Process Control Laboratory Using Honeywell PlantScape

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Abstract

The University of Tulsa has recently revised its process controls class from one 3-hour course to one 2-hour course covering transient modeling and one 3-hour course in advanced control techniques with laboratory experiments. These lab experiments use the equipment from our unit operations laboratory which is controlled with Honeywell PlantScape software. This allows the students to gain experience with process control software used in industry.

The first experiment is tuning a PID feedback controller for the flow manifold used with the double pipe heat exchanger experiment. The second experiment is tuning a feedforward controller (lead-lag unit) for the liquid level at the bottom of the packed tower absorber. The third experiment is cascade control of the temperature of an oil bath, and this is not part of the unit operations lab but used PlantScape. A fourth experiment, used only as a demonstration for this first year, is multivariable control of a distillation column.

PlantScape is designed for operating plants, not for pedagogical experiments, which led to challenges in designing the labs. This presentation will discuss those challenges and how we overcame them.

Industrial Process Control Course

This course is the second course in out process controls series. In the first course, the students learn to model transient systems, develop transfer functions from those models, create block diagrams and P&IDs, and select components for simple feedback PID control systems. This second course continues with tuning PID feedback controllers on physical systems and goes on to feedforward, cascade, ratio, and multivariable control systems. The textbook for the course is Process Dynamics and Control[1], and this text covers these control systems and tuning processes for them. The course is set up as 1 hour of laboratory and 2 hours of lecture per week, on average over the semester.

The class was scheduled to meet from 8:00 to 10:45 am on Tuesdays and Thursdays, taking up two 3-hour class slots. Lectures usually ran from 9:30 to 10:45 am. There were a total of three lab weeks during the semester. For each lab, the students were divided into groups of four and assigned a 90 minute time slot for the lab. The students came in at 8:00 am only during lab weeks, and then only if they were assigned an early lab. Each lab was run after the tuning information had been covered in the lectures.

Experiment Overview

Most of the experiments use equipment from our unit operations laboratory courses. Analyzers, sensors, and control elements are connected to a Honeywell automated control system that runs PlantScape software (Release 500.1). We plan to install the latest software version, Experion™, in the near future. More than 11,000 Honeywell automation systems have been installed since 1974, giving Honeywell the largest installed base in the automation industry[2]. Using this industrial software in the unit operations and industrial control laboratories prepares the students for using it on the job. The students will be familiar with the software that their plant operators are using, and they will already know how to generate step response curves. They will have seen advanced control techniques implemented and know how to tune them.

The first experiment is tuning a proportional-integral-derivative (PID) feedback controller for the flow manifold used with the double pipe heat exchanger experiment (Figure 1). The flowrate is measured by the pressure drop across an Annubar, and the flowrate is controlled with a valve. There are three flowlines, each with its own Annubar and control valve. The three Annubars have different flow ranges, and the control valves have different lift characteristics. The students experimentally determine the lift characteristics and the transfer function for the flowrate with

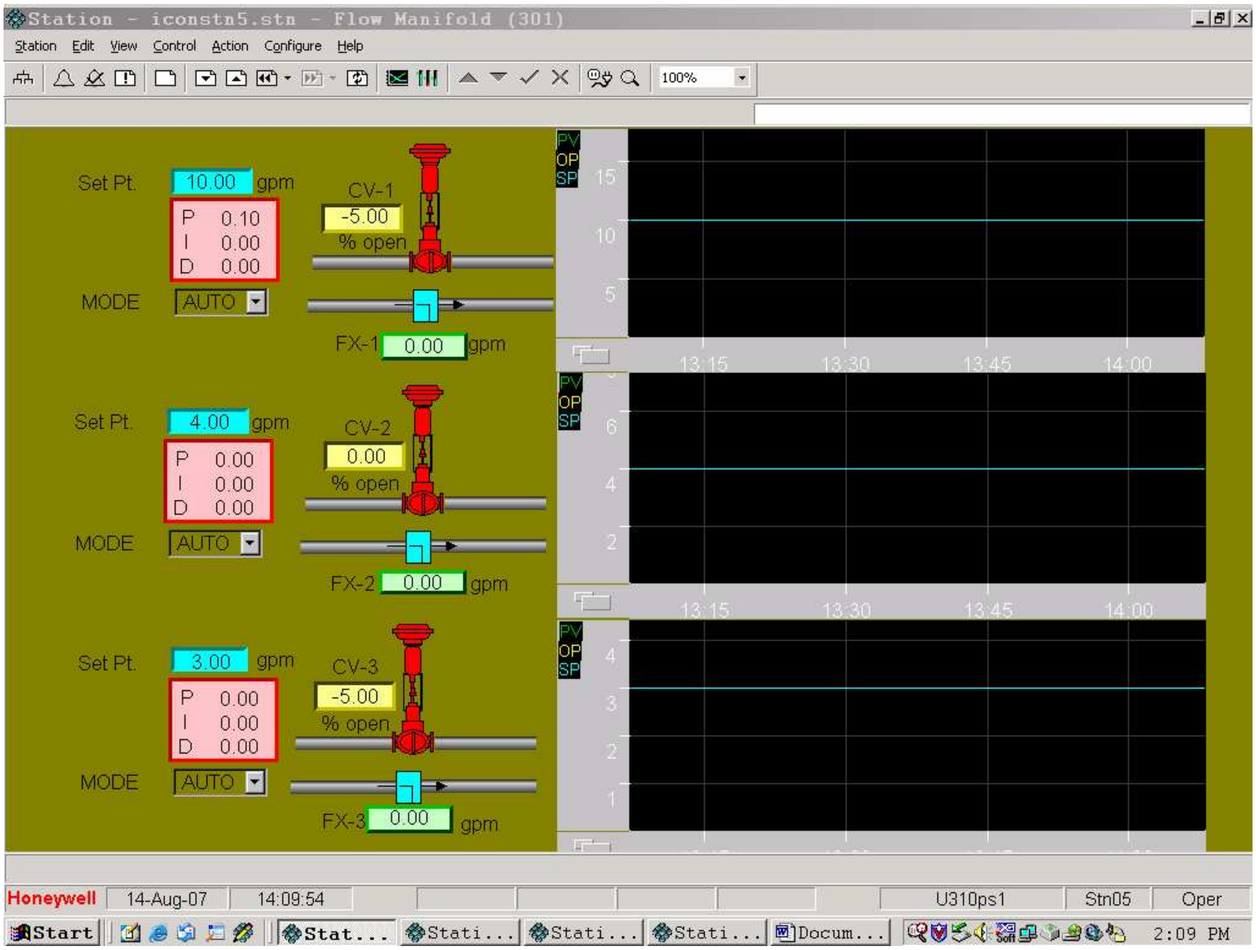

Figure 1. Plantscape screenshot for the Flow Manifold. Setpoints (Set Pt.); controller modes (MODE); proportional (P), integral (I), and derivative (D) controller settings; valve openings (CV-#, % open); and flowrates (FX-#, gpm) are all shown.

respect to the control valve opening. They tune a PID controller using internal model control setting, and then they implement and test the controller. At the end of the experiment they were supposed to apply their tuning to another flowline, but all of the students ran out of time.

The second experiment is tuning a feedforward-feedback controller with a lead-lag unit for the liquid level at the bottom of the packed column absorber (Figure 2). One existing feedback controller controls the flowrate into the top of the tower by manipulating a control valve on the inlet line, and another control valve manages the liquid level at the bottom with a control valve on the liquid outlet line. After determining transfer functions, the students add a lead-lag unit to the level controller that anticipates level changes due to the valve opening of the control valve for the inlet flow. They tune the lead-lag unit and test its response to small and large changes in inlet flowrate.

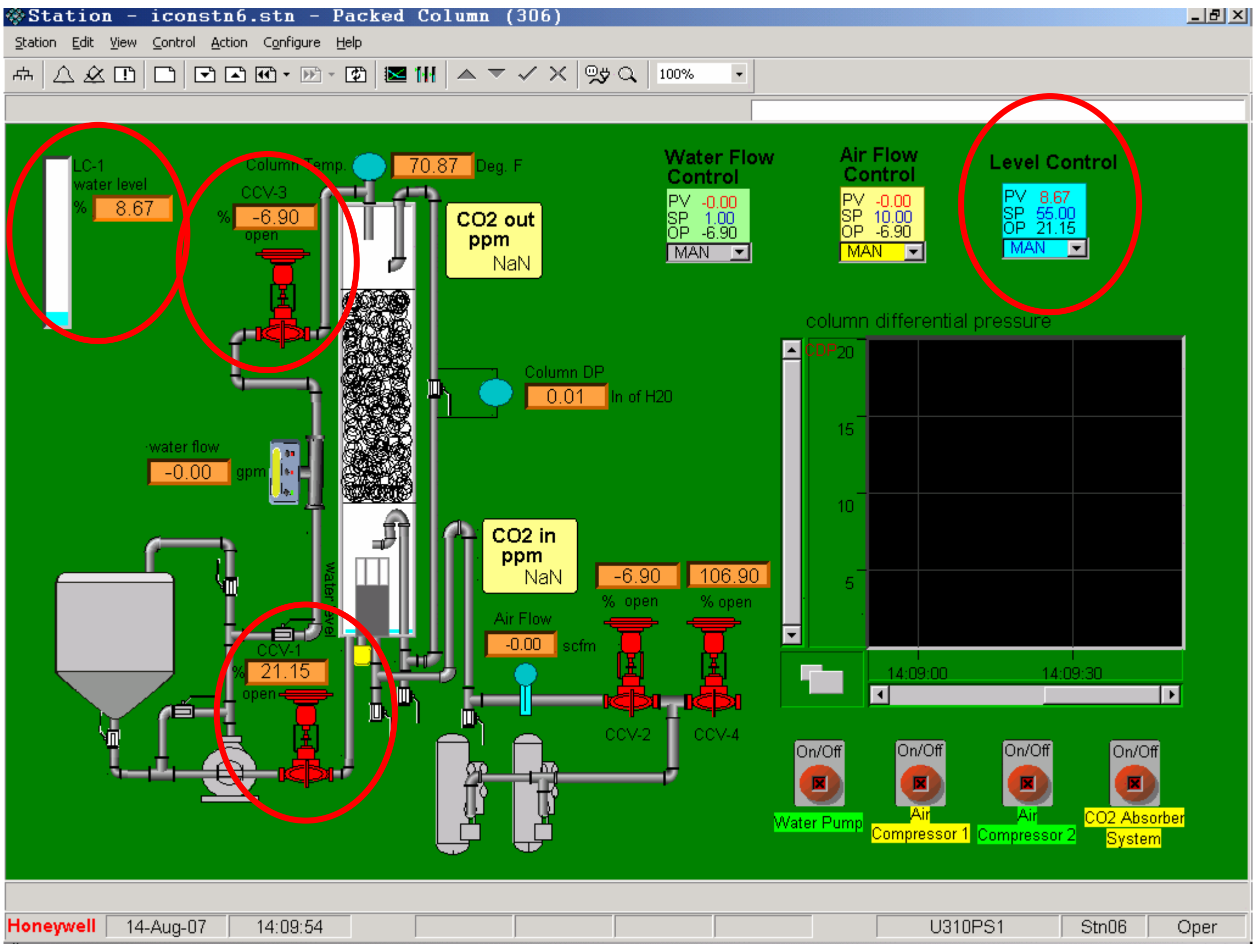

Figure 2. PlantScape screenshot of the Packed Column experiment. The feedforward controller adjusts the outlet flow valve (CCV-1) based on information from the inlet valve position (CCV-3) in order to keep the level at the bottom of the column (LC-1) steady.

The third experiment is cascade control of the temperature of an oil bath (Figure 3). This equipment is the only one that is not part of the unit operations lab, but it still uses PlantScape. The cascade controller attempts to control the temperature of oil in a beaker on a hotplate. The master controller sets the setpoint for the slave controller based on the oil temperature. The slave

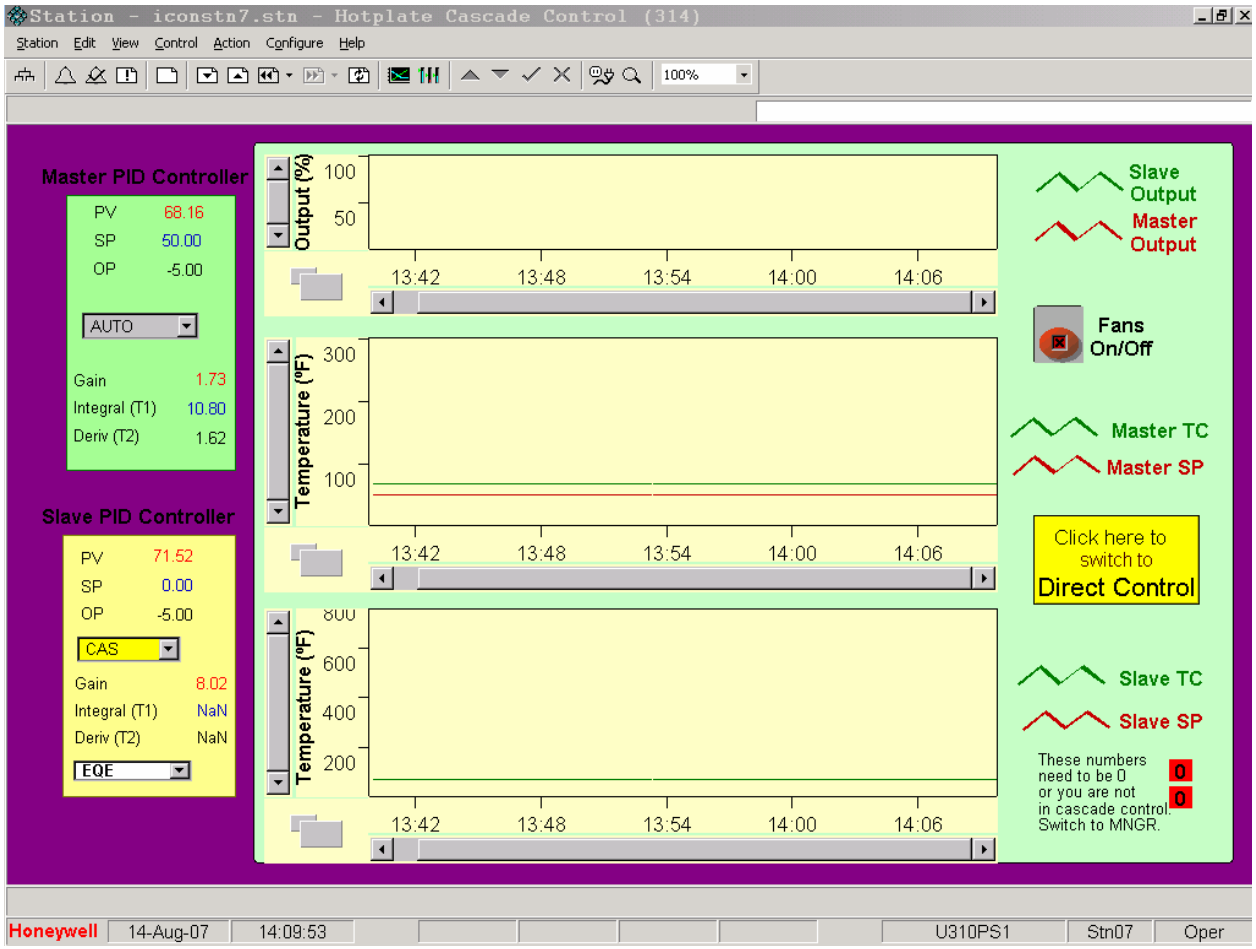

Figure 3. PlantScape screenshot of the Hotplate Cascade Control. The oil temperature is the process variable (PV) for the Master PID Controller, and the hotplate temperature is the process variable for the Slave PID Controller. The output (OP) of the master controller is scaled and becomes the setpoint (SP) for the slave controller.

controller adjusts the hotplate voltage based on the hotplate temperature and its setpoint from the master controller. In the first year, the students were asked to tune the slave and master controllers and test the response to a disturbance. Most were able to test at least two disturbances.

A fourth experiment, used only as a demonstration for this first year, is multivariable control of a distillation column (Figure 4). The column has five feedback control loops. Feed and distillate flowrate controllers both control the flow with a control valve on the pipe. The condensate temperature is controlled by manipulating the cooling water flowrate. The condensate accumulator level is managed by adjusting a control valve on reflux flow back to the chamber. The reboiler level is controlled by turning the bottoms pump on or off. The power to the feed heater and the reboiler can also be set. In the spring the column was still under development, but the students were able to watch the column as it approached steady state with only water. In future years the students will be asked to determine transfer functions for some interacting loops.

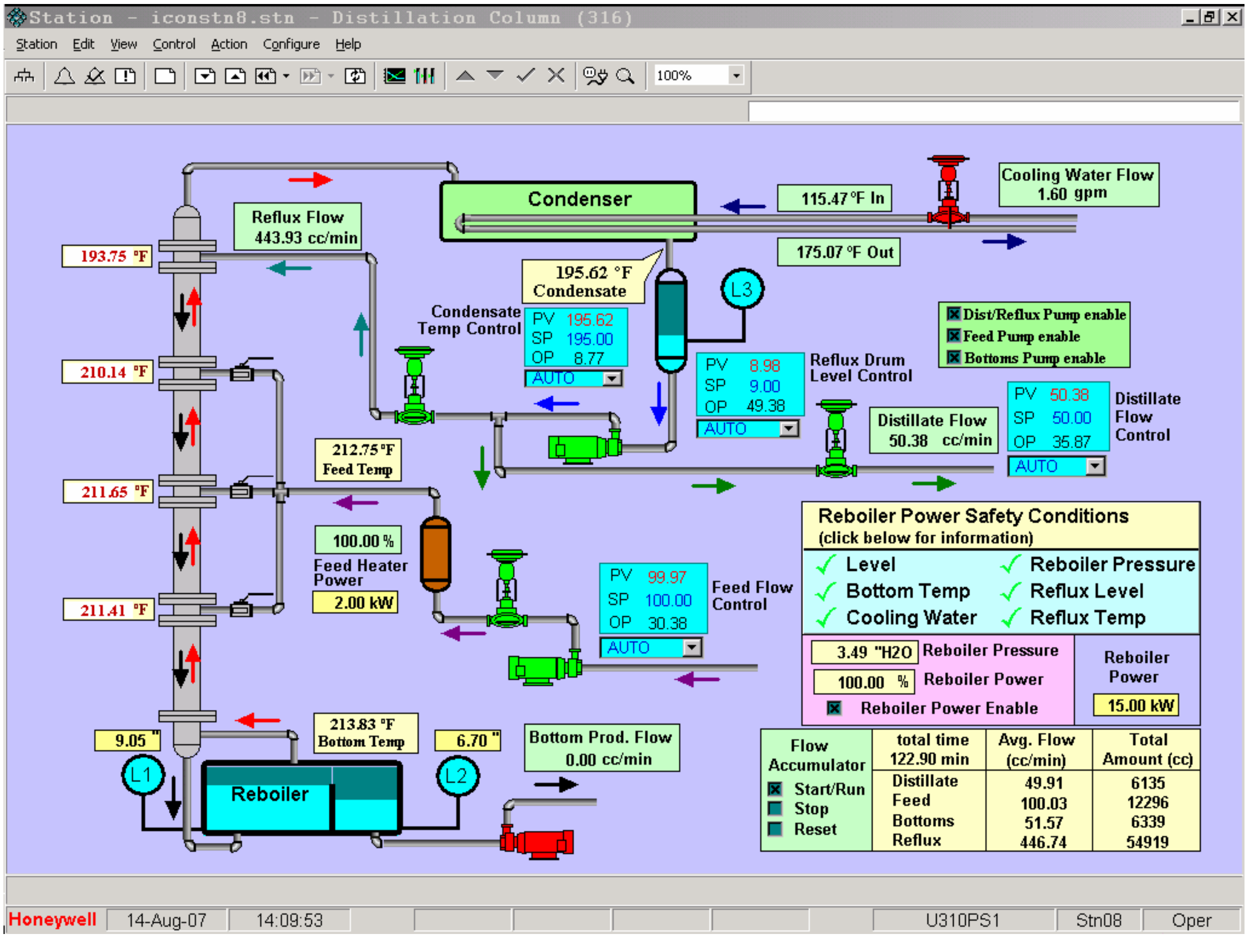

Figure 4. PlantScape screenshot of the Distillation Column. Control loops are indicated by the light blue boxes where the process variable (PV), setpoint (SP), and manipulated variable (operating variable, OP) may be set.

The PlantScape software allows the students to run experiments with the controller on (AUTO or CAScade modes) or off (MANual mode). With the controller off, the students may specify the manipulated variable value: the control valve percent opening or the voltage into the hotplate. With the controller on, the students may specify the process variable (flowrate, level, or temperature) setpoint and adjust the controller tuning (proportional, integral, derivative, lead, and lag constants). The software can be set up to record the manipulated variable and process variable values.

For some of the experiments, the students had data analysis to perform before running any experiments. All labs had a report, and the students were required to revise the first report and submit a second version.

Implementation Challenges

The first challenge in setting up these experiments arose due to the original intent of the equipment and limitations of the PlantScape software. The flow manifold was intended simply to set the stream flowrates for the heat exchangers, not for process control experiments. The lab-scale equipment is much smaller than most plant-scale equipment, and the corresponding time constant and time delay are order of seconds. The PlantScape software was set up to record data every 5 seconds. Data are updated on the screen much more often, but only the 5 second average was exportable to an Excel spreadsheet. [We have since changed this setting to 1 second.] Students cannot fit a first order plus dead time (FOPDT) model to a system with time constant and time delay under 5 seconds with data recorded every 5 seconds. To work around this problem, I used two features of the PlantScape software to alter the time constant and time delay of the process. One feature time averages the data[*], which is useful for noisy data and effectively changes the time constant of the process. The second feature adds a dead time to the data[†]. One could model the overall process as the original physical process followed by a measurement and transmission transfer function. We set the measurement and transmission time constants from 0.4 to 0.6 minutes and the dead time from 3 second to 9 seconds. At these settings, the measurement and transmission constants were much larger than the physical constants, and we could choose the transfer function for the process, as long as the constants were 5 seconds or longer. This released us from the restrictions of the physical equipment's constants and allowed us to choose values that worked better for our process control experiment.

Another major limitation was time. The students were given 1.5 hours to complete the experiments and in-lab calculations, and this often was not long enough. Different compensations could be or were made for each lab.

- In the first experiment, PID control of a flow manifold, the students recorded the flowrate response to step changes in valve opening. They fit a FOPDT model to the data and calculated PID tunings based on the model. They then implemented the tunings. The students had forgotten how to fit the FOPDT model to data and calculate tunings. Requiring a pre-lab report in which they fit a FOPDT model, calculate tunings, and provide a spreadsheet to calculate tunings based on the lab data will reduce the time limitations on this experiment.
- In the second experiment, the feedforward control of the tower liquid level, the students did an unsteady mass balance on the system before the lab. They also found the relationships between the disturbance transfer function and the lead-lag constants. The slow part of the lab was experimentally determining the disturbance and process transfer functions. The level at the bottom of the tank is an integrator process, and it is very hard to reach a steady state so that a step change in valve opening can be made. In the future, we will probably produce step changes for them to analyze in the pre-lab report and let them try a few in the lab to see how difficult this system is to control.
- The third experiment on cascade control of a heated bath had the opposite time problem from the flow manifold: the time constant of the overall process is 20 minutes. For this lab we did provide the results of step changes for the students to analyze before the lab. They also determined the tunings for the slave and master controllers before arriving in the lab. The system was at steady state before they arrived to run experiments. They adjusted their tunings and tested the response to a disturbance. We provided them with the response of a plain PID feedback controller to the same disturbance for them to use in comparison. This lab probably ran the best on time, mostly because we applied some of the lessons learned from the previous labs.

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[*] Under PID Point Detail, PV&OP tab, set Filter Time (minutes).
[†] In Control Builder, add a DEADTIME auxiliary block to the module.

- The fourth experiment, multivariate control, has not been run yet since the equipment is still in development. Based on previous labs, we will need to generate the step responses for the students to analyze before the lab. We will need to bring the system to steady state before they arrive. They will be able to test the responses of their tunings to setpoint changes during the lab time.

The total time in the lab was 6 hours, which is not enough for 1 credit hour. We may need to revise the class schedule in the future to relax the time constraints and make the lab portion of the class worth 1 credit hour.

One last challenge is that the original experiment Displays and Trends in PlantScape did not always include enough information for process control experiments, even though there was enough information for unit operations experiments. For example, the valve position on the inlet line for the tower (feedforward experiment) is not needed in the unit operations lab, but it is needed in the process controls lab. PlantScape must be told to keep a long-term history of data, or only the data on the screen since the last Trend rescaling are exportable to Excel. Expanding the list of variables that are "historized" is a simple change to make in Control Builder[‡].

Summary

Some unit operations experiments run with Honeywell PlantScape have been successfully adapted to process control experiments. Some difficulties were encountered with both fast and slow process kinetics. The fast kinetics were handled using PlantScape's time averaging and dead time features and changing the data recording rate. Slow kinetics were handled by providing the students with extra data to analyze before and after the lab exercise. Major time limitations on the experiments were handled mostly by providing data for analysis before the lab. A small problem in that the Displays and Trends were not set up for process control experiments was easy corrected by adding variables to the History Configuration. The students had the opportunity to practice measuring step responses, tuning controllers, and evaluating tuning effectiveness, all with commercial process control equipment that they may see on the job.

Bibliographic Information

1. Dale E. Seborg, Thomas F. Edgar, and Duncan A. Mellichamp, *Process Dynamics and Control*, 2nd Edition, John Wiley and Sons, 2004.
2. Honeywell FAQ page, hpsweb.honeywell.com/Cultures/en-US/AboutUs/FrequentlyAskedQuestions/HoneywellFAQs/default.htm, accessed June 25, 2007.

Biographical Information

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Dr. Patton is Applied Associate Professor of Chemical Engineering at The University of Tulsa. She received her B.S. in Chemical Engineering from Texas A&M University and her M.S. in Applied Mathematics and her Ph.D. in Chemical Engineering from The University of Tulsa. She is currently involved in applying fuel cells and reformers to hybrid-electric vehicles.

[‡] In the Project tab of Control Builder, right click on the module name. Choose Configure Module Parameters. Add the needed parameters under History Configuration on the Server History tab.

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