Computer Simulation: Students Take Plant Control In Their Hands

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Abstract

Process control is commonly taught from a theoretical point of view. Several examples of application-oriented educational simulations are presented here. The simulations were developed using Labview [1], and present the students practical problems to be solved using control engineering knowledge in a Distributed Control System (DCS)-type graphical interface. Control strategies developed vary from simple feedback in SISO systems to multivariable control applications [2].

Introduction

Control Engineering is more than a root locus diagram. It is decision-making, plant analysis, process understanding, and safety considerations. In other words, "Engineering at Work."

Based on the above statement, a set of educational tool was developed to support the teaching of Automatic Process Control in the Chemical Engineering Department at the University of South Florida. The tool consisted of computer simulations with a DCS-type graphical interface. The simulations were developed using Labview and the Control Toolbox, which allow the student to understand how changes in process parameters affect plant performance.

These simulations provide students an opportunity to tune process controllers, and design and implement other control strategies, as if they were in an actual plant environment. This theory-modeling-application scheme is followed during each of the three courses related to Process Control:

- ECH 4323 Automatic Process Control 1
  Undergraduate Level

- ECH 5324 Automatic Process Control 2
  Undergraduate Elective and Graduate Level

- ECH 6930 Automatic Process Control 3
  Graduate Level

The results of this practice show improvement in students' understanding about plant operation, ability to apply control theory to real life process problems, and a more integrated perspective of control and plant engineering.

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Laboratories Description

During the first course, students work with the Labview process simulation to understand concepts such as process dynamics, valve fail-safe position, steady state and transient operations, self-regulating and non self-regulating processes, and controller action. The students also learn to estimate process characteristics (gain, time constant, and dead time), and use them to, tune feedback controllers for SISO loops, and tune controllers for an integrating process.

During the second and third courses, the students use the simulations to tune cascade controllers, design and implement Feedforward controllers, implement Smith Predictor dead time compensation technique, Dynamic Matrix Control, Sliding Mode Control, and tune multivariable decentralized controllers. Some of the Virtual Plant Laboratories that have so far been developed are presented next.

1. Scrubber

The system shown in Figure 1 is a scrubber where the HCl concentration in air must be reduced, due to environmental regulations, before venting the air to the ambient. NaOH solution is used as the scrubbing medium. The main disturbance to the process is the airflow into the scrubber; three fans provide this flow. When the airflow increases, the HCl concentration in the outlet stream also increases. The control system should be able to respond not only to this disturbance, but also to set point changes.

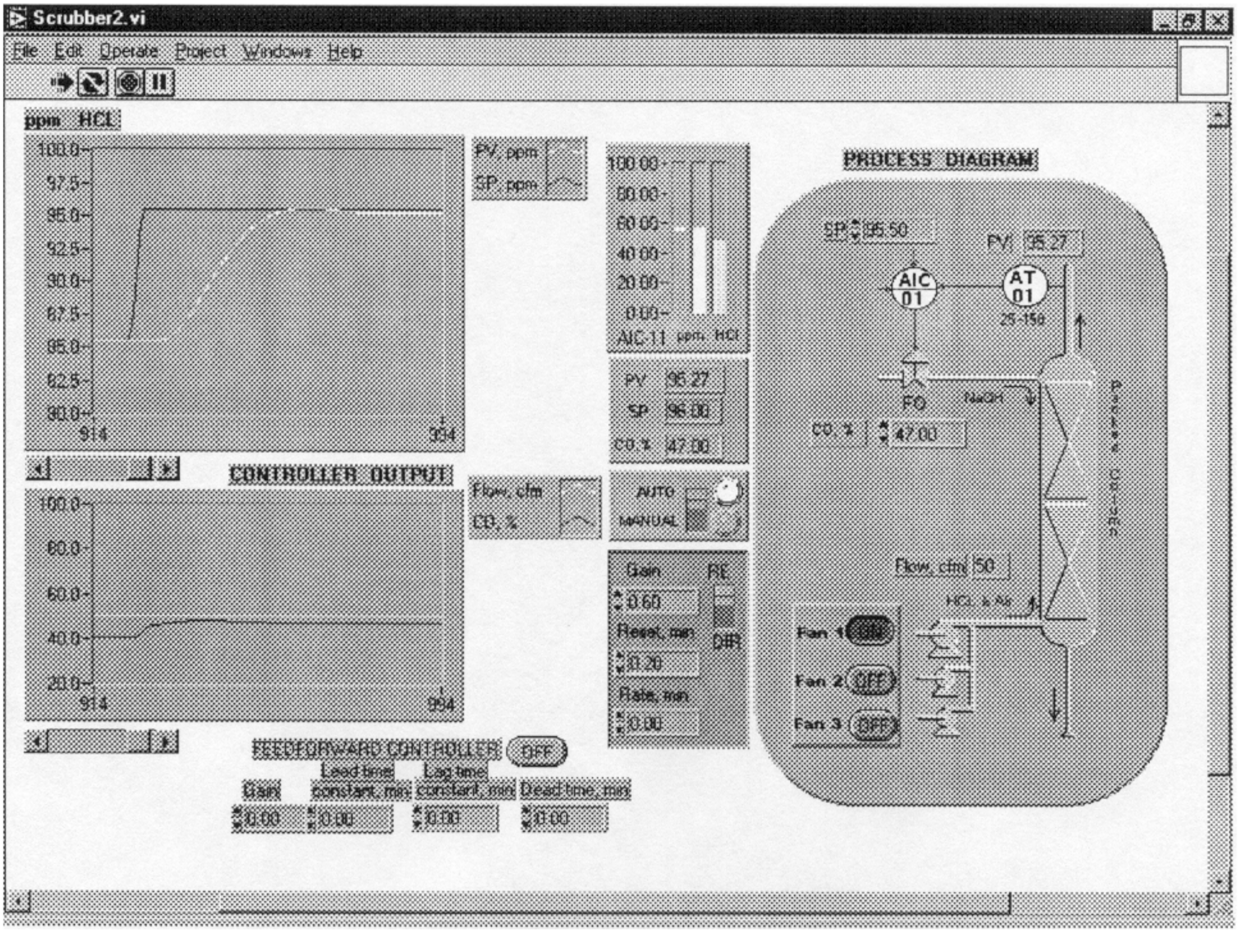

Figure 1. Virtual Lab for Feedback and Feedforward Implementation with PID Controller.

The way this lab is administered allows the student enough time to understand how each process variable affects the process performance. During the first week of classes of the first course, the students are asked to control the process manually that is, manipulating the valve manually, to control the outlet HCl concentration. This experience is very useful because it demonstrates the students how "good" manual process control would be. Later in the same course, they are asked to tune the controller to obtain automatic control.

During this experiment the students demonstrate the effect of changing controller tunings on the process response to disturbances or set point changes. They also learn the implications of selecting PV tracking.

This same process is used for the laboratory on Feedforward control during the second course.

2. Catalyst Regenerator

The virtual laboratory presented here, shown in Figure 2, simulates a catalyst regeneration operation.

During a catalytic dehydrogenation reaction, carbon deposits over the catalyst. After weeks of operation regeneration of the catalyst, removal of the carbon deposited, is required. The regeneration consists of reacting the carbon with oxygen obtained from air. The air is first heated in a furnace, and then sent to the R2 Unit where the regeneration takes place. During regeneration the temperature in R2 must be controlled to avoid damage to the catalyst.

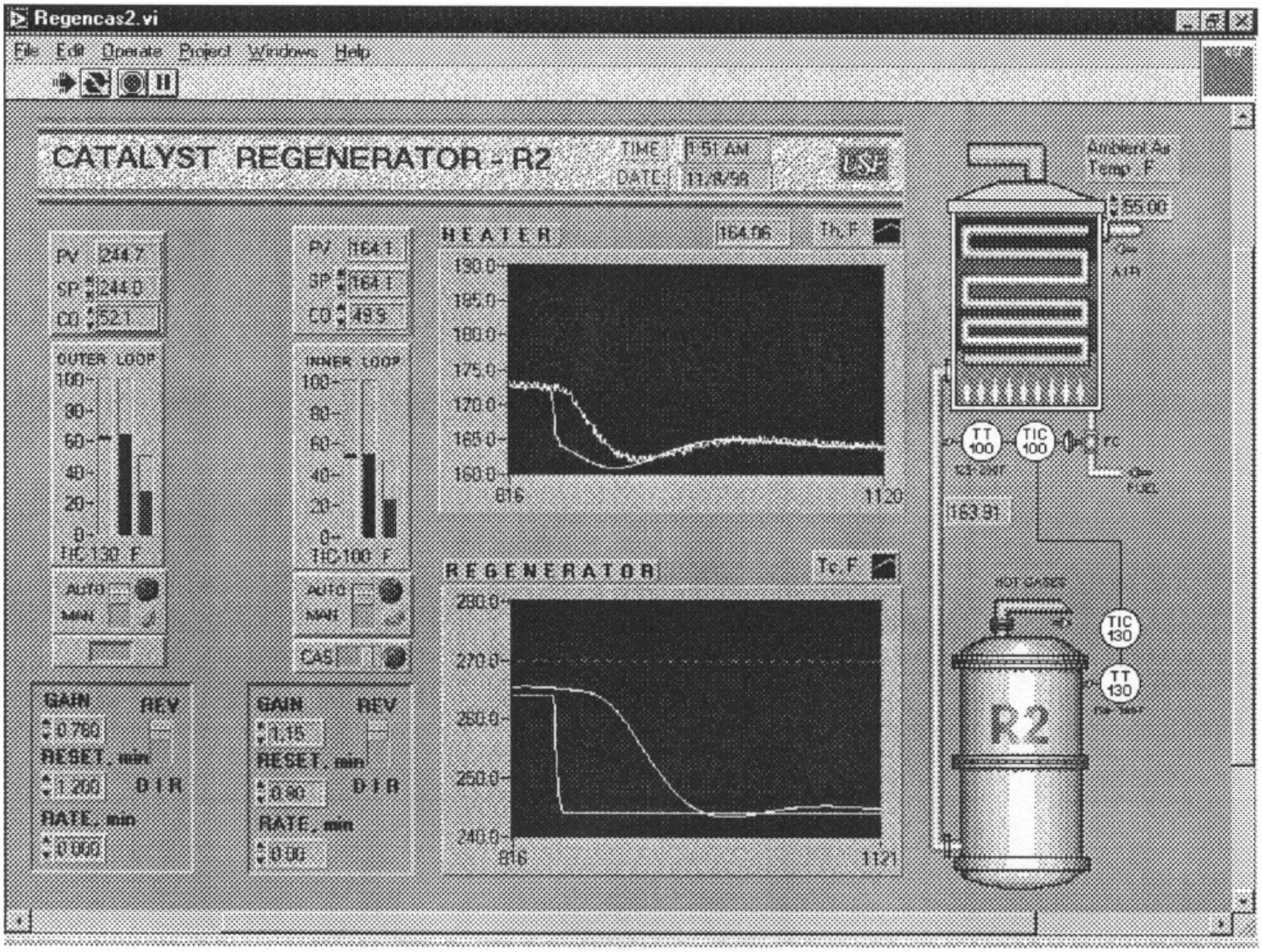

Figure 2. Virtual Lab for Feedback and Cascade Implementation with PID Controller.

The control strategy first calls for controlling the temperature by manipulating the fuel valve in the furnace directly that is, a common feedback loop; this control strategy is not shown in Figure 2, but is implemented through a Virtual Laboratory equivalent to the one shown in Figure 1.

A common disturbance to this process is changes in inlet air temperature to the furnace. If this is the case, a cascade control strategy, the one shown in Figure 2, improves the control performance, by perceiving the disturbance effect before it propagates through the whole system.

The students are asked to tune the controller(s) in the simple feedback loop and in the cascade strategy, and compare the control performance to changes in the inlet air temperature. Figure 2 shows that the inlet air temperature can be changed.

3. Override Control and Reset Feedback

By using this virtual lab, shown in Figure 3, students are able to implement flow and/or level control, incorporate an override control using a low selector, and decide if they want to use reset feedback to improve the control loop performance.

The system is a tank that is being fed with liquid from one to three other processes. The inlet flow is not being measured, and is the main disturbance. There is a level transmitter in the tank and a flow transmitter in the outlet stream. There are two controllers connected to those transmitters, and a low selector that can be enabled.

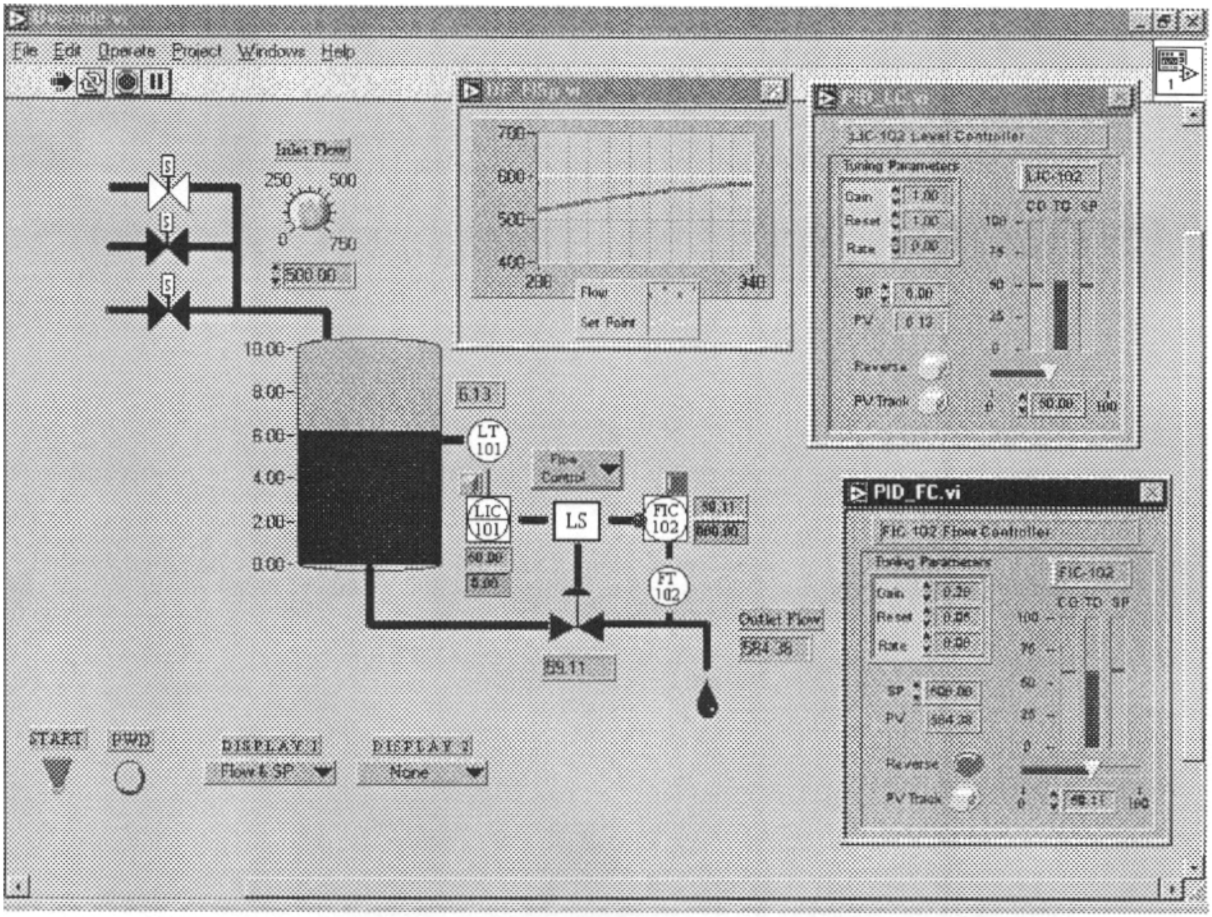

Figure 3. Virtual Lab for Flow and/or Level Control with Override and Reset Feedback.

This virtual laboratory allows the students to select between the following control strategies, depending on the control objective:

- Level Control only
- Flow Control only
- Override Control
- Override + Reset Feedback Control

The students see first-hand the meaning of an integrating process (level), and how to tune this controller to achieve either tight level control or average level control. During experimentation, the students can observe the effect of reset feedback on the non-selected controller when override control is being used. They also learn that not all plant control loops are set up to keep variables at desired values (set point), but they can also be applied to prevent non-desirable situations (safety, alarms, operational range). They also learn what are the implications of selecting PV tracking, and Reset Feedback as controller settings.

4. Advanced Process Control

During the graduate level course, students learn how to work with Advanced Control strategies, such as Dynamic Matrix Control, Sliding Mode Control, Dead Time Compensation using Smith Predictor and Dahlin's Algorithm, and Multivariable PID control with decouplers. There are virtual labs available for DTC using Smith Predictor and multivariable decentralized PID controllers with decouplers (developed using Labview).

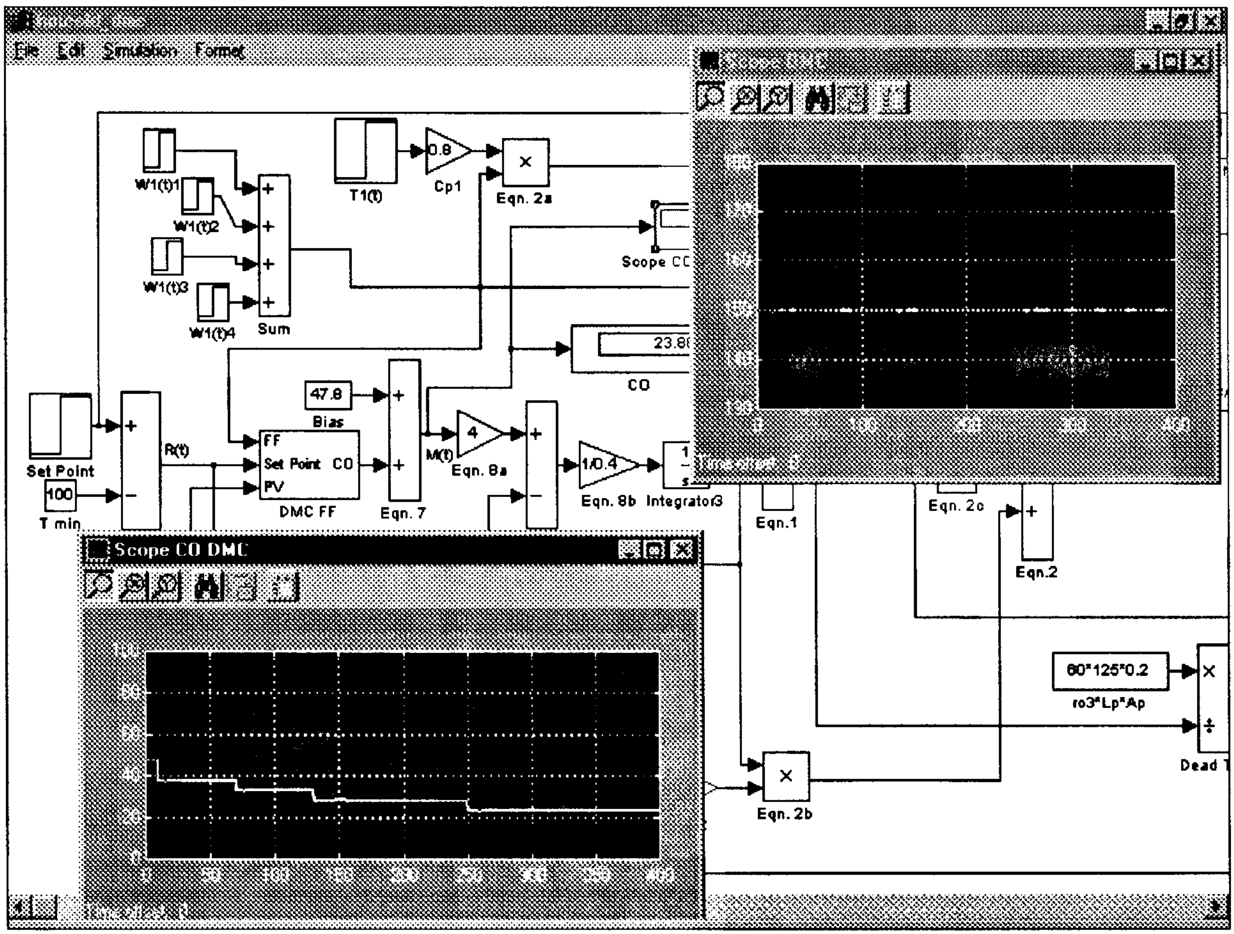

Figure 4. Simulation of a Tank mixing Hot and Cold Water controlled using DMC.

For the other set of strategies, students are asked to create their own process simulation (Figure 4), then implement several control strategies, and compare the performance of each one of them. As result of one of those class projects, a paper was published, analyzing the "Performance of Advanced Control Strategies in Process with Variable Dead Time" [4]. After all, publishing is one of the objectives in Graduate Education.

The process that has been simulated in the example below is a Tank where two streams, one hot, the other cold, are mixed. There are two possible problems that can be derived from this process. First, a SISO system where the controlled variable is the outlet stream temperature, and the manipulated variable is the cold flow. Second, a MIMO system, where the controlled variables are both outlet temperature and flow, and the manipulated variables are both inlet flows.

The system is considerably non-linear, and the main problem is the dead time variation when the total flow changes. To implement a control strategy that reject the effect of disturbances that increase the dead time is a perfect challenge that requires the application of control engineering at every level.

Conclusions

After the introduction of process simulation and control, using both Labview and Matlab, in the Control courses at USF, the following conclusions can be stated:

The learning process of control theory is reinforced with labs where students face actual plant problems. This type of applications helps to create an engineer with an integrated vision of the plant, and a better understanding of control principles.

The use of Labview in Ready-to-Use simulations give the student access to a DCS-type interface, where they can learn and manipulate the process in an environment close to the one that they are going to work with in a plant.

By asking the students to create their own process simulation, we are giving to them the necessary tools to be able to design and analyze plant behavior and equipment.

References

[1].*Labview 4.1 User Manual* . National Instruments Corporation,1996.

[2].Smith, C.A. and Corripio, A. *Principles and Practice of Automatic Process Control*, John Wiley and Sons, 1997.

[3].Cuttler, C.R., and B. L. Ramaker. 1979. "DMC – A Computer Control Algorithm." AIChE 1979 Houston Meeting, Paper No. 516, AIChE, New York, 1979. DMA, Inc., Houston, TX

[4].Otero, F., Sanjuan, M., Acuna, A., and Smith, C. "Performance Evaluation of Advanced Control Strategies' Proceedings of the LatinAmerican Conference in Automatic Control, 1998, Chile.

5] Dabney, J. and Harman, T. *Mastering Simulink 2 : Dynamic System Simulation for Matlab*, Prentice Hall, United States, 1998.

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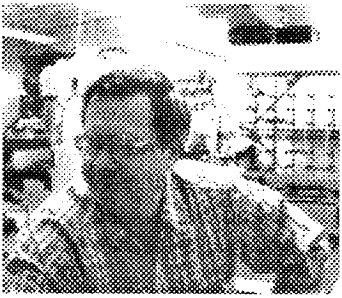

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