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Rigorous Dynamic Simulation and Optimization For FCCU Absorption-Stabilization System

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Abstract
This paper presents the rigorous dynamic simulation for the absorption-stabilization system of fluid catalytic cracking unit (FCCU). A new pressure control scheme is investigated to provide more stable and safe characteristics.

Keywords: dynamic simulation, optimization, absorption-stabilization system, FCCU

1. introduction

It is critical to understand the dynamic behavior of a plant for ensuring safe, economic and consistent plant performance. Through rigorous dynamic simulation the process operability, control performance and plant safety can be obtained. The rigorous dynamic simulation does not require the plant identification and does not affect the normal production. Therefore, it gets more and more extensive applications. (Nagrath & Prasad, 2002, Dolph, 2000)

FCCU is one of the most important facilities in refineries in the world. The absorption-stabilization system is the separation portion of FCCU, which consists of four columns: the absorber, stripper, secondary absorber and the stabilizer. As the absorption-stabilization system contains four recycles with large flow rates the interaction of different process parameters are very strong (Lu et al, 1998). Hence it is necessary to conduct intensive research to get profound understanding of the system. Only in this way an appropriate design can be obtained.

The existing absorption-stabilization system is shown in Figure 1. As the stabilizer is not included in this research, it is omitted. The system feedstocks are the rich gas and fractionator distillate. The absorber bottoms and the stripper overhead are returned to the upstream and mixed with the rich gas, then entering the equilibrium tank. (Lin, 1988, Lu , 1989) The pressure control PC1 is placed on the top of the secondary absorber and the relief valve is equipped on the absorber top.

PC1 controls the both pressures of the absorber and equilibrium tank stable with indirect mode by keeping the secondary absorber pressure unchanged. If the pressure in the equilibrium tank or the absorber increases, the pressure of secondary absorber goes up accordingly. Then PC1 increases the flow rate of the off gas to maintain the pressures stable.

The absorber separates C2 and C3 and its separation effect is very important to the system economics. From the view point of control theory, the pressure change in the

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secondary absorber will lag that in the absorber. Therefore, the PC1 is a delayed and weak control for the absorber.

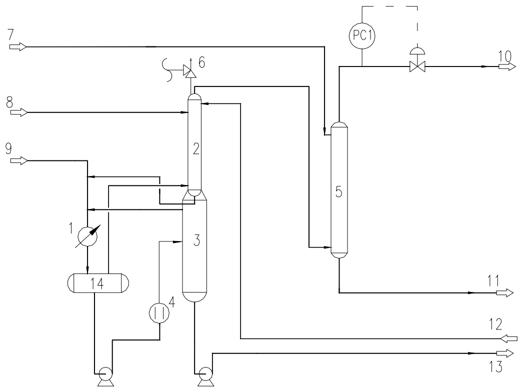

Figure1 The process for absorption-stabilization system

(1)pre-cooler; (2)absorber; (3) stripper; (4)pre-heater; (5)secondary absorber; (6) relief valve, (7) lean absorption oil, (8)fractionator distillate, (9)rich gas, (10)off gas, (11) rich absorption oil, (12) supplementary absorbent, (13) deethanized gasoline, (14)equilibrium tank

2. Dynamic characteristics research

A new scheme is investigated, which replaces the pressure controller at the absorber top, instead of at the top of the secondary absorber. The rigorous dynamic simulations are performed for the both the existing and the new schemes respectively.

2.1. Simulation models

The steady-state model for the investigated system is first established and performed in order to get the steady-state simulation results which are the initial estimates for the dynamic simulation. Aspen Dynamics^{TM} is then used to establish dynamic models and develop control strategies. For the dynamic simulation the additional necessary parameters, such as the configuration data for columns, vessels, heat exchangers and controller's data, have to be inputted via the dynamic interface. Afterwards, the Aspen Dynamics^{TM} software will automatically transfer the steady model into dynamic one and the dynamic simulation can be performed. The designated disturbances are generated in order to test the dynamic characteristics of the system.

2.2. Stability comparisons

So far as the dynamic simulation is concerned, when a disturbance is occurred it will take a certain time for the system to reach a new steady state. Suppose at the time 19.11 hour a small disturbance, which lowers the stripper reboiler duty from 17.466 GJ/hr to 17.266 GJ/hr, is added to the two schemes respectively. It leads the temperature of the stripper bottom decrease nearly 1 ℃ for the two schemes. The C3 mass flowrate change in the off gas is specified to less than 0.1 kg/hr/min to indicate reaching the new steady state. The transition times, which are the times for the system from the disturbance occurred until the new steady state reached, are 3.11 and 4.90 hours respectively. The results of two schemes are shown in Table 1.

As the integration effect, the pressure of the absorber maintains unchanged for the new scheme, and for the existing scheme the pressure of the absorber reduces by 0.148 bar under the same condition. The fluctuations of the absorber pressure are shown in Figure 2 and Figure 3 for the two cases respectively. From the dynamic simulation results it can be concluded that the new scheme suppresses the pressure fluctuation of the absorber, and makes system reach the new steady state 1.79 hours faster than the old scheme.

Table 1 simulation results of two schemes

scheme	new scheme	existing scheme
Transition time(hour)	3.11	4.90
Net change of the C3 flowrate in the off gas(kg/hr)	93.19	104.22
Net change of the absorber pressure （bar）	0	0.148

The net C3 flowrate of the off gas for the new scheme is less than that for the existing scheme by 11.03 kg/hr. This proves that the top pressure of the absorber has closer relationship to the net C3 flowrate of the off gas than that of the secondary absorber. Therefore, it is more important to control the absorber pressure stable.

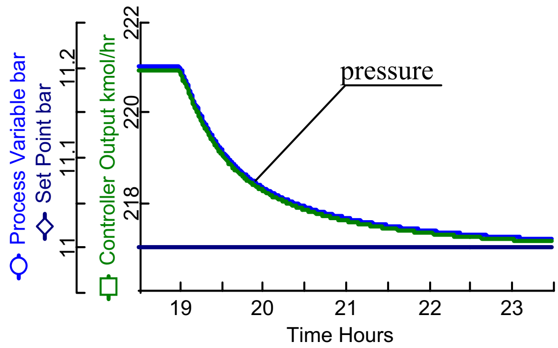

Figure 2 the fluctuation of the absorber top pressure for existing scheme

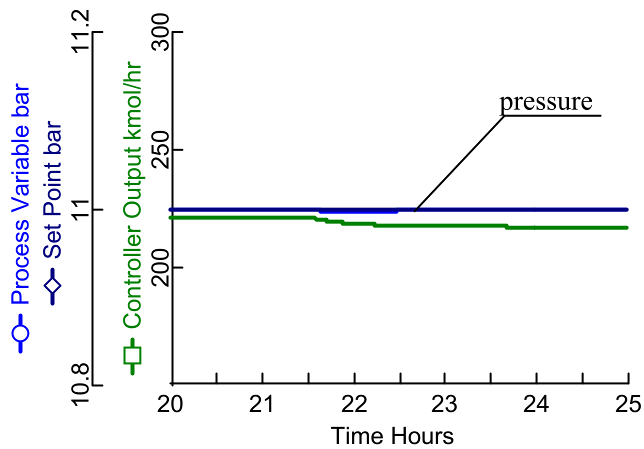

Figure 3 the fluctuation of the absorber top pressure for new scheme

The Figure 4 shows the fluctuation of the flow rate of components propylene, ethane and Isobutene in off gas for the existing scheme. The flow rate of propylene is reduced by 104.22 kg/hr in 4.90 hours, but the flow rate of ethane and Isobutene nearly unchanged. The reason is the former is more sensitive to the reboiler temperature of the stripper. As we know the less of the C3 flowrate in the off gas, the better the C3 recovery rate is. Therefore, the appropriate operation conditions can be determined through the dynamic simulation.

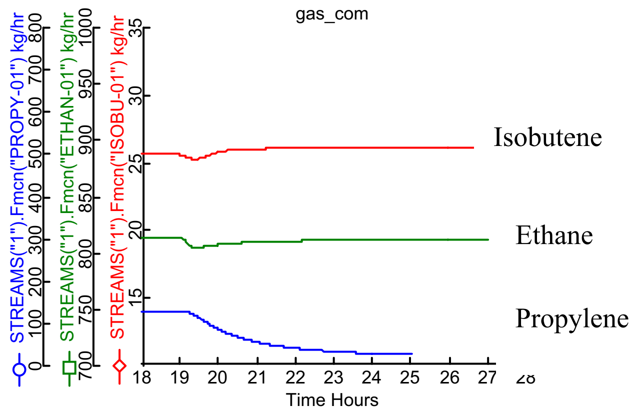

Figure 4. the fluctuation of components in the gas stream

Through the above dynamic analysis the following points are concluded:

- The absorber pressure can be maintained unchanged with some disturbances for the new scheme ;.it is vital for the normal operation;
- If there are some disturbances in process parameters, it is faster for the new scheme to reach a new steady state and the fluctuation is relatively small.

2.3. Safety analysis

The rich gas with temperature over 100 ºC should be cooled to about 40 ºC before it gets into equilibrium tank. If the cooling water supply is stopped in accident, the pre-cooler would not work. The high-temperature rich gas evaporates more liquid in the equilibrium tank. It would cause the pressure of the absorber increase dramatically. If the pressure exceeds the set point, the relief valve would be opened to protect the column.

Suppose the activate pressure of relief valve is set up at 13.5 bar. An accident of 3-minute water stop is assumed.

For the existing scheme, the top pressure of absorber reaches 12.82 bar in three minutes. Then the water supply is restored, but the pressure keeps on increasing within following 1.8 minutes and reaches the peak value of 13.38 bar. It is very close to the activate pressure and likely to force the valve to relief vapor. Figure 5 shows the pressure changes with the time.

For the new scheme, the pressure of the absorber will descends immediately after the restoration of water supply; the maximum pressure is 11.37 bar, as shown in Figure 6.

It is obvious that the new scheme has a better performance to the water supply accident.

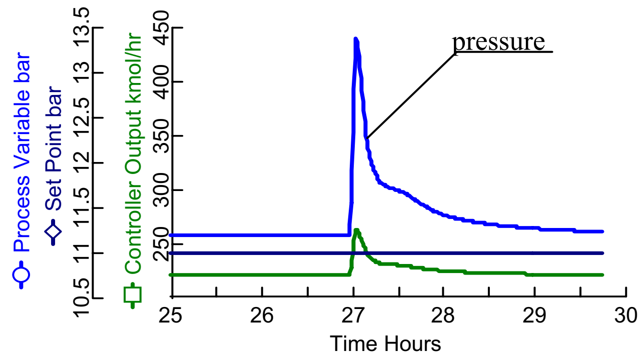

Figure 5. The fluctuation of the pressure in accident (the existing scheme)

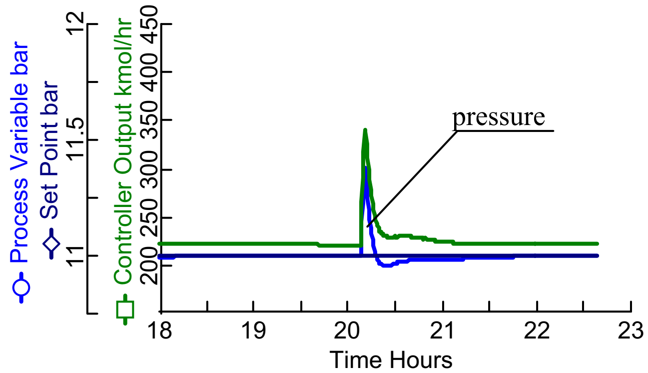

Figure 6. the fluctuation of the pressure in accident (the new scheme)

3. Conclusions

1. A rigorous dynamic simulation model for the absorption stabilization system is established, which can be used to examine the process operability, control scheme and evaluate plant safety.
2. A new pressure control scheme is proposed for the absorption stabilization system through the dynamic simulation. This new scheme can quickly respond to some disturbances and maintain the absorber pressure more stable.
3. It is very important to control the absorber pressure stable. If there are some disturbances, it is faster for the new scheme to reach a new steady state and the fluctuation is relatively small. The new control scheme can maintain the C3 content in the off gas in a lower level. Therefore, the new scheme has a better economic effect.
4. In case of the cooling water supply is stopped for a short time, the process fluctuation for the new scheme is relatively small. Therefore, the unit safety is enhanced.

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