Cost Estimation and Optimization of the Topping Unit Products in Khangiran Gas Refinery in the Steady State Condition

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ABSTRACT: Nowadays, optimization of chemical processes is of great importance from both economical and practical point of view. The aim of this research is to optimize the topping unit of Khangiran Gas Refinery using Hysys software. A nonlinear SQP (Sequential Quadratic Program) model has been adopted for the optimization purposes. The objective function of this work is chosen somehow that to maximize the annual income by considering the utility and maintenance cost. Taking into consideration that in the optimization of chemical process, the operating variables should not exceed from the permissible limits and the unit must operate in the steady state condition, one can impose limits on the primary and secondary variables. The primary variable that is used for the optimization in this study is the two feeds to the unit. Furthermore, given that the composition of the two feed differs and the product can be kept constant, we can obtain the optimal values. In addition, we can impose constraint function on the secondary parameters such as minimizing the reboiler heating load and condenser, maximizing the product rate of naphtha with respect to solvent and diesel and keeping it to the minimum with respect to kerosene and at the same time maintaining the overall capacity fixed. The findings of this study reveal that we can make a net profit of about $ 7863626 annually through the selling of the unit products, and raise the annual income by as much as 1.4 percent through the optimization scheme.

KEY WORDS: Optimization, SQP, Kerosene, Naphtha, Topping unit, Hysys software.

INTRODUCTION

Optimization pays an important role in the growing world of competition in the industrial countries. Justifications for the high energy cost, decline in the world raw materials, environmental problems and cost have led the companies to underline on such processes. Gaseous condensate distillation unit is of complex nature which makes the modeling more complicated [1-4]. In order to come up with a proper model and carry out the optimization, it is required first to carry out the simulation and then perform the exact sizing of the whole unit. The gaseous condensate distillation unit is unique in its kind for converting condensate into precious light hydrocarbons products such as solvents, naphtha, kerosene and diesel. Feed of this unit originates from the gas treating units (GTU), gas gathering centre and stabilizer. The categorization adopted for these feeds are based upon their volatility. As a result, the light and heavy feeds are named S-400 and S-500, respectively. This unit is comprised of a distillation unit of two different diameters, thirty one trays, a condenser, two side strippers and a reboiler. A schematic flow diagram of the unit is shown in Figure 1. In order to make the maximum income and keep the costs to minimum through optimization, we require an objective functions which are described through a correlation and links these parameters. To obtain this objective through handling it with the software, we are required to manipulate the variables and allow some crucial variables to be changed to achieve the require limits. Furthermore, to obtain a better result and to accomplish the required limits for a particular variable, it is essential to apply some constraints to the objective function.

OBJECTIVE FUNCTION

As discussed earlier, for the optimization purposes we need an objective function, which in this case is to maximize the profit and keep the costs to the minimum [5]. The objective function in the Hysys software is defined as follows:

$$\Phi = \Psi_1 - \Psi_2 - \Psi_3 - \Psi_4 - \Psi_5 \qquad (1)$$

If we require minimizing the objective function, it is defined as follows:

$$\Phi = -\left(\Psi_1 + \Psi_2 + \Psi_3 + \Psi_4 + \Psi_5\right) \qquad (2)$$

where:

Ψ_1: the profit obtained through selling the products such as solvent, naphtha, kerosene and diesel

Ψ_2: cost of raw materials (i.e., gaseous condensate)

Ψ_3: utility cost (i.e., cooling water and electricity)

Ψ_4: unit fuel cost

Ψ_5: unit maintenance cost

Furthermore, we can other costs such as labor and skilled workers which we was not needed in our case.

Income from selling the products

As mentioned earlier, from the gaseous condensate distillation unit we can obtain products such as solvent, naphtha, kerosene and diesel. If these are produced according to the standards, the profit obtained from selling them directly from the refinery can be expressed as shown in Table 1.

Costs of Raw Materials

Since the feeds to the unit are comprised of 40% of the sweet condensate of S-400 and 60% of sour condensate of S-600, the cost feed can be expressed as shown Table 2.

Utility Charges

The cost of cooling water and electricity charges for the unit is shown in Table 3.

Fuel Costs

The cost of fuel consumption which is mainly used in reboiler is shown in Table 4.

Table 1: Estimation of income from selling the products

Products	Flow rate (ton/hr)	Unit price ($/ton)	Sales profit ($/hr)
Solvent	0.127	360	45.72
Naphtha	1.890	360	680.40
Kerosene	3.360	470	1579.20
Diesel	0.448	430	192.64
			2498

Table 2: Costs of raw materials

Condensate	Cost at refinery ($/kg)	Consumption of the unit (kg/hr)	Total cost ($/hr)
S-400	0.291	2332.132	678.65
S-500	0.2109	3498.198	737.77
		5830.33	1416.42

Table 3: Utility Charges

Utility	Consumption	Unit price	Costs ($/hr)
Cold water	91670.48 (kg/hr)	0.00422 ($/kg)	3.874
Elecricity	372159.58 (Btu/hr)	0.00318 ($/Btu)	4.906
			8.780

Table 4: Fuel Charges

Fuel	Consumption (m^3/hr)	Unit price ($/$m^3$)	Charges ($/hr)
Gas	495	0.1147	56.814

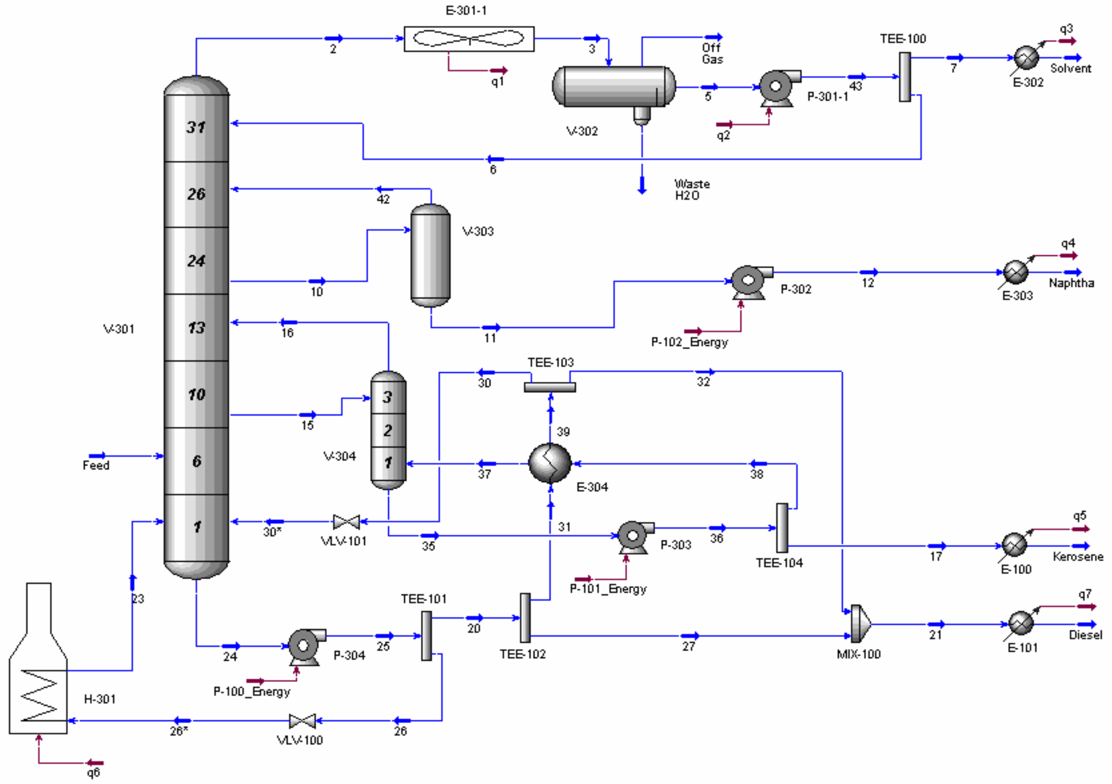

Fig. 2: Schematic flow diagram of the gaseous condensate distillation unit

Unit Maintenance Cost

The schedule maintenance causes the unit work properly during the operation. Approximately 2% of the total fixed capital cost goes towards this operation. The fixed capital cost on itself consists of the expenses of apparatus, insulations and other direct and indirect charges. However, in chemical industries, about 25% of fixed capital cost goes towards purchasing the apparatus. Therefore, as we have not had the purchasing information of the unit, we forced to add up the price of a single unit to come up with the total fixed capital cost.

TOTAL UNIT COSTS

In this unit 4 water coolers, 1 reboiler, 1 distillation tower, 20 pumps, 15 tanks, 1 air cooler, 1 heat exchanger, vessels (i.e., V-301, V-302, V-303 and V-305) and one packed side stripper (i.e., V-304) are employed. The unit prices according to updated Cost Index Chemical Engineering (CE) are shown in table 5. From these tables we can compute the total fixed capital cost as follows:

Fixed capital cost = (2292608.5)/(0.25) = $9170434
Maintenance cost = (0.02)(9170434) = $183408.68
Annual profits for 330 operating days can be computed manually as follows:

Ψ_1 : $19783843.2

Ψ_2 : $11218046.4

Ψ_3 : $69537.6

Ψ_4 : $449966.8

Ψ_5 : $183408.7

Φ: $7863626.5 / year

The result reveals that the annual profits are quite significant compared to direct selling of the condensate.

OPTIMIZATION

To obtain this objective, we first input the data for the all different expenditures and incomes to the software. To obtain the maximum profit, some fundamental variable which plays an important role in obtaining the product were also introduced to the software. Then, we impose some constraints on these variables [6]. To obtain the optimum conditions for both feeds, we adopted the condensate stream rates of S-400 and S-500. The limits specified for these variations are as follows:

$0 \langle \text{Flow } S-400 \langle 3280 \text{ kg/hr}$

$0 \langle \text{Flow } S-500 \langle 3599 \text{ kg/hr}$

These flow rate limits are obtained from the interactions of the unit with the variations on the maximum annual production capacity. To reach the optimum conditions, apart from the primary variables, we can impose some constraint function on the secondary variables as well. The limits imposed on the secondary variables are shown below:

$\text{Flow rate of naphtha} \rangle \text{Flow rate of solvent}$

$\text{Flow rate of naphtha} \rangle \text{Flow rate of diesel}$

$\text{Flow rate of naphtha} \langle \text{Flow rate of kerosene}$

$\text{Furnace heat flow} \langle 1423 \text{ kW}$

$\text{Condenser heat flow} \langle 715.6 \text{ kW}$

$\text{Total flow rate} \leq 5830.33 \text{ kg/hr}$

To obtain the maximum profit, the effective parameters and the method used in this work are shown in Table 6.
A comparative studies between the optimum primary variables which were obtained in this work by solving the objective function and the initial values are made in Table 7.

Table 5: Distillation unit expenditure

Apparatus	Numbers	Costs ($)
H-301-1	1	125500
V-301-1	1	74609.75
V-302-1	1	3976
V-303-1	1	6106
V-304-1	1	16352.45
V-305-1	1	6876
E-301-1	1	4359.55
E-302-1	1	27.81

E-303-1	1	708.99
E-304-1	1	195.955
E-305-1	1	483.32
E-306-1	1	483.32
P-301A/B	2	12424.5
P-302A/B	2	10165.5
P-303A/B	2	10040
P-304A/B	2	15060
P-305A/B	2	18323
P-310A/B/C	3	18448.5
P-311A/B	2	16942
P-312A/B	2	16315
P-313A/B	2	15060
P-314A/B	2	15061
T-301A/B	2	753000
T-302A/B	2	125500
T-303A/B	2	376500
T304A/B	2	527100
T-305A/B	2	122990
		$2292608.5

Table 6: Effective parameters in the optimization method

Data model	Original
Scheme	SQP
Maximum function evaluations	300

Table 7: Comparative studies between the optimum primary variables obtained from this work and the initial values

Operating variables	**Initial values**	**Optimum conditions**
Tower temperature (^{0}C)	68.9	70.2
24th tray temperature (^{0}C)	134	135
10th tray temperature (^{0}C)	209	209
Solvent flow rate (kg/hr)	127	135
Naphtha flow rate (kg/hr)	1890	1850
Kerosene flow rate (kg/hr)	3360	3420
Diesel flow rate (kg/hr)	448	420
S-400 flow rate (kg/hr)	2332	2231.4
S-500 flow rate (kg/hr)	3498	3599
Annual profit	7863626.6	7974838.3

CONCLUSIONS

In this research, the optimum primary variables were by solving the objective function. The result reveals that through selling the gaseous condensate distillation unit products such as solvent, naphtha, kerosene and diesel we can make a net profit of about $7863626 annually. Furthermore, we can also raise the annual income by as much as 1.4 percent through the optimization scheme.

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