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Cambridge weblabs: A process control system using industrial standard SIMATIC PCS 7

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ABSTRACT

Continually assessed project work forms a core part of the Chemical Engineering curriculum at Cambridge. We have designed and built a remotely controlled chemical reactor that has been used and evaluated in undergraduate chemical engineering education. The purpose was to provide a pedagogical and authentic experience to students with essential training when laboratory usage was impossible or impractical, and be able to run and share the experiments as a fully functioning chemical engineering plant. A state-of-the-art SIMATIC PCS 7 Process Control System from Siemens is used for controlling, monitoring and providing results output. We describe the experimental setup, the hard- and software used, the teaching assignment and finally the results of the student evaluation. We also describe the challenges on the sustainability of the weblabs.

1. Introduction

Hands-on laboratory experiments have enormous educational value, but traditional teaching laboratories are expensive and have complex logistics regarding space, staff, scheduling and safety. The Internet gives an option to include real laboratory experiments in teaching at any time and the experiments can be performed from any place with Internet access. The experimental equipment can be easily shared and used around the clock from anywhere in the world. This drastically changes the economics of providing laboratory experiments to students and, potentially, a huge number of experiments can be available for use, including experiments on expensive equipment, rare materials and at remote locations.

Weblabs, Internet-accessible remotely operated experiments, have been around since the late nineties and projects using both solutions developed in house (Guo et al., 2006; Aktan et al., 1996) and commercially available software (Ogot et al., 2003, 2000; Ewald and Page, 2001; Skliar et al., 1998; González-Casta no et al., 2001; LeRoux et al., 2010) have been reported as well as review type articles (Bourne et al., 2005; Bencomo, 2003).

Remote operation is widespread in industry, both in research and production. Processes found in today's chemical industry are usually operated remotely from control rooms using computers communicating in networks. The current chemical engineering curriculum offer students little training in what they are likely to meet when leaving the university and

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weblabs can provide access to real equipment and real data using up-to-date technologies for remote operation. Hence, they offer students essential training for what they are likely to encounter in their professional life. Weblabs also provide students with teamwork and communication skills.

We have created a powerful tool for use in chemical engineering education. A chemical reactor combined with industrial process control hard- and software. By operating a chemical process remotely with up-to-date technologies widely used in industry, the students not only get the traditional benefits of visualization of chemical engineering theory but will also gain insight how processes are controlled in the real world. Chemical reactors are at the very core of chemical engineering education and they appear in a wide variety of courses with applications ranging from simple residence time distributions to complicated, non-ideal mixing, reaction kinetics, modelling and biotechnology.

The University of Cambridge has developed a unique Internet-based system to facilitate experiments that can be conducted remotely over the web. Controlling, monitoring and providing results output for this groundbreaking development is a state-of-the-art SIMATIC PCS 7 Process Control System from Siemens.

Furthermore by making the experiment available on the Internet, rather than an Intranet, the experiment can be accessed and performed from any computer with an Internet connection opening up new possibilities for sharing experiments.

2. History of the Weblab at University of Cambridge

The Cambridge weblabs were developed as a result of collaboration between the Chemical and Biotechnology Engineering department at the University of Cambridge and the department of Chemical Engineering at MIT. In early 2003, the iLabs project coincided with larger scale collaboration known as the Cambridge-MIT Institute (Acworth, 2008). As a result, the MIT heat exchanger experiment was included in the course of Chemical Engineering at Cambridge, and ultimately became a reciprocal sharing arrangement which lasted 3 years (Selmer et al., 2005, 2007). During this period, the Cambridge weblabs team was able to extensively explore the ways in which online laboratories can be used and shared, which inspired the development of a unique internet-based system to facilitate experiments that can be conducted remotely over the web (Watson et al., 2012; Richter et al., 2012).

The purpose was to provide essential training to students of chemical engineering and related subjects when laboratory usage was impossible or impractical, and be able to run the weblab as a fully functioning chemical engineering plant. The designers assessed several control systems to use in order to identify the one that would be most relevant to Chemical Engineers. When it came to sourcing a hardware and software provider it was decided to call Siemens at Manchester. They have an organization to develop relationships between Siemens plc and educational institutions at all levels called ‘Siemens Co-operates with Education’ (SCE). As a result, Siemens were willing to support the Weblabs team by providing the majority of the hardware, software, financial sponsorship and technical support needed to complete the project.

In January 2006, SCE delivered a complete SIMATIC PCS 7 (Siemens, 2016) package to the University of Cambridge. The kit comprises: a SIMATIC AS-400 DCS controller; three industrial PCs; three Siemens Coriolis flow meters; temperature probes; various input/output modules; and fully functional control software. The flow meters and temperature probes in the PCS 7 system communicate over PROFIBUS PA to the three PCs, whereas the other devices use digital or analogue input/output modules. The whole system is controlled by the SIMATIC AS-400 DCS controller.

The Cambridge weblabs are built around a small reactor. So far, two experiments have been developed: one on chemical reaction engineering and the second on process control. The reaction weblab was developed by Cambridge alone, however the control weblab was developed as a result of collaboration with the Chemical Engineering department at Imperial College, London. Since 2006, the weblabs have been an assessed part of the Chemical Engineering course at Cambridge and has also attracted use in undergraduate and postgraduate courses at Imperial College London, the University of Birmingham, the University of Surrey, the University of Newcastle, Loughborough University and the National University of Colombia. Given that they are one of the most technically advanced experimental setups of their kind in the world, they were also adopted as a flagship experiment for the Library of Labs (LiLa) project (Richter et al., 2011).

3. PCS 7 controlled experiment

3.1. *Reactor system*

Fig. 1 shows the diagram of the piping and instrumentation for the reactor given to students. Physically, the reactor and its ancillaries are mounted in a cabinet for convenience and safety, as shown in Fig. 2a. The reactor itself and the peristaltic pumps are mounted in the front face of the cabinet, whereas supply tanks, flow meters, heater, dosing unit etc are enclosed with easy access provided through rear doors.

The reactor is manufactured from Perspex, has a variable volume of 100–300 ml and can be operated at controlled temperatures up to 50 °C. A dead-zone can be created in the bottom of the reactor by a movable effluent pipe and by varying the depth and speed of the stirrer, as depicted in Fig. 2b. Three feed streams can be controlled individually by Siemens Coriolis flow meters and peristaltic pumps.

Sodium Hydroxide (NaOH) and Phenolphthalein in dilute aqueous solutions are used as reactants. One of the products

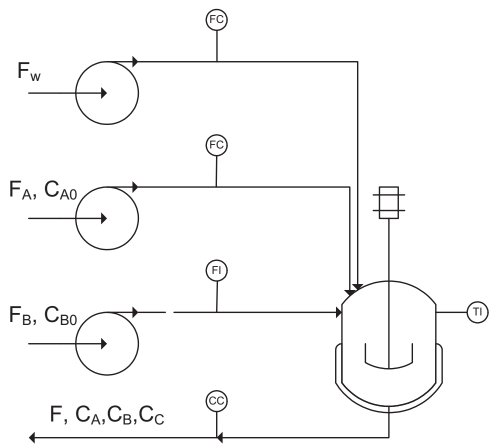

Fig. 1 – Piping and instrumentation diagram for the reactor.