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SIMULATION AND OPTIMIZATION OF NATURAL GAS PROCESSING PLANT USING ASPEN-HYSYS

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Abstract: Natural gas processing plants in India especially in the western part of the country have a very high presence off-shore when compared to the Eastern parts. ONGC Hazira, Gujarat is selected for the flowsheet development and simulation with optimization of a natural gas processing plant using Aspen-Hysys as the Hazira plant is India's largest gas-processing facility and a critical supplier of the fuel to domestic industries. Flowsheet development and simulation of 73 MMSCFD natural gas producing Hazira plant was done by Aspen-Hysys. The simulation was performed based on factors like design and physical property data of the plant. Then optimization was done to minimize the cost by controlling the stream flowrates and energy duties and hence maximizing the profit. Profit generated was taken as the objective function calculated by the difference of revenue obtained from Liquid natural gas and Liquefied Petroleum gas and the condenser, re-boiler and cooler duty expenses. Optimizer tool embedded in Aspen-Hysys is used to optimize this process which resulted in nearly 10% increase in the profit with minimal changes in the compositions of the final product.

***Keywords* -** Natural Gas, Aspen-Hysys, Simulation, Processing plant, Optimization**.**

I. INTRODUCTION

Natural gas contains methane, (CH_4) in large composition followed with some ethane (C_2H_6) and propane (C_3H_8), and impurities such as CO_2, H_2S, and N_2. Natural gas is free from any odour and is colourless in nature. Natural gas is formed when the residual matter of plants, animals and chunks of soil get deposited in the ocean bed and the matter gets decomposed. With the passage of millions of years, the matter gets piled up and high temperature and pressure is observed under the pile. Anaerobic bacteria which is present in the ocean bed acts on this organic matter where a complex chemical process is carried out. This results in the formation of natural gas.

Natural gas is one of the most used energy sources in the world. It has a good demand globally, especially in industrial sectors [4]. Therefore, it is vital that the processing and optimization of natural gas in a quick and efficient way is necessary to meet the demands. The Raw Natural gas is extracted from underground gas fields both onshore and offshore and brought up to the surface by gas wells and then sent to the natural ga processing plants where the raw natural gas with impurities like CO_2, N_2, H_2S are removed to a maximum extent.

In a Natural gas processing plant the removal of various hydrocarbons and components from the Natural gas is done in many ways like the Benfield process [2] or the amine-based removal technique and many more. In the next stage is the dehydration of natural gas to reduce the water content to a minute level in the stream. De-methanization is done and methane which is the major component in Liquefied Natural gas is obtained. A three-column system is used to recover higher amount of methane using less compression. Along with this the Liquefied petroleum gas is also recovered after the removal of Nitrogen, carbon dioxide and other vent gases.

Natural gas has various applications and uses in Residential, Industrial, Electricity generation, Transportation, etc. India is the third largest consumer of natural gas in the world. The consumption of Natural gas in India has increased gradually from 52517 MMSCFD in 2015-16 to 64143 MMSCFD in 2019-20. These statistics show the increase in demand for natural gas in India. In future, the natural gas demand will be up by 6.8% from that of 2019-20. The supply of natural gas is likely to increase in future with the help of increase in domestic gas production and imported LNG [7].

Oil and Natural gas plant in Hazira, Gujarat, India was established by the Government of India under the Ministry of petroleum and Natural gas in 1985. This plant produces 120 MMSCFD of natural gas and 6000 m^3/day sour condensate to produce sweet gas and other value-added products like LPG, Naphtha & propane.

The accessibility and availability of various simulation software allows the analysis of industrial scale process which are complex in nature. Aspen-Hysys is one such which provides the environment of process modelling, optimization of the process and removes the hurdles in analysing the process. Aspen-Hysys provides a precise and efficient design of the process. This software is now acceptable universally [1]. Aspen-Hysys reduces 80% of the problems which are encountered especially in gas simulation process like the inlet conditions affecting the quality and quantity of products [3]. These performances validate the use of Aspen-Hysys simulation to optimize the process conditions for maximizing the profit.

II. Simulation of Natural Gas Processing Unit

In the ONGC Hazira plant simulation, there are four units that are involved in the processing of the raw natural gas obtained from the reserves. These are the **Separation unit, De-hydration unit, De-methanizer unit**, and **purification unit**. The following are the description of each process:

A. Separation unit

The raw natural gas in three feeds is sent into the pressure control valves (valve-1, valve-2, valve-3) to reduce the pressure and then into 3 'three-phase separators' (sep-1, sep-2, sep-3) to separate the heavy fractions (Heavy-1, Heavy-2, Heavy-3). The three-light liquid streams (Light-1, Light-2, light-3) are mixed and sent into the distillation column (COL-1) the bottom of the column is liquefied petroleum gas (Bottoms-1) and stored in the tank (TANK).

B. De-hydration unit

The Three vapor streams from the 3 'three-phase separators' are mixed and sent into the absorption column (Absorber-1). This Absorber is considered to be the main part of the de-hydration unit, where the absorbent Tri Ethylene Glycol (TEG) is sent into the absorption column from the top. The overhead product (OVH-1) with less water content is obtained.

The bottom product of the absorption column (BOT-1) is sent into the pressure release valve (valve-4) where the pressure is reduced. Since, this stream (2PH-Feed1) is rich in water as this is the bottom of the absorption column (Absorber-1), the stream is sent into a two-phase separator (2P-Sep1) where most of the water content is separated in the form of vapor from the top as vap-1. The bottom of the separator (liq-1) is sent into a heat exchanger (HEX-1) on the tube side to lower its temperature which is very high. The Shell side liquid is the bottom product obtained from the distillation column (COL-3). The tube-side liquid from the heat exchanger is sent into the distillation column (COL-3). The distillate obtained from this column is rich in methane (LNG-2).

C. De-methanizer unit

The overhead stream (OVH-1) from Absorber-1 is sent into the cooler (COOL-1) where the temperature is reduced and then sent into a 'three-phase separator' (sep-4) where further the heavy liquids are separated and the lighter fractions are sent into the distillation column (COL-3) the distillate which is rich in methane is obtained (LNG-1). The bottom of the column BOTTOMS-3 rich in propane, i-butane, and n-butane which occupy the major composition of liquefied petroleum gas (LPG) is obtained.

D. Purification unit

The bottom products from COL-3 and TANK (BOTTOMS-3 and TL) are mixed and sent into the 'two-phase separator' (2PH-sep) where the unwanted gases like Carbon dioxide and Nitrogen are separated from the top (VENT GAS). The bottom of the column (LIQ-2) is further cooled to get the final product liquefied petroleum gas (LPG).

III. Optimization of Processing Plant

After the process simulation is completed. The next step is to optimize the process to get higher profits. Optimization is done using the Aspen Hysys Optimizer tool. The main objective of the optimization is to maximize the profit. Hence, the objective function is profit which is the function of total cost and revenue generated. The flow rates of LPG and LNG streams are considered as the decision variables. The objective function, Profit, was calculated from the difference of LPG and LNG selling revenue and condenser, cooler and reboiler duty costs.

After opening the Optimizer tool, we add all the required constraints (Fig-1) and then we add the decision variables and then maximize the profit function. The spreadsheet after optimization is completed (Fig-2). Aspen Hysys has the ability to use both static and dynamic simulation modelling tools and complete the optimization efficiently.

IV. Calculations

A. Revenue Calculation

Liquid natural gas volume = D1
Liquid natural gas price per unit volume, D2=7.85 INR/m^3
Liquefied petroleum gas volume= D3
Sales LPG price per unit volume, D4 = 57.04 INR/kg
Revenue, D7 = (D1*D2) + (D3*D4)

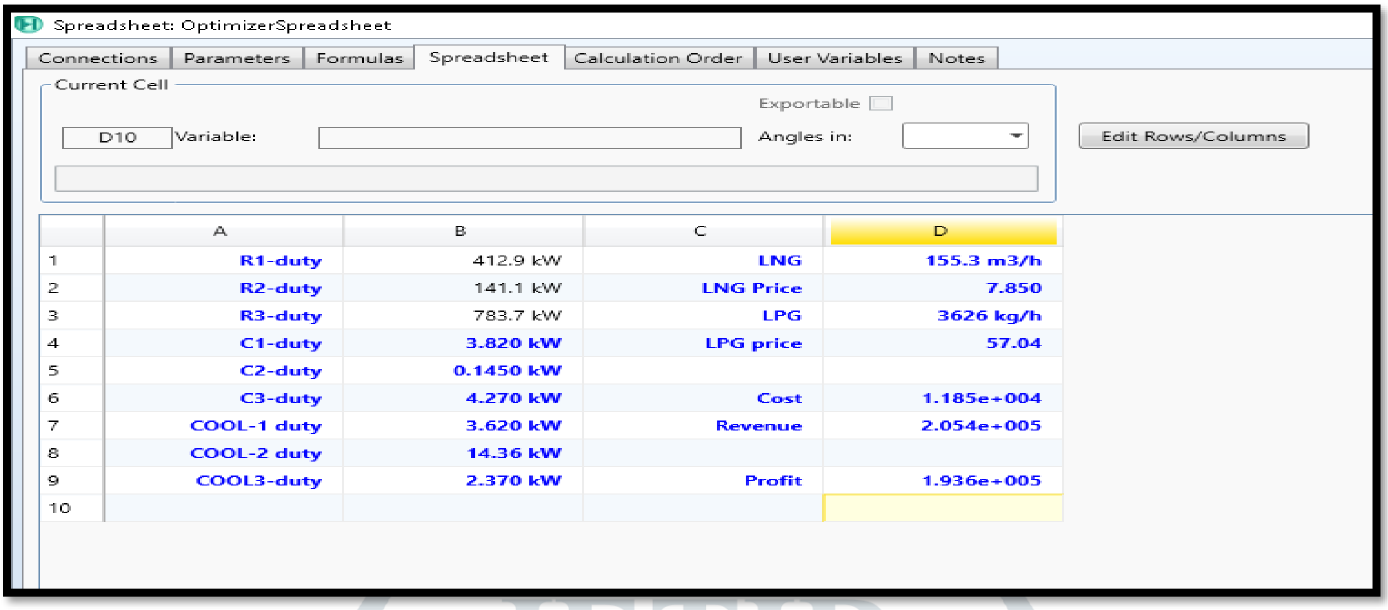
B. **Total Cost Calculation**

Re-boiler duties: B1, B2, B3
Condenser duties: B4, B5, B6
Cooler duties: B7, B8, B9
Price per kW.h: D5= INR 8.577
Total cost, D6= (B1+B2+B3+B4+B5+B6+B7+B8+B9) *D5

C. Profit

Profit generated, D9= D7-D6.

D. Tables/Figures



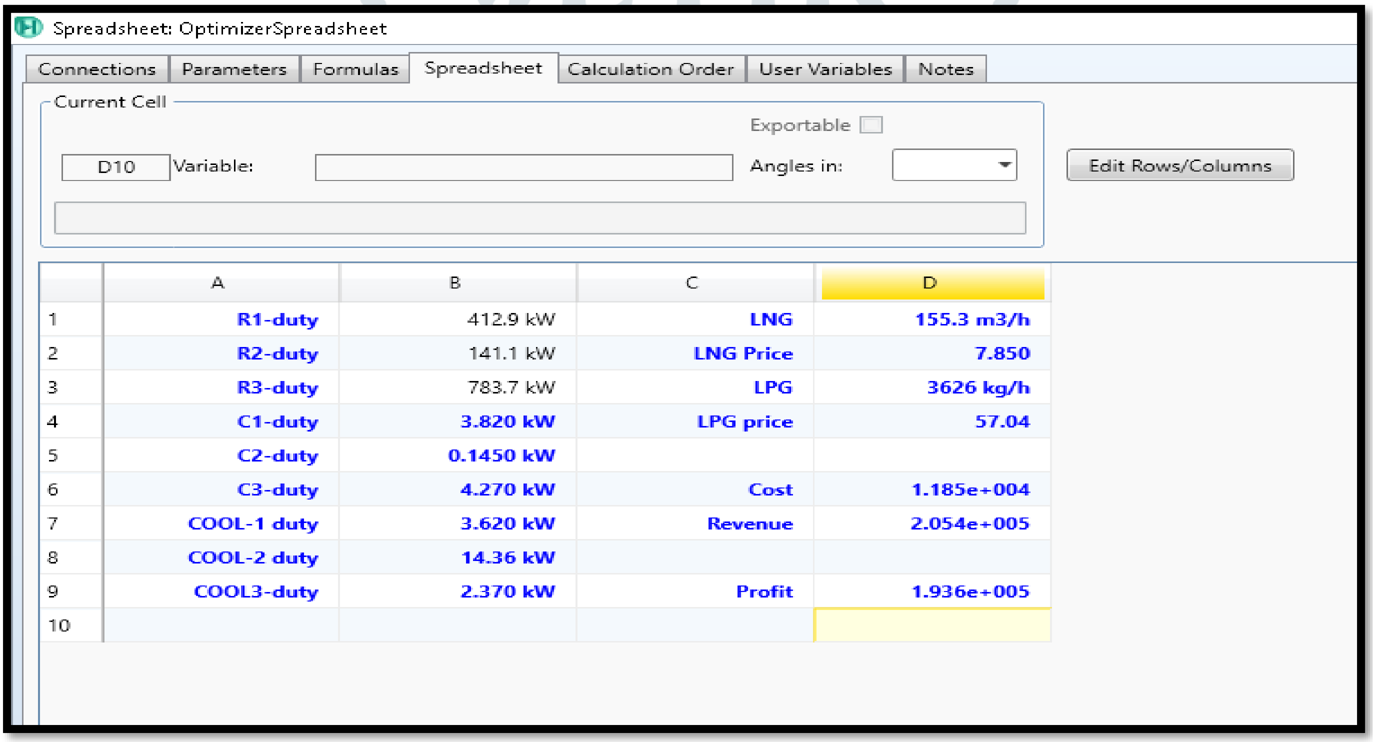
Spreadsheet: OptimizerSpreadsheet

Connections | Parameters | Formulas | Spreadsheet | Calculation Order | User Variables | Notes

Current Cell: D10 Variable: Exportable Angles in: Edit Rows/Columns

	A	B	C	D
1	R1-duty	412.9 kW	LNG	155.3 m3/h
2	R2-duty	141.1 kW	LNG Price	7.850
3	R3-duty	783.7 kW	LPG	3626 kg/h
4	C1-duty	3.820 kW	LPG price	57.04
5	C2-duty	0.1450 kW		
6	C3-duty	4.270 kW	Cost	1.185e+004
7	COOL-1 duty	3.620 kW	Revenue	2.054e+005
8	COOL-2 duty	14.36 kW		
9	COOL3-duty	2.370 kW	Profit	1.936e+005
10				

Fig-1: Values before optimization



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8	COOL-2 duty	14.36 kW		
9	COOL3-duty	2.370 kW	Profit	1.936e+005
10				

Fig-2: Values after optimization

Table-1: Market Value of Products and utilities [6]

Product/ utility	Price (INR)
LNG	7.85/m^3
LPG	57.04/kg
Heating/Cooling duty	8.577/ kW.h

V. Results and Discussions

1. After the simulation, the LPG obtained had the composition of 35.4% propane, whereas after the optimization the composition has marginally increased to 36.4%.
2. After the simulation, the LNG obtained had the composition of 91.3% propane, whereas after the optimization the composition has marginally increased to 92.3%.
3. After the simulation, the flowrate of LPG is 155.3 m^3/ h, whereas after optimization the flowrate of LPG is 156.3 m^3/h.
4. After the simulation, the flowrate of LNG is 3626 kg / h, whereas after optimization the flowrate of LNG is 3954 kg/h.
5. The Total cost of the process before Optimization was INR 11,848.56, whereas after Optimization it is INR 12,064.23.

6. The Revenue generated before Optimization was INR 2,05,407.53, whereas after Optimization it is INR 2,25,556.69.
7. The Profit generated before Optimization was INR 1,93,599.97, whereas after Optimization it is INR 2,14,719.80.
8. Fig-2 and Fig-3 shows the spreadsheets before and after optimization of the process.
9. After Optimization, both the flowrates of LPG and LNG are increased, theoretical increase of Revenue and profit is at 9.8% and 10% respectively.
10. The following tables show the composition of the products before and after optimization:

Tables/Figures:

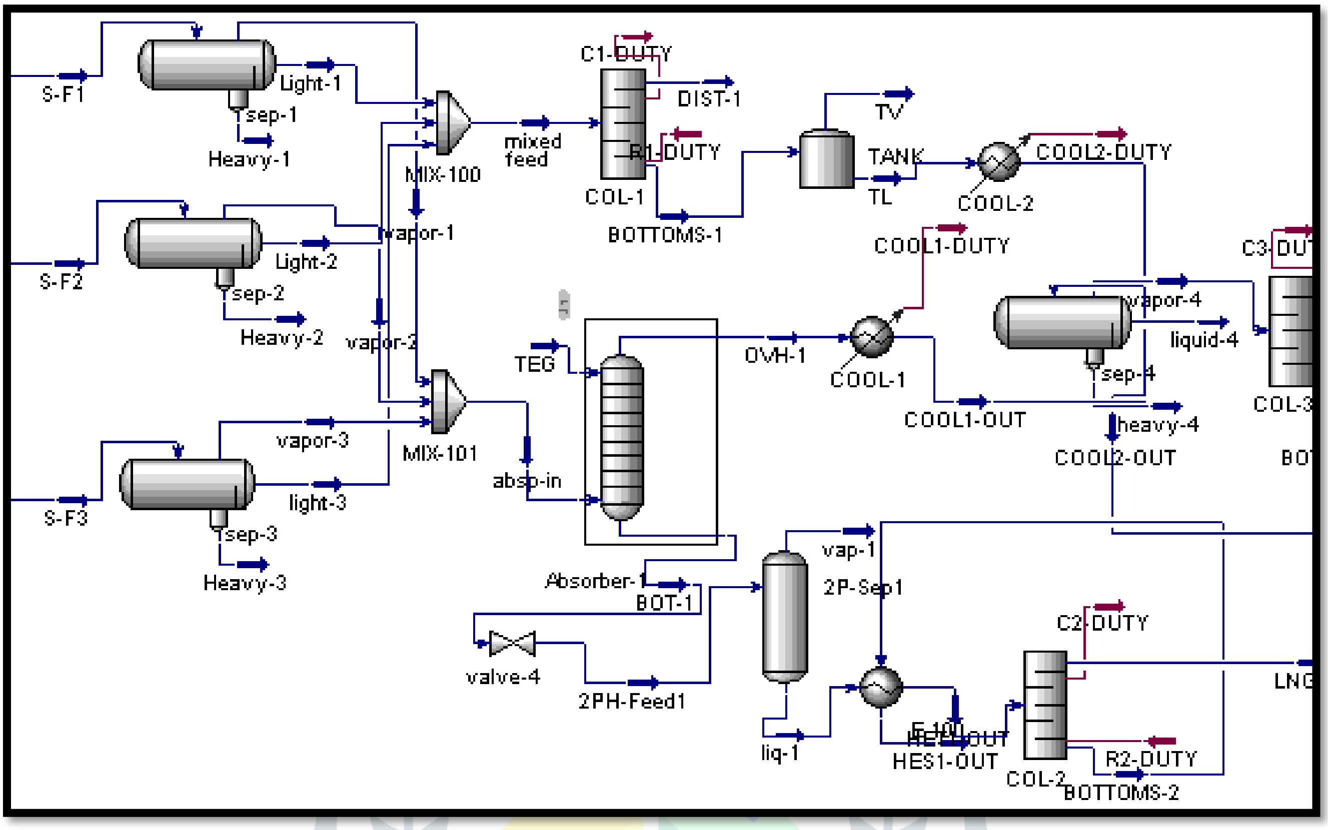

Fig-3: Part of the simulation flowsheet

Table-2: LPG Composition before Optimization

Components	Composition
Propane	0.354
i-Butane	0.194
n-Pentane	0.154

Table-3: LPG Composition after Optimization

Components	Composition
Propane	0.354
i-Butane	0.182
n-Pentane	0.106

Table-4: LNG Composition before optimization

Components	Composition
Methane	0.9130
Nitrogen	0.0827
Water	0.0123

Table-5: LNG composition after optimization

Components	Composition
Methane	0.9130
Nitrogen	0.0827
Water	0.0123

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. Hence, it is important to develop and optimize the existing process to meet the demand in the market. In the first problem statement after Optimization, both the flowrates of LPG and LNG are increased without much change in the composition, theoretical increase of revenue and profit is at 9.8% and 10% respectively.

The processes used in both the problems are derived from earlier processes, but has offered significant changes to the operating costs and investments. Optimization provides a better process with higher benefits.

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