THE MEASURING, MONITORING AND CONTROL SYSTEMS FOR THE REAL MODEL IN EDUCATION

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Abstract - This paper is focused on education in the field Measurement and control of technological processes. In one part of this field students obtain theoretical knowledge in an application of commercial systems for measurement, visualisation and control of technological processes. The data are measured by a programmable controller (PLC) and as the superior systems the system InTouch, Wizcon and ContolWeb2000 were used. All systems were tested on the real equipment. The programmable controller controls the surface of two communicating vessels and at the same time is a data source for master applications that are designed for the systems InTouch, Wizcon and ContolWeb2000.

Keywords: monitoring, PLC, visualisation.

1. INTODUCTION

The main task was to apply different monitoring and control systems to control of the water level in two communicating vessels model.

1, 2 - two calibrated vessels
3 - the tender
4 - the motherboard with the water pump
5, 6 - two water level sensors
7 - water pump
8, 9 - overfall
10 - interconnection with water cock
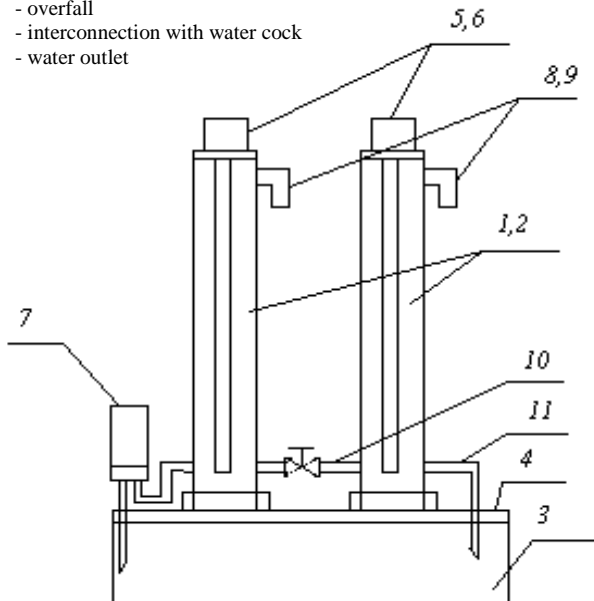**11** - water outlet

Figure 1. The model of the communicating vessels

2. COMMUNICATING VESSELS MODEL

This model consists of these parts: two calibrated vessels, the tender, the motherboard with the water pump, two water level sensors, overfall, interconnection with water cock and water outlet. The pump power is controlled by voltage of the pump motor. It is possible to input the disturbance into the system. We can do it by the profile change of the interconnection of the vessels. The change size depends on the water cock shift.

The water level is measured by capacitance sensor and its output is connected to the I/O (input/output) module of the PLC (10-bit D/A converter).

The scheme of the model is shown in Fig. 1.

3. CONTROL OF THE WATER LEVEL

To solve that problem, three controllers designed in different ways were consequently applied. The two-position controller [1], the PID-controller [2] and the pole-placement controller [3]. We have achieved best results with the third order pole placement controller. It was incorporated into control software.

3. 1. The 3rd Order Controller

The controller is designed especially for process control without overshoot of the process output.
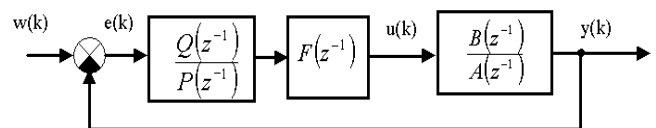

Fig. 2. Control system scheme

Let the controlled process be described by transfer functions in the form [3]

$$G_S(z) = \frac{Y(z)}{U(z)} = \frac{B(z^{-1})}{A(z^{-1})} \tag{1}$$

where

$$A(z^{-1}) = 1 + a_1 z^{-1} + a_2 z^{-2} \quad ; B(z^{-1}) = b_1 z^{-1} + b_2 z^{-2} \tag{2}$$

are second degree polynomials and $Y(z), U(z)$, $E(z)=W(z)-Y(z)$ are the Z-transforms of the process output, the controller output and the error.

In many cases we need to control the tank level on the reference signal with Z-transforms ($W(z)$ is the Z-transform of the reference signal$)$

$$W\left(z^{-1}\right)=\frac{z^{-1}}{\left(1-z^{-1}\right)^2} \qquad (3)$$

The controller is described by transfer [3] in the form

$$G_R(z^{-1})=\frac{Q(z^{-1})}{F\left(z^{-1}\right)P\left(z^{-1}\right)} \qquad (4)$$

where

$$Q(z^{-1}) = q_0+q_1 z^{-1} + q_2 z^{-2} + q_3 z^{-3} \qquad (5)$$
$$F(z^{-1}) =(1- z^{-1})^2 \qquad (6)$$
$$P(z^{-1}) =(1 + p_1 z^{-1}). \qquad (7)$$

We derive the following transfer function for the closed loop system

$$G_W\left(z^{-1}\right)=\frac{B\left(z^{-1}\right)Q\left(z^{-1}\right)}{A\left(z^{-1}\right)F\left(z^{-1}\right)P\left(z^{-1}\right)+B\left(z^{-1}\right)Q\left(z^{-1}\right)} \qquad (8)$$

In the denominator of the transfer function (8), there is the characteristic polynomial. We assume the following polynomial identity

$$A(z^{-1})\,F(z^{-1})\,P(z^{-1}) +\; B(z^{-1})\,Q(z^{-1}) \;= D(z^{-1}) \qquad (9)$$

We desired polynomial

$$D(z^{-1}) = (\,1 - c\,z^{-1}\,)^5 \qquad (10)$$

where c influences the speed of the closed control loop transient characteristic and controller output changes, too.

The polynomial identity (9) and polynomial (10) give a set of five linear algebraic equations

$$
\begin{aligned}
q_0 b_1 & & + p_1 & + a_1 - 2 & = -5c \\
q_0 b_2 + q_1 b_1 & & + p_1(a_1 - 2) & + 1 - 2a_1 + a_2 & = 10c^2 \\
q_1 b_2 + q_2 b_1 & & + p_1(1 - 2a_1 + a_2) & + a_1 - 2a_2 & = -10c^3 \quad (11) \\
q_2 b_2 + q_3 b_1 & + p_1(a_1 - 2a_2) & + a_2 & & = 5c^4 \\
q_3 b_2 + p_1 a_2 & & & & = -c^5
\end{aligned}
$$

Solving the equations (11) we obtain five unknown controller parameters q_0, q_1, q_2, q_3 and p_1

The resulting transfer function of controller is

$$G_R\left(z^{-1}\right)=\frac{q_0+q_1 z^{-1}+q_2 z^{-2}+q_3 z^{-3}}{1+\left(p_1-2\right)z^{-1}+\left(1-2p_1\right)z^{-2}+p_1 z^{-3}} \qquad (12)$$

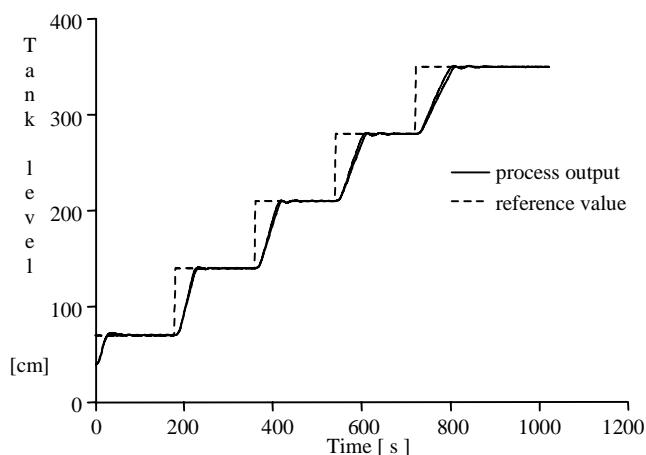The control with controller based on the pole placement approach is shown on Fig. 3 and Fig. 4.

Fig. 3. Tank level control with controller based on the pole placement approach – step shape of the reference value
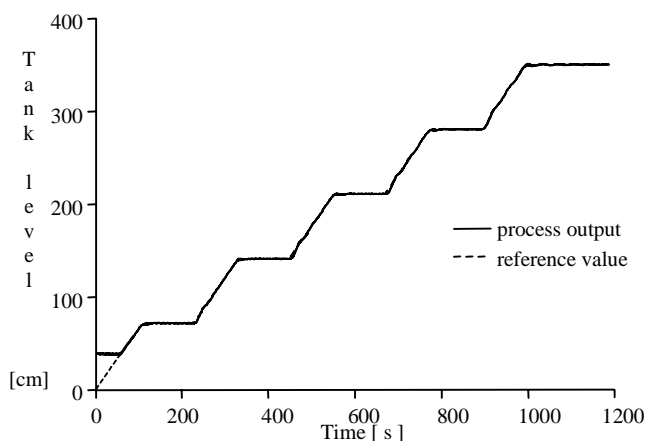

Fig. 4. Tank level control with controller based on the pole placement approach – ramp shape of the reference value

The system was controlled by programmable logic controller (PLC) Modicon TSX 3722 - Micro [4].

3. PLC DESCRIPTION

3. 1 PLC - Modicon

PLC Modicon TSX Micro is the PLC of choice for smaller machines, mobile systems and vehicles where minimal space requires maximum compactness, or when environmental conditions demand reliable performance. In perfect synergy with other Schneider products, Micro enables machines to perform to their fullest potential. The expertise of machine builders is also enhanced and increases their value to end-users.

The base configuration of the Micro includes the power supply (24Vdc or 220Vac), CPU with memory, mini operator dialog, as well as the different communication ports.To meet various size needs, the Micro offers a choice of 5 modular configurations, each offering several levels of integration (I/O, analog, counting) and openness (PCMCIA for communication).

The Micro offers over 40 different specialty modules, including positioning/rapid counting, measuring and regulation (lower upper level, sensor, thermo element),

safety, 24Vdc or 220Vac, single or double format, modularity (8, 16, 32, 64). All types of discrete I/O can be used within the same configuration.

PLC TSX 3722

1   3-slot base rack
2   Centralised display block
3   integrated analogue and counter modules
4   Terminal port (TER) (Uni-Telway or Modbus Master/Slave protocol) and Man-machine interface port labeled AUX
5   Cover for accessing the power supply terminals
6   Slot for a memory extension card
7   Slot for a communication module
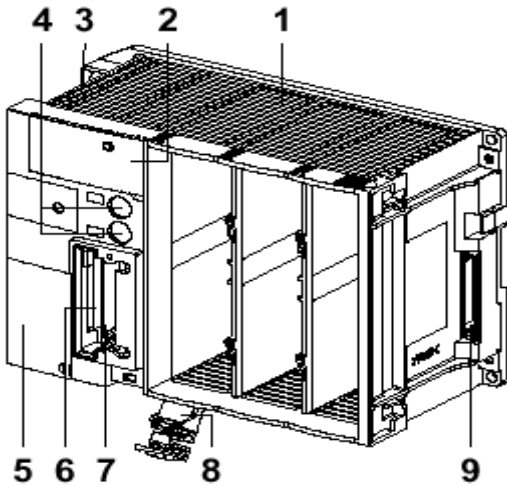8   Battery housing
9   Connector for extent racks

Fig. 5. The scheme of the PLC Modicon TSX Micro
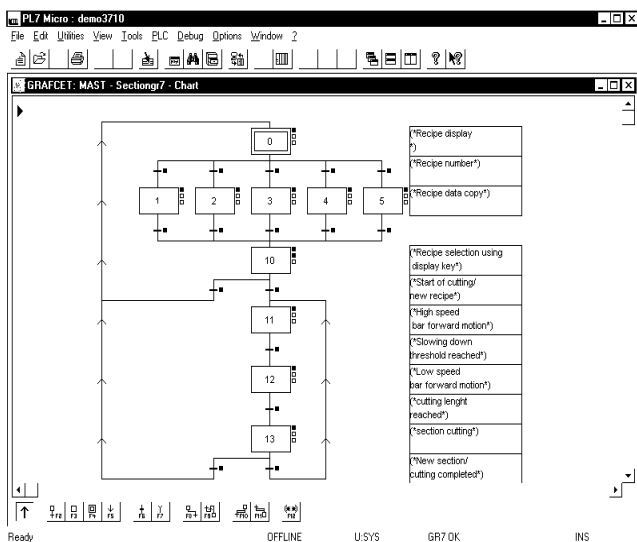
For PLC programming a special software PL7 Micro is used.

Fig. 6. Programming software PL7 Micro

3.2 MODBUS Protocol

MODBUS® Protocol is a messaging structure, widely used to establish master-slave communication between intelligent devices. A MODBUS message sent from a master

to a slave contains the address of the slave, the "command" (e.g. "read register" or "write register"), the data, and a check sum (LRC or CRC).

Since Modbus protocol is just a messaging structure, it is independent of the underlying physical layer. It is traditionally implemented using RS232, RS422, or RS485 over a variety of media (e.g. fiber, radio, cellular, etc.).

MODBUS TCP/IP uses TCP/IP and Ethernet to carry the MODBUS messaging structure. MODBUS/TCP requires a license but all specifications are public and open so there is no royalty paid for this license.

The basic structure of a MODBUS frame is shown below:

ADDRESS	FUNCTION	DATA	CHECKSUM

A master addresses a slave by placing the slave address in the address field of the message. When the slave sends its response, it places its own address in this address field of the response to let the master know which slave is responding.

4. MONITORING AND VISUALISATION SYSTEMS

The programmable controller controls the water level of vessels and at the same time it is a data source for master applications that are designed for the systems InTouch, Wizcon and ContolWeb2000.

4.1. Intouch

InTouch is one component of -based MMI system that gives users access to a full package of automation tools - FactorySuite 2000. It is the first fully integrated suite of software for industrial automation.

System provides a single integrated view of all your control and information resources. It enables engineers, supervisors, managers and operators to view and interact with the workings of an entire operation through graphical representations of their production processes.

InTouch gives users many significant advantages and improvements over previous releases. The new alarm architecture in InTouch replaces NetDDE with TCP/IP for increased performance and decreased network loading.
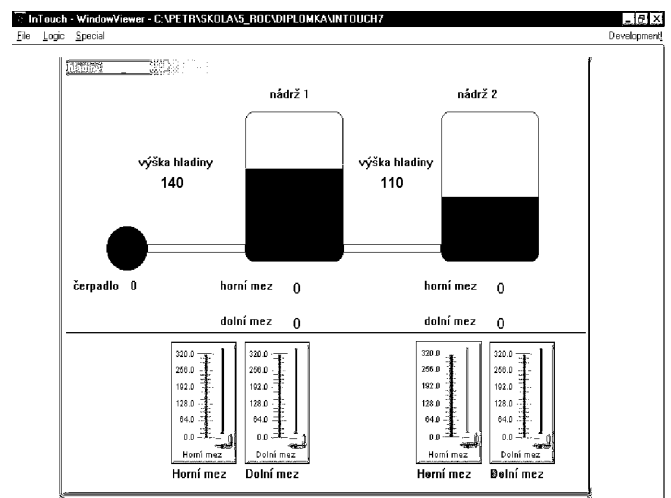

Fig. 7. The application made in system InTouch

4.2. Wizcon for Windows and Internet

Wizcon for Windows and Internet provides all of the tools users need to efficiently build effective operator interface and supervisory control applications. Productivity is further enhanced with Wizcon's online engineering which lets users design and run applications within a single environment. Users can make changes online and see the results immediately, minimizing initial configuration time and on-site installation efforts.

Wizcon's Application Studio offers easy access to all of the application's components

It provides a powerful Image Editor to create and view the Images that enable the operator to visualize part or all of a control process. An image consists of objects, which are geometric figures or text. Geometric objects can be either open or closed, and all objects can be filled with specified patterns and displayed in unlimited colors.

Using Wizcon.s Multilanguage support, tag descriptions, alarm text and image field text can be created in one language and exported to an ASCII file. This easy-to-handle file can be translated to another language and re-imported into Wizcon. The same procedure can be applied to multiple languages. During runtime, a user can choose the required language.
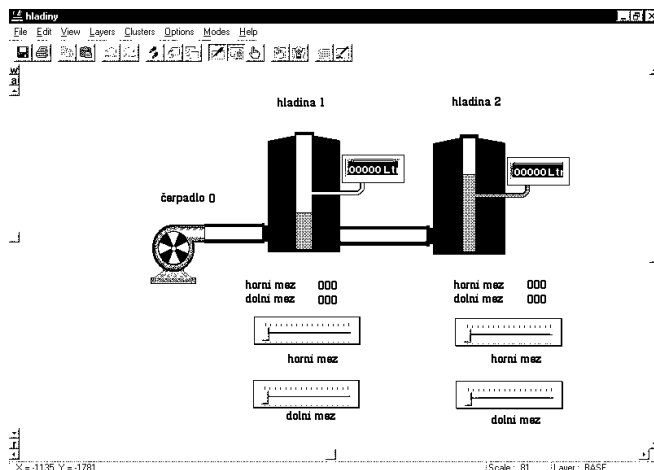

Fig. 8. The application made in system WIZCON

4.3. Control Web 2000

Control Web is a component, object-oriented system for the development and operation of visualisation, measurement, control, regulation and communication programs and programs for the collection, archiving and processing of data. Similarly, the application can control a machine or technological line in real time and simultaneously be incorporated into a large company information system.

The Control Web environment enables you to create programs using symbolic descriptions of the designed system. Based on *visual programming* you can very easily create your own application by arranging the objects with the mouse. All you have to do is to capture the relevant icon, which is a graphical representation of the required instrument, and insert it within the structure of the application you are developing. The data concerning the

inserted instrument are automatically transferred into the application source text.

Even programmers who are used to programming applications directly in source text can work in the text editor. The text that you enter via this editor automatically translates into the structures of the application you are developing.
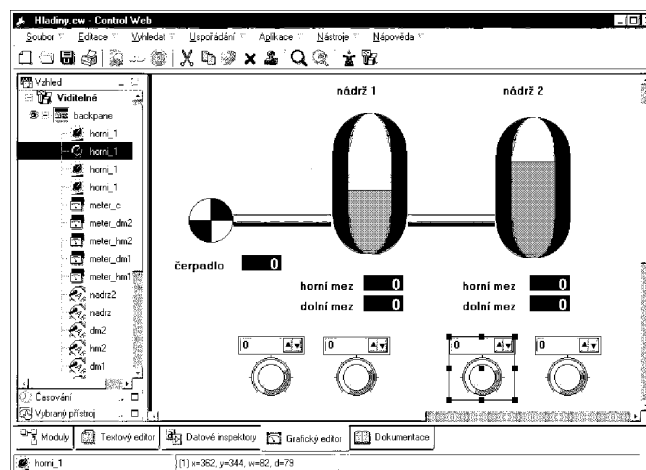

Fig. 9. The application made in system ControlWeb 2000

Examples of the projects made in different control systems are shown in Fig. 7, 8, 9.

In education students have to create applications in described system. They are preparing for implementation of these system in the factories, in industry, in their new job.

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