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Hierarchical Control of a Fractionation Column using HC900 Controller

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Abstract

The paper presents some aspects regarding hierarchical control of a fractionation column using Honeywell's HC900 controller. First, a two level hierarchical system is simulated in Simulink®. In the paper are presented the results for the simulation of both process (column) with the associated control systems, which represents level 1 of hierarchical control, and the control system from the level 2. Next, is presented the programming of the Honeywell's HC900 controller in order to implement the control algorithm from the second level of hierarchical control. At this point, the process is also simulated in Simulink®. The results obtained with this method are compared with the ones from the first case.

Key words: *hierarchical control, fractionation column, industrial controller, simulation.*

Introduction

The propylene-propane separation column takes part of hydrocarbon distillation plant, which belongs to the catalytic cracking unit. The hydrocarbon distillation plant refines all raw materials from main fractionator column from FCCU. The goal of hydrocarbon distillation plant is to recover as much as possible the C_3 - C_4 fractions from FCCU rich gas and gasoline. The propylene-propane separation column is one of the final columns with valuable products and 0.92-mole fraction purity is required in distillate product.

In general, these industrial processes and specially the chemical processes are characterized by complexity, nonlinearity, restrictions etc. As a result, modeling and controlling these processes represent a quite difficult problem. In most cases a hierarchical approach can be the solution for the chemical processes control problem, this paper presenting a hierarchical control system for the propylene-propane separation column.

System simulation

The control configuration for the propylene-propane separation column is the *LB* configuration. That is, the reflux flowrate *L* is used to control the distillate composition and the bottom product flowrate *B* is used to control the bottom product composition. In this case, the column pressure is controlled with the flowrate of the cooling agent from the condenser, the reflux drum level is controlled using the distillate flowrate and the column bottom level is controlled with the flowrate of the heating agent from the reboiler [3, 5].

This configuration represents the level 1 of hierarchical control (fig. 1).

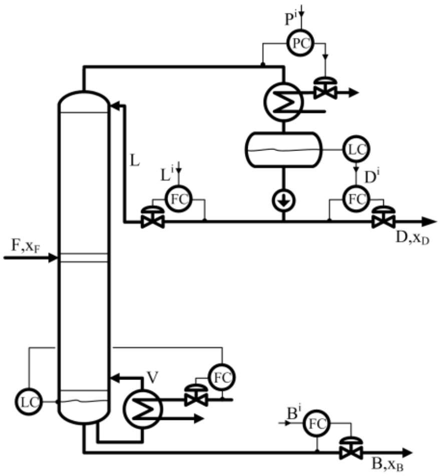

Fig. 1. Control structure associated with hierarchical level 1.

To analyze this level a simulation of the column was made using the Simulink® environment.

The mathematical model [6, 7] used for simulation takes into account the following assumptions: binary mixture; constant pressure; constant relative volatility; equilibrium on all stages; total condenser; constant molar flows; no vapor holdup; linearized liquid dynamics. These assumptions may seem restrictive, but they capture the main effects important for dynamics and control.

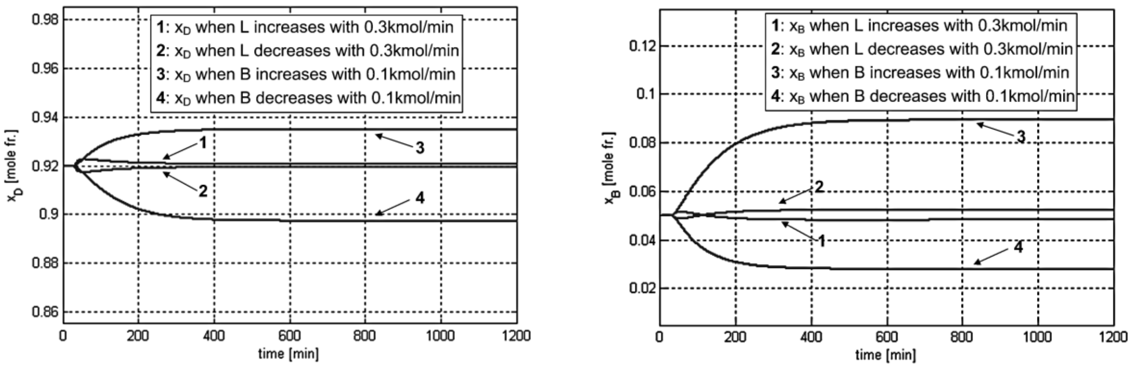

Fig. 2. x_D and x_B responses to an increase/decrease in commands.

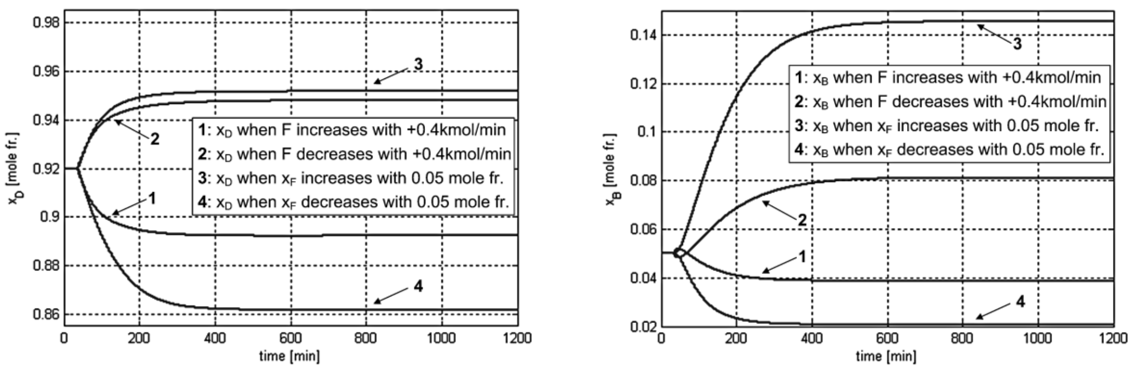

Fig. 3. x_D and x_B responses to an increase/decrease in disturbances.

The simulation of the column included changes of the *L* and *B* commands and also changes of the disturbances, feed flowrate *F* and feed composition x_F. The evolution of the distillate and bottom product compositions was recorded [4].

Analyzing the evolutions from the above figures it can be observed that the two disturbances have an important influence on the compositions. This fact led to the choice of a feedforward control system for the hierarchical level 2.

The mathematical model used for this control system has the Fenske-Gilliland-Underwood form [3].

The hierarchical control system (fig. 4) has a structure which comprises level 1, the regulatory control level, and level 2, associated with the feedforward control system (FFCS) for the propylene-propane compositions.

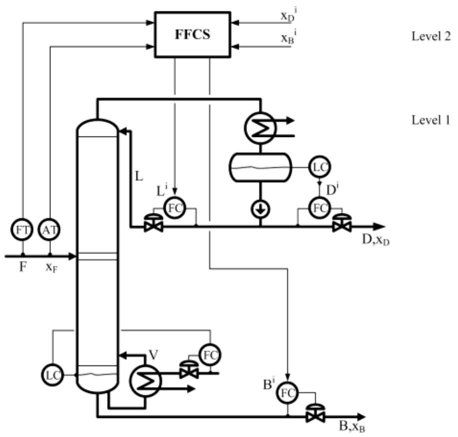

Fig. 4. The control system with two hierarchical levels.

The structure of the control system with two hierarchical levels was simulated using the Simulink® environment.

Because the model from the second level is a steady-state one, first was studied the behavior of the hierarchical system to disturbances changes, emphasizing the steady-state compensation of their effects.

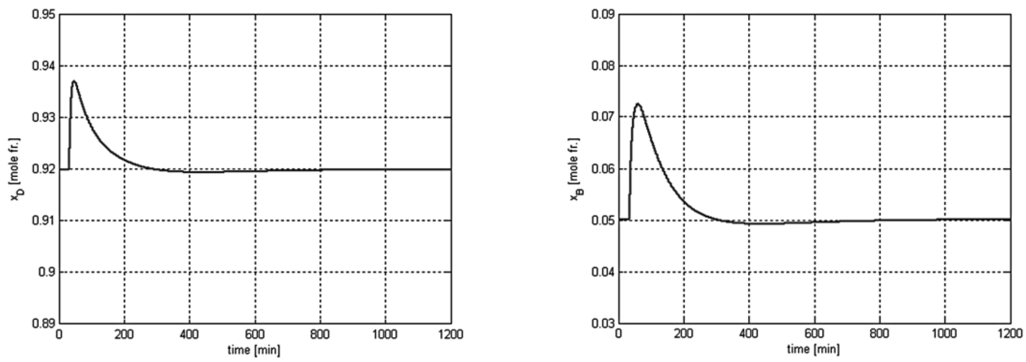

Fig. 5. Steady-state compensation of *F* when increased with 0.4 kmol/min.

As it can be seen in fig. 5, introducing the feedforward controller lead to the compensation of the effects of the disturbance *F* on the two compositions.

The next step was the adding of a dynamic component to the feedforward controller. The two commands were delayed according to the following differential equations:

$$T_L \frac{dL}{dt} + L = L_{st}; \tag{1}$$

$$T_B \frac{dB}{dt} + B = B_{st}, \tag{2}$$

where: T_L and T_B are the time constants and the L_{st} and B_{st} are the steady-state commands computed by the feedforward algorithm.

In the next figures are presented the evolutions of the compositions in three cases: no compensation, steady-state compensation and dynamic compensation when F increases with 0.4 kmol/min.

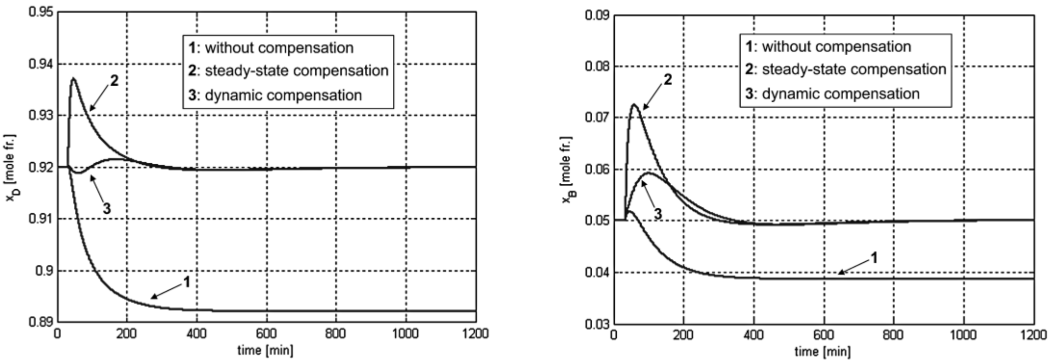

Fig. 6. Compositions evolutions when F increases with 0.4 kmol/min.

Although the steady-state compensation was good (fig. 5), using a dynamic component in the controller assures an even better compensation of the disturbance F effects (fig. 6).

HC900 programming

The Honeywell's HC900 Hybrid Controller is an advanced loop and logic controller offering a modular design sized to satisfy the control and data acquisition needs of a wide range of process equipment.

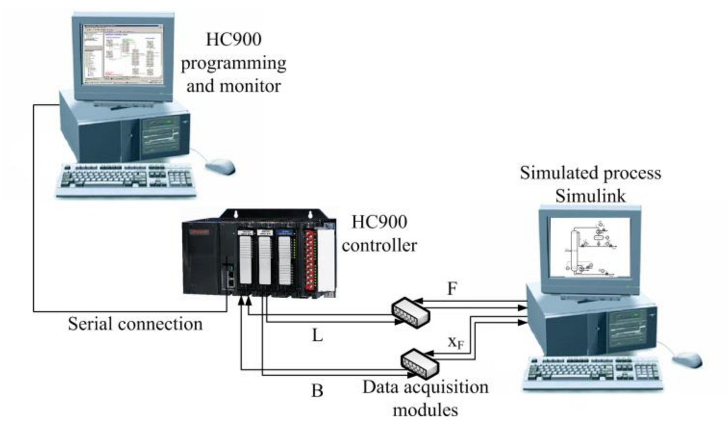

Fig. 7. Connection scheme between HC900 and simulated process.

HC900 controller is used to implement the feedforward control algorithm from level 2 of the hierarchical system.

In this case, the process is simulated in Simulink® and the controller from the upper level is the HC900 controller, the connection scheme between these two levels being presented in fig. 7.

HC900 receives the values of the disturbances F and x_F, and sends the values of the commands L and B. These operations are possible using data acquisition modules.

For the programming of the HC900 controller special software is used [1, 2]. This software uses function blocks as main control unit. In this particular application, the necessary function blocks include: two analog input blocks (for the acquisition of the signals associated with the two disturbances), many mathematical blocks for the computing of the parameters in the control model and the commands, blocks for different constants and variables, two analog output blocks (for the two computed commands generation). These blocks are interconnected in order to achieve the proposed goal.

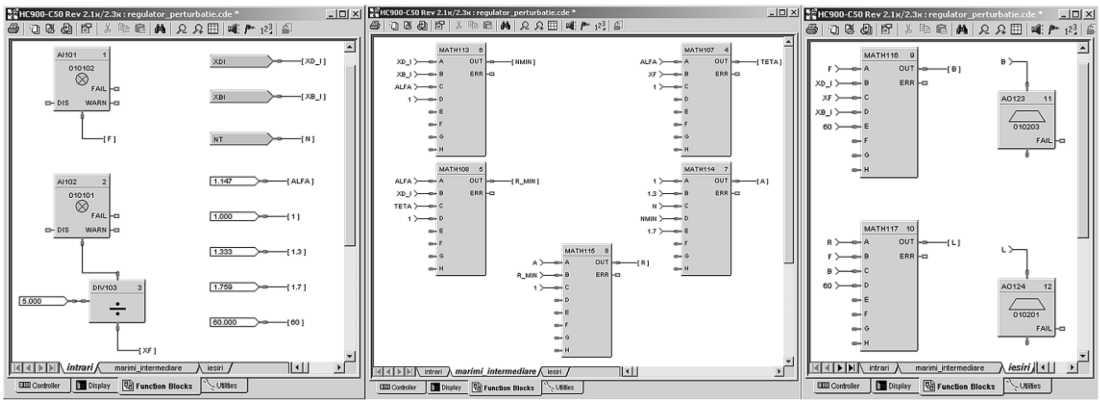

Fig. 8. Function blocks associated with the inputs, outputs and other controller parameters.

Using the connection scheme from fig. 7 simulations were done to observe the system's behavior to changes in the disturbance F.

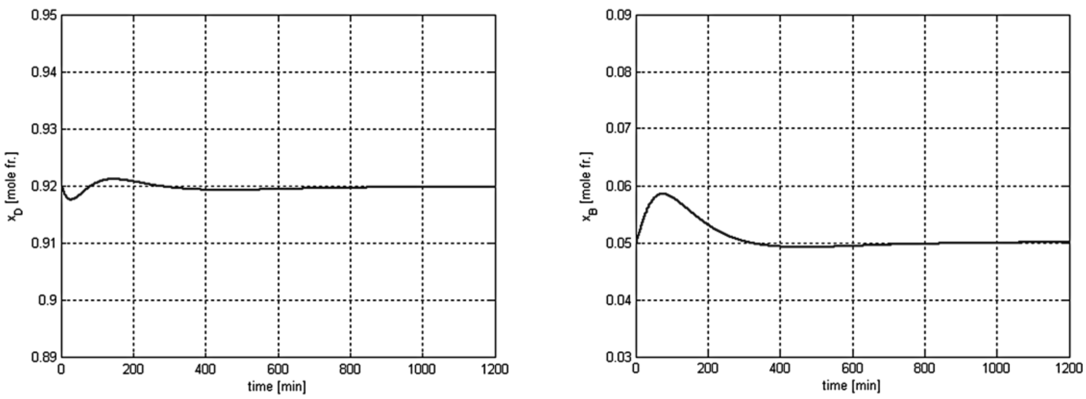

Fig. 9. x_D and x_B evolutions to change in F of 0.4 kmol/min.

As it can be seen, the above figures are similar to the ones obtained in the case when the whole system (both hierarchical levels) was simulated.

Conclusions

The two-level hierarchical control system for the propylene-propane separation column proposed in this paper was analyzed in two situations. First, the system was simulated in the Simulink® environment; simulation included both hierarchical levels. Analysis of the level 1 led to the choosing of the control system from the second hierarchical level. Simulation results for this level pointed out that the feedforward control system from level 2 compensates (in steady-state) the effect of the disturbances on the two compositions. A dynamic component was also added to the feedforward controller. In the second case, the controller role was played by the Honeywell's HC900 controller, which was programmed to compute the commands according to the algorithm used in the first case. The system in this configuration was simulated and the results were very similar to the ones from the first case, leading to the conclusion that using an industrial controller connected to a simulated process is a viable solution in solving this kind of problems.

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Conducerea ierarhică a unei coloane de fracţionare utilizând echipamentul HC900

Rezumat

Lucrarea prezintă unele aspect privind conducerea ierarhică a unei coloane de fracţionare utilizând echipamentul HC900 de la Honeywell. Pentru început, sistemul ierarhic cu două niveluri este simulat în Simulink®. În lucrare sunt prezentate rezultatele simulării, atât a coloanei împreună cu sistemele de reglare asociate, aceasta reprezentând nivelul ierarhic 1, cât şi a sistemului de reglare de la nivelul 2. În continuare, este prezentată metoda de programare a echipamentului HC900 în vederea implementării algoritmului de conducere de la cel de-al doilea nivel ierarhic, procesul fiind simulat în Simulink®. Rezultatele obţinute cu această metodă sunt comparate cu cele obţinute în primul caz.