Hydraulic plants for face-to-face training and remote experiments

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***Abstract*— This paper describes simple physical hydraulic laboratory models that are able to communicate with computer via both the standard USB interface and through converter cards. They show to be appropriate for evaluating different control approaches to linear and nonlinear controllers design and for demonstrating basic control features in both university laboratories as well as via Internet.**

I. Introduction

The trends in control education show worldwide increasing use of physical laboratory models. This follows from both the necessity to verify different theories in quasi-authentic conditions, by developing student's skills in such quasi-authentic environment, by meeting learning styles of several types of students and, what is also very important, by increased student's motivation to approach the theory in treating real control problems.

As it was mentioned e.g. in [7], or [11], experiments appropriate for teaching control theory should yield:

- clear physical "visibility" of the controlled dynamics,
- time constants in the range from miliseconds to minutes,
- safe manipulation,
- reasonable price of purchase or of the own development,
- availability of sensors and actuators,
- easy maintenance.

In the last years, these criteria have been extended by the requirement of

- possible approach via Internet.

This should provide an access to the experiments [13] and at the same time also develop students' skill in the use of Internet, which is becoming to be important communication and control tool.

Of course, with respect to the authenticity of experiments, these should face typical problems of controlling plants met in practice and so to enable acquisition of necessary knowledge, attitudes and skills.

Among the most popular systems used in education today one should mention hydraulic plants that are of different shapes and sizes and are distributed worldwide practically at each university or laboratory being active in teaching control theory. The broad availability, however, does not mean that all of them are equally appropriate for education.

Figure 1. The coupled-tank hydraulic laboratory system uDAQ28/2H

We have bought the first two-tank hydraulic plant (described in [13]) already in 1990. Due to some practical requirements we have started with its modifications and some time later we have started our own development. From that time we are permanently experimenting in modifying different features of our systems - by keeping in mind all above requirements on the experiments appropriate for education.

II. Basic Description

Nowadays, we are working with coupled two- and three-tank plants.

Both are aimed to provide support in education and developing skills in input-output data manipulation, communication with outer computer environment, plant identification and control. They can be used to study automation, control engineering, process control and applied and industrial informatics.

The configuration of the plant can easily be modified, for instance in Matlab/SIMULINK, by setting respective pimps, tanks and valves active or inactive. This may be used for developing broad scale of different experiments ranging from simple identification up to complex nonlinear and hybrid control applied directly in labs, or remotely via Internet.

The plant allows measuring the levels of liquid in respective tanks by means of the pressure sensors positioned at the bottom of the tanks.

III. Measurement & Communication Systems uDAQ28/2H and uDAQ28/3H

The Measurement & Communication Systems uDAQ28/2H and uDAQ28/3H in cooperation with the company Digicon and the non-profit organization E-Academia Slovaca / Slovenská e-akadémia, n.o. use own microprocessors for the data processing and communication. They can be connected to standard computers via USB port without necessity of using special converter cards and special real time control software. At the same time, they simplify the communication and control. The plants are supplied by a safety 9V and 24V voltage adaptors.

The pumps are controlled by analogue inputs 0-9V, the valves by on-off signals 24/0 V.

The levels are measured by pressure sensors 0-0.5Pa enabling individual calibration for each level, with passive temperature compensation by a constant feed current. The achievable precision better than 1% (in steady state the level varies by +/- 0,5mm).

Settling time for control processes is in the range approximately 100 s (with respect to the level change).

Matlab Communication Interface works with sampling periods 250 ms and more, whereby the serial port timeout for purpose of data readout can be lowered down to 250 ms. There is ability to raise Matlab process priority above priority of common tasks running under MS Windows.

Similarly as described in [11], [12] the build in processor avoids necessity to build a simulation scheme all the time you change it. This results in the possibility to use SIMULINK block Matlab Fcn that may contain own algorithms stored in M-file and in the possibility to adjust all communication parameters in single user dialogue window

Figure 2. The three-tank hydraulic laboratory system uDAQ28/3H

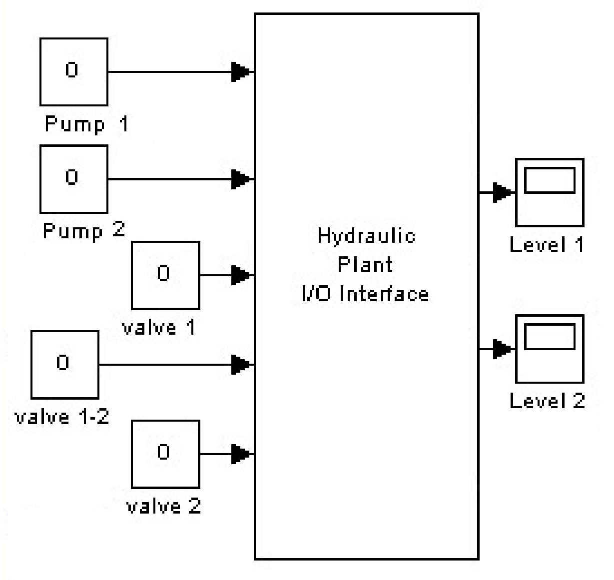

Figure 3. Simple schematic diagram of the Coupled-tank hydraulic system uDAQ28/2H in Matlab/Simulink

IV. Identification and Control Software

The developed plant includes all drivers necessary for operating in Matlab/SIMULINK where it is represented as a single block. The communication interface for the open source SCILAB is under development.

The plant is delivered together with a package of the basic algorithms for identification and control.

For calibration of level sensors and for identification of the full nonlinear model it is possible to use fully automatically running programs [19].

Programs for many tasks related to nonlinear control are available as well, see for instance papers devoted to algebraic generalized transfer functions based approaches [5], [6], [16], [17], or to design of constrained controllers for nonlinear plants of different complexity [1], [8], [18].

For organization of the study and laboratory work enables to use modern blended learning approach [9], [10], [11], [13]: after introductory preparation by the course materials in Moodle and initial face-to-face visit to laboratory, the extension module WebLab [2], [3], [4] gives to your students the 24/7 access to the plants via Internet enabling to enjoy a rich experience from controlling a real process.

V. Conclusions

The developed laboratory plants bring a revolutionary solved communication, universal connectivity to all computers via the USB port, small & handy, maintenance free, portable, easy assembly & disassembly!

Control of two or three output variables by two-eight inputs yields a broad spectrum of performances with different static, dynamic and stochastic properties.

Low price of the control system is enabled by sparing the real time control software & converters – instead of buying one traditional piece of equipment you may have plants and teachware for the whole class.

The plant offers:

- visual, quasi-authentic, simple and safety student's work environment supporting the "learning by playing", "learning by doing", or "learning by discovering" constructivist approach, motivating students for experimenting and study,
- simplified real-time control design & implementation that extends the possibilities of simulation tools and develops experimental skills required by practice.

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