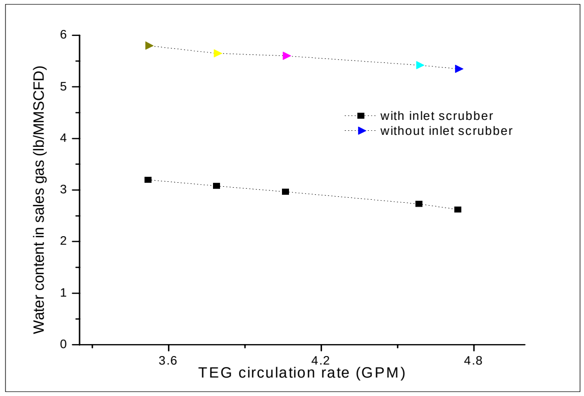

Fig. 6. Water content VS circulation rates in different settling time.

Stripping gas flow rate is actually a parameter in the stripping column of TEG regeneration system, which is a function with the reboiler efficiency.

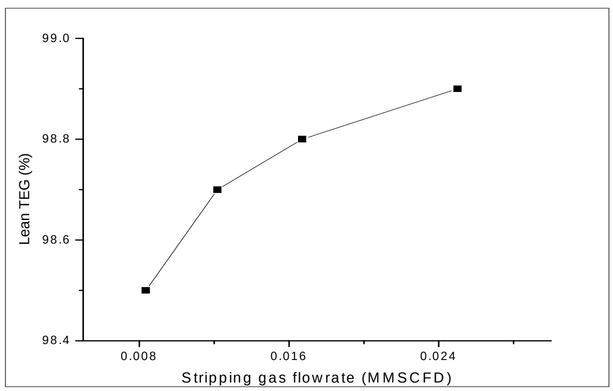

Fig. 7. Water Removal Efficiency VS Stripping Gas Flow Rate.

It was tested different stripping rate conditions of the reboiler and found the water removal efficiency from the rich glycol at given circulation rates. Increasing the stripping gas flowrate in the TEG reboiler, purity of Lean glycol can be increased to a certain limit. As countercurrent absorption in contactor is directly dependent on the quality of the lean TEG fed to the contactor, higher efficiency of water removal (≥ 99%) is one of the main areas of concern in optimization of this process.

	Mole Fractions
Nitrogen	0.003707
CO2	0.004900
H2S	0.000000
Methane	0.956841
Ethane	0.025543
Propane	0.004301
i-Butane	0.001199
n-Butane	0.000599
i-Pentane	0.000299
n-Pentane	0.000199
n-Hexane	0.000784
n-Heptane	0.000475
n-Octane	0.000266
n-Nonane	0.000234
n-Decane	0.000558
TEGlycol	0.000000
H2O	0.000097

Fig. 8. Composition of sales gas before fuel gas scrubber.

Some equipment in this process plant can be removed without hampering product quality. Process parameters must be maintained well. Considering more safety they are installed. Here it was supposed to eliminate Fuel Gas Scrubber (V-104) and Air/ Glycol Exchanger (E-205). Stream 11 at the outlet of TEG contactor to the sales gas line, there contains very negligible amount of water, even it shows no Liquid phase in the conditions tab. So V-104 which was used for further gas/liquid separation can be eliminated. Composition of stream 11 is given above Figure 8.

Stream Name	32
Vapour / Phase Fraction	0.0000
Temperature [F]	120.0
Pressure [psig]	1045

Stream Name	33
Vapour / Phase Fraction	0.0000
Temperature [F]	115.0
Pressure [psig]	1040

Fig. 9. Inlet and outlet condition of air/glycol cooler.

Air/ glycol exchanger (E-205) decreasing the temperature of TEG from 120 ^{o}F to 115 ^{o}F only to maintain the TEG contactor tower inlet temperature (Fig. 9). This 5 ^{o}F temperature can be easily reduced by either E-202 (gas/glycol heat exchanger) or E-201 (glycol/glycol PFE heat exchanger) by little amount of higher overdesign. The process conditions of E-205 inlet (stream nr 32) and E-205 outlet (stream nr 33) is showing below.

6. Conclusion

In this paper a simulation model of natural gas processing plant is developed using the process simulator HYSYS. Properties and conditions of different unit processes were optimized. For the plant equipment optimization also done to make more cost effective. Process optimizes the operating conditions that maximize the overall profit for the process with reduction of loss, cost and modification in present plant equipment. Experimental results are based on certain operating conditions, however it provides the trend of the data and any proactive action could be taken following the results on the experimental conditions. Experiments to determine effect of one parameter were carried out keeping the other ones fixed based on the optimum operative conditions.

7. References

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