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ENERGY IMPROVEMENT FOR NGLS DIRECT INDIRECT SEQUENCE FRACTIONATION UNIT

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ABSTRACT

The objective of this paper is to present the study and analysis of the energy saving improvement for the natural gas liquids (NGLs) direct-indirect sequence fractionation unit by using driving force method. To perform the study and analysis, the energy efficient NGLs fractionation sequence methodology has been developed. Accordingly, the methodology consists of four hierarchical steps; Step 1: Existing Sequence Energy Analysis, Step 2: Optimal Sequence Determination, Step 3: Optimal Sequence Energy Analysis, and Step 4: Energy Comparison. The capability of this methodology is tested in designing energy efficient distillation column sequence for NGLs fractionation process, which consists of nine compounds (methane, ethane, propane, i-butane, n-butane, i-pentane, n-pentane, n-hexane, n-heptane) with eight direct-indirect sequence of distillation columns. The results show that the maximum of 6.44 % energy reduction is able to achieve using sequence changes suggested by the driving force method. It can be concluded that, the sequence determined by the driving force method is able to reduce energy used for NGLs fractionation process. All of this findings show that the methodology is able to design minimum energy distillation column sequence for NGLs fractionation process in an easy, practical and systematic manner.

Key Words: Keywords: Energy Efficient; Distillation Columns Sequence; Driving Force; Natural Gas Liquid.

1. INTRODUCTION

The distillation process is utilized to recover 95 % of all fluid separations in the chemical industry and accounts for 3 % of global energy consumption [1]. While based on Department of Energy United States of America (USA), about more than 40,000 distillation columns in North America and they consume about 40 % of the total energy used to operate plants in the refining and bulk chemical industries [2]. Thus, a major problem with this kind of application is that its large energy consumption will increase the operating cost. This becomes the reason why the plant designer must take the different energy saving solutions into consideration and choose the best distillation columns systems design for the specific separation task.

A large number of researches have been conducted to focus the advantages of a variety of methodologies for determining the best sequence from a given number component feed mixture. These include early methodologies such as the use of heuristics, genetic algorithms, mixed integer nonlinear programming (MINLP) methods and others [3]. Distillation continues to be the most significant separation technique not only for non-ideal mixtures but also for azeotropic mixtures even on the negative side that is quite expensive operation in terms of capital and operating costs [4]. There is lots of a general review of distillation synthesis [5 – 8]. Superstructure optimization [9], graphical method [10], heuristic methods [11] and evolutionary techniques [12] are several approaches to design efficient separation systems.

The heuristic method will help to determine more economical sequences without requires a column design and also cost. There are various reviews of synthesis of distillation sequence by heuristics [13 – 15]. Several steps through heuristics are: (1) Thermally unstable, corrosive or chemically reactive components is removed early in the sequence, (2) Final products is removed one-by-one as distillates (the direct sequence), (3) Sequence separation points to remove, early in the sequence, those components of greatest molar percentage in the feed, (4) Separation points is sequenced in the order of decreasing relative volatility so that the most difficult splits are made in the absence of other components, (5) Separation points is sequenced to leave last those separations that give the highest purity products, (6) Separation points that favor near equimolar amounts of distillate and bottoms in each column is sequenced [16]. Heuristic methods are potentially uncertain or conflicting results may be obtained, thus, it is preferable to employ sequencing methods that rely on column design and, in some cases, cost estimation. In this method, analysis should be done for each columns and possible sequences in order to find the optimal sequence [17].

Due to practical constraints of previous method, optimization methods can be used to find efficient distillation sequence [18 – 19]. In this method, all possible configurations of separation tasks will be embedded through superstructure which is used to extract the desired sequence by a nonlinear programming problem [18]. To produce multicomponent products from a single multicomponent feed through minimum number of columns using a nonsharp separation sequence, a bounding procedure could be used [19]. But the disadvantages of this method are that it requires special mathematical background and computational skills from the user.

The graphical method can be categorized into several categories which are McCabe-Thiele, driving force and pinch technology which can be used to determine the optimal design of distillation columns sequence. To determine the design values of distillation column in a simple technique, the McCabe-Thiele has been proposed [20]. In distillation column, driving force is the difference between composition in vapor phase and liquid phase as a result of difference of properties such as boiling point and vapor pressure [21]. In this method, a pinch technology method is proposed which produces minimum energy usage as part of the energy monitoring [22].

Generally, driving force is applied in multicomponent systems that has varies physical or chemical properties between different phases will existing together. In distillation column, the driving force can be shown by facing distinction in composition of a component i between the vapour and liquid phase due to the difference of properties such as boiling point and vapour pressure of component i and the others. Driving force can be measured by the binary pair of key multi-component mixture or binary mixture. In theoretical, when the driving force near to zero the separation of the key component binary mixture becomes difficult, while, when the driving force near to high peak or maximum value, the separation between two components become more easier. This is because the driving force is inversely proportional to the energy added to the system to create and maintain the two-phase. Through a systematic synthesis of energy integrated distillation column systems, external energy input can be reduced and as a result the heat exchange between the integrated columns is maximized [23].

No previous study has investigated the method to design the optimum distillation column sequences without involving major modification units at the minimum cost. The objective of this paper is to study and analyze the energy saving improvement for natural gas liquids separation processes using the driving force method without having any major modifications to the major separation units. There will be only modifications to the separation sequences based on the driving force results, which will reduce the energy requirement.

2. METHODOLOGY

To perform the study and analysis, the energy efficient NGLs fractionation sequence methodology is developed [24]. In this section, the step-by-step algorithm which consists of four stages for finding the best sequence in distillation columns design briefly mentioned in Figure 1 are discussed in more details.

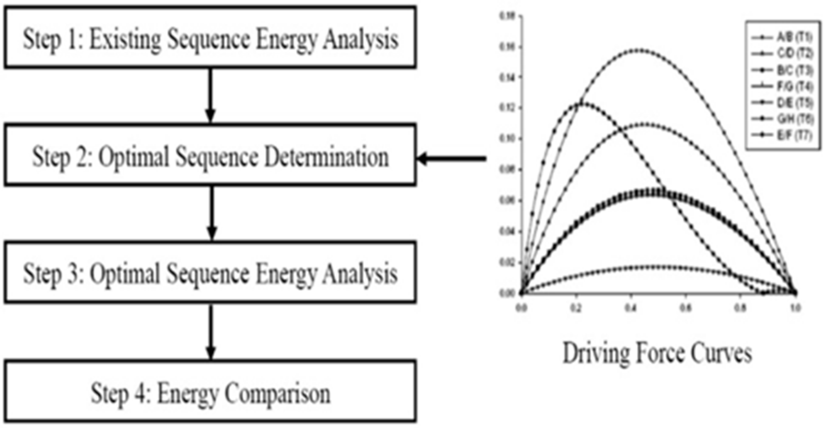

Figure 1: Energy efficient distillation columns sequence methodology [24]

The objective of the NGLs fractionation process is to recover individual fractions of NGLs by using a distillation columns. NGLs normally have significantly greater value as separate marketable products that as part of the natural gas stream. Light NGLs fractions, propane, i-butane and n-butane, can be sold as fuel or feedstock to refineries and petrochemical plants, while the heavier fractions can be used as gasoline-blending stock. The NGLs fractionation process consists of nine compounds (methane, ethane, propane, i-butane, n-butane, i-pentane, n-pentane, n-hexane, n-heptane).

The first step deals with the existing sequence energy analysis, which will become the base sequence used for verification purposes. In this step, the existing sequence for NGLs is simulated and the energy used is analyzed by using a simple and reliable shortcut method distillation column in Aspen HYSYS environment.

Then in the second step, the optimum sequence was determined by using driving force method to improve energy efficiency distillation column. In the third step, the optimum sequence was analyzed in term of energy analysis by using a simple and reliable shortcut method distillation column in Aspen HYSYS environment. Finally, the energy analysis between the existing sequence and the optimum sequence by using driving force method are compared in the fourth step.

According to the driving force method, separation becomes simple and the energy required maintaining the separation is at the minimum when the value of driving force is maximum. Whereas, at the lowest value of the maximum driving force, separation becomes difficult and energy required making the separation feasible is at the maximum [21]. Once the optimal sequence has been determined, the new optimal sequence is then simulated in step three using a simple and reliable short-cut method (using Aspen HYSYS), where the energy used in the optimal sequence is analyzed. Finally, the energy used in the optimal sequence is compared with the base sequence. The capability of this methodology is tested in designing minimum energy distillation column sequence for hydrocarbon mixture separation process, which consists of 9 compounds (methane, ethane, propane, i-butane, n-butane, i-pentane, n-pentane, n-hexane, n-heptane) with eight direct indirect splitter sequence (see Figure 2).

3. DISCUSSIONS

3.1 Existing Sequence Energy Analysis

The feed composition, temperature and pressure are described in Table 1. The purity of the recovery products in NGLs mixture is set to 99.9%. After the sequence has been simulated, the data in terms of utilities (cooling and heating requirements) is extracted. Then, the energy used to recover individual fractions of the NGLs mixtures in the existing sequence is analyzed and taken as a reference that will be used in the next step for comparison purposes. A total of 369.83 MW energy used to achieve 99.9% of product recovery.

Table 1 Feed conditions of the NGLs mixture

Component	Composition	Mass Flow (kg/hr)	Molar flow (kgmol/hr)
Methane	0.5952	47744	2976
Ethane	0.0536	8059	268
Propane	0.0471	10385	235.5
I-Butane	0.0203	5900	101.5
N-Butane	0.0239	6946	119.5
I-Pentane	0.018	6494	90
N-Pentane	0.0161	5808	80.5
Hexane	0.026	11203	130
Heptane	0.1998	100105	999
Total	1	202642	5000
Temperature (^0C) Pressure (Bar)	55.83 31.37		

3.2 Optimal Sequence Determination

A new optimal sequence was determined by driving force method. The binary pairs are methane-ethane, ethane-propane, propane-isobutane, isobutene-butane, butane-isopentane, isopentane-pentane, pentane-hexane, and hexane-heptane, which requires data for Antoine equation. All individual driving force curves was plotted as shown in Figure 3, and the optimal sequence was determined based on the plotted driving force curves. The new optimal sequence based on the driving force method is shown in Figure 4.

The first column should be the one with the largest value of the maximum driving force. Theoretically, the largest value of the maximum driving force means the easiest separation task with the minimum energy requirement. In addition, the lowest value of the maximum driving force means the most difficult separation task with the maximum energy requirement, which should be the last column.

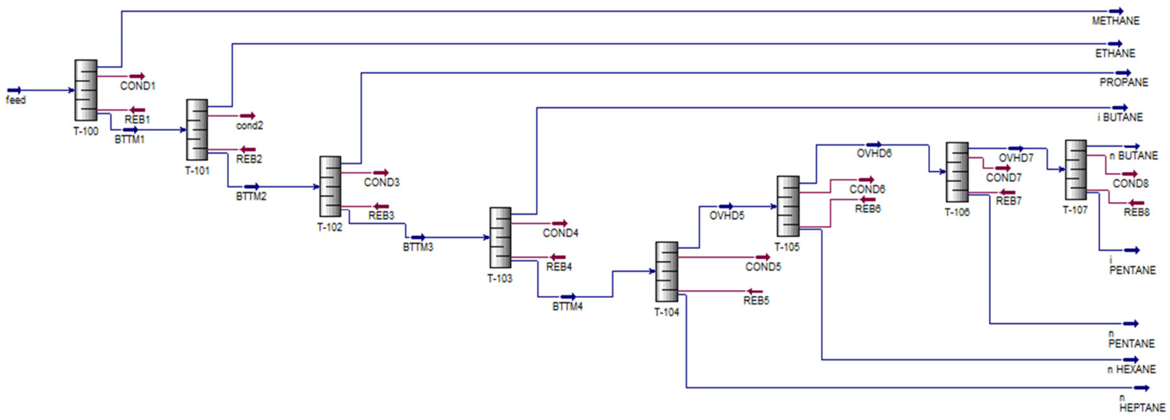

Figure 2: Flow sheet illustrating the existing direct indirect sequence of NGLs fractionation process

3.3 Optimal Sequence Energy Analysis

The objective of this step is to analyze the energy requirement of the optimal NGLs sequence. The feed composition, temperature and pressure are described as same in Table 1 Once the optimal sequence has been determined, the new optimal sequence is then simulated in this step using a simple and reliable short-cut method (using Aspen HYSYS), where the energy used in the optimal sequence is analyzed (see Figure 4) where a total of 346.02 MW of energy was used of the same product recovery.

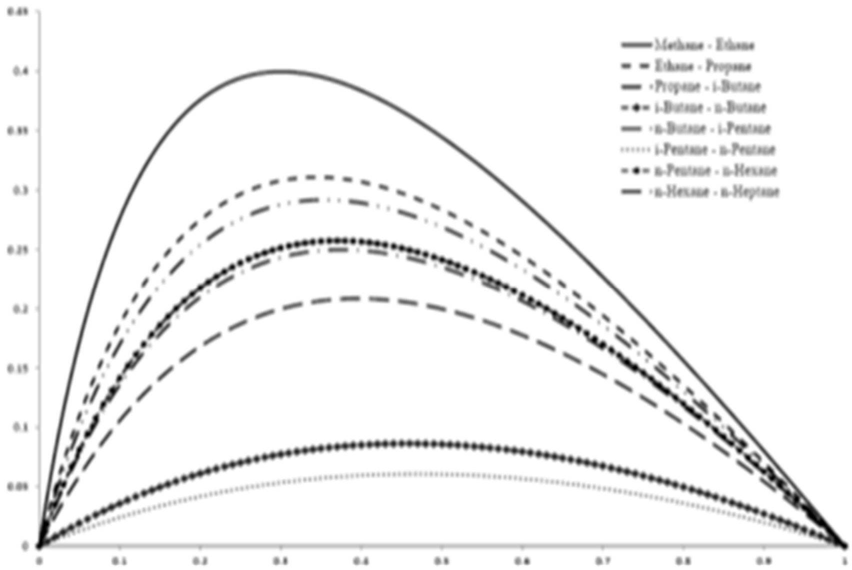

Figure 3: Driving force curve for set of binary component at uniform pressure

3.4 Energy Comparison

Total energy used to recover every single NGLs fraction for the existing and the new optimal sequences are shown in Table 2. The results show that the maximum of 6.44 % energy reduction was able to achieve by changing the sequence suggested by the driving force method.

Table 2: Energy Comparison between Direct-Indirect sequence and Driving Force sequence for NGLs fractionation process

Distillation Column Unit	Direct Indirect Sequence (MW)	Driving Force Sequence (MW)	Percentage Difference (%)
Total Condenser Duty (MW)	178.00	170.38	4.23
Total Reboiler Duty (MW)	191.83	175.64	8.44
Total Energy (MW)	369.83	346.02	6.44

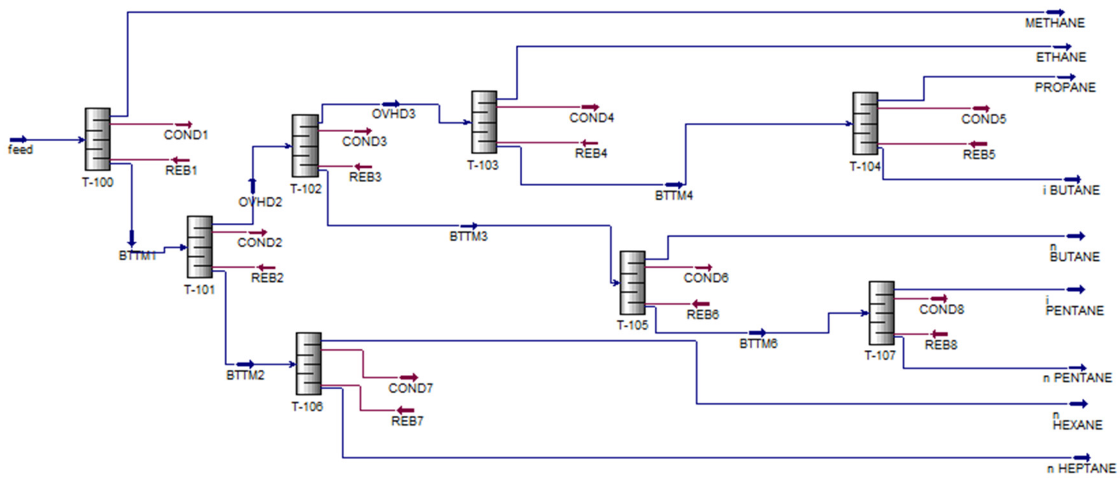

Figure 4: Simplified flow sheet illustrating the optimal driving force sequence of NGLs separation process

4. CONCLUSION

Distillation columns are the primary separation process widely used in the industrial natural gas processing. Although, it has many advantages, the main drawback is its large energy requirement, which can significantly influence the overall plant profitability. However, the large energy requirement of these processes can be greatly reduced by changing the sequence of the distillations columns. All of this findings show that the methodology is able to design energy efficient splitters for NGLs fractionation sequence in an easy, practical and systematic manner. The results (see Table 1) show that the maximum of 6.44 **%** energy reduction was able to achieve by changing the sequence suggested by the driving force method.

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