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Process Dynamic and Control for Nonconventional Column/Rectifier Configuration with Aspen Hysys v10.0

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Abstract. Nonconventional column/rectifier configuration is the new alternate design for the sequence multicomponent separation of three or more products. It can accomplish an efficient energy. There are two columns, the first is the rectifier and the second is the main, the vapor sidestream is taken out from the location under the feed tray of the main column then fed to the rectifier column and the liquid that from the bottom of the rectifier column is turned back to the main column. In order to completely understand the dynamic behavior of complex process of this configuration, process dynamic and control of it has to be studied intensively. The implementation of it is demethanizer and deethanizer column. The configuration has been simulated for dynamic by using Aspen Hysys v10.0. The results show that the graph of rejecting disturbance from all controllers of the main column need more attention especially for inventory control i.e. level controller for reflux drum, sump level reboiler and pressure controller for condenser. The overshoot for level controller of reflux drum of main column is 10% from set points. The better algorithm of tuning is required. The results of this studied could provide guidance for composition controller of this configuration.

1. Introduction

The sequence multicomponent separation of three or more products is usually performed in distillation column with conventional configuration [1]. Many research have studied for conventional configuration in distillation column, and the results showed that it has consumed excessive energy [2]. Increasing the need for an efficient energy, the alternate design for distillation column is required. Nonconventional column/rectifier configuration is one the alternate design for nonconventional column configuration in distillation process [3]. Thermally coupled distillation sequence was used for the basic concept for nonconventional column/rectifier configuration system. Several studies have reported it [4][5][6][7][8]. It does not use reboiler but still uses condenser. There are two columns, the first is the rectifier column and the second is the main column, the vapor sidestream is taken out from the location under the feed tray of the main column then fed to the rectifier column and the liquid that from the bottom of the main column is turned back to the main column [3]. Energy and cost saving can be accomplished by it [6]. The significant problem of nonconventional column/rectifier configuration is the recycle stream in requirement for the dynamic and control [5]. It has been proof that plant uses the recycle system is more profit in steady state condition, because it can minimize the operation cost [9]. When in dynamic system

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it need more caution [5]. Process simulator such as Aspen Hysys gives good enviroments for dynamic simulation of distillation column in addition to PID controller [10]. In order to completely understand the dynamic behavior of complex process of nonconventional column/rectifier configuration, so the study about process dynamic and control of nonconventional colom/rectifier using process simulator i.e. Aspen Hysys is being important.

2. General study

2.1. Process description

The process chosen for this study is a modified demethanizer and deethanizer column [3]. Methane is mostly involved in Natural Gas coming from wells. The other important component is ethane, propane, and heavier hydrocarbons. Demethanizer and deethanizer column separate methane, ethane and propane with the heavier hydrocarbons. The top products of demethanizer are methane and small amount of ethane, the top and bottom products of deethanizer are ethane and propane with the heavier hydrocarbons [11]. There are many reasons why methane, ethane, propane and heavier hydrocarbons are separated from natural gas wells. The reasons depend greatly on the commercial products requirement. For Liquefied Natural Gas (LNG) requirement, ethane and propane with the heavier hydrocarbons have to be removed to avoid the solid formations at low temperature [3].

2.2. Process simulation

Demethanizer and deethanizer column used nonconventional column/rectifier configuration. Demethanizer was the rectifier column and deethanizer was the main column. Demethanizer had 8 stages and 31 stages for deethanizer. Feed entered the second stage of demethanizer column. The vapor sidestream was retreated from the seventh stage of deethanizer column then settled to the base stage of demethanize column and the liquid from the base of demethanizer column was fed back to seventh stage of deethanizer column [3].

Process Flow Diagram (PFD) from demethanizer and deethanizer column was simulated by Aspen Hysys v10.0. In flowsheet of Aspen Hysys, Demethanizer column used Refluxed Absorber Column model. It had a tower and condenser but no reboiler. For steady state, demethanizer column was specified 1479 kmol/hr for the distillate rate and 2950 kmol/hr for vapor sidestream rate. Deethanizer column used Distillation model. Distillation model has tower with both a condenser and reboiler. To achieve convergence simulation, deethanizer column has three specifications i.e. 507.2 kmol/hr for the distillate rate, 0.784 for reflux ratio, and 2950 kmol/hr for vapor sidestream rate. For dynamic requirement, demethanizer column needed vessel for liquid level control in the bottom of column. Pressure changers like valve, pump and compressor were added. Pump was added to transfer liquid from the base of the demethanizer column to seventh stage to deethanizer column. Compressor was given to transfer vapor from the deethanizer to demethanizer column. Valves were added in streams that will be the manipulated variables.

2.3. Control strategy

The purpose of control system was to keep the purity of methane, ethane, and propane. Nonconventional column/rectifier configurations had ten degree of freedoms i.e. Feed rate (“F”) two distillates rate (“D”), one bottom product rate(“B”), Vapor sidestream (“Vss”), reflux rate (“R”) one reboiler duty (“Qr”), and two condensor duty (“Qc”). The stability of column was made by keeping levels in reflux drum, column bottom of the main column and top pressure of column.

This study focusses on the control configuration that will influence the dynamic behavior of nonconventional column/rectifier configuration. The control configuration for demethanizer and deethanizer column is designed with the inventory control. It will keep the production rate and mass balance [7]. Vapor sidestream flowrate is controlled. Because vapor sidestream is the recycle stream so it has to be controlled [12]. When this configuration in dynamic mode, the recycle stream that from vapor sidestream makes trouble for level controller. The recycle stream is free flow when it is not controlled. It becomes a disturbance for level controller especially for level controller system in the main column. The dynamic model uses pressure changer i.e. Compressor and pump. They need attention when temperature on the reboiler suddenly increases or decreases. When it suddenly increase, it causes the entry of vapor in pump. On the contrary if it suddenly decreases, it generates the entry of liquid in compressor. As a result the temperature controller is required. Figure 1 below shows the proposed control configuration.

All controllers that used in nonconventional column rectifier/configuration was PID controller. Flow controller was put on feed. Levels in reflux drum were made by choosing distillate rate as manipupated variables. Flow controller was put on Vapor sidesstream to control the vapor rate rate from the main column that was treated to rectifier column. Pressures in top column were controlled by making condensor duty as manipulated variables and levels in the bottom of columns were controlled by chosing bottom product rate as manipulated variables. Because the main column had reboiler so temperature controller was added to keep purity the bottom product of the main column.

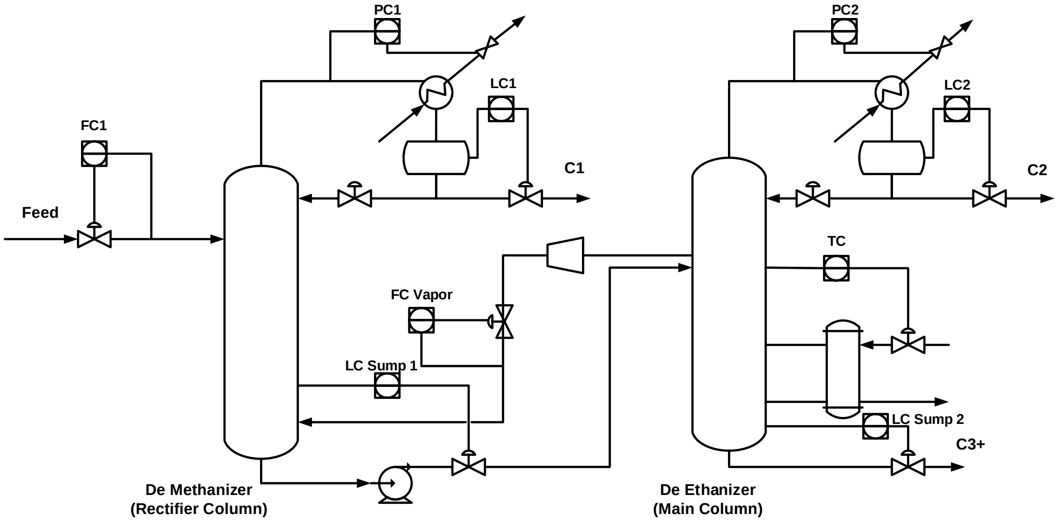

Figure 1. The proposed control configuration.

3. Results and discussion

Demethanizer and deethanizer with nonconventional column/rectifier configuration is simulated for dynamic by using Aspen Hysys v10.0. The proposed control configuration in Figure 1 is implemented in flowsheet of Aspen Hysys. All Controllers uses Proportional Integral Derivative (PID) controller. Tuning parameter for PID controller is got by Autotuner in Aspen Hysys v10.0. It uses the oscillations that will be got Ku or the ultimate gain and Pu or the ultimate periode [13]. The ultimate gain is formulated as Eq(1) below:

$$K_u = \frac{4h}{a\pi} \tag{1}$$

After getting the ultimate value, the PID tuning parameters are computed by the rule of Tyréus-Luyben as Equations (2) – (4) below:

$$K_c = \frac{K_u}{2.2} \tag{2}$$

$$\tau_I = 2.2P_u \tag{3}$$

$$\tau_D = \frac{P_u}{6.3} \tag{4}$$

For tracking set points and rejecting disturbances, Plant in Aspen Hysys v10.0 is given new set points. Disturbances is given by changing the flowrate of feed with adding +10% and-10%. Figure 2a until Figure 2h below show the results of set points and rejecting disturbances for each controller.

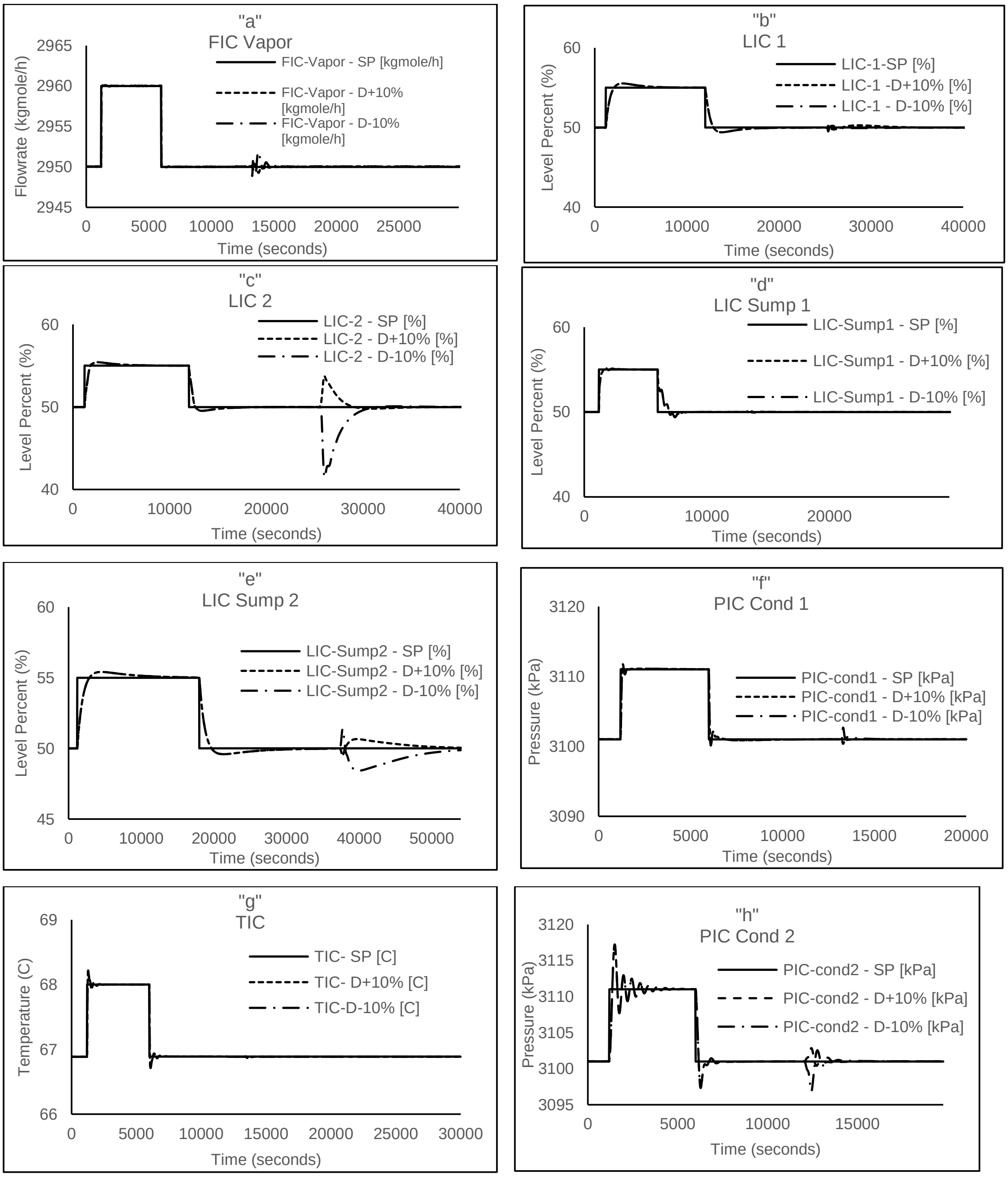

Figure 2a: Response of Flow controller for vapor sidestream. **2b**: Response of Level controller for reflux drum in the rectifier column. **2c**: Response of Level controller for reflux drum in the main

column. **2d**: Response of Level controller for sump level reboiler in the rectifier column. **2e**: Response of Level controller for sump level reboiler in the main column. **2f**: Response of Pressure controller for condenser in the rectifier column. **2g**: Response of Temperature controller in the main column. **2h**: Response of Pressure controller for condenser in the main column.

4. Conclusion

Demethanizer and deethanizer with nonconventional column/rectifier configuration has been simulated for dynamic by using Aspen Hysys v10.0. The proposed control configuration has been implemented in flowsheet Aspen Hysys v10.0. The results show that the level controller of reflux drum in the main column is most in need of attention for this proposed control configuration of Demethanizer and Deethanizer with nonconventional column/rectifier configuration. The implementation for other better tuning is required for it. The proposed control configuration can be used for composition control by creating methane from the top product of the rectifier column and ethane from the top product of the main column as process variables, and making reflux rate of the rectifier column and reflux rate of the main column as manipulated variables.

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