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Energy Saving in Distillation with Side-stripper and Side-rectifier Sequence of Natural Gas Liquid Processing

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Abstract: Distillation process is one of the common separation methods typically for three or more components despite involving energy intensive procedures. In natural gas liquid processing, propane and butane are the most expensive and widely used products, together with ethane and stabilized condensate are produced through series of conventional distillation columns. This sequence consume massive amount of energy which contribute more than 40% of the overall plant energy. Therefore, process modification of conventional distillation sequence can lead to reduce energy consumption thus minimizing annual operating cost. A strategy in this work is focusing in promoting energy efficient design through adaptation of complex column to existing columns by introducing side-stripper and side-rectifier schemes. A steady state approach using Aspen Plus HYSYS comparing between conventional and two complex columns scheme (side-stripper and side-rectifier) and energy analysis resulting favourable result which offers energy reduction for both side-stripper and side-rectifier sequences. Side-stripper gives higher percentage compared to side-rectifier which is 68% (for reboiler) and 70% (for condenser). Side-rectifier shows reduction of 55% (for reboiler) and 60% (for condenser). Both sequences give promising result to introduce energy saving by complex columns design replacing conventional sequence in future.

Key words: Distillation, natural gas liquid processing, energy

INTRODUCTION

In this 21st century, the rate of energy demand around the globe kept increasing day by day. It is related to the growth of human population and living standard improvement with the introduction of technology nowadays (Holtberg *et al.*, 2010). As the energy usage ascends, oil and gas companies had taken measures into several alternatives to meet customers' demand at the same time earn great return (Click *et al.*, 2013). One of the intense focuses is to reduce operating cost and improve reliability. In Natural Gas Liquids (NGL) processing plant, it consist four to five distillation columns which known as fractionation process to recover number of types of products. Distillation is listed as one of the most energy extensive process where it represent more than 40% of total plant energy consumption (Khan, 2006).

Conventional distillation columns used in NGL processing obtain one product in each column, therefore, number of columns required to produce each pure component is equal to the number of components minus one (Dejanovic *et al.*, 2010). Primarily methane is separated in the form of gas while ethane, propane and butane are liquified as NGL; whereas condensates are liquids at room temperature and pressure. These valuable gases have their own particular use as fuel or feedstock (PETRONAS, 2011). Due to numbers of distillation columns used to product recovery, separation processes are pointed to have massive energy consumption compared to other units.

In order to reduce operating cost is through improvement of energy efficiency of the distillation process. Considerable research interests had been developed into this subject (Blancarte-Palacios *et al.*, 2003; Emtir and Etoumi, 2008; Long *et al.*, 2011) such as adjustment of the internal column structures (type of trays and sizing) and changing the operating conditions (feed conditions, operating pressure and temperature). Other than that, to achieve energy efficient as well as reduction in cost, the adoption of integrated sequence known as complex column had been introduce to substitute the old fashion conventional columns.

Complex column structures involves either partially or fully thermally coupled sequence (Malinen and Tanskanen, 2007). This integrated design includes side-stripper and side-rectifier which been widely use in

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oil refining process in crude distillation column (Jones and Pujado, 2006). Previous research showed that those concepts attain reduced energy usage and wise operating cost compare to conventional column (Dejanovic *et al*., 2010; Bandyopadhyay, 2007).

This study presents a simulated conventional column, side-stripper and side-rectifier arrangement using Aspen Plus HYSYS software. It focused on energy reduction from the separation of valuable gas of NGL; ethane, propane butane and stabilized condensate in steady state. Energy analysis conducted and discussed based on amount of energy usage of conventional and both complex column arrangement (side-stripper and side-rectifier).

PROCESS MODELLING

Conventional columns (Base case): The traditional arrangement of columns involves in NGL product recovery consists of four distillation columns; deethanizer, depropanizer, condensate column. Each column's name indicates the product outcome of the column. The sequence of these columns are illustrated in Fig. 1 which 'a' designate as ethane, 'b' as propane, 'c' as butane, 'd' as condensate and 'e' as C5+(pentane to decane). This column sequence assembled of direct and indirect sequence.

The impurities and acid gas in this pipeline had been eliminated in previous processes before entering the distillation columns. Molar flowrate for deethanizer and condensate column are 3800 and 370 kg mol h^{-1}, respectively, based on actual plant operating condition. Table 1 shows each column operating temperatures and pressure used in Aspen Plus.

The simulation must comply with the product specifications shown in Table 2.

COMPLEX COLUMNS

Side stripper: Side-stripper arrangement consists of three main columns as illustrated in Fig. 2. The first two columns are the same configuration from conventional column arrangement where condensate column and deethanizer column being used to separate stabilized condensate and ethane.

Table 1: Operating conditions for conventional distillation columns

Column	Operating temperature (°C)	Operating pressure (bar abs)
Deethanizer	122	35.0
Condensate column	207	22.0
Depropanizer	101	19.0
Debutanizer	183	17.5

Table 2: Product specification

Products	Specification (allowable range)
Ethane	Methane content: 2.0 mol% max
	Ethane content: 93.0 mol% min
	Propane content: 2.0 mol% max
	CO_2 content: 3.0 mol% max
Propane	Ethane content: 2.0 mol% max
	Propane content: 95.0 mol% min
	Butane content: 4.0 mol% max
	CO_2 content: 3.0 mol% max
Butane	Propane content: 2.0 mol% max
	Butane content: 97.0 mol% min
	isoPentane content: 1.0 mol% max Total Olefins content: 0.1 mol% max
Condensate	Reid vapor pressure: 0.83 bar (abs) max

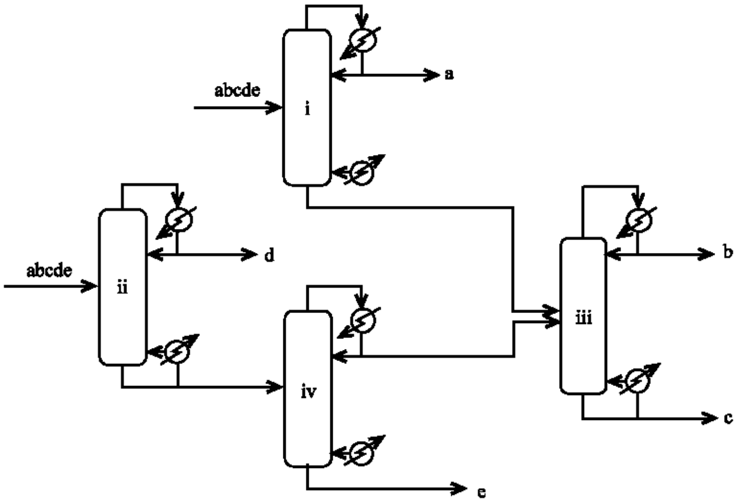

Fig. 1: Conventional distillation columns of NGL processing, (i) Deethanizer, (ii) Condensate Column, (iii) Depropanizer and (iv) Debutanizer

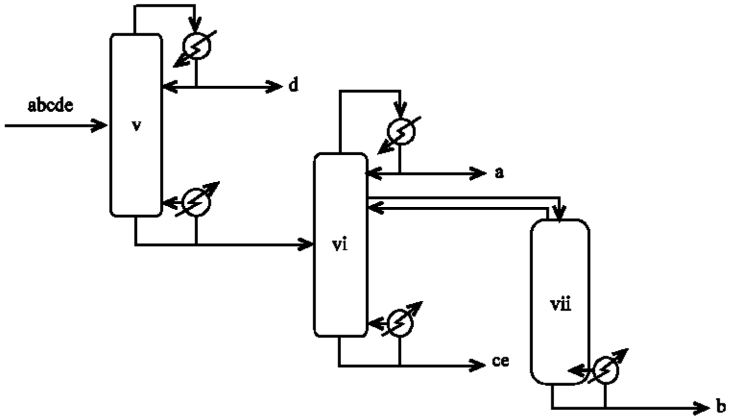

Fig. 2: Side-stripper arrangement; (v) Condensate column, (vi) Deethanizer and (vii) Side-Stripper

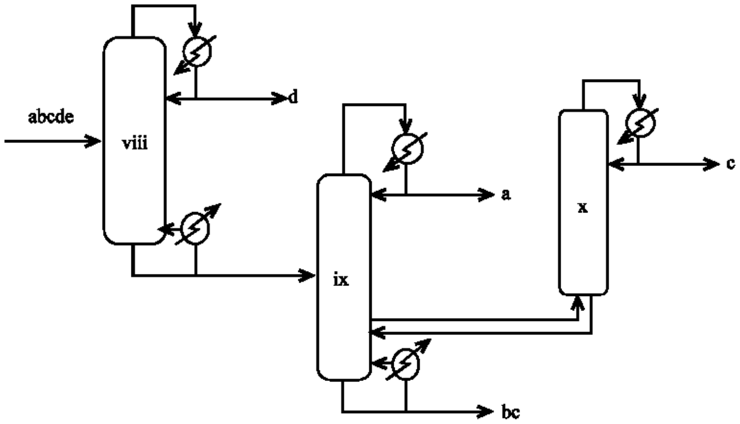

Fig. 3: Side-rectifier arrangement; (viii) Condensate column, (ix) Deethanizer and (x) Side-rectifier

By combining deethanizer and side-stripper, it produced three major products which are ethane, propane and butane. The butane together with C5+ at the bottom of deethanizer will be treated to achieve desired product specification. As for side-stripper, a thermal link connected with deethanizer at the top caused the elimination of condenser. This is an advantage where number of condenser is reduced that will promote less energy usage.

Side-rectifier: On the other hand, side-rectifier is attached with deethanizer and produce butane instead of propane. Propane combined with C5+ will be treated separately according to product specification. The advantage for side-rectifier is the reduction of reboiler at the bottom part by having side-draw from deethanizer to maintain the temperature thus saving up fuel consumption for burning process. Side-rectifier sequence as simulated in Aspen Plus is illustrated in Fig. 3.

RESULTS AND DISCUSSION

Both conventional and complex columns are simulated using Aspen Plus HYSYS V7.2 software. The condenser and reboiler duties for all models are calculated and compared by Microsoft Office Excel as shown in Fig. 4a, b and 5a, b.

Figure 4a shows the usage of two instead of four condensers are the big advantage for side-stripper to gain less cooling duty compare to conventional. Reduction of one reboiler also gives significant effect to the heating duty. Inversely for side-rectifier, only two reboilers used contribute to heating duty savings.

Based on Fig. 4a, b, the conventional columns were found to consume higher energy compared to side-stripper for both reboiler and condenser duty. The same trend goes to conventional vs. side-rectifier. The energy saving potential based on percentage difference is shown in Table 3.

Thermal links existed at both side-stripper and side-rectifier creates a heat transfer with deethanizer

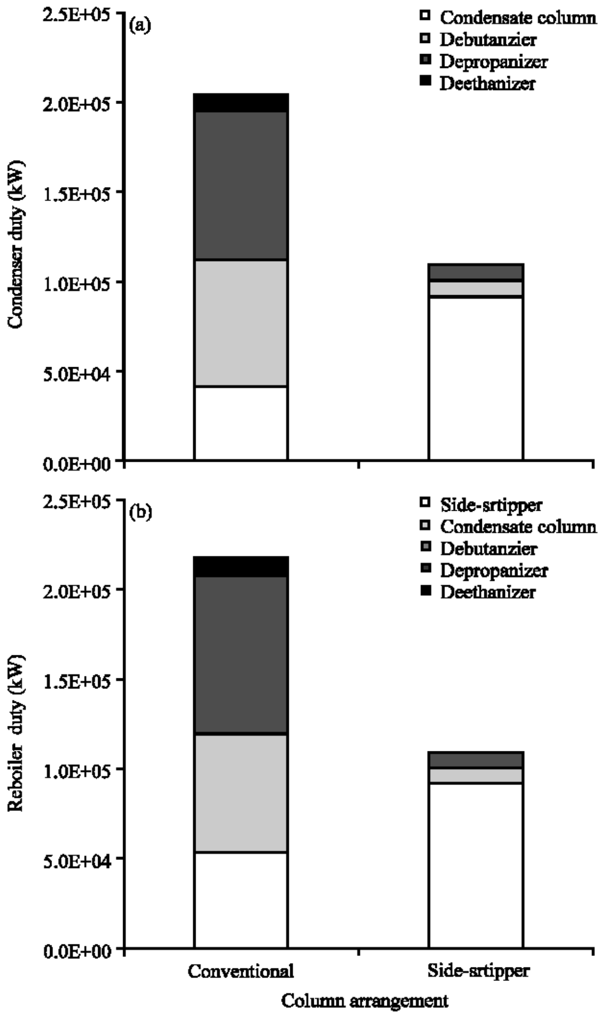

Fig. 4(a-b): Conventional vs. Side-stripper: (a) Condenser duty (b) Reboiler duty

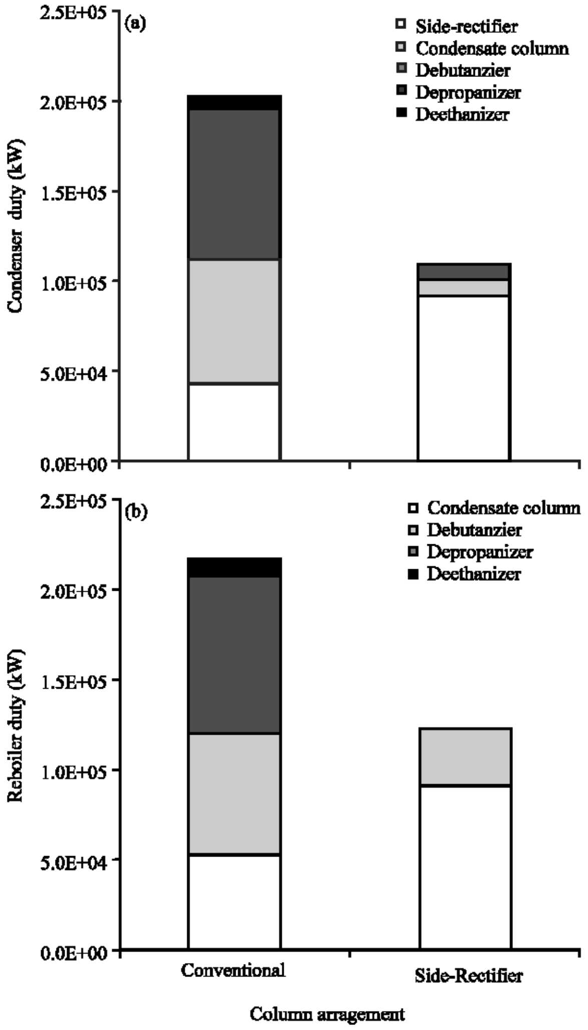

Fig. 5(a-b): Conventional vs. Side-rectifier: (a) Condenser duty (b) Reboiler duty

Table 3: Energy saving potential for conventional vs. complex columns

Duty savings	Conventional	Side-stripper	Side-rectifier
Heating	Base case	67.7	55.0
Cooling	Base case	70.0	59.5

which helps to maintain the top (for side-stripper) and bottom (for side-rectifier) temperature by elimination of condenser and reboiler. Because of this the utility cut is significant due to equipment reduction. Side-stripper gives higher values of saving compare to side-rectifier is the influence of the side-draw stage temperature and pressure from deethanizer which is close to top temperature of side-stripper that optimize the production of propane. The results are quite significant might due to steady-state processes where many variables remain constant.

From the results obtained in Table 3, both complex column arrangement promotes a reduction in utilities usage that may lead to cost saving. The application of side-stipper and side-rectifier is well known in crude oil processing where the existence of these systems saves up to 40% of energy by retrofitting of existing distillation columns (Alhammadi, 2008). Therefore the introduction of these system to NGL processing will lead to a future energy saving. Extra modification that can be enhanced together with these complex columns arrangement is feed preheat system. More precise results can be obtained by using dynamic mode of operation that requires extra data and constant from processing plant to be developed. The drawback of complex columns implementation is a rising concern of process control systems for these systems (Dejanovic *et al*., 2010).

CONCLUSION

The study shows complex column arrangement benefits the conventional columns in term of hot and cold utility saving which also promotes a promising reduction of capital and utility investment due to reduction of number of equipment and energy usage. Further implementation of complex column in existing distillation columns leads to a more sustainable processes by introduction of lower energy usage.

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