World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:1, No:10, 2007

Distillation Monitoring and Control using LabVIEW and SIMULINK Tools

J. Fernandez de Canete, P. Del Saz Orozco and S. Gonzalez-Perez,

***Abstract*—** LabVIEW and SIMULINK are two most widely used graphical programming environments for designing digital signal processing and control systems. Unlike conventional text-based programming languages such as C, C++ and MATLAB, graphical programming involves block-based code developments, allowing a more efficient mechanism to build and analyze control systems. In this paper a LabVIEW environment has been employed as a graphical user interface for monitoring the operation of a controlled distillation column, by visualizing both the closed loop performance and the user selected control conditions, while the column dynamics has been modeled under the SIMULINK environment. This tool has been applied to the PID based decoupled control of a binary distillation column. By means of such integrated environments the control designer is able to monitor and control the plant behavior and optimize the response when both, the quality improvement of distillation products and the operation efficiency tasks, are considered.

***Keywords*—** Distillation control, software tools, SIMULINK-LabVIEW interface.

I. Introduction

LabVIEW [1] and SIMULINK [2] are properly two widely used graphical code development environment which allow system-level developers to perform rapid prototyping and testing. Such graphical based programming environments involve block-based code development and offer a more intuitive approach to modelling and control task in a great variety of engineering disciplines, such as process engineering. Besides, both environments can be linked together through the LabVIEW simulation interface toolkit (SIT) allowing control engineers to custom user interface to interactively verify SIMULINK models and easily deploy these models to real-time hardware for control prototyping and hardware-in-the-loop testing, with proven results in industrial applications [3].

Manuscript received June 15, 2007. This work was supported in part by CICYT project DPI2005-08344 (sponsor and financial support acknowledgment goes here).

J. Fernandez de Canete is with System Engineering and Automation Dpt. of University of Malaga, Plaza El Ejido s/n 29013 Malaga, SPAIN (34-52-132887; fax:34-52-133361; e-mail: canete@isa.uma.es).

P. del Saz Orozco is with System Engineering and Automation Dpt. of University of Malaga, Plaza El Ejido s/n 29013 Malaga, SPAIN (34-52-131412; fax:34-52-131413; e-mail: delsaz@isa.uma.es).

S. Gonzalez Perez is with System Engineering and Automation Dpt. of University of Malaga, Plaza El Ejido s/n 29013 Malaga, SPAIN (34-52-131412; fax:34-52-131413; e-mail: sgp@isa.uma.es).

Distillation columns constitute a major part of most chemical engineering plants and remains as the most important separation technique in chemical process industries around the world [4]. Therefore, improved distillation control can have a significant impact on reducing energy consumption, improving product quality and protecting environmental resources. However, both distillation modelling and control are difficult task because the plant behaviour is usually nonlinear, non stationary, interactive, and is subject to constraints and disturbances [5]-[6]. Besides the application of such techniques to real experimental plants are limited by the high cost of distillation equipment.

The aim of this paper is to show the integration of the SIMULINK environment used for simulating the distillation column dynamics with the LabVIEW environment used for its monitoring and control. This combined scheme has been employed to the control of a binary distillation column modeled in SIMULINK including non linear hydrodynamic effects. The LabVIEW graphical user interface designed enables the visualizing of both, the closed loop performance and the user selected control conditions, where the front panel has been designed mimicking the distillation column control scheme .

In section II we describe the overall structure of distillation control system while the distillation column model programmed in SIMULINK is summarized in section III. The design of the monitoring system under LabVIEW is described in section IV, and computer simulation results for a 40 trays methanol - n propanol column are also shown in section V. Finally, conclusions and future works are also discussed in section VI.

II. Description of the Distillation Control System

The proposed architecture for monitoring and control of the distillation column is shown below (Fig. 1). The system is composed by:

1) A SIMULINK model of the distillation column, based on mass and enthalpy balances.
2) A graphical user interface for monitoring the PID controlled distillation column based on LabVIEW.

The measures taken from the SIMULINK distillation column model will be used to adjust the controller parameters, which in turns once set will feed the distillation plant to operate under working specifications. The outcome of both modules will be displayed at front panel of LabVIEW to show the user the state of the plant at any time.

The overall system allows also the control of the experimental plant instead of the simulation model, using instead the measuresform the sensors of the column in order to adjust the controller under LabVIEW interface.

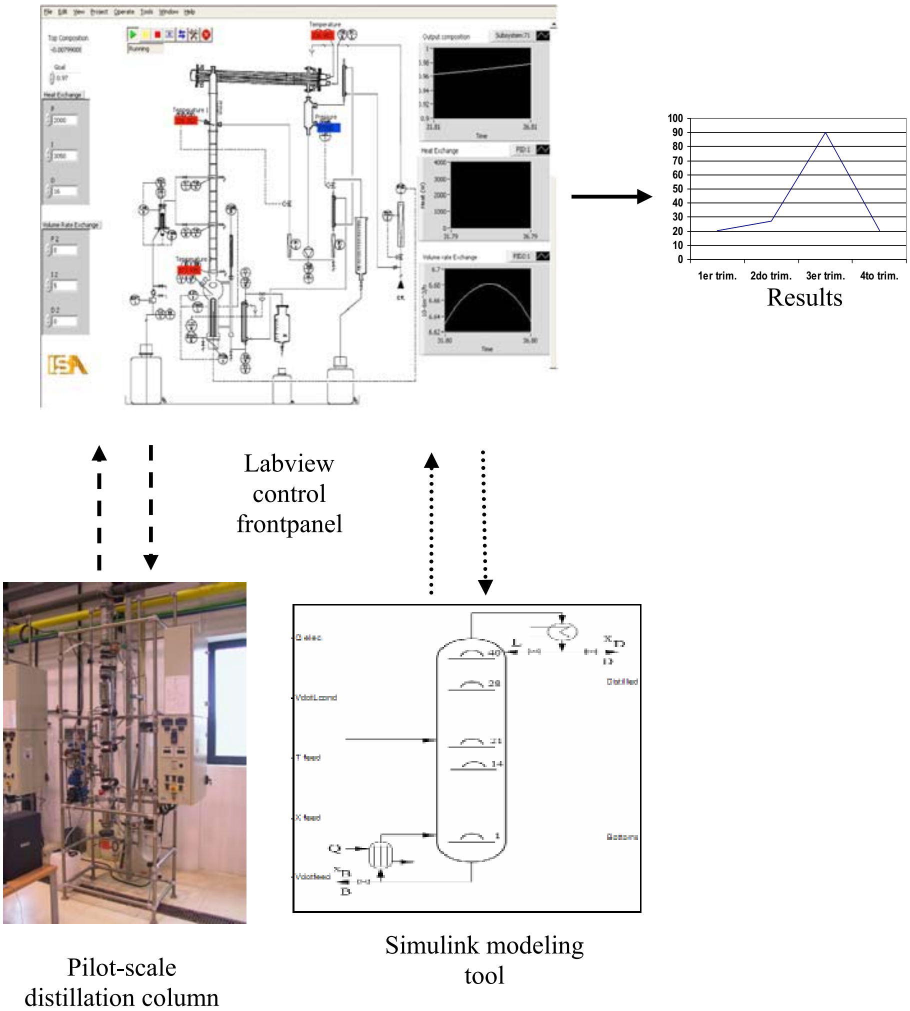

Fig. 1 Scheme for monitoring and control of the distillation column

III. Distillation Column Model

The distillation column is used for the separation of a binary mixture of methanol and n-propanol which enters as a feed stream with flow rate F_{vol} and composition X_F between the rectifying and the stripping section (Fig. 2). Mass transfer occurs between the vapour flowing up and the liquid flowing down the column. The vapour exiting at the top of the column is condensed, and part of the resulting liquid flow is returned at the column at the top (reflux), while the remainder is taken as the distillate product stream D_{vol}. Part of the liquid flow out of the bottom of the column is vaporized in a reboiler and sent back to the bottom of the column, while the remainder is taken as the bottom product stream B_{vol}. The column consists of 40 bubble cap trays. The overhead vapour is totally condensed in a water cooled condenser which is open at atmospheric pressure. The reboiler is heated electrically, and the preheated feed stream enters the column at the feed tray as saturated liquid. The process inputs that are available for control purposes are the heat input to the reboiler Q and the reflux flow rate L_{vol}.

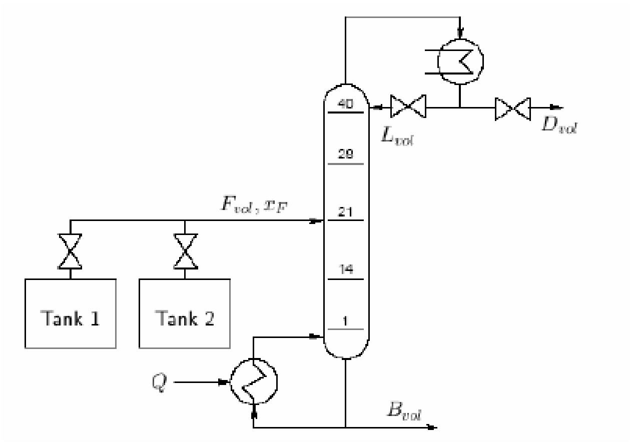

Fig. 2 Flowsheet of the distillation column

The model of the distillation column used throughout the paper is developed by [7], composed by the mass, component mass and enthalpy balance equations used as basis to implement the SIMULINK diagram (Fig. 3)

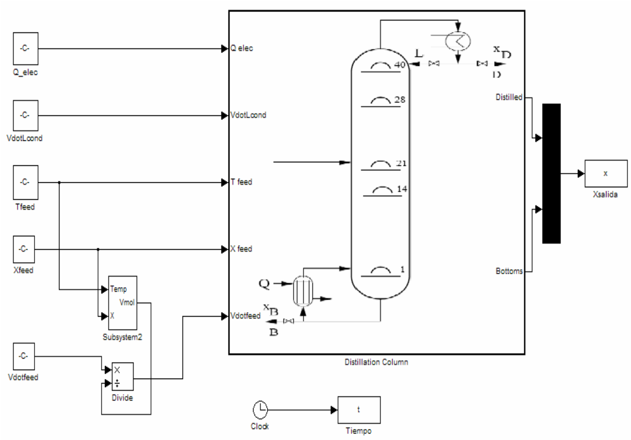

Fig. 3 SIMULINK model of the distillation column

IV. MONITORIZATION OF THE DISTILLATION COLUMN

One of the goals of the present work is to develop a LabVIEW based system for on line monitoring and manipulation of the variables that take part in the distillation process, as well as for interaction with the dynamic model developed in SIMULINK. The solution we propose is a graphic user interface developed in National Instrument's graphical programming language LabVIEW [1]. In this way, the observation and control of the variables is carried out using virtual instruments while the connection between the virtual instruments and the SIMULINK model is solved using the Simulation User Interface. In this way we have a flexible and versatile tool, being an efficient, economic and simple way to monitoring and control the distillation column programmed in SIMULINK. Details of the LabVIEW front panel designed for this application are depicted in Fig. 4.

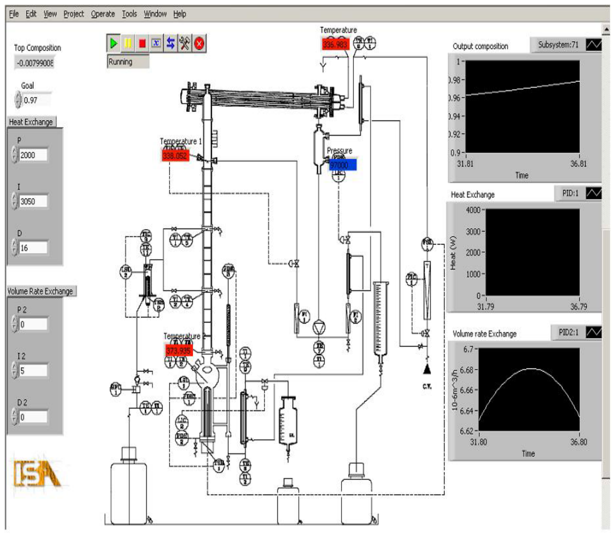

Fig. 4 Front panel of the monitoring tool

V. RESULTS

In order to show the validity of the proposed control scheme, we have selected a binary high-purity distillation column, for separating a mixture of methanol and n-propanol, which consist in 9 bubble caps trays with heated electrically reboiler and water refrigerated tubular condenser.

We have designed two decoupled PID for maintain composition specifications for the distillate and bottom products streams taking the heat input to the reboiler Q and the reflux flow rate L_{Vol} as manipulated variables. The PID parameters are given by P-97500 I-1000 D-16 for the reboiler control and P-150 I-70 D-10 for the reflux flow rate. The flow feed rate, feed composition and feed temperature have been taken as disturbances to the process.

In Fig. 5, we show how the PID controllers exhibit adequate control action to compensate a pulse change in distillate composition from 95% to 98% in t = 100 s during 30 s, with distillation column recovering its initial steady state.

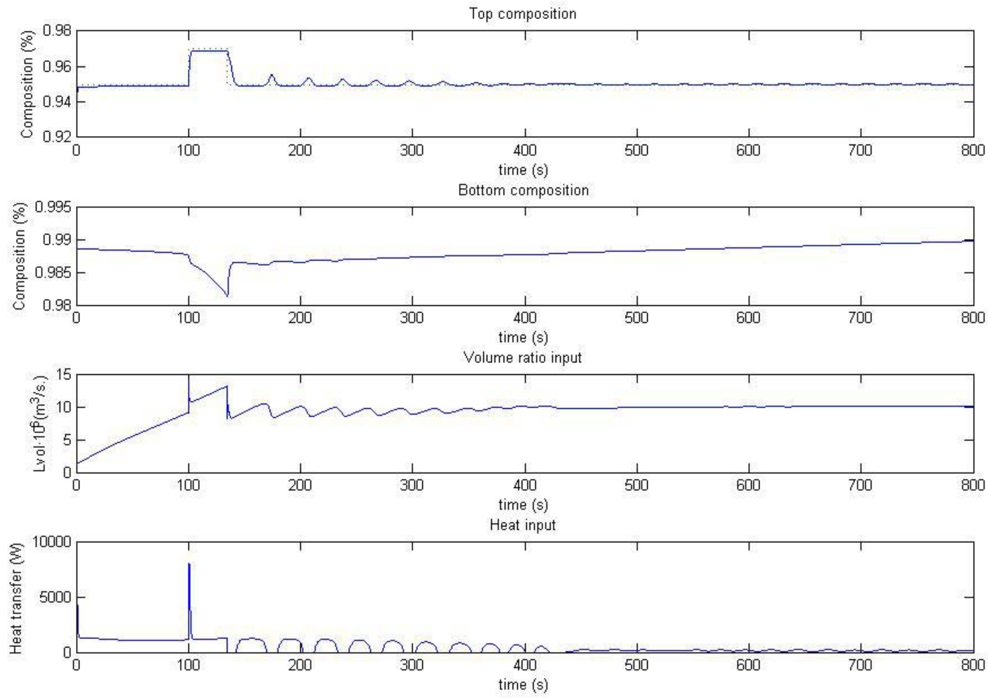

Fig. 5 Response of the distillation control system to pulse changes in top composition

VI. Conclusions and Future Works

This paper describes the integration of the SIMULINK with the LabVIEW environment for monitoring and control of a binary distillation column The results obtained demonstrate the potential use of this control strategy in this field.

Future works are directed towards the application of the described toolset to a experimental distillation column as is actually being made by the System Engineering and Automation Group as part of the researching project DPI2005-08344, which utilizes the same scheme as Fig. 1 but replacing the simulation model by an experimental distillation column DELTALAB DC-SP, whose technical characteristics are displayed at web page below

(http://www.isa.uma.es/C4/Control%20Neuroborroso/Document%20Library/index.htm)

At the same time, the stability issued involved in the neural control task are also object of research, since nonlinear and multivariable dynamics are present.

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