A LABORATORY FOR PROCESS CONTROL ENGINEERING EDUCATION

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Abstract: At ACE'94 the concept of a process laboratory for analysis, education and research of control engineering approaches and methods was presented. Three years later we are in the middle of the work on the realisation of this laboratory, which serves a number of purposes: development and application, research, training and education in the area of industrial process control. The paper describes in detail the configuration of the process laboratory, the upgraded control system and the software tools used during our research and educational programs.

Keywords: Process control, conventional control, computer control, control system design, education.

1. INTRODUCTION

One of the activities of the *ConTech Center* (established at the *Jožef Stefan Institute*, Ljubljana as a technology transfer center for industrial computer automation and control technology) is the program of continual education and training of professional staff from industry in the area of industrial process control (Černetič, *et al., 1994*). The experiences from this program show that the control engineering courses for an industrial staff are much more interesting and more useful when they are practically oriented. That encouraged us to start the construction of a process control laboratory as a base for our educational courses. The laboratory should be semi-industrial, it should consist of a pilot chemical plant highly equipped with industrial sensors and actuators, different industrial controllers and monitored by a computer control system. The installed process equipment should enable the realisation of different real-life experiments. Modern control equipment should also assure 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.

2. BASIC CONCEPTS AND GUIDELINES

During the period from 1993 to 1995, our team was involved in the European educational project, Tempus - Aliac ("*Active Learning in Automatic Control*") (Juričič, *et al., 1994*), where one of the tasks was to detail the concept of the process control laboratory which would serve a number of purposes classified roughly into three groups:

2.1 Development and application

In this sense the process laboratory can represent a base which would enable the development and testing of advanced control engineering approaches and methods on commercially available industrial process equipment, the testing of new application solutions, familiarising with properties and use of modern industrial measuring and control equipment as well as of a variety of control software, and analysis of compatibility, the design of interface elements, consulting for industrial users and possible test pilot production.

2.2 Training and education

The process laboratory will be useful in the practical part or training courses for industrial personnel (use and calibration of classical industrial controllers, intelligent transducers programming, etc.) and occasional student excursions aimed at familiarising students with the real form and operation of industrial process equipment. It will represent an attractive source of engineering problems which could serve as the basic B.Sc. and M.Sc. theses.

2.3 Research

Practical problems are simultaneously an important source and selector of new fundamental research in the field of automatic process control. Contact with reality prevents the emergence of useless ideas and solutions. The envisaged laboratory will therefore permit the setting up of new research programs and the conducting of quality research whose results will be directly applicable in practice.

In 1994 we were able to present at ACE'94 (Vizjak, *et al., 1994)* the basic concept with the following guidelines:

<u>*Construction:*</u>

- 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 technologi-cal subprocesses, each of which is a source of certain typical classical and advanced control problems.
- The technical equipment 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 techno-logical subprocesses.
- Substantial possibilities of raw material and power recycling are desired.
- The cost of technical apparati must not exceed the financial capacities planned.
- The construction of the pilot plant must not be too demanding.

<u>*Signals:*</u>

- Signal connections should be uncomplicated, robust and inexpensive, but safe and reliable.
- Short circuits or incorrect wiring must not cause permanent damage to the devices or wiring.
- Basic wiring of the apparatus and signal wiring must be set up professionally, giving the user a sense of professionalism and a positive experience.
- Analog and digital signal connections should be separated completely.
- Sensor outputs, transducer inputs/outputs, stand-alone controller and PLC inputs/outputs and will be standard (0-20 mA, 4-20 mA, 0-10V, 0-24V, contact, open collector, etc.).
- All non-standard control elements must be adapted to the standard signal system with appropriate interfaces.
- Several signal destinations can be connected to one signal source.
- All measuring signals must be equipped with appropriate independent indicators (analog display, digital display, LED).
- In principle, the user should not be concerned about the polarity, levels and forms of signals.
- The execution of signal connections must be uncomplicated and fast.
- It should be possible to perform additional measurements using standard measuring instruments (multi-meter, oscilloscope, recorder, etc.) and generate control signals with power-supplies, function generators, calibrators, etc.
- It is necessary to design a system of electro-magnetic disturbance simulation characteristic of industrial environments.

<u>*Control:*</u>

- The control system should consist of both a classical command panel and a computer based process control system.

- The computer control should consist of a supervisiory and a technological computer, both with the possibility of contemporary software usage tools and packages.

3. REALISATION

The above guidelines were followed during the design of the particular technological process and for the choice of necessary process equipment and belonging control eleme-nts, (such as different sensors, actuators, con-trollers and computer con-trol system). The project of building the process laboratory is not finished yet, but some of it's equip-ment is already in regular use (Jovan, 1996).

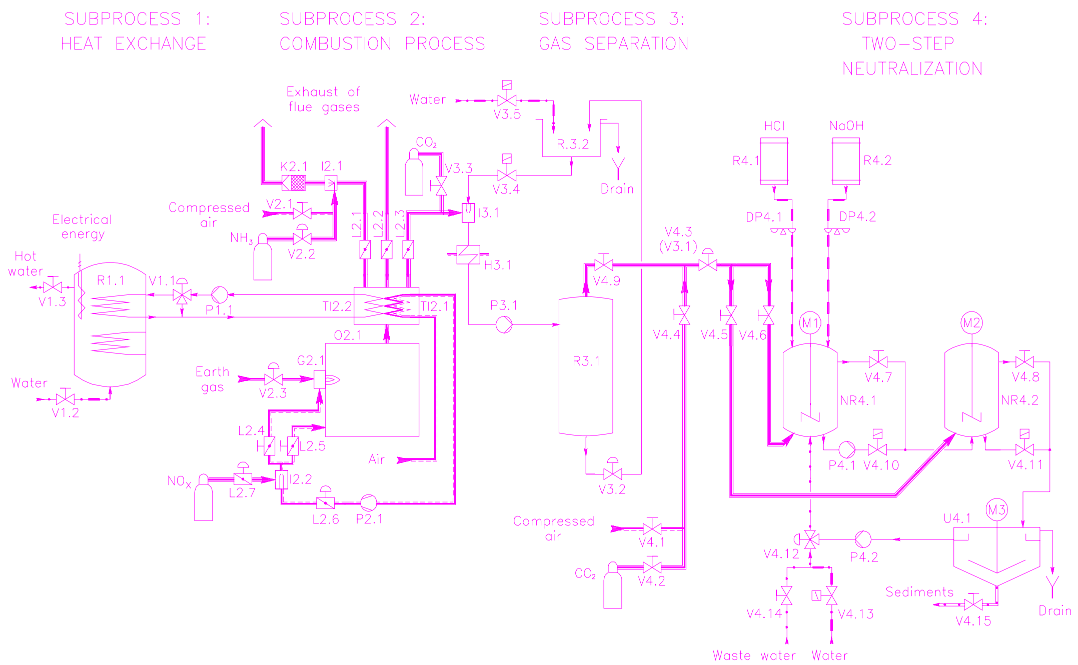


Fig. 1. *Technological scheme of the process laboratory*

Fig. 2. *The technological equipment of the process laboratory*

3.1 Technological process

A pilot plant was con-structed as a technological line for the neutralisation of alkaline industrial waste water using CO_2 produced

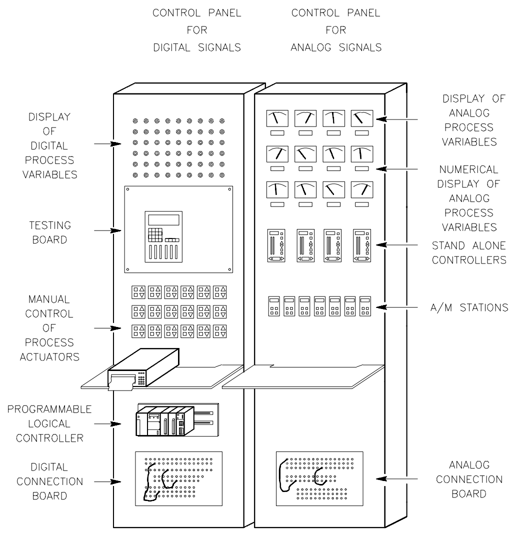


Fig. 3. *Scheme of the classical control panel*

during a combustion process. It consists of four subprocesses (*Figures 1 and 2*) which can be treated separately.

The process equipment is fully supplied with industrial

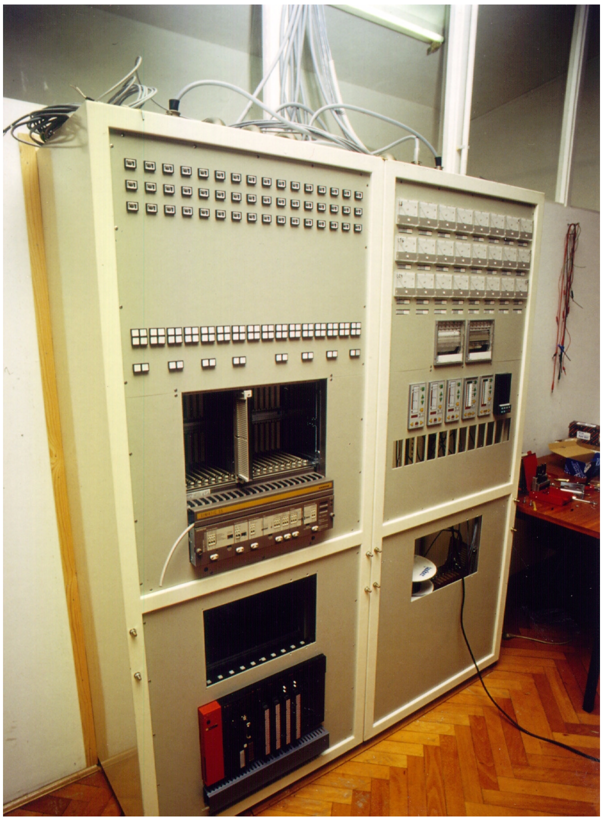


Fig 4. *Classical control panel (under construction)*

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.

3.2 Laboratory control system

The technological set-up was upgraded with a classical control panel and a computer based monitoring and control system.

The classical command panel (*Figures 3 and 4*) serves to display analog and digital process variables and the manual control of actuators. It contains interface elements; elements to 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 analog and digital connection boards represent a common point of the technological apparatus and the control system.

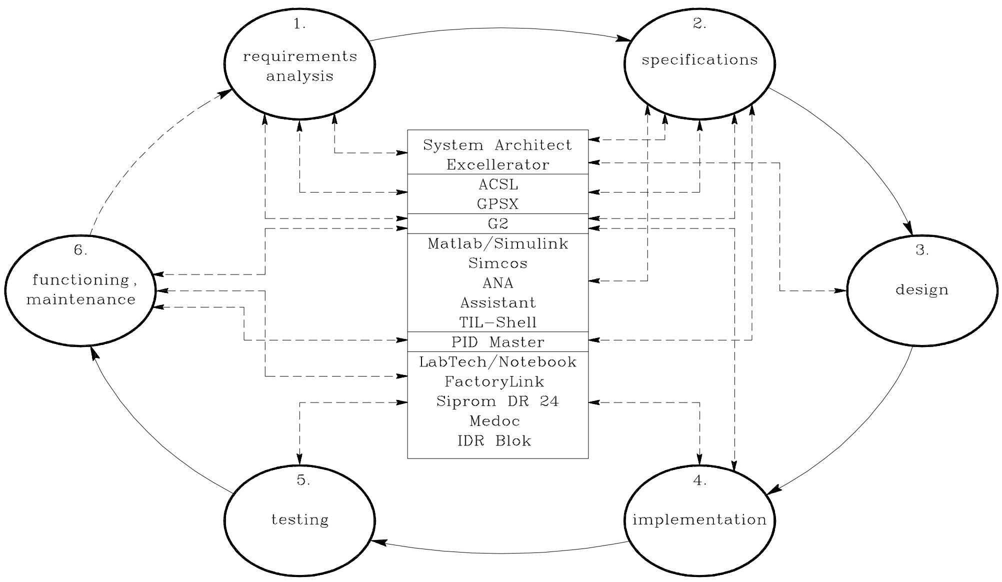
Each connection board is divided into four connector fields, as follows:

- process signals source field (adapted sensor signals...);
- control elements input field (stand-alone controllers and PLC inputs, inputs into the BB PCI-20000 I/O system);
- control elements output field (stand-alone controllers and PLC outputs, outputs from the BB PCI-20000 I/O system);
- actuators input field (all signals are connected with actuators via automatic/manual terminals which provide safe manual control of all actuators, ensure voltage/current conversion of signals, etc.).

Within the framework of analog and digital connection boards the unified principle of analog and digital connection of signal sources and desti-nations (inputs and outputs) is realised in the sense of the above guidelines. According to the selected principle, the system provides a connection of seve-ral signal sinks to a single signal source and of seve-ral signal sources to a single signal sink (wired OR).

3.3 *Computer control*

The computer control system has a supervision and a technological computer. These two computers and the process stations (PLC's, etc.), included in the classical command panel, are connected through a communication link. The supervision computer is used to monitor the current state of the technological process, to alarm and enable the operator to actively intervene in the technological process (for instance: the download of production parameters, recipes, etc.). The technological computer is intended to perform advanced and complex control algorithms, statistical analysis, long-term data storing, etc., and will primarily serve for experimental research and preliminary testing of advanced and complex control algorithms. The 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



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 configuring 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*

Fig. 5. *Software products used in the process laboratory*

computer system primarily serves for experimental research and preliminary testing of advanced and complex control algorithms.

3.4 Process control software

Since the early eighties, several software products for the area of process control have been developed (Control Engineering, 1994). 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 either 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 realisation of single phases of a control system's life cycle. As software tools are becoming an integral part of control engineering practice, in our courses special attention is also given to process control software education. For our audience, we selected some of the most popular process control software products which cover all the activities during the design and operation of a particular control system (see *Figure 5*).

4. CONCLUSION

We expect that the present technological equipment of the process laboratory will be up-to-date for a while. 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 install up-to-date control elements and to possess contemporary software tools.

The process laboratory already plays a central role in our continual education programme on the area of industrial process control. We believe that practical courses involving the equipment of the process laboratory can significantly help to raise the level of know-how of process control engineers in Slovene industry. So by keeping the industrial people informed about new trends in control technology in the mentioned way, several long term effects are expected, all related to the necessary technological restructuring of our economy.

5. REFERENCES

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