DISTRIBUTED PROCESS CONTROL SYSTEM FOR DISTANCE LEARNING

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Abstract. Distributed process control systems have already reached a pretty high degree of use in industrial projects. Web-based technologies enable the implementation of remote monitoring and control of industrial plants. In this paper, some solutions and advantages of using distributed process control systems are presented. In the area of process control teaching, practical experience plays an important role. Web-based technologies enable the implementation of remote experiments with real technical plants for effective engineering education. We will present our experiences with remote experiment based on distributed control system realised on simple laboratory hydraulic plant. The remote experiment user-interface is implemented using the professional supervision tools realised with Web-based SCADA technology. Furthermore a real-time video streaming is used for the online visualization of the plant. Finally, the successful evaluation of the tool is presented by example how the remote experiment has been used by undergraduate and graduate students.

1 Introduction

Technologies of remote and distributed control are important technologies of modern control and automation systems in industrial processes. In milestone report [1] that summarizes future challenges for area industrial automation in order to identify which areas are expected to grow in the near future, information technologies were found to improve production as they play a key role in industry. Telecommunication technology is providing a large number of opportunities for enhancing the speed and quality of the support process by enabling remote access to equipment. The Ethernet network technology is several years a dominant technology which links business information systems and represents more than 80% of the market share in the field of local computer networks (LAN). Fast development of the Ethernet technology, which is the consequence of the huge market of information technology and big investments of computer equipment providers, assures constant development of this technology. The consequences of these investments are evident in new versions of technologies, such as Gigabyte Ethernet and wireless networks. Presently, intensive research is performed in the area of 10 and 100 Gigabyte Ethernet network. A number of vendors are offering industrial communication technology based on Ethernet with TCP/IP protocol as a way to interconnect field devices to the first level of automation. Ethernet is the cost-effective solution, has component maturity and hence reliability. Besides its large bandwidths (10Mbps, 100Mbps, 1Gbps, 10Gbps), the fact that it is a de facto standard, it also takes advantages of many widely spread the facilities and user protocols TCP-UDP/IP, HTTP, FTP, SNMP, TELNET and other implemented on the top of Ethernet. These properties make it use very easy and allows integrating many applications like OPC (OLE for Process Control), Java/RMI, CORBA, C#, .NET etc.

In the field of engineering education, practical experience plays an important role. With the increase in bandwidth through high speed communications, web-based distance experiments can play a significant role in supporting the learning process. Many institutions for engineering education are providing a web-based access to real experimental facilities to their students. Earlier systems, rely on custom software development e.g. cgi/Perl, Java/C++, etc. By those solutions a maintenance and upgrade of the codes become problematic. Furthermore, some system lack real-time streaming capabilities due to the client side control privilege. The more recent implementations of the web experiments are based on existing software platforms such as LabVIEW or Matlab [2], [4]. In this paper we will present how the technologies of the remote and distributed control and Web-based SCADA can be exploited for distance learning of courses Instrumentation and Control, Process modelling and Process Identification. Web-based SCADA programs use the latest Internet technologies to help customers to increase plant floor productivity, to improve automation system flexibility, and to minimize Supervisory Control and Data Acquisition (SCADA) system costs.

2 The laboratory model of remote and distributed control system

The laboratory model of the remote and distributed control system is developed as a part of the project »The technologies of the remote and distributed control« within the research activities of the Centre of Excellence (CoE) for modern technology control. The main objective of the project was to perform research and development activities in the area of new communication technologies for the purpose of the remote and distributed control systems. The project was supported by European Fund for Regional Development and was finished in December 2006.

The part of the project was realization and testing of the laboratory model of remote and distributed control system, presented on Figure 1.

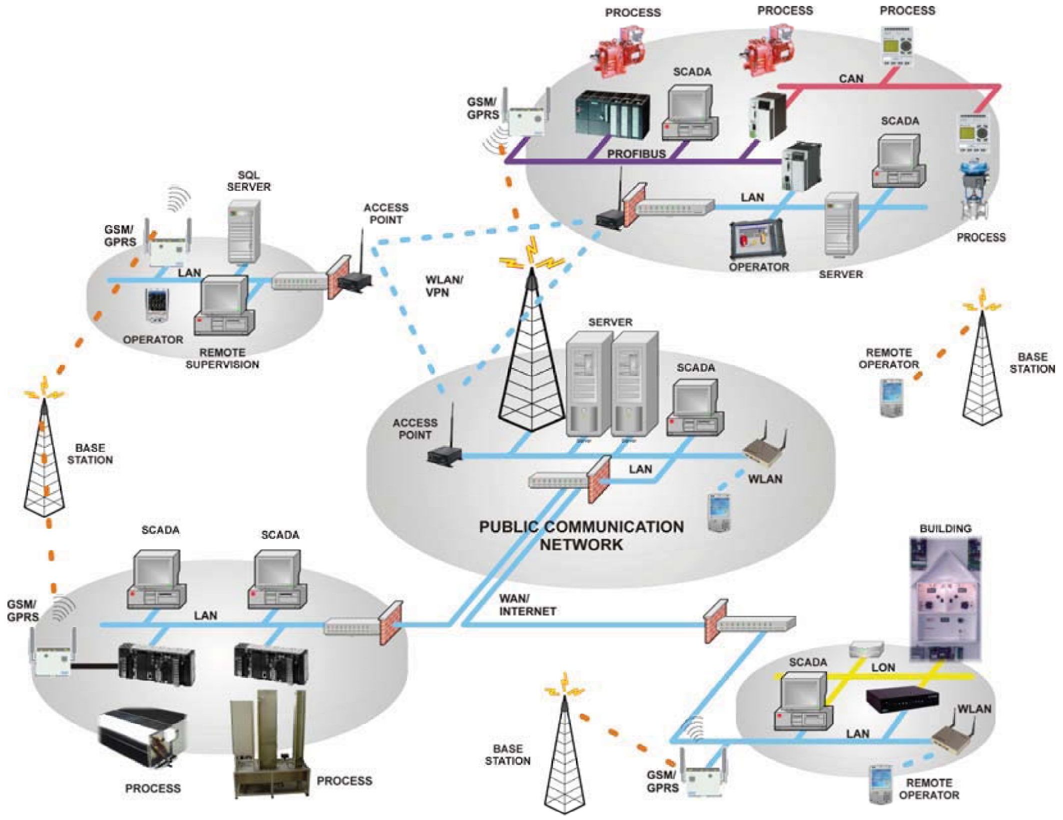

Figure 1. The laboratory model of remote and distributed control system realised in Laboratory for process automation, FERI, University of Maribor.

Laboratory plants (distillation process, electric furnace, hydraulic system, air-conditioning plant, heat exchanger) and models (building automation), which are automated locally are connected and supervised with distributed control system. Different communication technologies and standard protocols were used by laboratory realization of this industrial communication network. The industrial standard protocols PROFIBUS, CAN, LON and TCP/IP are used with wire (Ethernet) and wireless (GSM, GPRS) communication technologies. The model is suitable for testing of industrial communication networks such as:

- *Wide Area Network* (WAN) – a industrial network that covers a broad area and that uses public communications links;
- industrial WLAN and VPNs – wireless industrial networks based on GSM/GPRS technologies and remote control applications with point-to-point communication technologies.

Supervisor system is realized with professional commercial software (SCADA and Data Base server) and with a parallel solution, which is based on open-source supervisor system (Free SCADA System project).

In this paper we focus on the upper right part of the Figure 1, where the distributed control system of a hydraulic process is symbolically depicted. The process consists of main water reservoir, pipes, two tanks, some level, pressure, and flow sensors, frequency controlled hydraulic pumps, and control valves. All sensors and actuators signals are connected to three controllers (PLCs), where local control algorithms are implemented. PLCs communicate with each other through several communication technologies (Profibus, CAN, and Ethernet). Several control concepts can be realised on this process: two separate level control loops, coupled and decoupled level control of two tank system, flow control, cascade control, etc..

For remote experimentation, the process can be controlled in real-time via internet using a Web-based SCADA technology. Real-time data trend diagrams are displayed for the observation of different process signals from sensors like level sensors, flow sensors, and pressure sensors. The user is connected to the process control system (PLCs) via OPC technology and CietctSCADA Server installed on the main computer. Figure 2 shows the communication structure in detail. The MySQL Connector/ODBC is the MySQL ODBC driver that provide access to a MySQL database using the industry standard Open Database Connectivity (ODBC) API. All data are saved in MySQL data base installed on main computer. Values, parameters and other process data are transferred in text format. CitectSCADA use Cicode function for manipulation the *data.txt* files between CitectSCADA and

MySQL modules. On the main computer the Internet web server (IIS) is installed and it is used for hosting graphical user interface (GUI) as a web application.

On the client-side, only the web browser programme is needed to run the user interface (GUI) embedded in web browsers. This architecture ensures scalable and reliable access to our laboratory resources. As shown in Figure 2, the bridge between client and server side PCs consists of all professional programme modules and technologies, which are often used in industrial automation projects.

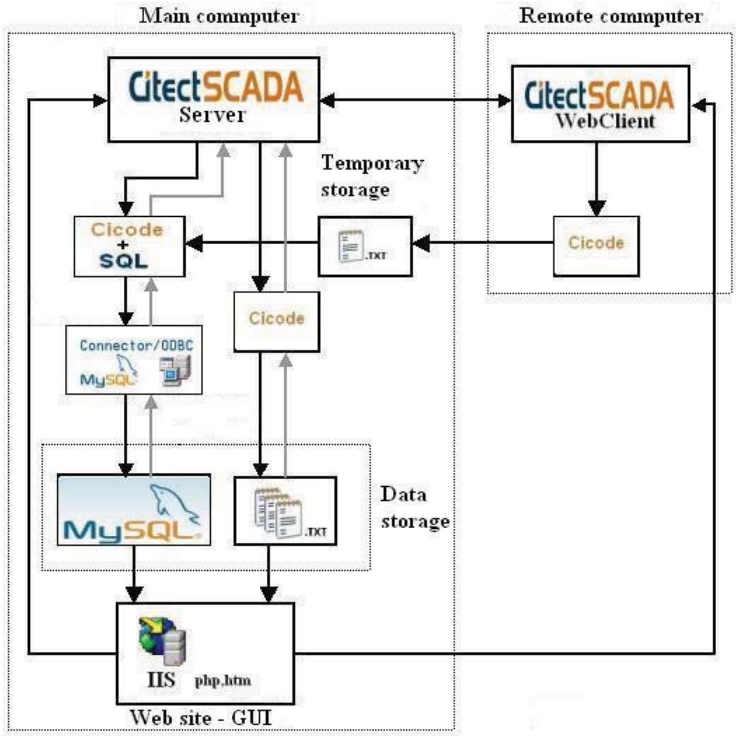

Figure 2. Block presentation of the information flow between client and server side PCs with all used technologies.

We use this laboratory model of remote and distributed control system for

- testing different industrial communication technologies,
- testing control algorithms suitable for using in distributed or remote control systems,
- performing practical experiments as a part of courses such as are Process modelling, Industrial automation, and Process control systems.

Another application is the distance learning, realised as a web-based teaching and learning with performing remote experiments. The lecturer can access the experiment from a lecture, as well as into practical exercises, where for instance students can handle the process control system themselves to see the process responses of certain disturbances, set-point changing, and controller parameter tuning. The results of the experiments can be exported to MS EXCEL for ferther analyse.

3 Simulation model of the water tank level control realised on laboratory hydraulic model

Computer modelling and simulation plays an important role for student's understanding of the process structure, behaviour, function or control. By use of simulation environment the abstractive view of mathematical equations can be reduced, hence the behaviour of the process is more transparent. The process model is based on mathematical analysis and is usually derived from the first principles (mass, momentum and/or energy balance equations) which can be according to the process complexity sometimes very difficult to obtain. More simple processes like parts of hydraulic systems, heat exchangers, shock absorbers, inverted pendulums, can be derived with minimal effort, and lots of such mathematical models can already be found in modelling literature. Of course, due to the un-modelled dynamics of the process, estimated values of parameters, non-linearities in the process, the mathematical model of the process is actually only approximate function of the real process behaviour and has to be properly validated to assure, that the model behaviour is adequate to the real process behaviour. By using the adequate process model, the behaviour of the process can be studied in many simulation environments such as Matlab/Simulink, Omola, Modelica, Dymola, for purposes of control design, process parameter identification, process supervision, fault detection, etc.

Process units in hydraulic systems are usually connected by pipelines where pressure or flow of the media is controlled by control valves or pumps. In most cases, when modelling hydraulic process, elements along a pipeline (valve, pump) are deliberately neglected, although mathematical models of these elements can be obtained from literature. These models of hydraulic processes are based upon mass balance equations and the non-linear model of the process is due to the short pipelines adequate to the real process. In case of long distances between tanks, the affect of elements along pipeline should be taken into consideration. In our case we built partial models of hydraulic elements and then formed mathematical model of a full processes. Modelling of the partial models of hydraulic elements is presented in detail in paper [3]. We used those models to simulate the simple process level control system with PID controller. The simulation block diagram is presented on Figure 3.

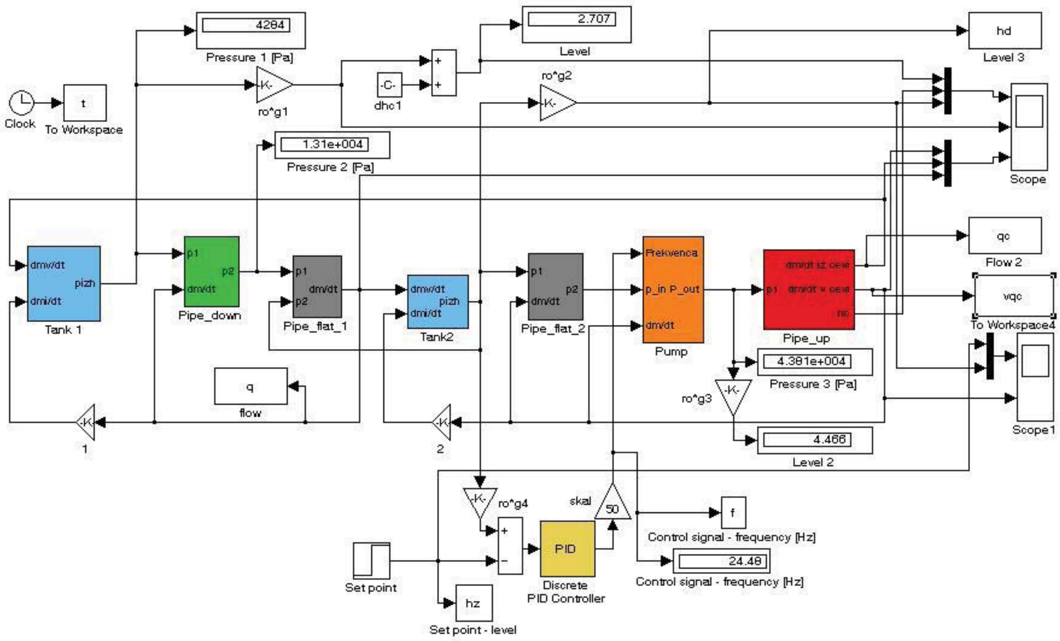

Figure 3. The simple process level control system with PID controller formed by partial blocks in Matlab/Simulink.

In the beginning a simple mathematical model of two connected tanks is presented, from which partial models of hydraulic process (pipeline, pump, and control valve) were derived. The model of the pipeline together with valves and pump is derived by using the momentum balance equations, and the model of the tank is derived by the mass balance equations. The emphasis is how to properly describe behaviour of the partial hydraulic elements, by defining their main parameters which contributes to the system behaviour.

Toolbox consists of simulation blocks of hydraulics elements is useful for the rapid development of new simulation models of different hydraulic structures. The suitability of the simulation model, verification of the software and data validity must be addressed to make a model credible. Credibility resides on two important checks that must be made in every simulation: validation and verification. Validation is the process of determining that the *right model* is built, whereas verification is designed to see if the model is *built right*. For validation and verification of the model we need the data form the real process. In the context of the distance learning the idea to perform the remote experiment to collect data from process is very effective.

4 Process modelling and control experiments suitable for remote engineering education

In remote laboratories, real physical processes can be accessed by remote users through the Internet.

There are different didactical applications of online remote experiments possible:

- teachers can use it during lectures for demonstrations;
- students can use it during scheduled lab sessions as an experiment sharing tool;
- students can use it outside class as a self-training tool.

During an experiment session, users can normally change some parameters, observe the results and download data. To make the remote experiment sessions more stimulating a live video window is provided. Students can watch the real process in such window, having a most sense of presence in the laboratory. For video transmission, the web camera software is used, which can display on-line video, and it is not necessary for the user to install special software on the client side to perform this task. The user interface of such a remote laboratory experiment is presented in Figure 4. Additionally, the streaming webcam picture is displayed.

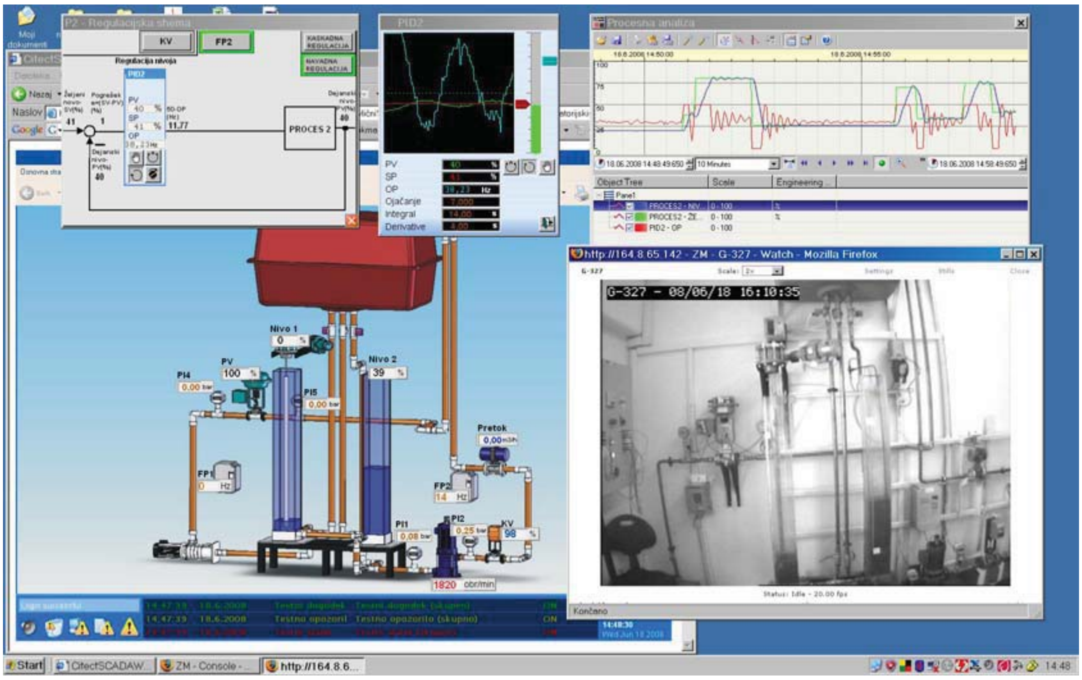

Figure 4. The user interface of remote laboratory experiment.

This experiment provides different PID controlling techniques to control the water level or flow of the hydraulic system. The aim is to remotely control the tank at a certain level of water height. In order to do this, the students select the control system from different controller structures (PID controller, cascade controller, pump as actuator, control valve as actuator, etc). While the remote experiment is running, the user can change on-line the reference input and PID controller parameters, and can observe the controller, process reference and process output signals. Live webcam window shows what is going on in the remote laboratory. First the system track needs to be recorded in order to find out what kind of system it is and how it behaves. The next step would be to design an appropriate controller with optimal controller parameters. The lecturer illustrates the physical model of the process, emphasizing its nonlinear dynamics, and then suggesting the students to use Ziegler-Nichols controller tuning method. At the end of the experiment it is possible to download data for off-line data processing.

In a course Process modelling the students use remote experiment to understand process modelling procedures (mathematical modelling, simulation, model verification and data validation), parameter identification and control design. With remote access to the process they can acquire the open loop transfer functions by means of the input-output data. The students are also provided with the corresponding simulation block diagram as shown in Figure 3. The goals of this experiment are

- to determine the process (two tanks connected with pips), sensor (level sensor), and actuator (frequency controlled hydraulic pump) parameters and dynamic characteristics through a combination of analysis and simulation;
- to design an appropriate controller with optimal controller parameters, and
- to compare the response of the simulated control system with response of real control system realised with PLC on the laboratory plant.

Response of simulated closed loop level control can be easy compared with response of level control acquired on real process. Simulated control results and real process control results presents on screen capture of the GUI on the client side is shown in Figure 5.

This remote experiment has been used by undergraduate and graduate students at the Faculty of Chemical Engineering and Technology, University of Zagreb in spring 2007 and 2008. It has been used in Process Dynamics and Control classes to demonstrate how to tune a PID controller in real-time, quantify a response to disturbances, and to provide experience in data collection, analysis and presentation, and technical report writing. The response of students to the online experiment has been assessed, and it has been favourable in general.

5 Conclusions

The remote laboratories increase the teaching performance of control theory classes. In this paper, web-based distance experiment for real time control and process modelling is described. Technically, there are several methods to offer remote experiments online. One of the methods using commercial accessible technologies of the remote and distributed control systems has been presented here. The use of professional web-based control technologies has enabled the experiments to be run securely, safely, and from remote locations. Since the remote access to different laboratory equipment based on internet applications raises the security becomes more important.

The implemented experiments ware positively evaluated in a study process and has been introduced into two lectures: Industrial automation and Process modelling. Overall, the student experience has been very positive and the stated goals of improving learning and enhancing student motivation have been achieved. However, further development is necessary to fully optimize the experiments.

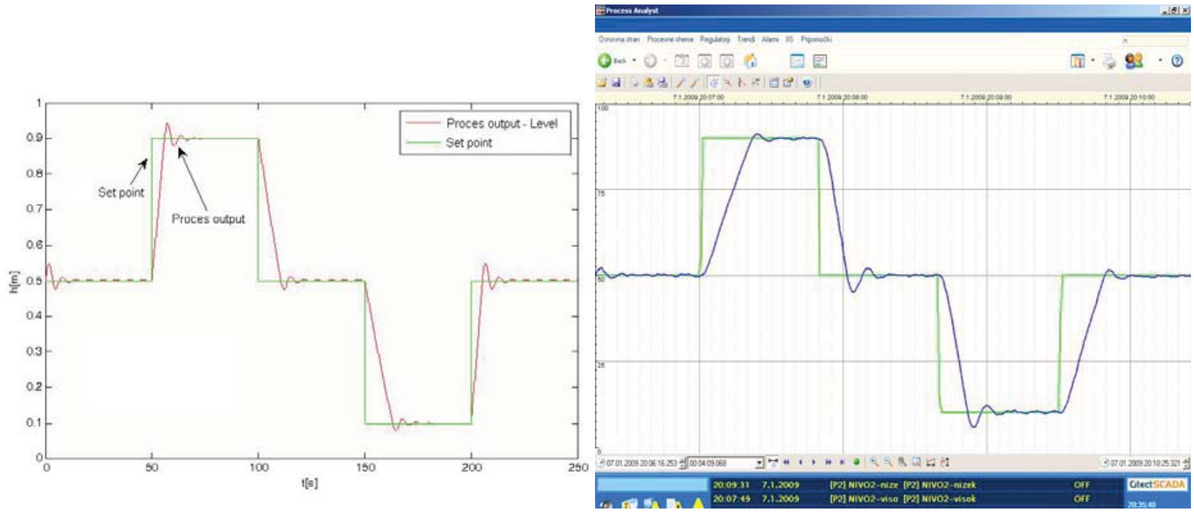

Figure 5. Simulated control results (a) and real process control results (b).

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6 References

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