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PROCESS LABORATORY - A NECESSARY RESOURCE IN CONTROL ENGINEERING EDUCATION

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Abstract - Our experiences from continuing education on the field of industrial process control show that the control engineering courses for an industrial staff are much more interesting and more useful when they are practically oriented. That was one of the reasons to build a process laboratory that consists of a pilot chemical plant highly equipped with industrial sensors and actuators, different industrial controllers and monitored by a computer control system. A process laboratory serves a number of purposes: development and application, research, training and education. The technological process equipment is fully supplied with industrial control elements so the great number of different real-life experiments can be performed. Modern control equipment assures that a variety of contemporary control techniques and metodologies (feed-forward control, single and multiloop feedback control, advanced control, etc.) can be tested and implemented. The paper describes in detail the configuration of the process laboratory, its control system and the software tools used during the educational process.

INTRODUCTION

Slovenia, like other East European countries has to solve the problem of significant lag in technological development of the industrial sector compared to that in the countries of the European Union. A necessary condition for restructuring of the Slovenian economy is promotion of new technologies and increased automation in the production processes. However, the technological transfer itself is only a part of solution. To be really successful it must be accompanied by a modern educational system capable to promote highly qualified industrial research and development professionals.

The intensive establishment of technology transfer centers begun in Slovenia in 1991 by a strong support from the Ministry of Science and Technology. The main role of the *ConTech Center*, established in the *Jožef Stefan Institute*, Ljubljana as a technology transfer center for industrial computer automation and control technology is the adapting of contemporary knowledge of computer automation and control technology to Slovene industry. The task is successfully achieved through on-going activities in subsequent areas: *a*) maintenance of an interdisciplinary skilled staff with longterm experience in and appropriate knowledge of industrial process control and equipped with all neccessary equipment, *b*) assimilation of this knowledge by industry, through different services and consulting, continual education and training of professional staff from industry. During the last three year period (1993-1995), our team was involved in the European educational project, Tempus - Aliac ("*Active Learning in Automatic Control*") (Juričić et al., 1993, Černetič et al., 1994) where our task was to establish continuing education in industrial process control in order to upgrade the existing level of process control know-how among the professional industrial staff in Slovenia.

As stated in De Vaal (1993), a trained specialist in control engineering should possess:

- a fundamental background regarding control theory (technology of control),
- the ability to integrate plant control requirements with plant design requirements,
- the practice of using numerous numerical or software tools to perform the necessary control system design calculations,

- the skill to implement results of a design to an actual process.

The implementation of the results of a design means that an industrial control engineer must also be familiar with contemporary industrial control equipment (sensors and actuators, controllers, computer hardware, software tools). Currently, software tools are becoming a necessary integral part of control engineering practice, so special attention should be given to process control software education.

PROCESS LABORATORY

Our experiences from continuing education in industrial process control show that the control engineering courses are much more interesting and more useful when they are more practically oriented than theoretical. That was one of the reasons to build a process laboratory (Vizjak et al., 1994) that consists of a pilot chemical plant highly equipped with industrial sensors and actuators, different industrial controllers, and monitored by a computer control system. A process laboratory serves a number of purposes: development and application, research, training and education. As we beleive that real-life processes are the most appropriate fundamental topic of control engineering education, the technological and control equipment is indispendable in the practical part of courses for industrial personnel.

The core of the process laboratory is a technological system of devices constructed of several interconnected

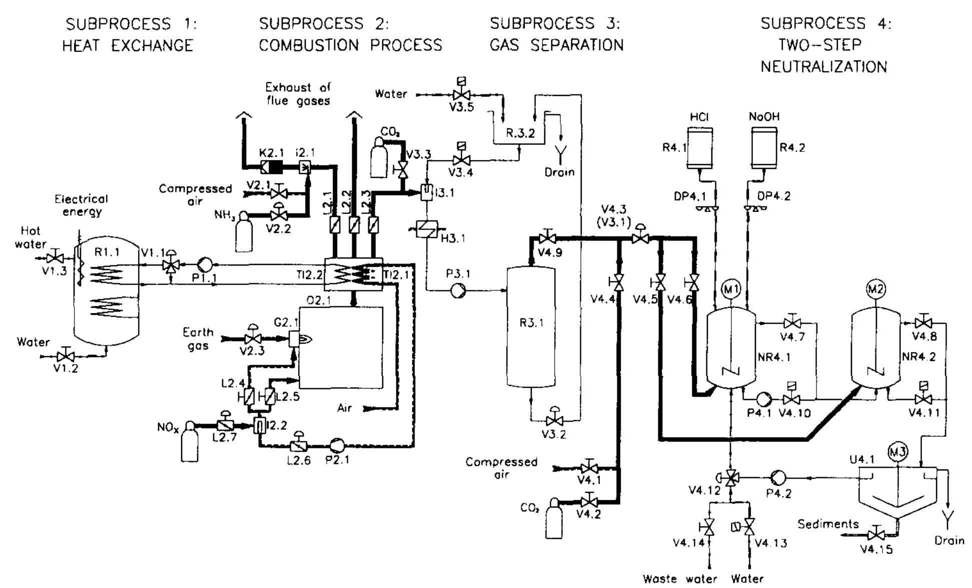

Figure 1: *Technological scheme of a pilot plant*

subprocesses. The essential criteria which have influenced the choice of technical apparati were as follows:

- the pilot plant must possess the appearance of an industrial plant,
- the pilot plant must incorporate as many industrial control elements as possible,
- it must be possible to physically separate the pilot plant into several independent technological subprocesses, each of which is a source of certain typical classical and advanced control problems,
- the technical apparatus should be of the "semi-batch" type, and it should encompass successive sequence and semi-continuous technological procedures,

- the structure and properties of the pilot plant must allow its further enhancement with a view to continuously simplified addition of technological subprocess,
- substantial possibilities of raw material and power recycling are desired,
- the cost of technical apparati must not exceed the financial capacities planned and
- the construction of pilot plant must not be too demanding.

A pilot plant is constructed as a technological line for the neutralization of alkaline industrial waste water using CO_2 produced during combustion processes. It consists of four subprocesses (*Figure 1*) which can be treated separately. The process equipment is fully supplied with control elements, so a great number of different experiments can be performed: level control, pressure control, temperature control, combustion control, catalytic reduction of NO_x, heat exchange control, liquid and gas flow control, pH control, etc. Modern control equipment assures that a variety of contemporary control techniques and methodologies (feed-forward control, single and multiloop feedback control, advanced control, etc.) can be tested and implemented.

Figure 2: *Technological part of the process laboratory*

LABORATORY CONTROL SYSTEM

The technological set-up is upgraded with a computer monitoring and control system. The system structurally resembles modern industrial control systems to a great extent, while it can, at the same time, be adapted to research purposes. The control system consists of a *classical command panel* and a *control panel for computer control* (*Figure 3*).

The classical command panel serves to display analog and digital process variables and the manual control of actuators. It contains interface elements, elements for control the individual process variables or subprocesses (stand-alone controllers), and it allows the testing of various control elements. The classical command panel includes separate analog and digital portions placed in two industrial racks. A distinct feature of the classical command panel (as opposed to industrial types) are two adapted connecting boards for analog and digital signals, serving efficient, fast and safe "programming" of signal connections, much like an analog computer. This allows various signal connections between control elements which are situated in the technical devices (analog and digital sensors, actuators, etc.) and the control system (inputs and outputs of stand-alone controllers, PLC's, etc.).

The panel for computer control is supported by a supervision and a technological computer. These two computers

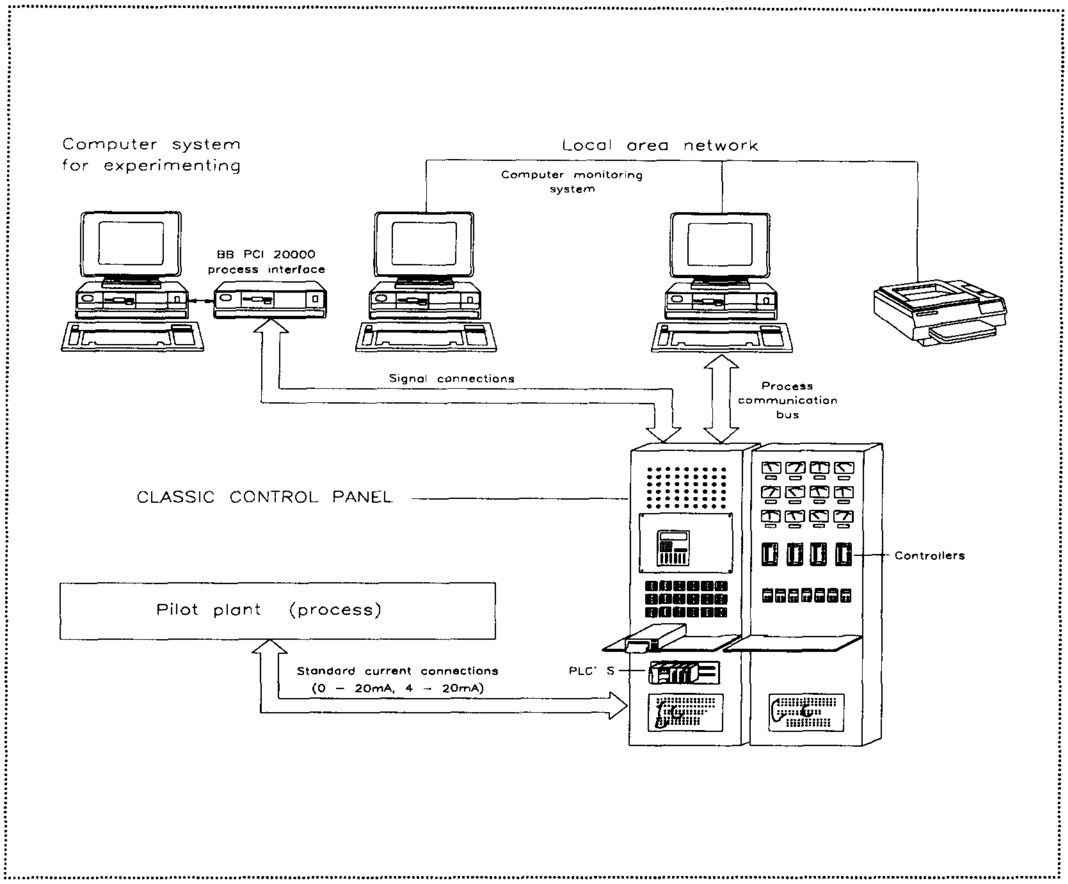

Figure 3: *Classical control panel and supervisory computer control system*

and the process stations (PLC's, etc.), included in the classical command panel, are connected through a communication link. The computer system serves to implement as well as to analyze performance of different process control software. The supervision computer is envisaged to supply graphic displays and follow the current state of the technological process, alarming and enabling the operator to actively intervene in the technological process (for instance: the download of production parameters, prescriptions, etc.). The technological computer is intended to perform advanced and complex control algorithms, statistical analysis, long-term data storing, etc. The control panel for computer control includes an independent experimental computer system which consists of a smaller I/O process system (e.g. BurrBrown PCI 20000) and a data processing computer system. The experimental computer system primarily serves for experimental research and preliminary testing of advanced and complex control algorithms.

PROCESS CONTROL SOFTWARE

The appearence of the personal computer in the early eighties accelerated the application of all kinds of microcomputers in industrial control (Control Engineering, 1994). Several programming development tools have also been developed for process control during the last decade. This software opens the door further to the wider use of computers for process management and control applications.

Today, process control software is used in control engineering during all life cycle activities of a particular control system. Process control software can be incorporated as an integral part of different process control equipment (intelligent sensors or actuators, controllers, computer monitoring systems, communication lines, etc) or it can be used as a development tool during the realization of single phases of a control system's life cycle. So, for a control enginner, it is essential to be familiar with the concepts of real-time software design, formal specification methods, programming languages and different software tools, which are today available in great quantities on the process control software market.

Currently hundreds of software products exist for process control (Control Engineering, 1994). For our audience, we selected some of the most popular process control software development tools in our field. The choice of the next group of process control software depends on our existing hardware and on the traditional process equipment suppliers for our industry. The list of software products which are used in the practical part of our process control software education courses is listed in *Table 1.*

Table 1. *Software products used in our educational courses*

name of a software tool	used for	life cycle phases of a control system: 1-*requirements*, 2-*specifications*, 3-*design*, 4-*implementation*, 5-*testing*, 6-*maintenance*					
		1	2	3	4	5	6
System Architect	*software tool for system analysis and design*	*	*	*			
Excellerator	*software tool for system analysis and design*	*	*	*			
ACSL	*general purpose simulation language*	*	*				
GPSX	*simulation packgage for waste-water treatment plant processes*	*	*				
G2	*expert control system development tool*	*	*		*		
Matlab/Simulink	*high-performance numeric computation and visualization software*		*				
Simcos	*software package for simulation of continuous and discrete systems*		*				
ANA	*software package for analysis and design of control systems*		*				
Assistant	*programming tool for inductive learning*		*				
PID Master	*programming tool for tuning of controllers*		*				*
TIL-Shell	*software tool for fuzzy methodology based control systems*		*				
LabTech/Notebook	*integrated software package for process measurements and data analysis*				*	*	*
Medoc	*software tool for programming Mitsubishi PL Controllers, series A and F*				*		
Siprom DR 24	*software tool for configurating Siemens Sipart DR 24 controller*				*		
IDR Blok	*block oriented programming language for control of continuous systems*				*		
FactoryLink	*SCADA (Supervisory Control and Data Acquisition) programming package*				*	*	*

CONCLUSION

The present technological equipment of the process laboratory will be up-to-date for a long time. Control elements and software products are growing old faster, but since they represent minor costs for the pilot plant, they can be updated step-by-step with modern products. The latter coincides with our intention to possess up-to-date control elements and helps us to gain an audience for our future courses.

The equipment of the control laboratory plays a central role in transferring the contemporary knowledge to industry. We beleive that practical courses involving the process pilot plant, using commercially available process equipment and software products, can significally help to raise the level of know-how of process control engineers in Slovene industry. So by keeping the industrial people informed about new trands in control technology in the mentioned way, several long term effects are expected, all related to the technological restructuring of Slovenian economy. Only in this way Slovenia as a very young country can increase its chances to become an equal partner in the European Union.

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