УДК 45

W. Blacharski
Gdansk University of Technology (Poland)
Departament of Automation and Manufacturing Engineering

TRAINING LABORATORY FOR TEACHING ELEMENTS OF MECHATRONICS ON SPECIALTY OF MANUFACTURING ENGINEERING

Описано лабораторію, яка сформована на кафедрі Manufacturing Engineering and Automation в Гданському технологічному університеті. Лабораторія обладнана набором навчальних пристроїв для програмування диспетчерів PLC і для випробування додатків. Автор виявив зауваження щодо потреби переорієнтації навчальних планів на факультеті Mechanical Engineering в напрямку навчання мехатроніки.
Ключові слова – навчання мехатроніки, учбові пристрої, програмування ПЛІС

The paper presents a laboratory that is developed in Department of Manufacturing Engineering and Automation in Gdańsk University of Technology. The laboratory is equipped between others with a set of training devices for programming PLC controllers and for testing the applications. The author's remarks about needs of reorientation curricula on Faculty of Mechanical Engineering in direction on mechatronic teaching.
Keywords – teaching mechatronics, training devices, programming PLCs

Introduction

A quick improvement of the industrial automation based on computers, ICT, programmable controllers, sensors, modern drives and other actuators influences the labour market from the point of view skills and knowledge that employees on different positions in a factory are expected to have. They are responsible for operating and keeping in good repair the modern machines and their subassemblies that are in fact mechatronic objects. The changes concern also new standards of the demands that young graduates of specialty "Manufacturing Engineering" has to meet with. Listening the feedback opinions from graduates of Mechanical Faculty and their employers lead to the conclusion, that maybe they were too strictly trained in traditional, especially theoretical, mechanical subjects at the costs of modern practical knowledge and skills, from the border of mechanical, electrical and electronic engineering. The idea of 'mechatronic teaching' on Faculty of Mechanical Engineering is not a new one and its elements were gradually adopted during some recent years. Different mechatronic subjects are strongly connected not only with specialties named as Mechatronics, Automation and Robotics or similar, but also with others including 'Manufacturing Engineering'. It should be noticed that idea of 'mechatronic teaching' is also adopted on Electrical and Electronic Faculties that do not hesitate to introduce different "mechanical" subjects into their curriculas. As a result also their graduates often candidate for positions that were traditionally addressed for mechanical engineers in the past, like operational, maintenance and test engineers in plants or positions in the small companies that render different outsourcing services connected with designing, modernisation and maintenance of manufacturing machines. On the other hand the young mechanical engineers quite often undertake a job connected with automation of manufacturing machines and processes.

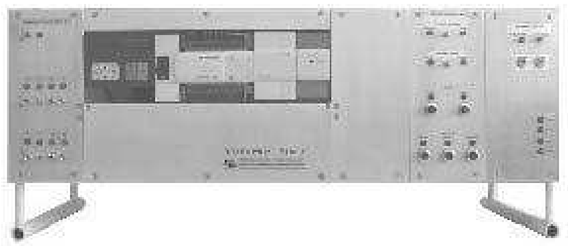
The question is how the multidisciplinary demands created by industry and the labour market can be effectively fulfilled on a Mechanical Faculty. The author's opinion is that there is a necessity to reorient curricula and that the reorientation should include much more modern practical subjects comprising not only lectures but also enough hours for practical training the students in laboratories oriented for industrial mechatronics. The laboratories should be enough equipped and able to serve the main purpose – to familiarise students with different mechatronic subjects and devices, especially from the area of a specialty.

Detailed contents of the curricula should include elements useful for employees on the positions, that a specialty is addressed for. It can be assumed that graduates of Manufacturing Engineering have to be engaged in productive plants of different branches, on the positions like process end product engineers, maintenance engineers, test engineers and more. They will be responsible for different automated manufacturing machines and processes. Their familiarisation with mechatronics traditionally concerns problems connected with CAD/CAM/CAE, machining on the CNC machine tools and elements of robotics. However, this is not enough because the needs of future graduates contain wider area of issues connected with automation of manufacturing in different branches. On the other hand also in the metal working plants there is in use a variety of automated machines. For the reason in Department of Manufacturing Engineering and Automation a laboratory was organised [1,2,3] in order to introduce to the curricula a set of mechatronic issues, between others PLC control, HMI/SCADA systems, motion and motor control, sensors and transducers, measurements and controlling by means of DAQ systems. One of the stands that was build in the developed laboratory is described below.

TRAINING STAND FOR TESTING PLC APPLICATION PROGRAMS

One of the elements of the mechatronic training that can be useful for graduates of Manufacturing Engineering is their understanding of operating principles and skill in programming of different industrial controllers. It especially concerns PLCs because they are commonly applied in manufacturing machines and processes. In the Laboratory was built a training stand (Fig.1) for teaching principles of programming the PLC controllers and for testing application programs.

a)



b)

Fig. 1. Training stand for testing PLC application programs:
a) device with Mitsubishi FX2N PLC controller and with additional replaceable function modules,
b) device with Mitsubishi Alpha controller

Table I

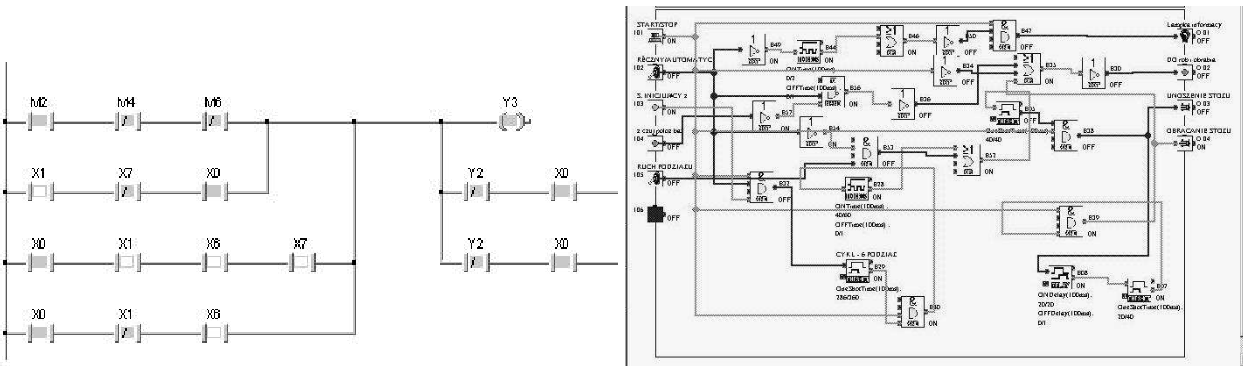
Methods of Testing PLC Application Programs

A – virtual test (simulated monitoring)
Operating of a PLC program or subprogram is simulated by using software tools designed especially for the simulation purposes. Actuation the inputs and observing both the inputs and the outputs states are carried out in a computer without any necessity to connect the PLC controller with.
B – semi-virtual test (partly simulated monitoring)
Functioning of the PLC programs or subprograms is monitored by connecting a computer with an operating PLC via an interface and by using software tools for the monitoring purposes. The interfaced states of the inputs and the outputs are displayed in a computer whereas the inputs can be actuated also via the interface or truly by external signals from a process or from a hardware simulator;
C – measurement of the digital and analogue signals on the selected inputs/outputs
Functioning of a PLC program or subprograms is evaluated on the basis of measurement the actual values of the signals on the selected inputs and outputs of an operating controller. The courses of the recorded signals can be off-line analysed and compared in details.
D – monitoring and evaluation of the controlled process
Functioning of a PLC program or subprograms is evaluated on the basis of resultant quantities of a controlled process. A measurement system has to be applied in order to observe the courses of resultant quantities and compare them with input signals.

During programming, reprogramming or tuning a PLC controller, having at disposal a set of efficient tools for testing how the application operates can be very helpful. Usually there is a necessity to carry out the tests in a possibly simple way at some stages:

- testing subprograms and the whole PLC application as a computer program using software simulation tools;
- testing how a PLC controller operates with the application program implemented in;
- testing how a process or a machine operates under control of the PLC application.

Some ways that can be useful for testing the PLC application programs has been compared in the Table 1. The examples shown in the Fig.2, Fig.3 and Fig.4 represent the first and the second groups of the ways and are possible to be used both during the virtual and the semi-virtual tests. During designing a simple program or a subprogram one of the tests for observing how the binary states of different devices used in the program respond for actuation the selected inputs can be quite enough (Fig.2, Fig.3). On the other hand these kinds of the tests are able to give only little information about time- dependent behaviour of the system. Another test that uses a timing chart (Fig.4) usually is able represent the time-dependent relations as more detailed. However, when a semi-virtual test is carried-out it should be always taken into account that the observed course of signals (Fig.4) can differ from the actual course, for instance because of properties of the data transfer via interface .The course of the signals is presented only as a simplified model by a monitoring program and should not be recognized as an accurate result of a measurement. Additionally it is difficult to observe quickly changed states of some input devices and there is a need to record them.



a) *b)*

Fig. 2. Examples of virtual and semi-virtual tests where active elements are pointed out by a color illumination, for instant coils, contacts and other devices in the ladder diagram (a) or active blocks and wires in the function blocks diagram (b)

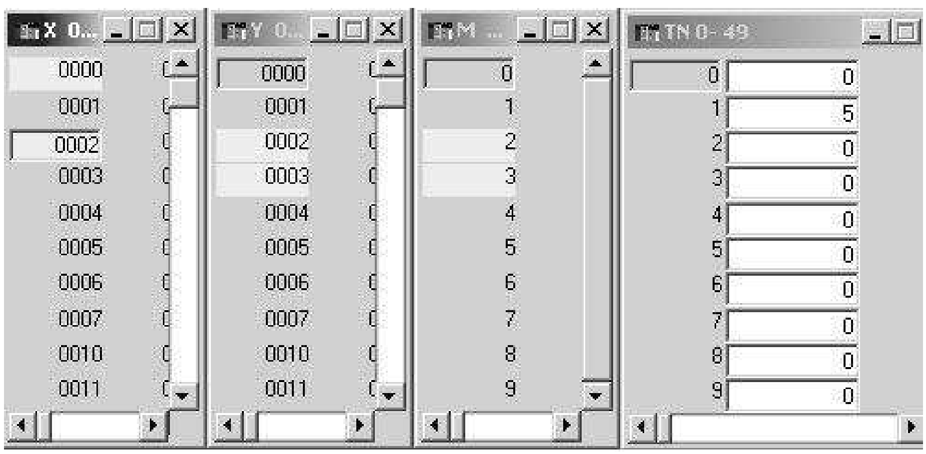


Fig. 3. Example of a virtual or semi-virtual test where binary states of coils, contacts and other devices of a program are pointed out and also numerical values of parameters can be displayed in a chart

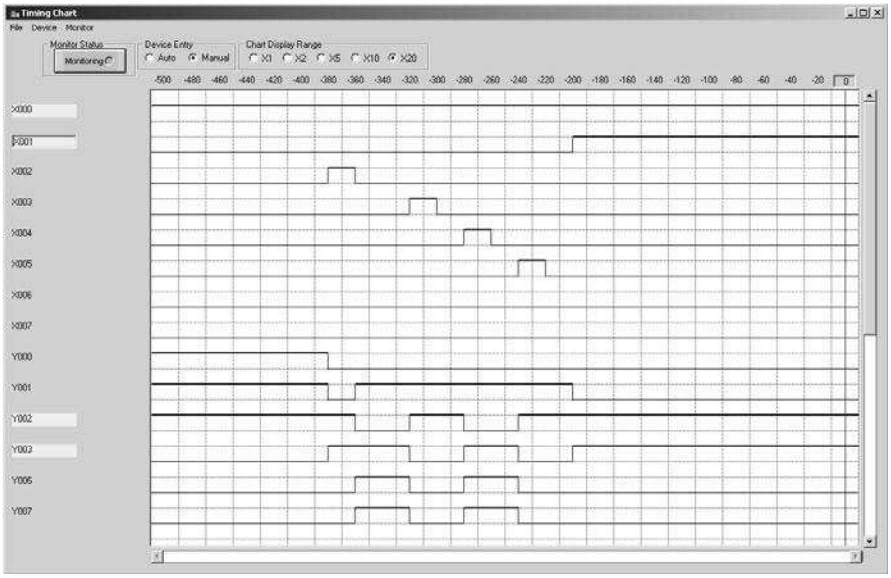
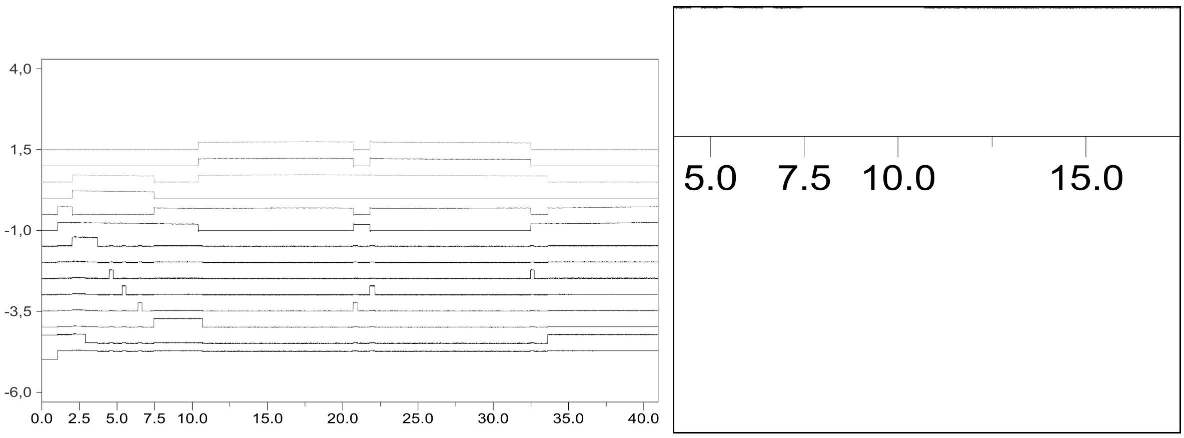


Fig. 4. Example of a virtual or a semi-virtual test where changes of binary states of coils, contacts and other devices of a program are displayed as a timing chart

Two examples of tests carried out by measurements of the digital or analogue signals on the selected inputs/outputs of an operating controller have been presented in the Fig.5 and Fig.6. This test demands proper measuring equipment. The useful solution can be applying a standard multifunctional DAQ board with an A/D converter and a dedicated DAQ application. The measured timing chart (Fig.5) differ from the virtually modeled that has been shown as an example in Fig.4. The time-dependent relations are represented more accurately in the records and the actual state of the real input/output signals can be observed. The records of the measured signals can include also different disturbances (Fig.5.b) that from diagnostic point of view would be quite valuable information. The result can be also analyzed in details in off-line mode. However, applying measurements for testing the PLC application programs has some essential limitations. For instant only a limited number of the selected inputs/outputs can be tested concurrently because of the DAQ boards performances. Inputs and outputs of a controller have to be additionally wired and connected with the DAQ board during the test.



a) *b)*

Fig. 5. Example results of a measurement (a) of the binary signals on selected digital inputs and outputs of a controller during a test run, and (b) different kinds of disturbances in enlarged view

Also only a finite number of samples can be recorded with an accessible sampling frequency what in turn keeps within limits both the obtainable accuracy and the total time of a test. It can be a problem when an unknown reason of a fault has to be found, but the flexibility and the performances of the DAQ systems seem to be practically enough for this kind of tasks. A DAQ system is able to measure and record digital and analogue signals concurrently (Fig.6). This in turn allows observing not only sequences of binary signals but also different time-dependent relations on the all selected input/output. It can be an important task during commissioning and diagnostics of a PLC controlled machine or process .

Evaluation of the controlled process is a final and sometimes the most demanding stage during preparing and testing a PLC application program. When the application is prepared with a clearly separated set of parameters that are responsible for specific resultant quantities of a process, both the evaluation and the correction of the parameters can be much easier. There are a lot of possibilities to adopt the above rule when an application is designed. However, in many cases tuning of the parameters can not be done effectively without observing how they influence behaviour of the entire controlled system. Appropriate measuring equipment is needed in the cases again.

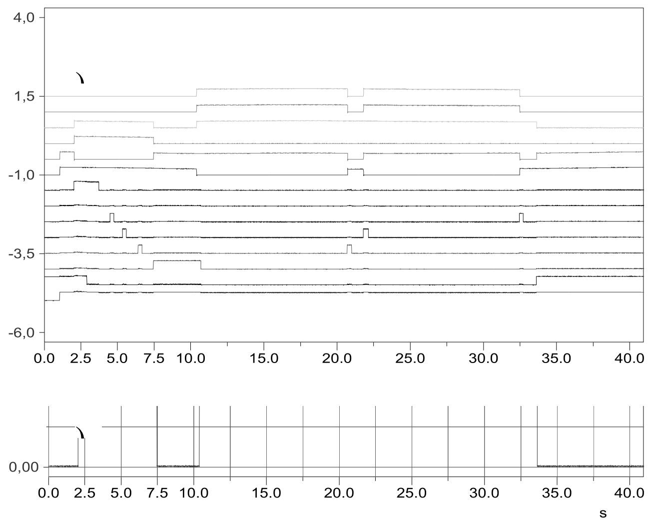


Fig. 6. Comparison of results of a measurement carried out concurrently on the selected digital (a) and analogue (b) inputs/outputs

Equipment for Tuning PLC Controlled Drives

a) *b)*

Fig.7. Training device for testing and tuning PLC controlled drives:
a) set of three devices for supplying asynchronous motors
(relay-contactor circuit and two different inverters),
b) example driving unit with asynchronous motor, gear box switched
by means of electromagnetic friction clutches and encoder for closed loop positioning

Movements of a slide, a table or another driven subassembly of a manufacturing machine can be a good example of processes where low cost PLC controllers can be applied. The control can include both programmed positioning and the stepped or the stepless velocity regulation. On the training stand motion control can be adopted also in collaboration with another process controlled in open loop mode or by feedback or feed-forward loops. Parameters in the PLC program or inside of the inverters can be adjusted manually or remotely by means of a computer and some different programs. There is a variety of situations that demand a setting of adjustable parameters. Tuning the parameters can be a quite complex task whereas a need of retuning them periodically should be considered as a result of different factors affecting entire system.

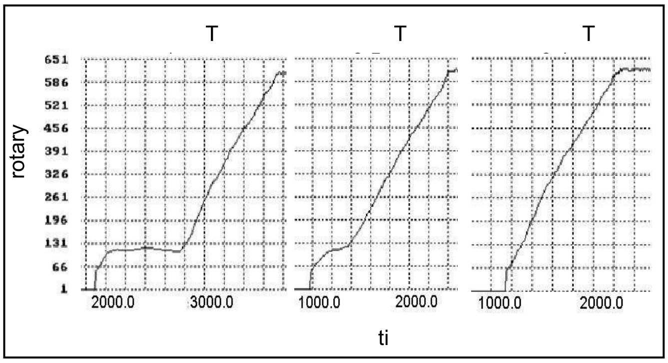


Fig. 8. Example of experimental tuning a PLC application for motion control; influence of a time-dependent parameter on the course of rotary speed of an output shaft during starting a drive; TA – delay between switching on the inductive motor and the electromagnetic friction clutch in the drive

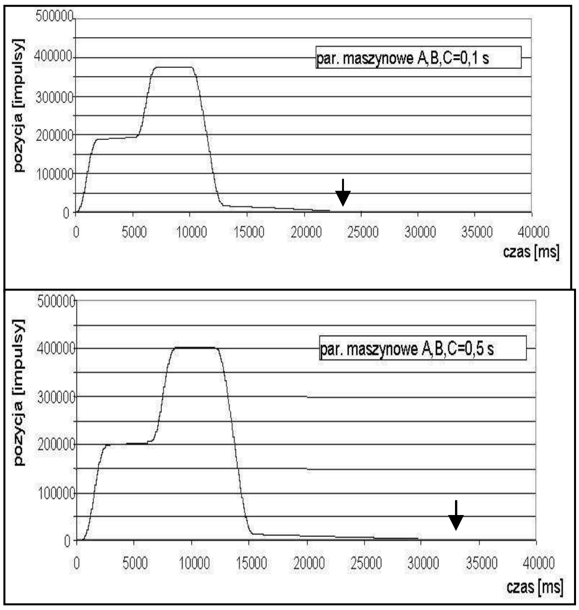


Fig. 9. Example of experimental tuning a PLC application for motion control; graphs present how the total time of the cycle of positioned movement can be influenced by parameters for adjusting necessary delays between switching on/off electromagnetic friction clutches in the drive

In the PLC applications for motion control the time-, the position- and the velocity-dependent parameters are the most often needed to adjust. This also means that the better tools for measuring position and velocity are at disposal the easier commissioning and the more efficient tuning of the overall system can be done. On the training stand two earlier designed measuring devices for digital measurements of velocity and position were applied. Now a DAQ system based on Labview applications is developed for this purpose.

Two examples of testing and tuning a PLC controlled movement have been presented in the Fig.8 and Fig.9. The graphs in the Fig.8 show how a time-dependent parameter in the PLC program can influence the course of rotary speed of an output shaft during starting a drive. The tuned parameter TA was responsible for delay between switching on the inductive motor and the electromagnetic friction clutch in the double stepped drive. The two graphs presented in the Fig. 9 show a cycle of positioning that was done by the same double stepped drive. The PLC controlled positioning was carried out with using an incremental encoder in a feedback loop and FX2N-1HC fast counter as an additional module. The result shows how the total time of a cycle can be influenced by the delays between switching on/off the electromagnetic friction clutches that change over fast to slow phases of the motion before activating braking at the desired position. The total time of regulation is influenced only partly by the delays. However, much more significant is an additional delay time that appears when a phase of the slower movement starts to be longer. This effect is signed with the arrows added to the graphs in the Fig.9. On the other hand incorrectly small values of the delays can influence accuracy of the positioning.

Conclusions

1. Understanding and practical skill of programming PLC controlled devices tends to be one of the important requirement that a lot of graduates of a Mechanical Faculty meet with when undertake a job in production plants of different branches. It concerns different specialties and should be one of the elements of mechatronic teaching. Practical teaching the rules of PLC programming demands having at disposal proper training devices. The training device described in the paper is a proposal. It was adopted for laboratory exercises and for projects, also for diplomas.

2. One of the most important features of a PLC application is easiness of its testing and tuning. A necessary set of parameters to adjust should be implemented into application and clearly defined what they are responsible for. It is an important condition of effective maintenance of a PLC controlled machine or process. Having at disposal a set of proper instruments for carrying out the testing and tuning has essential meaning. In the paper some useful ways of the tests were reviewed.

1. Blacharski W. Training Stand – Multifunctional PLC-based Controller for Automated Drives. XII. Intern. Tag. Wissenschaft, Praxis, Didaktik. Köln, 23.-25. Oktober 2002. Köln: Institut f. Analgen- u. Verfahrenstechnik. Fach-hohschule Köln. 2. Blacharski W. "Wielozadaniowy steownik PLC do zautomatyzowanych napędów – stanowisko badawczo-szkoleniowe. Napędy i Sterowanie. IX Seminarium towarzyszące IX Targom Producentów, Kooperantów i Sprzedawców Zespołów Napędowych i Układów Sterowania. 18.02.2003. Politechnika Gdańska, MTG S.A. Gdańsk, 2003. 3. Blacharski W. Testing and Tuning PLC Application Programs. International Symposium Research-Education-Technology, 43-48. May 2005. Gdańsk: Gdańsk University of Technology, Faculty of Mechanical Engineering.