Available online at www.sciencedirect.com

ScienceDirect

IFAC-PapersOnLine 49-6 (2016) 194–197

Remote Level Monitoring and Control Solution

Maria de Fátima Chouzal *, Maria Teresa Restivo*, Fernando Gomes Silva*, Fernando Gomes Almeida*, Tiago Faustino Andrade*

*LAETA-INEGI, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal
(Tel: +351225081776; e-mail: fchouzal@fe.up.pt, trestivo@fe.up.pt, ftgsilva@hotmail.com, fga@fe.up.pt, tfa@fe.up.pt).

Abstract: This work presents a remote monitoring and control solution for a level measurement system. The level measurement system comprises two tanks in a closed loop water circuit, some level transducers, detectors and two actuators. The developed solution is based on microcontrollers and web services. The web interface allows the user to remotely interact with the level measurement and control system.

Keywords: Remote experiments, web interface, embedded system, level control, remote control.

1. INTRODUCTION

The increasing use of computer-based communications and mobile devices makes possible to offer online experimental activities. Remote experiments, being part of online experimentation (Restivo et al., 2013), remotely access a real set-up, which can be monitored and controlled at a distance, through the internet.

Despite the relevance of remote experiments in education (Villa-Lopez et al., 2013; Wenshan et al., 2013; De la Torre et al., 2016) and the remarkable increase of interest and reported works in the area (Heradio et al., 2016), as well as its significance for industrial, research and medical purposes, there still are different problems related with the remote labs features due to hardware and software solutions (Fabregas et al., 2011; Tawfik et al., 2013). At present, another important issue is preparing them for being easily accessed by mobile devices (Štefka et al., 2016; Papadopoulos et al., 2013).

In this context, the set-up described herein has been used not only as a system available for training the topic of level measurement and control but also to be open to the implementation of different solutions for remote access experiments.

In a first stage, a solution combining a PLC for controlling and LabVIEW software for developing the user interface was used. However, this was an expensive approach.

In the present work, an alternative solution based on embedded systems and web services is developed to provide the monitoring and control of the closed loop water tanks system and make it easily accessed by mobile devices.

Therefore, the present set-up for testing level transducers and detectors is a didactic test bench in both perspectives: as a training system and a basis for implementing new solutions for remote access. Different types of level transducers and detectors are available to put in evidence different working principles, characteristics and limitations, in a closed loop water circuit using two tanks and two actuators. The transducer selection has to take into account the adequate ranges for the present tank and to provide very distinct features to force different behaviours. In order to house all the transducers and detectors, the tank dimensions strongly compromise the system dynamics.

Therefore, the controller must be computationally light and also enable the remote control of the fluid level. A control policy based on the use of an on-off controller with dead zone and hysteresis was chosen. All parameters defining the dead zone and hysteresis functions may be selected by the user. The online experimentation of different parameter sets and the observation of their influence on system dynamic behaviour is thus made possible.

An embedded system based on PIC® microcontrollers was implemented for processing and web monitoring all signal information of sensing and actuating systems. The interface of Remote Level Monitoring and Control was made on Easy Javascript Simulations (EJsS) application (Christian et al., 2011) to be easily integrated in a Moodle platform. This integration requires to install EJSApp plug in (De la Torre et al., 2013), which can be combined with the EJSApp booking system resource.

This system is under use to give the students of the Instrumentation for Measurement course (2nd year, 2nd semester of Integrated Master in Mechanical Engineering, at the Faculty of Engineering of University of Porto), the opportunity to contact with an additional type of measurement, transducers characterization and an easy control strategy. During the Demo Session, results of the use of this remote experiment based on a sample of around 320 students will be available.

In the present work, Section 2 describes the workbench, comprising several level transducers and detectors. Section 3 presents the solution adopted for making the system remotely

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.07.144

available. Section 4 provides details of the control algorithm implemented. Section 5 presents the user interface for remote access to the experiment.

2. THE WORKBENCH

One of the closed-loop water circuit tanks, the upper tank, is visible in Fig. 1. Different working principles of level transmitters (magnetostrictive, ultrasound and differential water level pressure) and detectors (conductive limit switch, vibrating limit switch), as shown in Fig. 1, can be perceived and their performance can be evaluated and compared in distinct perspectives. The transmitters' characteristics can be observed on Table 1, where the dead zones are setup geometry dependent. The detectors present different hysteresis (of the order of 3 and 4 mm) that can also be observed.

Table 1. Transmitter characteristics

Level transmitters	Sensitivity [µA/mm]	Nominal range [mm]	Dead Zone [mm]
Magnetostrictive	53.3	300	0 - 230
Ultrasound	36.3	60 - 500	0 - 44
Pressure	16.0	1000	—

Fig. 1. Level transmitters and detectors workbench.

The system also includes two electrical actuators: an on/off normally-closed (NC) outlet valve and a submersible circulation pump controlled by a DC motor. A flow transducer measures the pump water flow (range: 1.5 to 30 l/min).

3. IMPLEMENTED SOLUTION

The embedded system includes two microcontrollers, in order to achieve a modular solution for two well-defined and distinct functions. The goal is to reduce the development and debugging time, make the system run faster, permit an easy replacement of any of the modules, expedite the testing of other solutions (in both modules) and have a scalable solution for future developments. The acquisition and actuation module is associated to one of the microcontrollers and the web server module is performed by the second one. Synchronous serial communication in a master-slave mode is used between both microcontrollers, as shown in Fig. 3.

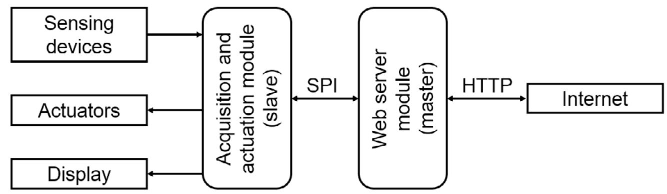

Fig. 3. Modular architecture of the implemented system.

3.1 Acquisition and actuation module

The acquisition and actuation module deals with signals acquisition, processing data from transmitters and detectors, as well as with the valve and pump actuations for controlling actions.

In this module, the microcontroller was selected considering the required number of analogue and digital I/Os, the range of the frequency pulse rate of the water flow transducer, the synchronous serial communication between both modules and the requirement of guarantying, at least, 1 mm resolution in the level measurement, with any of the transmitters.

3.2 Web server module

This module is responsible for the communications and the web page hosting. It includes a microcontroller with an Ethernet controller that meets all of the IEEE 802.3i specifications.

4. CONTROL ALGORITHM

A relay controller with dead zone and unequal pull-in and drop-out level error, with the general characteristic shown in Fig. 4, was chosen given its straightforwardness, its capability to control the process and its low computational load.

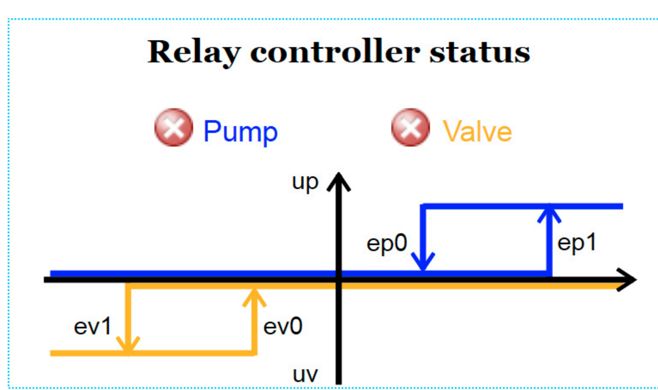

Fig. 4. Relay controller with dead zone and hysteresis

As the controller must provide two control actions, one for the DC pump, u_p, and one for the NC outlet valve, u_v, it was implemented as two independent controllers enabling a high degree of flexibility in the overall controller behaviour. Both controllers act on the level error, *e,* which is the difference between the desired level set point and the actual measured level.

Therefore, if e is greater than ep_1 then u_p will be ON; if e is smaller than ep_0 then u_p will be OFF; and if e is between ep_0 and ep_1 u_p will keep its previous state. In a similar way, if e is greater than ev_0 then u_v will be OFF; if e is smaller than $ev1$ then u_v will be ON; and if e is between ev_1 and ev_0 u_v will keep its previous state.

By defining the values ep_0, ep_1, ev_0 and ev_1 different behaviours may be imposed. If these four variables are made equal to zero the result is a relay controller with neither dead zone nor hysteresis, as shown in Fig. 5.

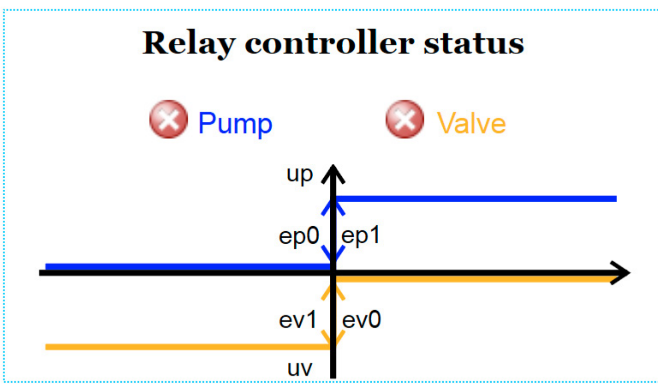

Fig. 5. Relay controller without dead zone or hysteresis.

A relay controller with hysteresis but no dead zone may be obtained, as represented in Fig. 6, if ev_1 is given the same value as ep_0 and ep_1 takes de value of ev_0. If these two values are symmetric, the hysteresis loop will also be symmetric around zero. Otherwise, a positive or negative bias will be introduced.

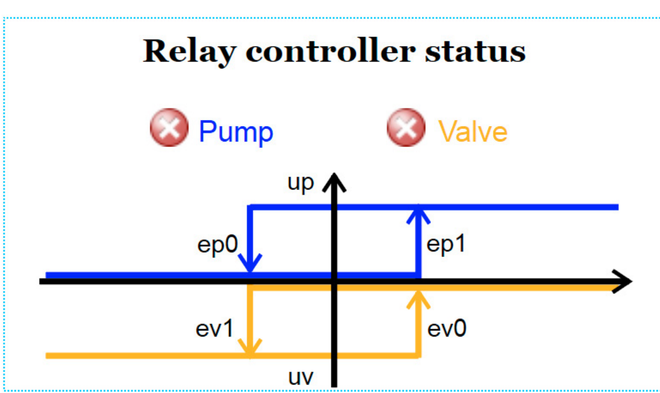

Fig. 6. Relay controller with hysteresis but no dead zone.

Finally, if the four variables are given arbitrary values some strange behaviours may result, as the one presented in Fig. 7 that enables u_p and u_v simultaneously ON in some conditions.

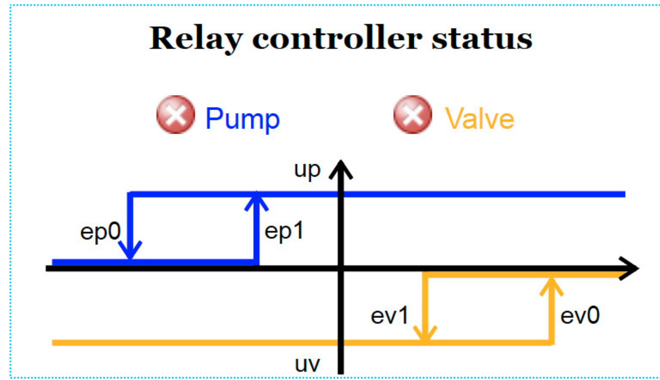

Fig. 7. Relay controller with unusual behaviour.

This flexibility enables the user to experiment with different controller configurations and observe its results without the constraints that must be introduced in a real process to ensure its survivability.

5. USER INTERFACE

The user interface is a HTML5 web page for system monitoring and remote control. HTML language is a standard for developing web pages and offers great compatibility with different browsers, in both computers and mobile devices. The user interface is presented in Fig. 8.

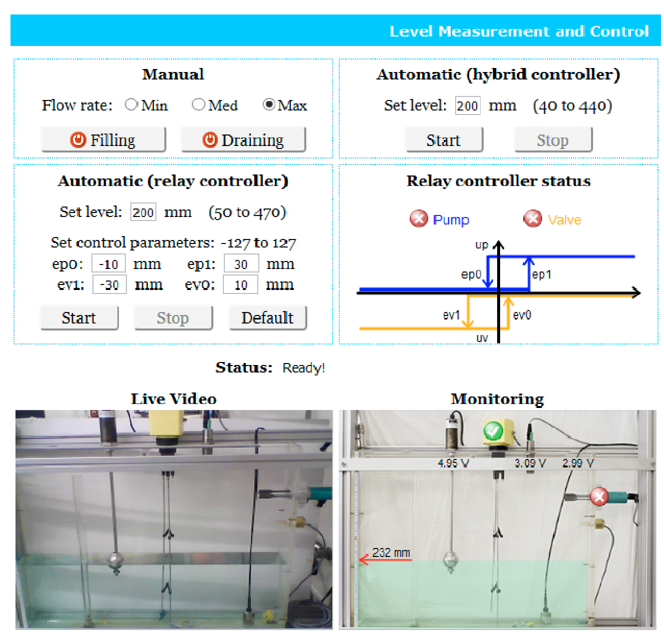

Fig. 8. User interface.

Two operating modes are available for controlling the tank water level: Manual and Automatic.

In the Manual mode, the user will get control of the pump by clicking the “Filling” button and actuate the on/off NC outlet valve by clicking the "Draining" button. In addition, the user can select the suitable filling flow rate.

In the Automatic mode, two controllers are available:

- Hybrid Controller based on a P controller
- Relay Controller with dead zone and hysteresis

In the first one, the user may introduce the set-point value. The software will then automatically perform the pre-established procedure based on the implemented controller (Hybrid Controller based on a P controller).

In the second (Relay Controller with dead zone and hysteresis), the set-point value and the control parameters may be introduced (or the default ones kept). The software will then automatically perform the pre-established procedure. The pump and/or valve indicator lights, if of green color, indicate that the pump and/or valve are actuated. This information can be observed in the relay controller status. The graphical presentation automatically displays the introduced parameter in order to allow the user a better perception.

In each case, the user interface provides in the monitoring section the numerical value of the water level, the voltage output of each transmitter and the detectors state, while the live video of the real system permits the user to follow the level evolution.

By using any of the two possibilities, manual actuation and the automatic mode using Hybrid Controller based on a P controller, the students may be able to perform the sensing devices characterization. For that purpose, a very simple animated indicator on the animation window gives the constant level value in the animated tank of the Monitoring Section of the user interface.

6. CONCLUSIONS

This setup contributes with a new technological solution to the remote experiments of "online experimentation @ FEUP", (https://remotelab.fe.up.pt). This solution is presenting a very good performance.

The flexibility allowed by the solution used for developing the interface is a valuable tool for adapting the remote experiment to different requirements of learning objectives.

Combining both the use of HTML and the commitment to optimize the elements dimensions to the dynamic positioning, makes the application available through any mobile device.

The system is under evaluation at present.

The main electronic solution was the result of an Integrated Master in Mechanical Engineering thesis and, as such, it has also been a student project in a learning context.

ACKNOWLEDGEMENTS

This work has been funded by Calouste Gulbenkian Foundation under Project U-Academy and by the Portuguese Foundation for Science and Technology under the project (PEst-OE/EME/LA0022/2013).

REFERENCES

Christian, W., Esquembre, F., and Barbato, L., (2011), Open Source Physics, Science, Vol. 334, pp. 1077–1078.

De la Torre, L., Heradio. R., Jara, C. A., Sanchez, J., Dormido, S., Torres, F. and Candelas, F. A., (2013), Providing Collaborative Support to Virtual and Remote Laboratories, IEEE Transactions Learning Technologies, vol. 6, pp. 312-323.

De la Torre, L., Sánchez, J.P., Dormido, S., (2016). What remote labs can do for you, Physics Today, vol. 69 no. 4, pp. 48-53.

Fabregas, E., Farias, G., Dormido-Canto, S., Dormido, S. and Esquembre, F. (2011). Developing a remote laboratory for engineering education. Computers & Education, vol. 57, pp. 1686-1697.

Heradio, R., de la Torre, L., Galan, D., Cabrerizo, F.J., Herrera-Viedma, E., Dormido, S. (2016) Virtual and remote labs in education: A bibliometric analysis, Computers & Education, 98, pp. 14-38.

Papadopoulos, A.V., Leva, A., (2013) "Laboratories over the network: from remote to mobile", 10th IFAC Symposium Advances in Control Education, Sheffield, United Kingdom.

Restivo, M. T., Cardoso, A., (2013). Exploring Online Experimentation. Guest Editorial, *iJOE*, Vol. 9, pp. 4-6.

Štefka, P., Žáková, K., (2016), Mobile Application for Remote Control of Thermo-Optical Plant, 13th International Conference on Remote Engineering and Virtual Instrumentation (REV'16).

Tawfik, M., Sancristobal, E., Martin, S., Diaz, G., Peire, J. and Castro, M. (2013). Expanding the Boundaries of the Classroom: Implementation of Remote Laboratories for Industrial Electronics Disciplines. Industrial Electronics Magazine, IEEE, vol. 7, pp. 41-49.

Villa-López, F. H., García-Guzmán, J., Enríquez, J. V., Leal-Ortíz, S. and Ramírez-Ramírez, A. (2013). Electropneumatic System for Industrial Automation: A Remote Experiment within a Web-Based Learning Environment. Procedia Technology, vol. 7, pp. 198-207.

Wenshan, H., Guo-Ping, L. and Hong, Z. (2013). Web-Based 3-D Control Laboratory for Remote Real-Time Experimentation. IEEE Transactions on Industrial Electronics, vol. 60, pp. 4673-4682.