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Performance Evaluation of Deethanizer Column Using Real Time Optimization

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***Abstract*— Increasing competition in chemical and petrochemical process industries leads many companies to get more profits in dynamic global market. This leads process industries to optimize their process to adapt with the dynamic global market requirements that can reduce process operating cost. Applying the optimization technology in the process industry can increase competitive profit. This work is to evaluate the performance of deethanizer column with dual reboiler in the ethylene plant PT CAP using RTO in Aspen Plus by modifying operating condition to reduce the energy consumption of the process. The result shows that the heat duty of reboiler EA-401 decreases 12.4% from initial value to 6052 kW and therefore the flow of heating medium, which is hot water decreases from 558300 kg/h to 488600 kg/h. The heat duty of reboiler EA-402 decreases 6% from initial value to 6979 kW and therefore the flow of heating medium, which is low pressure steam decreases from 10935 kg/h to 10298 kg/h.. The top product ethylene slightly increases from 0.827 to 0.829 mole fraction while ethane slightly decreases from 0.159 to 0.158. Stage temperature 10 decreases from 9.2ºC to 4.5ºC. Stage temperature 40 is constant at 57ºC.**

Keywords*— deethanizer column, real time optimization, reboiler duty, simulation

I. Introduction

Real Time Optimization is an effective approach to improve economical aspect of the process and reduce raw materials needed in chemical or petrochemical process industry [1]. Real Time Optimization using an automated system is intended to adjust operating condition of the process based on product scheduling and production control. Thus, one can maximize profit and minimize pollutants emission by adjusting the optimized set point to the distributed control system [2]. This research is to evaluate distillation process of deethanizer column with dual reboiler in ethylene plant PT Chandra Asri Petrochemical (PT CAP) using Real Time Optimization in ASPEN PLUS simulation software by modifying the utility operating condition to minimize the required energy for the process.

Preliminary data was based on PT CAP operating condition. This research began with the steady state calculation and further dynamic process model applied in ASPEN PLUS 7.3. Real Time Optimization cycle by trial and error is carried out to get the optimum set point of the process. Therefore, the energy required is minimized.

II. PROCESS DESCRIPTION

Deethanizer is generally a distillation column to separate ethane and the lighter components from heavier components such as propane, propylene and a small amount of butane. This work uses a configuration where the feed of deethanizer comes from bottom of demethanizer, top product and recycle from knock out drum [3]. Fig. 1 shows the process flow diagram.

The top product of deethanizer is all C2 that flows to acetylene hydrogenation unit, while the bottom product which is heavy fractions of hydrocarbons such as C3s and a small amount of C4 flow to depropanizer column. This deethanizer has two reboilers to separate hydrocarbons into liquid and vapor phases. Two heating medium are used that is hot water and low pressure steam. The bottom tower temperature is kept not too high nor too low. If it is too high then some heavies may be going up to the top column, while if it is too low then some lights may be going down [3].

III. FEED SPECIFICATION OF DEETHANIZER COLUMN

Table I presents the feed specification of deethanizer column [3].

TABLE I. DESIGN DATA FOR DEETHANIZER FROM PT CAP

	Stream 4201
Phase	Liquid
Component	% mole
Methane	0.01
Acethylene	0.89
Ethylene	62.01
Ethane	10.17
Propadiene	0.61
Propylene	15.9
Propane	3.45
Butadiene	2.51
Butylene	2.1
Butene	1.52
$C5^+$	0.6
C6 – C8 non aromatic	0.09
Benzene	0.13
Toluene	0.01

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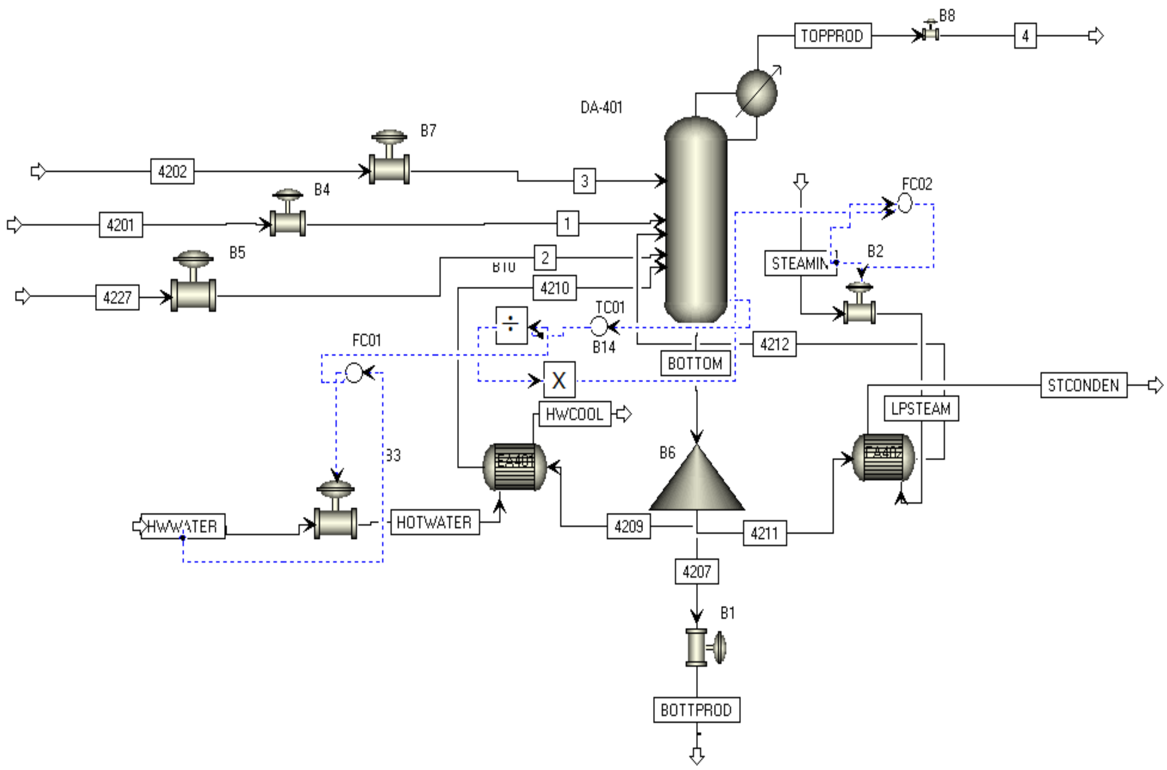

Fig. 1. Process flow diagram of deethanizer using dual reboiler in ASPEN PLUS

IV. RESULTS AND DISCUSSION

Before running in the dynamic mode, a steady state calculation is applied. A design data is provided based on the data given from the plant from PT. CAP as given in Table II [3].

TABLE II. DESIGN DATA FOR DEETHANIZER FROM PT CAP

Variable	Value
Number of trays	70
Column Diameter	2.7 m
Column Height	33.25 m
Tray Spacing	0.450 m to 0.550 m
Type Head	Ellipse
Reflux Drum Diameter	2.1 m
Reflux Drum Length	8.3 m
Feed Tray	16 and 34
Top pressure	21.486 kg/cm^2
Bottom pressure	22.342 kg/cm^2

Using the data in Table I and Table II, one can obtain top temperature and bottom temperatures to be -22.55 °C and 67.45 °C respectively. The reflux ratio is found to be 1.42.

The steady state process model that has been validated is then converted into dynamic mode and therefore subsequently into Real Time Optimization. The objective function is geared to minimize the required energy of the hot water and low pressure steam.

The problem is then formulated as follows [4]:

$$\underset{x}{Minimize} \sum[Q1+Q2] \qquad (1)$$

Subject to $g(x) \geq 0$

$h(x) = 0$

Q1 = Reboiler Duty EA-401 (Hot Water)
Q2 = Reboiler Duty EA-402 (Low Pressure Steam)
g(x) = inequality constraint given in the process
h(x) = equality constraint given in the process

with the constraints shown in Table III:

TABLE III. REAL TIME OPTIMIZATION CONSTRAINTS

Lower Bound		Variable		Upper Bound	Unit
59	<	Stage Temperature 40	<	61	°C
4	<	Stage Temperature 10	<	9	°C
3000	<	Reboiler Duty EA-401	<	6900	Kilo Watt
4000	<	Reboiler Duty EA-402	<	7200	Kilo Watt
0.15	<	Top Product Ethane		-	Kmol/kmol
0.82	<	Top Product Ethylene		-	Kmol/kmol
		Condensor Duty	=	11096.3	Kilo Watt

This optimization process needs 155 hours with 3 hours of computation time in the simulation process after 52 iterations.

Real Time Optimization in ASPEN PLUS uses FEASOPT optimization algorithm (Feasible Path Successive Quadratic Programming). FEASOPT works by detecting the infeasible part of a proccess model and doing change on process operating condition without change or modify the process model [5]. FEASOPT gives new constraints, thus process model reaches the feasibility. Fig. 2 shows the duty optimization result of Reboiler EA-401 and EA-402.

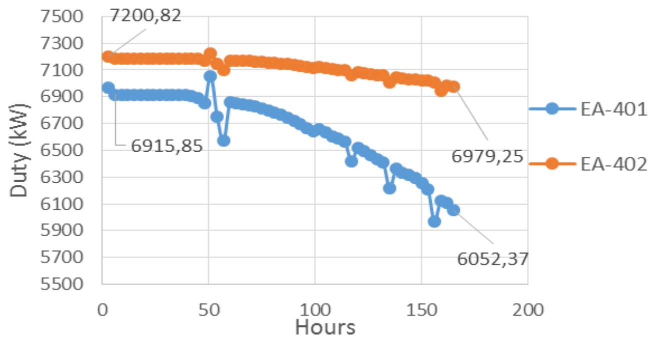

Fig. 2. Reboiler duty optimization graph of deethanizer column

Fig. 2 presents that the duty of Reboiler EA-401 and EA-204 decrease after doing optimization for 155 hours of computation time in ASPEN PLUS. Time for one iteration of optimization is 3 hours of computation time in ASPEN PLUS and the real time is 3-5 minutes.

The duty reduction of Reboiler EA-401 is 12.4% from the initial value 6915 kW to 6052.37 kW, while the duty reduction of Reboiler EA-402 is 6% from the initial value 7200.82 kW to 6979.25 kW. After optimization, the duty saving of Reboiler EA-401 is 826.63 kW while the duty saving of Reboiler EA-402 is 221.57 kW.

The optimization of reboiler duty afffects the operating condition of the deethanizer column. The pressure at top column and bottom column vary due to the reboiler duty changes.

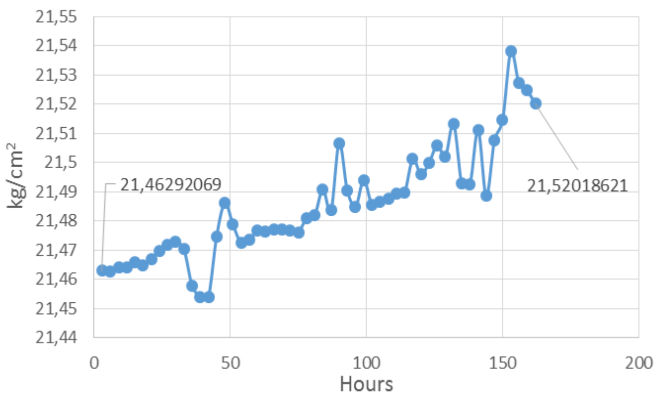

Fig. 3. Pressure change graph of deethanizer top column

Fig. 3 presents the top column pressure change. Although it is small, varying reboiler duty affects the top column pressure. It can be seen in Fig. 3, by decreasing the reboiler duty makes the top column pressure higher. However, since the increasing of top column pressure less than 5% (0.46% increasing) therefore the top column pressure is in safe operating condition [1].

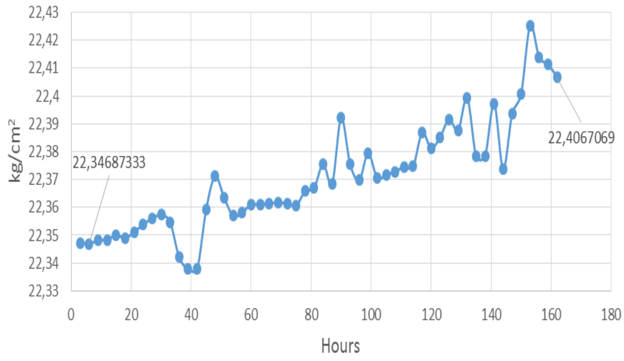

Fig. 4. Pressure change graph of deethanizer bottom column

Fig. 4 shows the bottom column pressure change. As shown in Fig. 4, varying reboiler duty affects the bottom column pressure. The reduction of reboiler duty makes the bottom column pressure higher. However, since it is not significant increasing (0.31% increasing) therefore the bottom column pressure is also in safe operating condition.

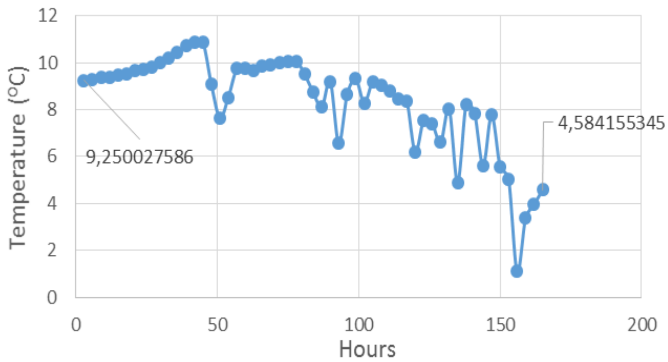

Fig. 5. Temperature change graph of deethanizer column at stage 10

Fig. 5 shows the temperature change at stage 10. It can be seen in Fig. 5 that the temperature at stage 10 decreases from 9.25^{O}C to 4.58^{O}C.

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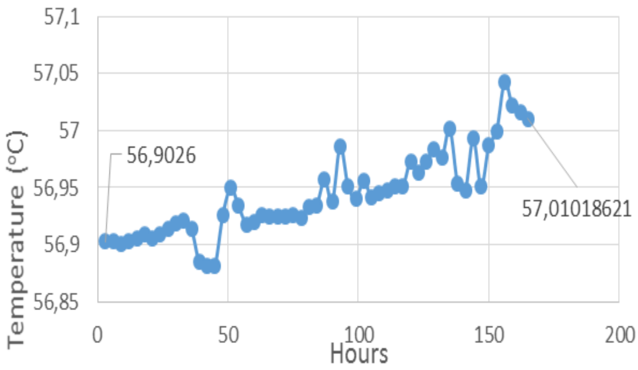

Fig. 6. Temperature change graph of deethanizer column at stage 40

Fig. 6 shows the temperature change at stage 10 and 40. In Fig. 6, it shows clearly that the temperature at stage 40 increases from 56.9^{O}C to 57.01 ^{O}C. The temperature changes at stage 10 and 40 affect the product quality.

The optimization results of deethanizer column top product are shown below.

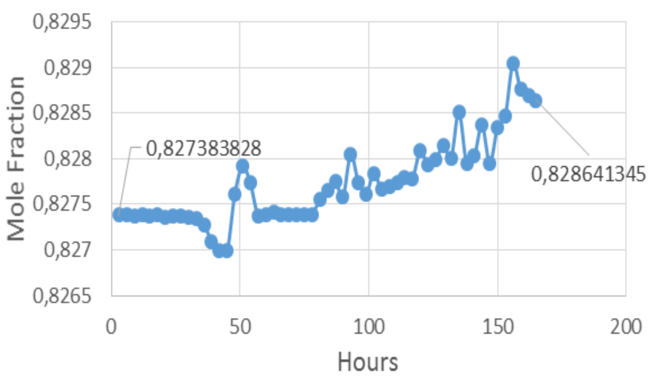

Fig. 7. Composition change graph of top product ethylene

Fig. 7 presents the ethylene composition change at top product. After optimizing the simulation for 155 hours, the ethylene composition increases from initial value 0.82738 mole fraction to 0.82864 mole fraction (0.15% increasing). It is clear that the optimization result for the ethylene composition at top product is greater than 0.82. Therefore this results satisfy the constraint of ethylene composition.

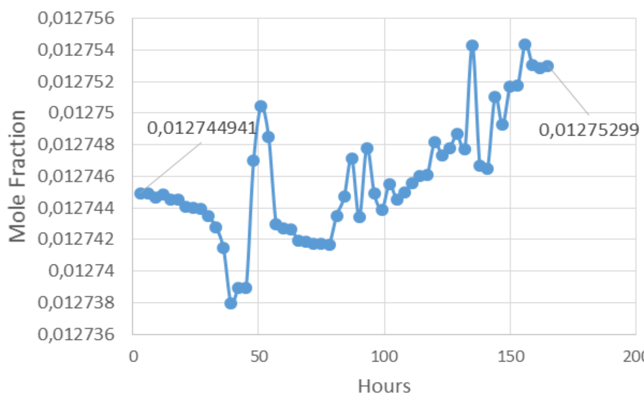

Fig. 8. Composition change graph of top product acethylene

Fig. 8 shows the acethylene composition change at top product. The reduction of reboiler duty makes acethylene composition at top product higher. The acethylene composition increases from initial value 0.012744 mole fraction to 0.012752 mole fraction (0.063% increasing).

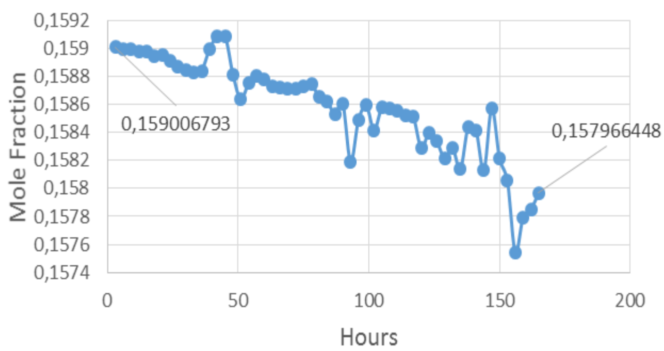

Fig. 9. Composition change graph of top product ethane

Fig. 9 presents the ethane composition change at top product. The results reveal that the ethane composition decreases from the initial value 0.159007 mole fraction to 0.157967 mole fraction.

An updated controller set point due to Real Time Optimization is given below in Table IV.

TABLE IV. UPDATED SET POINT AFTER REAL TIME OPTIMIZATION

Variable		**Initial**	**Final**
Temperature	Stage 10	9.2 ^{O}C	4.6 ^{O}C
Temperature	Stage 40	56.9 ^{O}	57.0 ^{O}C
Flow	Hot Water	558300 kg/h	488587 kg/h
Flow	LP Steam	10935 kg/h	10298 kg/jam

From Table IV it can be seen that there is adjustment of temperature set point change and flow rate set point change since the real time optimization uses cascade controller. After running the optimization for 155 hours in ASPEN PLUS using real time optimization, the optimum set point of TC (temperature control) at stage 10 and 40 and the optimum FC (flow control) set point of hot water and low pressure steam were obtained . The set point of hot water decreases from 558300 kg/hour to 488587 kg/hour (12.4% reduction), while the set point of low pressure steam decreases from 10935 kg/hour to 10298 kg/hour (6% reduction).

V. CONCLUSION

Real Time Optimization method applied to deethanizer column has been succeeded to give a less energy required to separate C2 from the heavier hydrocarbons. The reduction of energy for the hot water is found to be 12.4 % from the initial value of 6915 kW, while the reduction of energy for the low pressure steam is found to be 6 % from the initial value of 7200 kW.

References

[1] R. M. Naysmith, Real Time Optimizer Of Chemical Process, Thesis, Canada: University Of Waterloo, 1997.

[2] S. Shokri, Real Time Optimization as a Tool for Increasing Petroleum Refinery Profits, Iran: Research Institute of Petroleum Industry, 2009.

[3] Engineering Toyo, Basic Engineering vol 1 section 4 PT Chandra Asri Petrochemical, Cilegon: PT CAP, 1991.

[4] D. E. Seborg, T. F. Edgar, D. A. Mellichamp, and F. J. Doyle, Process Dynamics and Control. 3rd edition, California: John Wiley and Sons Pte Ltd, 2011.

[5] Aspen Plus, Getting Started Modeling Petroleum Processes, Aspen Technology Inc., Cambridge, 2006.