AC 2009-268: A MODERN MANUFACTURING ENVIRONMENT FOR CHEMICAL ENGINEERING PBL PROBLEMS

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A Modern Manufacturing Environment for Chemical Engineering PBL Problems

Abstract

The use of Problem-Based Learning (PBL) is growing in popularity because educational research has shown its effectiveness versus traditional teaching methods. This educational approach provides students with a realistic problem as motivation and then guides them through the process of setting objectives and locating appropriate learning materials that will allow them to solve or attempt to solve the well constructed PBL problem. The PBL problem must be realistic in order to provide sufficient student motivation; thus, the best environment for a chemical engineering PBL problem is arguably the actual industrial modern manufacturing environment. However, some schools lack proximity to industrial modern manufacturing environments, and there can be serious safety and confidentiality issues with working on actual industrial problems.

We propose to create a flexible modern manufacturing setting in the classroom for realistic chemical engineering PBL problems by configuring an industrial quality laboratory Distributed Control System (DCS) and connecting it to a high fidelity dynamic process simulator. Such an environment can be made virtually indistinguishable from an actual industrial process control room but located in the safety and convenience of a classroom. We can construct our PBL problems in the chemical manufacturing facility of our choice by integrating the appropriate DCS configuration with a suitable dynamic simulation case study. This approach provides students with a realistic chemical manufacturing PBL problem for motivation and also allows them to engage in authentic inquiry by interacting with this simulated process operation via an industrial quality DCS interface.

Project Approach

This work supports the NSF CCLI project “Improving Engineering Curricula by Integrating PBL Pedagogy with Modern Manufacturing Case Studies” (0737089). This project involves the development of real-world learning modules to illustrate to engineering students educational concepts such as:

- safety (alarm management, emergency shutdown systems, and flare management),
- control (cascade, ratio, feedforward, override controls, and model predictive control),
- data acquisition (knowledge generation, information technology, data mining)
- application of modeling to manufacturing improvements (real-time optimization, computer aided modeling and simulation, and data reconciliation)

Our goal is to improve the problem solving ability of engineering graduates while familiarizing them with the Information Technology (IT) tools found in a modern automated environment. Students must learn to recognize and analyze problems, develop and propose solutions, implement solutions, and analyze their effectiveness in the context of a modern manufacturing environment.

The Distributed Control System (DCS) is at the center of operations and either incorporates or interfaces with all of the devices and computer applications used to operate a chemical process including regulatory controls, advanced process controls, optimization systems, and process shutdown systems. The DCS is also the primary source of process operating data for modern manufacturing. These data can be viewed live on operating graphics or retrieved historically and, as supplemented by P&ID, equipment drawings and original design specifications, these data are valuable company assets used to improve operations continuously. Modern manufacturing processes are often highly automated using temperature, pressure, flow, and other measurements to sense the process state and using remotely adjusted valves and other devices such as pumps and other machinery to adjust the process state. Process alarm settings are also managed in the DCS and it also may contain special "operator assist" safety driven process control strategies in addition to typical operating process control configurations.

One of the premises of this project is that a suitably configured DCS system can be an ideal environment for chemical engineering Problem-Based Learning (PBL) problems by providing a realistic simulated modern manufacturing control room. Research has established the effectiveness of PBL techniques over more traditional lecture based delivery systems.[1] By means of these PBL problems, we want students to learn the capabilities of the DCS system and its role in chemical manufacturing, since this knowledge is central to understanding modern automated manufacturing systems. The specific chemical manufacturing process controlled by our DCS system will depend on the desired educational objectives. PBL type problems have been pioneered for the chemical engineering discipline in the area of problem solving.[2,3] This approach could also incorporate more operational material in the chemical engineering curricula as has been proposed by some authors.[4]

HYSYS,[5] an off-the-shelf dynamic process simulation program, will be configured to represent the chemical process being operated. To connect our HYSYS dynamic simulation to our DCS system we use the OPC Data Access standard. OPC is a communication standard developed by a consortium of instrumentation companies to transfer data between control applications.[6] It defines a client-server data exchange structure for alarms, OPC events, and other information.

Modern manufacturing PBL modules will be created for our process control laboratory, process control, advanced process control, kinetics, and advanced analysis undergraduate courses. The learning objectives of our introductory process control PBL problem will be to tune and troubleshoot PID and intermediate regulatory control structures. For advanced process control the student learning objectives will involve tuning and troubleshooting advanced regulatory control structures and model predictive control applications. For the process control lab the learning objectives will involve alarm rationalization issues. Learning objectives for the kinetics course will involve evaluating alarm and safety system design issues based on a reactor runaway scenario. Finally, learning objectives for the advanced analysis course will involve evaluating process events and their root causes using modern process IT tools such as data and alarm historian applications. We also feel that this is a good environment to teach students how to work in teams effectively. This skill will contribute to their future career success and is one of the criteria used by ABET in evaluating undergraduate engineering programs.

Manufacturing Environment

An Experion DCS system was purchased from Honeywell International with an initial license for 1000 DCS tags.[7] The Honeywell OPC interface software was also licensed and we plan to use this OPC-standard-based software interface to connect our dynamic simulation scenarios to the DCS environment. A non-redundant Experion server maintains the DCS system database and two C200 controller servers simulate Honeywell C200 controller modules. The system also includes a Honeywell Application Control Environment (ACE) server for advanced control applications and a license for 12 Honeywell flex stations for students and instructors. We also purchased an actual C300 controller module, a fieldbus interface module and assorted IOP modules: analog input, analog output, digital input, digital output, and thermocouple inputs for demonstration purposes. The following diagram shows the basic network connectivity of this system.

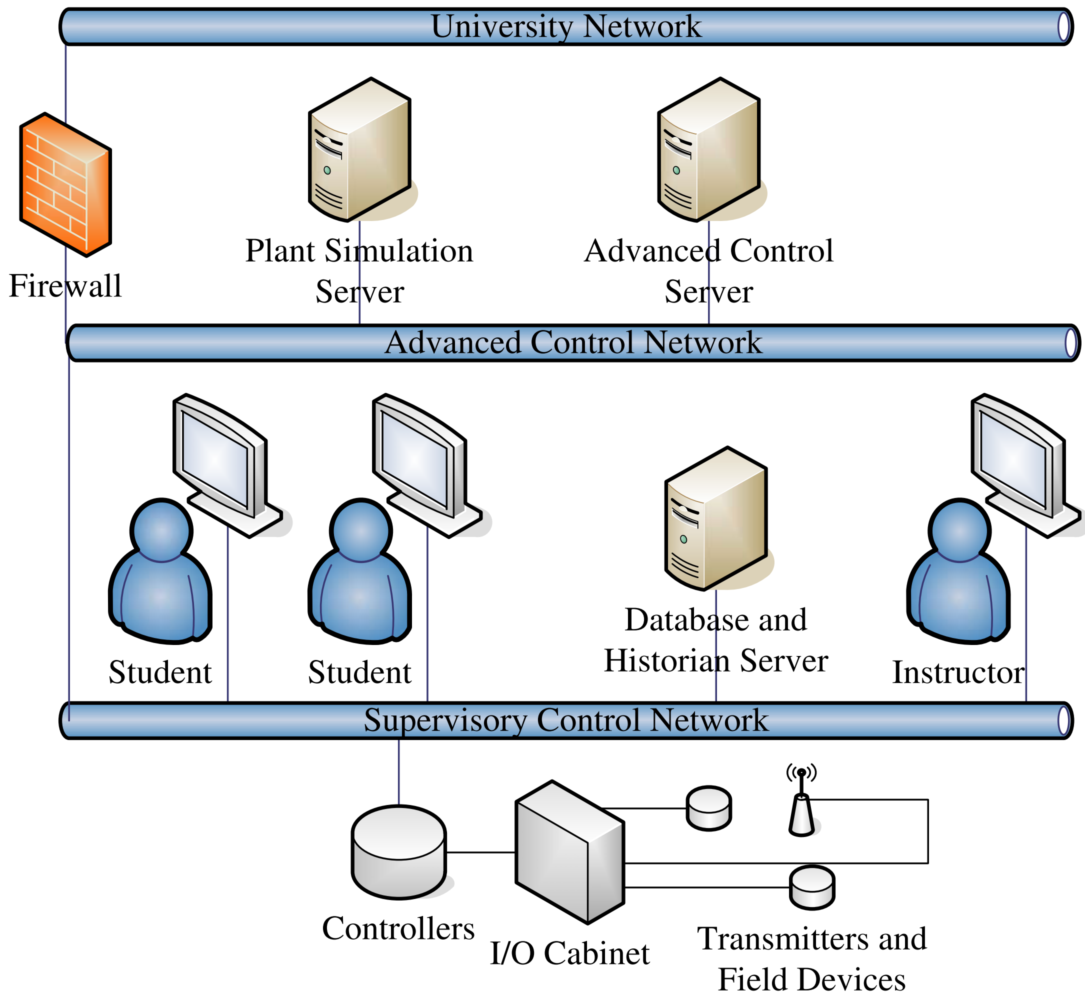

Figure 1. Honeywell Experion DCS System for PBL.

We plan to use HYSYS to develop dynamic process simulations to be controlled by our Experion DCS system and thus to represent the plant environment for our PBL problems.

Dynamic simulation cases that have also been published to study plant wide control could also be used.[8]

The control configuration will be implemented in the Simulated C200 Honeywell Experion controllers using configurations similar to those found in industry. Although our HYSYS models will include PID controller blocks that can be used to run HYSYS stand-alone for control what-if studies, when the HYSYS models are connected to the DCS environment these controllers will be placed in manual and the corresponding DCS PID controller will be used to control the HYSYS plant. The equipment and licenses purchased would also allow students to configure controls using the simulated C200 controller modules; however, our initial intent is to pre-configure the regulatory and intermediate regulatory control strategies to be studied as part of our PBL instruction modules.

The alarm settings will be configured as required for the instruction so that students can experience the effect of different alarming practices in industry as well as how these practices affect the reliability of actual process units. We also plan to implement advanced regulatory and advanced process control applications such as plant level strategies, model predictive control, and real time optimization using a Honeywell ACE server and its Custom Algorithm Block visual basic programs or by using the OPC interface to connect to advanced process control applications running on our Advanced Control server machine. The alarm and event history and data historian will support authentic inquiry by the students for all of the scenarios that we develop as part of our PBL modules.

Information Technology

Manufacturing control system hardware and software have been moving away from vendor proprietary systems to more modern systems including Windows based operating systems to take advantage of the enormous advances in information technology (IT) and to allow companies to leverage their existing base of IT expertise. The importance of IT to the chemical engineering profession has also been recognized by AIChE Computing and Systems Technology division by the formation of a new section devoted to using IT to leverage the enormous expansion in computing technology.[9] Future engineers will have to be much more involved with information technology.[10] In chemical manufacturing the roles of the information technology specialist are merging with the traditional process control responsibilities, blurring the lines of demarcation between the two areas.

Because the modern manufacturing environment we plan to use is Windows based, university IT professionals can be leveraged to support our industrial quality DCS environment. This allows us to focus more on the dynamic simulation case studies and the DCS control configurations required to provide a realistic manufacturing environment. Engineers must understand the capabilities of typical DCS infrastructure software applications in a modern control environment to be effective at optimizing and troubleshooting plant operations. It is not important that they learn the specifics of a particular automation product, but they need to be aware of the capabilities that most automation products provide to help them perform their jobs.

The approach we used to connect our dynamic simulation scenarios to their associated modern manufacturing environment was to automate HYSYS and transfer data to and from the DCS system using OPC. Automation is the ability to interact programmatically with an application through software objects exposed by that application. The HYSYS dynamic simulation application makes most of its program features available via automation so that a dynamic simulation can be initiated by our automation client. The automation client developed using Microsoft Visual Studio 2005 C++ loads a HYSYS dynamic simulation case from a HYSYS file, reads the DCS tag information, and then runs the HYSYS dynamic simulation scenario. The program loads the appropriate DCS tag and configuration information from a HYSYS table created as part of each case. Figure 2 is a screenshot of the automation program developed as part of the project.

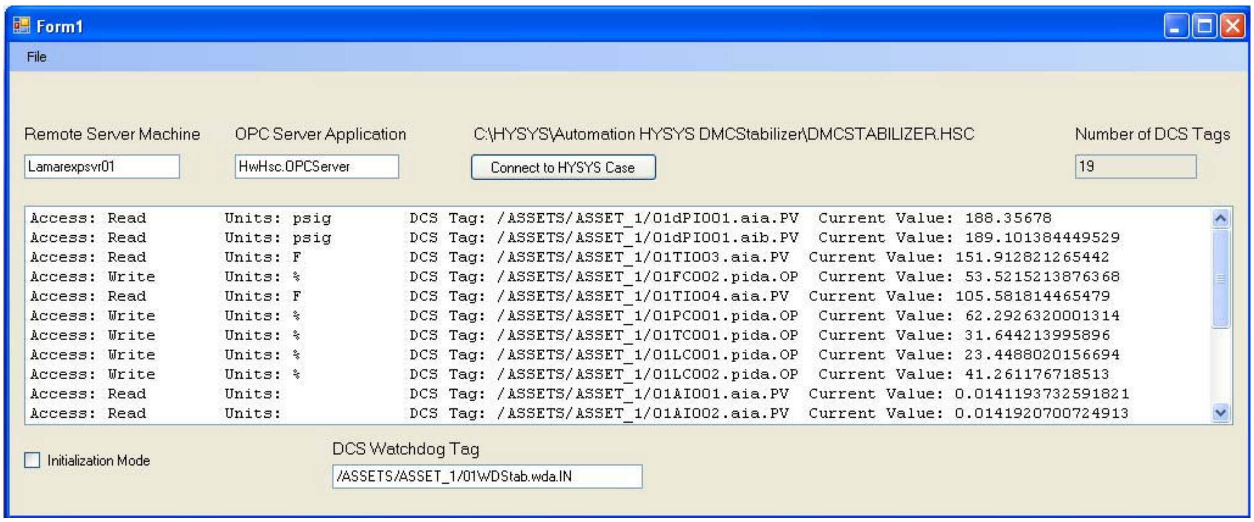

Figure 2. HYSYS OPC Automation Client Program.

The automation program and HYSYS are run on a Plant Simulation Server machine that is connected to the DCS system by Ethernet cable as illustrated in Figure 1. Disturbances can be introduced during the simulation run through the standard HYSYS interface to provide students with a particular scenario while they are interacting with the DCS system.

Example Activity

The PBL activity being developed for the control lab PBL module is described in this section. The student learning outcomes defined for this lab are as follows:

At the successful completion of this lab the student will be able to perform the following tasks:

- Use DCS tools to review chemical process event and historical data
- Distinguish between alarms which should be enunciated and alarms which should be logged
- Evaluate and classify alarms based on their safety justification
- Explain alarm priorities and setpoints in terms of their justification

Problem Statement

The reformate stabilizer column is typical of many columns in refineries across the country. Its primary purpose is to remove the light gases created by the reformer operation for reformate, an important gasoline blending component. This operation is required to enable the refiner to meet the gasoline Reid Vapor Pressure (RVP) specification. The stabilizer column schematic can be displayed by selecting the Graphic Stabilizer menu item from the Station application.

The operations group has requested Process Engineering to assist in rationalizing the operating alarm settings on this unit. A control engineer will be available to assist you as required. You have been assigned to perform these tasks:

- *review the current alarm settings and priorities,*
- *review the process safety reason for each alarm and its priority, and*
- *recommend changes for alarm setpoints and priorities*
- *provide suggested responses for each alarm*

Note that alarms should not be enunciated unless an operator action is required.

Additional information is provided concerning the current alarm settings on the stabilizer column and their justification and the expected consequences of inaction.

Each student chooses two reformate stabilizer DCS tags and leads the group in a discussion about each configured and possible alarms for those tags. To determine what if any alarms should be enunciated to the operator, they are provided with an alarm Documentation and Rationalization (D&R) procedure. After the D&R is complete, the recommended alarm priorities and setpoints are implemented in the DCS system while each student designs an experiment (or operating scenario) to test the tag's alarm settings and recommended operator response. Rather than requiring the students to master the commercial DCS system (which other authors[11] have found could detract from learning basic concepts), the instructor or another aide will take on the process control role and assist the students with DCS specific tasks such as configuring alarm priorities and setpoints.

The results of the experimental design part of this exercise will be used to help assess ABET outcome (b) *an ability to design and conduct experiments, as well as to analyze and interpret data*.[12] Therefore, one of the proposed operating scenarios will be chosen so that the students can implement it and respond to any alarms. After the scenario concludes, the students can use the event history and historical data to analyze and interpret the data and evaluate the effectiveness of their experiment.

Conclusion

An industrial DCS system was configured and connected to a dynamic process simulation program to provide a modern manufacturing environment for PBL educational activities. Modern manufacturing PBL modules including case studies and related scenarios will be developed based on individual course objectives. The courses that will use this system include process control laboratory, process control, advanced process control, kinetics, and advanced analysis undergraduate courses. Specific learning opportunities developed for this system will involve using the integrated tools and capabilities common to many modern chemical manufacturing facilities.

Students will interact with operating scenarios by obtaining DCS alarm records and DCS historian data, trending key operating variables and reviewing supplementary information such as process equipment drawings and operating procedures as applicable. To be successful in today's modern manufacturing environment an engineer must understand what tools exist and be able to use the IT applications available.

Operating scenarios allow students to experience both the operator's and the engineer's viewpoint which will broaden their understanding of the impact of engineering choices on chemical manufacturing operations. An industrial control room setting allows the instructor to present industrial operating scenarios designed to reinforce and enhance learning objectives. The students will actually see how process control strategies are implemented in practice and gain a better understanding how process control aids chemical manufacturing.

Acknowledgments

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