

# NETWORK PROCESS CONTROL LABORATORY

BARRY LENNOX, MICHAEL BRISK\*

*Control Technology Centre • University of Manchester • Manchester, United Kingdom*

The difficulties that are faced when teaching process control as part of a chemical engineering degree course have been highlighted by a number of authors.<sup>[1-3]</sup> These difficulties range from a lack of time available to teach even the most fundamental principles of process control, to providing sufficient engineering practice of the theory taught in the classroom. Consequently, the effectiveness of many university process-control courses, judging from industrial feedback, is poor.<sup>[4]</sup>

A number of recent publications have suggested the use of process-control computer-simulation packages to overcome these difficulties.<sup>[5]</sup> These simulations typically allow the student to progress through a number of practical process control problems ranging from simple PID controller tuning to the development of complex model-based control strategies. Although these software applications do provide valuable experience for students, they unfortunately fail to provide the real engineering practice that is essential for students who wish to pursue a career in control engineering. This experience can only be gained through development and analysis of process control applied to real industrial equipment. It has further been suggested<sup>[1]</sup> that students find control engineering courses much more interesting and useful when they are practice oriented.

A simple and relatively cheap method of providing students with some practical experience of process control is to set up a laboratory experiment that regulates the level of liquid in a tank using a control valve. Installing a single-loop controller to such a system will even allow the student to become familiar with simple forms of industrial controllers. Unfortunately, this type of experiment tends to trivialize the role of modern control engineers in industry where, typically, complex chemical processes are controlled with the

aid of sophisticated process-control hardware.

The Department of Chemical Engineering at Monash University has recently made moves to provide a link between university teaching and the industrial application of process control. This has been achieved by investing a significant amount of resources in the development of a process-control experiment that incorporates both industrial process equipment and an advanced control platform. This paper describes both the equipment and the experiments that have been developed at Monash University.

## EXPERIMENTAL EQUIPMENT

The system was set up to meet three requirements. The first was to provide all students in the chemical engineering course with exposure to an industrial control problem. The second was to provide a limited number of final-year students with increased process-control exposure by way of a six-month project, and the final requirement was that each of the experiments could be used for demonstration purposes throughout the course. The experiment that was developed to fulfill these requirements is detailed in the following section.

*Barry Lennox received his BEng in Chemical Engineering (1991) and his PhD in Process Control (1996) from the University of Newcastle-upon-Tyne. He subsequently transferred to Monash University where he worked as a Research Fellow in the Department of Chemical Engineering, and in 1998 became a lecturer in Control Engineering at the University of Manchester. His research interests lie in the advancement and application of process control and monitoring techniques to batch and continuous process systems.*

*Michael Brisk obtained his PhD in Chemical Engineering from the University of Sydney in 1965. He worked for six years for ICI in the United Kingdom before becoming a senior lecturer in chemical engineering at the University of Sydney, where he spent the next eleven years before transferring to ICI Engineering in Melbourne and establishing an Advanced Process Control Group. In 1994 he became Adjunct Professor of Process Control and became Dean of Engineering at Monash University in 1995.*

\* Address: Monash University, Melbourne, Australia

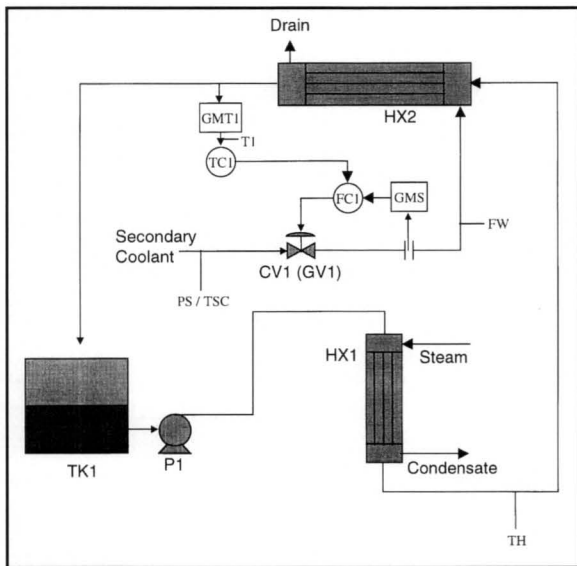


Figure 1. Heat exchanger process diagram.

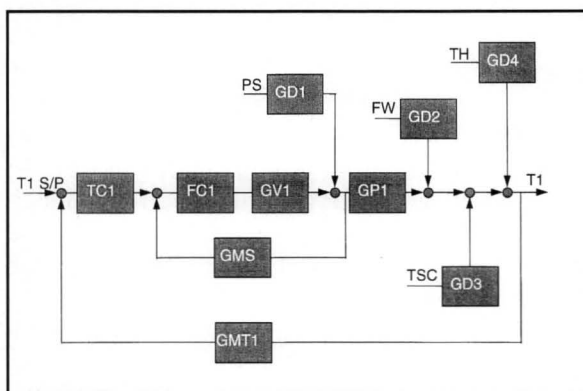


Figure 2. Process control block diagram.

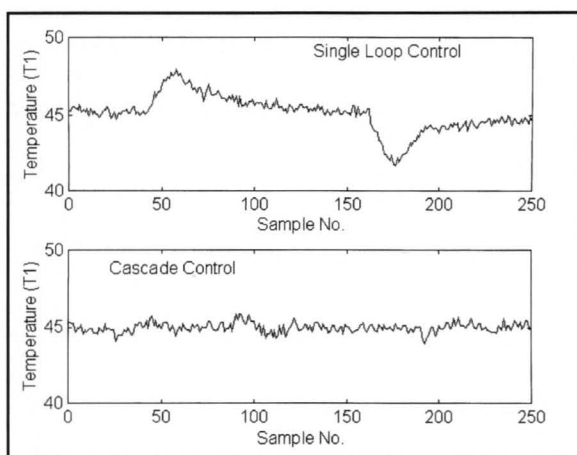


Figure 3. Comparison of single loop and cascade control.

## CONTROL EXPERIMENT

Within the ever-present financial constraints that beset a university department, the decision was made to modify and use an existing experimental rig. The apparatus, originally designed to study heat-transfer processes, was chosen for the following reasons:

- ▶ The time constant of the system is approximately 5-10 minutes. This means that during a typical laboratory period lasting three hours, a student has sufficient time to tune and modify a number of control loops and strategies.
- ▶ The equipment used in the system is relatively large (2-inch pipes and 2-meter-long heat exchangers) and has the appearance of an industrial plant, which is essential if the students are to gain familiarity with industrial process control.
- ▶ Only minor modifications, such as the installation of control valves and thermocouples, were required for this piece of equipment to be transformed into a process-control experiment.

Figure 1 shows a schematic of the modified process. The steam heater, HX1, heats the circulating water stream, fed from tank TK1, by condensing steam on the tube walls. The outlet water from this heat exchanger is then fed to HX2, a horizontal shell-and-tube heat exchanger, which cools the water using a secondary coolant. Once cooled, the water returns to the circulating tank. To provide the control in the process, a control valve, CV1, was installed on the supply line of the secondary coolant.

The objective of the experiment is to design a controller capable of regulating the temperature of the circulating water as it exits HX2. Once designed, the controller is tested for its effectiveness at regulating this temperature in the presence of set-point changes and process disturbances.

The overall process-control block diagram of this process is illustrated in Figure 2. In this diagram, TC1 represents a conventional PID feedback controller that can either regulate the temperature, T1, independently or can be configured to form the primary loop of a cascade controller, which incorporates FC1 as the secondary loop. GMS and GMT1 measure the secondary coolant flow rate and the outlet temperature, respectively. GV1 and GP1 represent the dynamics of the valve and heat exchanger, respectively. GD1, GD2, and GD4 represent the disturbances to the system, which are the secondary coolant supply pressure, circulating-water flow rate, and the temperature of the water as it exits the heat exchanger.

During the experiment, the students are asked to develop and compare a conventional feedback controller with cascade control. In doing so, they are expected to make a number of important decisions alone; for example when tuning the controller, the decision must be made as to what size step test should be performed to enable a step response of the system to be analyzed for tuning purposes.

If the experiment is performed correctly, the result is that the feedback controller and the cascade controller operate similarly for servo control. But due to the relatively fast dynamics of the secondary control loop, cascade offers significant improvement for regulating the process during process disturbances. This is confirmed in Figure 3, which shows the temperature control of both the single loop and the cascade controllers during a process disturbance. The top graph in

this figure shows the control obtained using single-loop feedback control, and the graph below shows the control resulting from cascade control. In each case, there are two process disturbances, a reduction in upstream coolant supply pressure at sample number 45, and an increase in upstream coolant supply pressure at sample number 160 (each sample represents five seconds).

## PROCESS CONTROL EQUIPMENT

The control interface for the experiment was an ABB MOD300 distributed control system (DCS), which is typical of systems widely used in the chemical and process industries. By using this system, the students become aware of the features of a control system that they might expect to encounter after leaving the university. Standard remote input/output blocks were used to transmit the on-line measurements to the DCS. As with all the process-control equipment, these blocks were placed in such a way that the students were able to view them.

## PC INTERFACE

Particular disadvantages when using many types of distributed control systems are

- *The graphical and data analysis capabilities of the systems are restricted.*
- *The systems were designed for conventional control structures, such as PID, cascade, ratio, and simple forms of model-based control. Although these control structures will be all that is required for the student experiments, the system will also be used in postgraduate research, where more advanced forms of model-based control will be required.*
- *It is difficult to give a demonstration of the systems, since to do so the demonstration has to take place in the laboratory, where space is limited.*

To combat the first of these drawbacks, a novel software package has been developed at Monash University that enables two personal computers (PCs) to communicate directly with the DCS. Figure 4 shows schematically how the hardware has been configured for this system.

A short piece of code was written on the DCS in Taylor

Control Language (a programming language similar to PASCAL). This program operates in the background and periodically (currently every five seconds) sends the collected process data, such as setpoints, values of the measured variables, and controller modes, via a serial link to a PC positioned beside the DCS. A software package running continuously in the background on the PC receives the data and makes it available to any other Windows-based software application via a dynamic data exchange (DDE) link. At present, the data is transferred to an open MATLAB session. MATLAB allows the data to be collected in the background, thus allowing the advanced graphical and data-analysis functions, available in MATLAB, to be run in the foreground in real time.

Furthermore, the system has been configured so that at the same time as receiving data from the DCS, the PC is also able to transmit data to the DCS. The DCS has a second program running in the background that continually monitors one of its serial ports and detects any signals that are sent from the PCs. It is therefore possible to change parameters such as process set points and loop modes from the PC. This feature enables complex control systems to be developed and operated from the PC, with the DCS acting as an interface between the PC and the process hardware.

To enable the system to be demonstrated in the classroom, a final piece of software has been developed that can be operated by any PC connected to the Internet. This software package allows the user to access identical displays to those available on the DCS. Periodically, the software package transmits a signal via the standard TCP/IP protocol to the PC positioned locally to the DCS. The local PC replies to this signal by transmitting the most recent process data. At present, the signal that must be sent to the local PC, before data is transmitted, is an ASCII string. But, if required this signal could be encrypted to increase the security of the system. Once the data is received, the relevant displays on the PC are subsequently updated. It is also possible for any computer connected to the Internet to change process setpoints and controller modes remotely. This feature allows the experimental systems to be operated via any computer connected

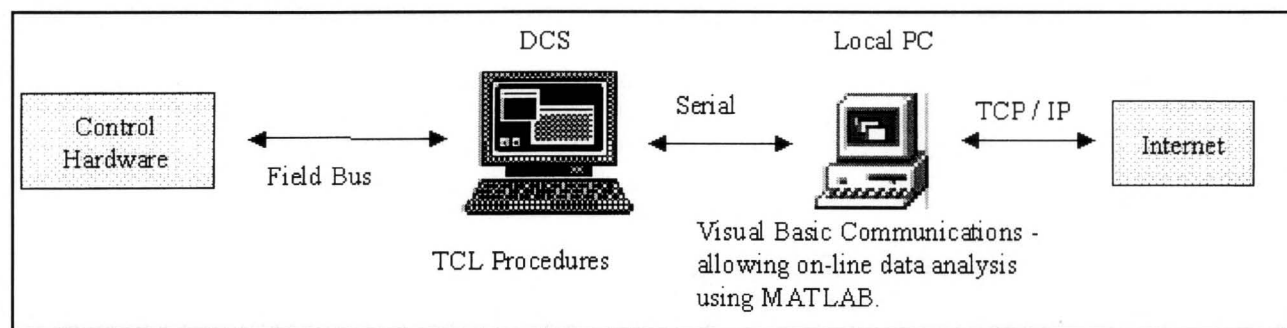


Figure 4. DCS hardware set-up.

to the Internet. In particular, it allows the process-control hardware to be operated from the lecture room, thus allowing the system to be used for lecture theater demonstrations. Although it is possible to use a dynamic simulator for demonstration purposes in lectures, we feel that the students take more interest and consequently gain greater appreciation of the application of control by operating the real equipment through the remote interface. Figures 5 and 6 show two example screens that are provided by the PC software package. The graphics are almost identical to those available on the DCS.

This software package may in the future provide an opportunity to improve the distance education courses offered by the university, since it would be possible to conduct the experiment well away from the university campus.

A further advantage that the system offers is that it is also possible for the students to run other applications in the foreground because all the software on the local PCs has been designed to operate in the background. For example, all the process control course notes, developed in Lotus Freelance, are available for the students to read through while they are conducting the experiment.

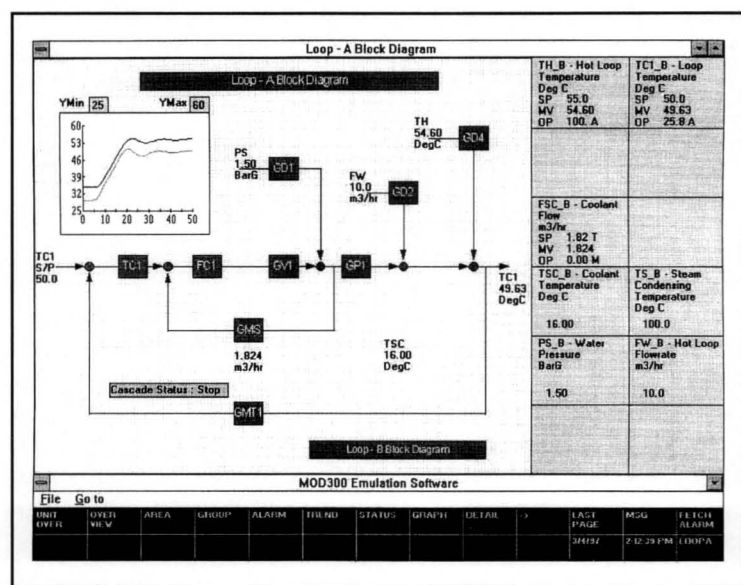


Figure 5. Example of a group graphic.

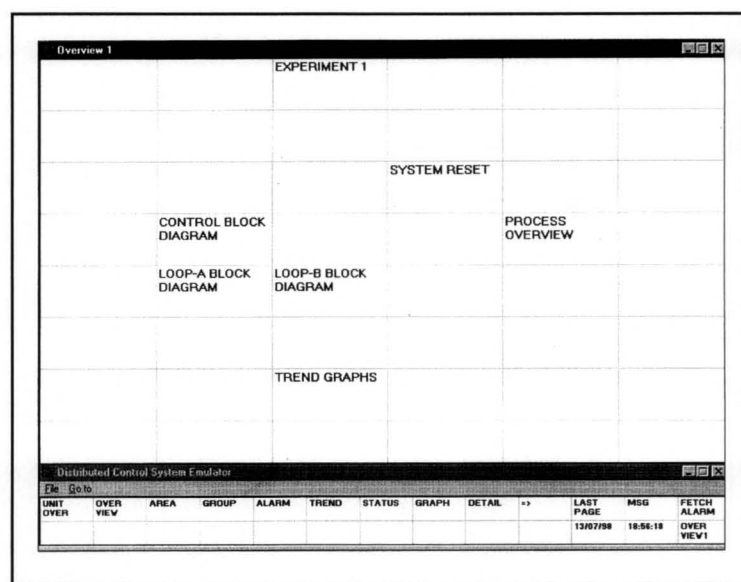


Figure 6. Example of an overview display.

## CONCLUSIONS

The experimental system that has been designed and commissioned at Monash University provides students with the opportunity to gain familiarity with some of the process-control structures and hardware commonly used in industry. This experiment will lead the students to a greater understanding of what they may expect to see if they become involved with process control after graduation.

The advanced communications package developed to allow PCs to communicate directly with distributed control systems greatly enhances the flexibility of the system for teaching. It enables the user to receive and transmit data to the control system from anywhere in the world, provided the user is connected to the Internet and has TCP/IP compatibility. This facility has many applications, including distance education and remote contact with process equipment.

## ACKNOWLEDGMENTS

The authors would like to acknowledge the help and support of the Chemical Engineering Department at Monash University. Particular thanks are due to Gill Atkin for supplying the expertise in modifying and installing most of the process equipment. The support of ABB is also gratefully acknowledged, as is the encouragement provided by Ming Tham.

## REFERENCES

- Jovan and J. Petrovic, "Process Laboratory: A Necessary Resource in Control Engineering Education," *Comp. Chem. Eng.*, **20**, 1335 (1996)
- Lewin, J. Rockman, and R. Lavie, "Teaching Advanced Process Control to Undergraduates," *Comp. Chem. Eng.*, **20**, 1347 (1996)
- Chung and R.D. Braatz, "Teaching Antiwindup, Bumpless Transfer and Split-Range Control," *Chem. Eng. Ed.*, **32**(3), 220 (1998)
- Merrick and J.W. Ponton, "The Ecosse Control Hypercourse," *Comp. Chem. Eng.*, **20**, 1353 (1996)
- Bequette, K.D. Schott, V. Prasad, V. Natarajan, and R.R. Rao, "Case Study Projects in an Undergraduate Process Control Course," *Chem. Eng. Ed.*, **32**(3), 214 (1998) □