

# REMOTE LABORATORY PLANT CONTROL

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**Abstract:** In this paper we introduce newly developed solution in remote control of laboratory plant. It is achieved by combining industrial router with modern Web technology capabilities and programmable logic controller (PLC). This approach offers simple implementation of remote control and low cost of acquisition. Moreover VPN connectivity of industrial router provides secure way of managing PLC programs and Web application code. The graphical user interface (GUI) is created using HTML5, CSS3, jQuery and XML. Noticeable properties of this GUI are responsive design and dynamically updated trend charts.

**Keywords:** Remote control, On-line laboratory, Industrial systems

## INTRODUCTION

Laboratory experimentation is one of most important aspects of control education. In modern approaches of obtaining practical experiences, the traditional hand-on labs are gradually replaced by remotely controlled experiments, affecting various fields of education and science [Saygin and Kahraman, 2004]. The actual trend in educational institutions is to reduce the price of laboratory experiments implementation by using the non-commercial low-cost hardware and software [Hong et al., 2000; Hashemian and Pearson, 2009]. The most commonly seen approaches are based on traditional server computers, equipped with self made technological software solutions to provide the remote access and control. In this way, many different information technologies are available for server-side software programming. In the available literature we often meet the solutions based on Java [Ferrero et al., 2003], PHP [Santos et al., 2008; Nechifor et al., 2009] or computational environments like MATLAB [Žáková and Kohút, 2009], LabVIEW [Davoli et al., 2006] and Modelica [Martin-Villalba et al., 2012].

On the other side the educational institutions are often equipped with industrial control systems like logical controllers (PLCs), data acquisition hardware (DAQ cards) and software (SCADA systems). In practice there are several methodology approaches to provide the remote Internet control of industrial systems. The first is based on direct connectivity of PLC to the local area network or the Internet, using built-in or additional connection modules, but this feature is supported only by some of available devices. In the case when this feature is not supported, the most commonly used method is based on supervisory control and data acquisition systems (SCADA) [Marques et al., 2008; Aydogmus and Aydogmus, 2009]. In this approach the cost of remote lab implementation raises rapidly, due to number of components used in it (controlled plant, PLC, server computer, operating software, SCADA system).

In our approach we propose a different lower-cost way of industrial system based remote laboratory. Unlike the above mentioned method, our solution is based on two control devices, the PLC and industrial VPN router, without need of server computer or additional software. All necessary functions like network communication, data acquisition, PLC management and visualization are provided by router device, which rapidly simplify the implementation of remote laboratory. In this paper we describe the operationally effective remote control laboratory based on above mentioned industrial-aimed devices.

## 1 LABORATORY PLANT

The laboratory system of storage tanks [Honc and Dušek, 2006] shown in Fig. 1 is used as remotely controlled experiment. The plant consists of four main vertically mounted tanks and two compensatory tanks. By closing the compensatory valves, the plant can be split in two independent systems

of two tanks in serial connection. The controlled variables of system are liquid levels in main tanks, which are measured by pressure sensors at the bottom of tanks. The manipulated variables are input flow rates to the top tanks, represented by pumps voltage.

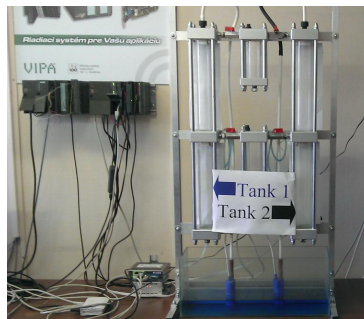


Figure 1 – Laboratory plant: system of storage tanks

## 2 CONTROL DEVICES

Our remote control solution is based on programmable logic controller PLC VIPA [VIPA GmbH, 2009] and industrial router eWON4005CD [eWON Inc., 2011]. The PLC is used as runtime environment for control algorithms, which directly interact with the controlled process through analog inputs (signals from pressure sensors) and outputs (voltage on pumps). For PLC algorithm programming the Siemens Step 7 software was used. In our on-line laboratory architecture the PLC represents the base level of experimental plant control (Fig. 2), containing the main functionality for manual and automatic control. In the program memory of PLC the three types of automatic control methods were implemented: the simple relay controller; the PID controller; and the fuzzy controller.

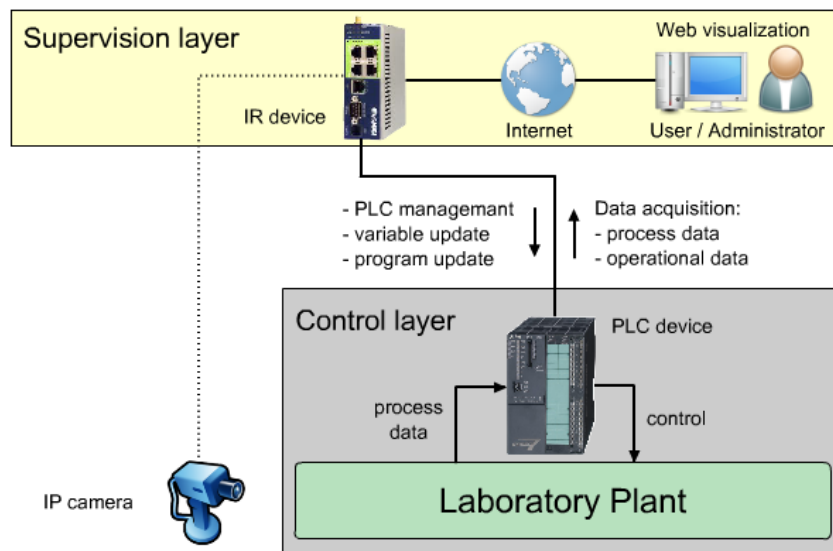


Figure 2 – Operational architecture of on-line lab

The eWON4005CD is the industrial router (IR) with advanced features like remote PLC management, data acquisition and history logging, industrial protocol translation, communication through secured service, mobile communication network capabilities, and others. The IR can manage the several PLCs connected to the local network, therefore it can be described as PLC coupler device. Interesting

feature of IR is capability of FTP and Web server. Through Web server of router the advanced visualization of PLC controlled experiment is performed. In our approach the IR device represents the supervision layer of hardware architecture (Fig. 2), providing following features:

- direct access to PLC program variables (read/update)
- PLC program update
- process/operational data acquisition from PLC
- data and event logging
- Web server based visualization

### 3 SOFTWARE PART

The visualization of on-line laboratory (Fig. 3) is based on client-side Web technologies HTML, CSS and JavaScript. The Web page of GUI consists of several informative areas.



Figure 3 – Graphical user interface of on-line lab

On the top of page the state panel is situated, containing basic control elements like turn on/off switch, button for external light control and text box with actual event logs. On the left side of GUI user can observe the behavior of plant in two forms. The first is the live video channel from remote IP camera aimed on plant and second is JavaScript based visualization showing measured states in numerical and graphical form (Fig. 4(a)). This part of GUI also contains buttons which display the box with definition of control algorithm parameters (Fig. 4(b)). In this box, user can define the control setpoints and exact parameters for relay, PID and fuzzy controller. On the right side of GUI, user can observe the behavior of plant in form of dynamically on-line generated graphs, based on JavaScript technology *Highcharts* [Highsoft Solutions AS, 2012]. The graphs are updated automatically in every period of data reading from PLC, showing the actual values of plant's states. User can choose between two sets of graphs: the

levels in tanks representing controlled variables and input flow rates representing manipulated variables. The process data in the format of structured text can be displayed by pressing the corresponding log buttons. This feature provides the data of tank levels, input flows and control setpoints.



(a) Plant visualization

(b) Input box for control setup (const-  
nats/setpoints)

(c) Dynamic graphs of measured states

Figure 4 – Layout of GUI components

The processing and communication part can be described as follows. In the control layer of laboratory architecture all measured and controlled variables of experimental plan are connected as analog signals to the PLC where main processing algorithms are running. In the PLC, each signal of process is represented as memory variable with unique address identifier. The IR device located in the supervision layer access the variables in every sampling period of read/write operation and store their values in associated tag variables in its runtime environment memory. The variable tags are linked to the JavaScript functions of GUI Web page, implemented in built-in Web server of IR device. In this way, the user or administrator of laboratory can directly read or change the process variables by Web based visualization through the Internet. The remote accessibility of IR can be provided in two forms: the direct access through Internet (secured by login and password) and access through specialized VPN service that brings higher security level of remote laboratory.

## CONCLUSION

In this paper we have shown that traditional approaches of remote laboratories development based on industrial aimed technologies can be simplified by choice of appropriate software and hardware architecture. We have developed the on-line Web solution for laboratory experiment control, based on two hardware devices, the programmable logic controller (PLC) and industrial router (IR). The described architecture consists of base control layer with controlled laboratory plant and PLC, and supervision layer with IR device, providing PLC management/control and visualization features.

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