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Optimization of the ABB Randall process of NGL recovery

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Abstract

In the simulated ABB Randall Process before optimisation, it was found that the process initially achieved a yield of 72%, indicating the potential for further improvement and optimization. Replacing J-T valves with an expander, led to a remarkable drop in the DeMethanizer inlet temperature, from -150°C to -274°C, resulting in more efficient recovery of heavier hydrocarbons. This lower temperature was attained through isentropic expansion, with the expander's work driving a compressor to enhance overall plant efficiency. A comparative analysis between the unmodified ABB Randall process and the optimized version demonstrated the clear advantages of the latter. The optimized process exhibited higher annual revenue, increased annual savings, a shorter payback period, reduced energy costs, and a substantial improvement in natural gas liquids (NGL) recovery, with a recovery rate of 96.4%. While the initial capital cost investment for the optimized process was slightly higher, the accrued financial and operational benefits make it a more attractive and cost-effective choice in the long run.

Keywords: ABB Randall Process; Optimization; Simulated Model; Natural Gas Liquids (NGL) Efficiency

1. Introduction

The amount of research that are being done on primary energy alternatives has increased with the growing need for energy throughout the globe. Natural gas is the obvious victor when compared to coal and oil due to its extraordinarily clean burning and decreased flue gas emissions [1]. In recent years, there has been a considerable increase in the need for natural gas. According to the projections, there will be an increase at a consistent rate over the following several years. It is anticipated that the use of natural gas will expand at a compound annual growth rate (CAGR) of 1.6 percent between 2015 and 2035, which will be faster than the CAGR of 7 percent that would be achieved by the combined use of coal and oil. It is anticipated that annual compound growth rates (CAGRs) of 0.7 percent and 0.7 percent, respectively, will persist indefinitely for oil prices [2]. In contrast to the raw gas that is found under the earth's crust, which may sometimes include certain components such as heavier hydrocarbons and other impurities, the demand for methane gas is quite high. Natural Gas Liquids are what are left over after the heavier hydrocarbons have been separated out of the natural gas (NGLs). Impurities may include hydrogen sulphide, nitrogen, carbon dioxide, helium, water, and even minute quantities of mercury and arsenic. Impurities may also be present in tiny levels. In order to purge these contaminants, the liquefaction of natural gas necessitates a step that is known as "conditioning." It is common practice to condition natural gas in facilities that are kept completely separate from those used for the processing and extraction of heavier hydrocarbons. After being purified and made ready for distribution, the gas is then let go into the pipelines that run throughout the city. Natural gas liquids (NGLs) are heavier hydrocarbon liquids such as ethane, propane, iso-butane, normal butane, and pentane plus. NGLs are also known as natural gas condensates [3].

Natural gas liquids (NGLs) are extracted from a natural gas stream not only to ensure that the gas is suitable for sale and to prevent the formation of a dew point, but also to provide additional revenue to the gas processor. This is because

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NGLs are more valuable when sold individually than when they are left in the natural gas stream. Natural gas liquids are extracted from natural gas streams. The heavier component of NGL 1 is employed as gasoline-blending stock, whilst the lighter fraction, which may contain ethane, propane, and butanes, may be used as feedstock for petrochemical plants [4]. The heavier portion of NGL 1 is comprised of butanes, propane, and ethane. The initial stage in recovering lighter hydrocarbon liquids from natural gas streams is controlling the dew point at which the streams are being produced. The volume of liquid that has to be recovered has a considerable bearing on the levels of complexity, process selection, and processing facility cost. Gas composition often has a significant bearing on the economics of natural gas liquids (NGLs) recovery as well as the process options that might be made. When there are more liquefiable hydrocarbons in the gas source, there will be more products, and when there are more products, the gas processor will make more money. NGL recovery may be accomplished by a variety of methods; however, the following are the most crucial: [5].

- Cooling process
- Joule-Thompson expansion
- Refrigeration
- Turbo- Expander
- Absorption by lean oil
- Adsorption by solid bed
- Membrane Separation
- Twister Supersonic Separation

After purification units, hydrocarbon recovery units are the next bare minimum in a gas processing plant. Many new NGL facilities are being built all over the globe to meet the soaring demand for ethane used in the petrochemical industry and in the fluid, mixing required for the increased process of recovering oil. The rising price of energy sources and other economic stresses have increased the significance and need of cryogenic NGL extraction facilities [6].

In state-of-the-art hydrocarbon recovery equipment, refrigeration is employed as a tried-and-true standard approach. The supply gas may be cooled in one of three ways: by absorption refrigeration, expansion through a Joule-Thompson valve, or a combination of the two. We design the mixed refrigerants and expander technique to achieve lower cooling temperatures. The performance of a process is heavily impacted by factors such as its setup and operating conditions. DeMethanizer top product is often used to chill the treated natural gas in the NGL plant's numerous heat exchangers. Reflux of the cool liquid into the column aids in the separation of heavier hydrocarbon components [7]. Separating NGL from light hydrocarbon gases like ethane allows for their subsequent cracking in a continuous stream to create ethylene [8][9].

2. Materials and methods

2.1. Modelling Procedure for the NGL Plant

The modelling and simulation of the NGL recovery facilities were carried out with the assistance of the ASPEN HYSYS V11 software. To build up the model, the Peng-Robinson Fluid package (thermodynamic equation) was used.

2.1.1. Unit Operations Used in Hysys

Cooler, Chiller, Separators, Column absorber, Heat Exchanger, Compressor, Mixer, Pump, Expander, Recycle and Splitter.

2.1.2. Component needed

Methane, Ethane, Propane, i-Butane, n-Butane, i-Pentane, n-Pentane, n-Hexane, n-Heptane, and Nitrogen.

2.1.3. Feed Condition

The feed selection for simulating this NGL recovery plant was based on the same type of feed utilized by an NLNG company located in Nigeria. The composition and operating conditions of the natural gas feed are provided in Table 1. It was assumed that the gas did not contain any water or acid gases. In other words, the gas used for the simulation was assumed to be devoid of water and acid gases.

Table 1 Inlet conditions of the feed used in modeling the NGL plants [1]

Parameter	**ABB Randall(Jiang & Zhang, 2019)**
Temperature	90 °F
Pressure	4226 Kpa
Molar Flow	2229 Kgmole/h

Table 2 Composition of the feed used in modelling the NGL recovery plants [1].

Component	**Mole fraction**
N_2	0.0012
CH_4	0.8606
C_2H_6	0.0640
C_3H_8	0.0425
i- C_4H_{10}	0.0118
n- C_4H_{10}	0.0117
i- C_5H_{12}	0.0031
n- C_5H_{12}	0.0030
n- C_6H_{14}	0.0013
n- C_6H_{14}	0.0009

Table 3 Typical LNG Product Specification

Component	**Limit (Maximum)**
H_2S	3 – 4 ppmv
Total Sulphur	30 milligrams per normal cubic metre
CO_2	50 – 100 ppmv, 2 -3 mol %
Hg	0.01 micrograms per standard cubic metre
N_2	1 mol %
H_2O	1 ppmv
C_6H_6	1 ppmv
C_2H_6	6 – 8 mol %
C_3H_8	3 mol %
C_4H_{10} and heavier	2 mol %
C_5H_{12} and heavier	1 mol %
HHV	1050 Btu/Sef (Europe and USA) > 1100 Btu/Sef (East Asia)

2.2. Process Description of Simulated Model

2.2.1. ABB Randall Process

The LNG heat exchanger LNG-100 lowers the temperature of the gas to -60 degrees Fahrenheit when it is subjected to a pressure of 4226 kPa and a temperature of 90 degrees Fahrenheit. Before being fed into the absorber column T-100, the condensed liquid that had been produced by the separator V-100 was cooled to -130 degrees Fahrenheit in the J-T valve VLV-100. The NGL is generated at the bottom of the absorber column, while the gas from the absorber column above is heated by the input gas in an LNG heat exchanger (LNG-100), compressed to 51 degrees Fahrenheit by K-102, and then recompressed to 90 degrees Fahrenheit by K-103. The exit streams are then divided in half by a splitter; one part of it is evacuated as leftover gas, while the other is recycled back to the absorber column T-100 via RYC-1 and a Chiller, and the temperature is lowered to -120°F and -150°F, respectively, as shown in Figure 1:

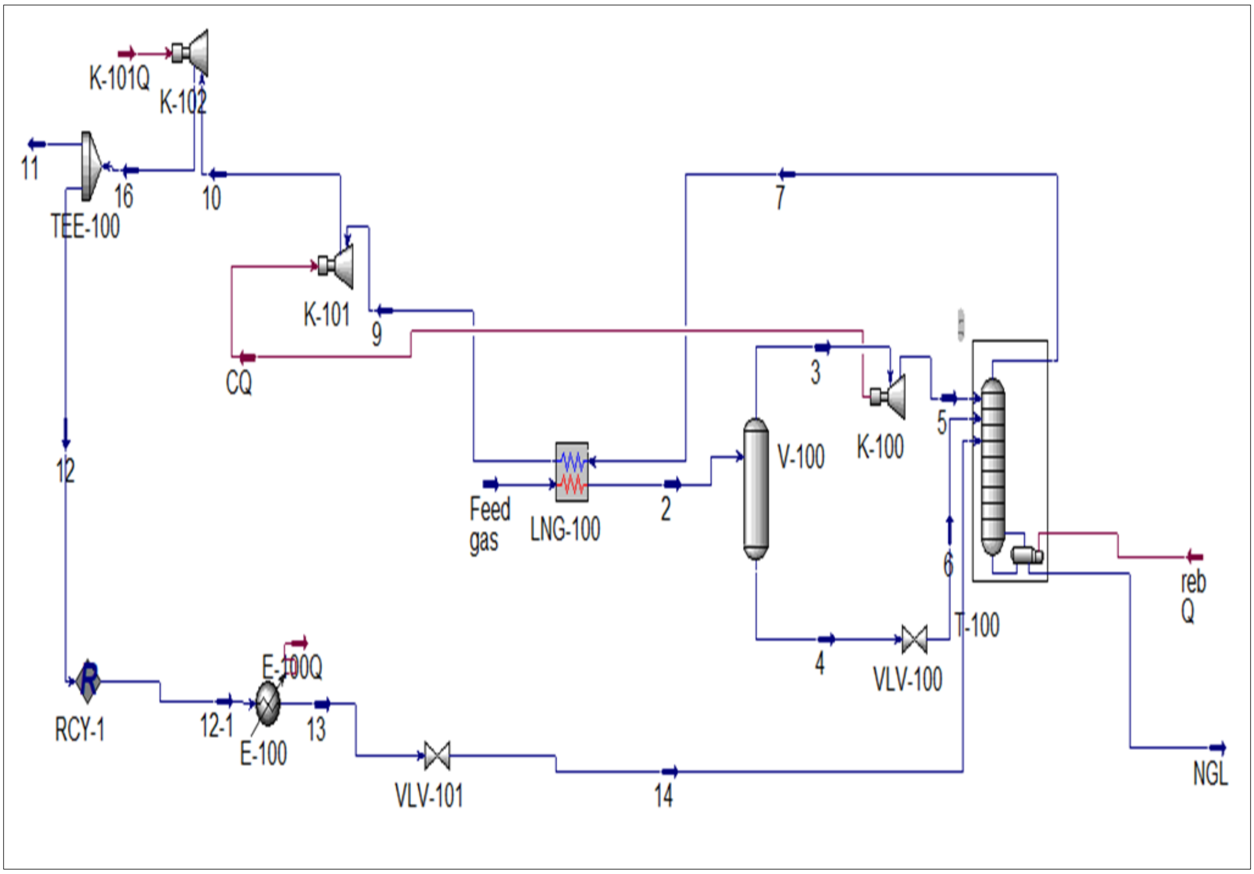

Figure 1 Simulated flowsheet for NGL recovery

2.3. Percentage yield of NGL (%NGL)

$$\%NGL = \frac{mass\ flow\ of\ NGL\ in\ the\ bottom\ product}{mass\ flow\ of\ C2{+}in\ the\ feed} \times 100 \qquad (1)$$

3. Results and Discussion

3.1. NGL Recovery

3.1.1. ABB Randall Process (Simulated 2023) - 72% yield

This result indicates that the ABB Randall Process achieved a yield of 72% in the simulation conducted. It shows further improvement or optimization is needed.

Table 4 Table of Results

Column overload	**NLNG FEED GAS**	**Component**	**% of NGL recovered**
Nitrogen	0.0013	Other Component	72%
CO2	0.0000		
Methane	0.9409	Methane	
Ethane	0.0554	NGL	
Propane	0.0024		
i-Butane	0.0001		
n-Butane	0.0000		
i-Pentane	0.0000		
n-Pentane	0.0000		
n-Hexane	0.0000		
n-Hepane	0.0000		
n-Octane	0.0000		
COLUMN BOTTOMS	**NLNG FEED GAS**	**Component**	
Nitrogen	0.0000	Other Components	
CO2	0.0000		
Methane	0.0000	Methane	
Ethane	0.1565	NGL	
Propane	0.4722		
i-Butane	0.1371		
n-Butane	0.1371		
i-Pentane	0.0360		
n-Pentane	0.0347		
n-Hexane	0.0154		
n-Hepane	0.0110		
n-Octane	0.0000		

3.2. Optimised ABB-Randall Process

Process optimization of ABB Randall process was carried out by replacing a J-T valves by an expander which further dropped the DeMethanizer inlet temperature from -150 ^{o}C to -274 ^{o}C which in deep recovery of heavier hydrocarbon. A lower temperature is achieved in isentropic expansion since an expander utilizes its work to drive a compressor which helps to increase the overall efficiency of the plant.

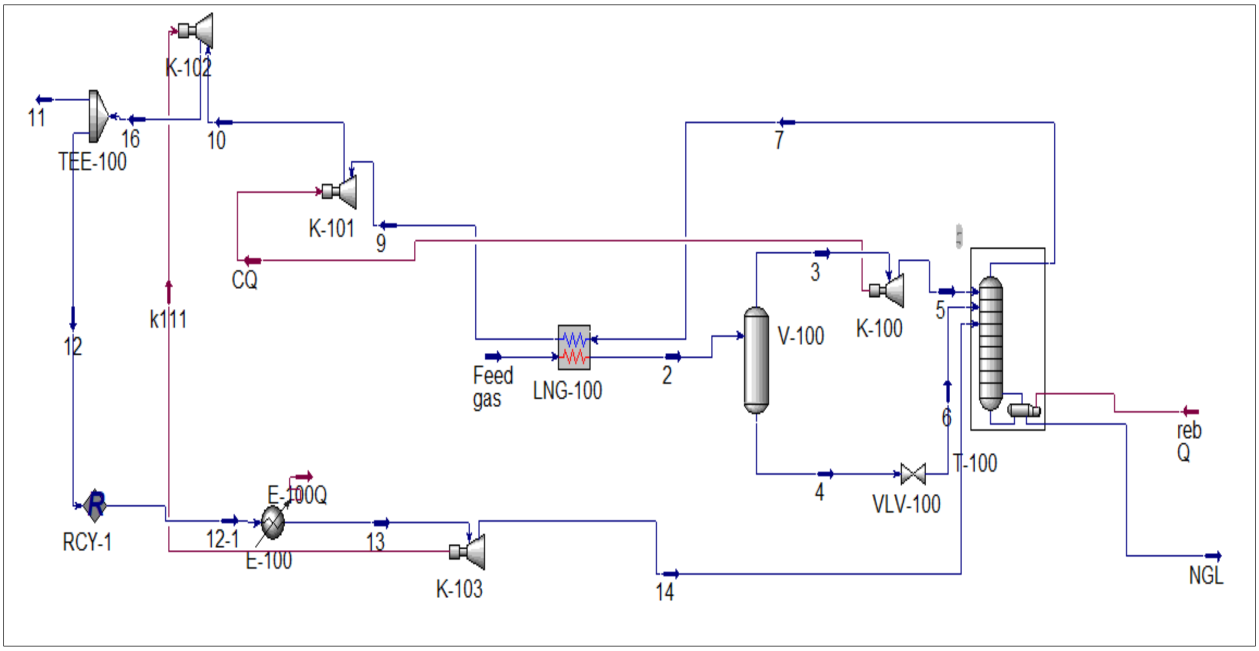

Figure 2 Process flow sheet for Optimized ABB Randall process

Table 5 Comparison between ABB Randall Process and Modified ABB Randall Process

Tools for comparison	**ABB RANDALL (UNMODIFIED)**	**OPTIMIZED ABB RANDALL PROCESS**
Capital cost investment (MM)	$ 221.75	$ 227.97
Revenue/Year (MM)	$ 74.77	$ 90.41
Annual Savings (MM)	$ 53.60	$ 68.24
Payback period (years)	4.2	3.9
Energy cost/year (MM)	6.01	4.68
% NGL recovery	72%	96.4%

The comparison between the unmodified ABB Randall process and the optimized ABB Randall process reveals that the optimized process has several advantages, including higher annual revenue, increased annual savings, a shorter payback period, reduced energy costs, and significantly improved natural gas liquids (NGL) recovery. Although the initial capital cost investment is slightly higher for the optimized process, the overall financial and operational benefits make it a more attractive and cost-effective choice.

4. Conclusion

In the end, the simulation of the ABB Randall Process showed a yield of 72%, which means there is still room for improvement and optimization. As part of the process optimization, J-T valves were swapped out for an expander. This caused the inlet temperature of the DeMethanizer to drop from -150°C to -274°C, which made it much easier to recover heavier hydrocarbons. This lower temperature, which is reached through isentropic expansion, not only helps the plant recover more deeply, but it also makes it more efficient by using the work of the expander to power a compressor.

When the unaltered ABB Randall process was compared to the optimized version, many benefits were found. These benefits include more money coming in every year, more money saved every year, less energy use, and a much better ability to recover natural gas liquids (NGL). Even though the optimized process may require a slightly higher initial capital cost, it will save you a lot of money and time in the long run thanks to its many financial and operational benefits. This optimization shows how important it is for process engineers to keep improving and coming up with new ideas in order to find better, more cost-effective solutions for industrial processes that are always changing.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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