

A Remote PLC Laboratory (RLab) for Distance Practical Work of Industrial Automation

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Abstract. A laboratory is an essential equipment for engineering students to do a useful practical work. Therefore, universities should provide an adequate facility for practical work. On the other hand, industrial automation laboratory would offer students beneficial experience by using various educational PLC kits. This paper describes the development of Web-based Programmable Logic Controller (PLC) remote laboratory called RLab. It provides an environment for learners to study PLC application to control the level of the non-interacting tank. The RLab architecture is based on a Moodle and Remote Desktop, which also manages the booking system of the schedule of practical work in the laboratory. The RLab equipped by USB cameras providing a real-time view of PLC environment. To provide a secured system, the RLab combines Moodle and Remote Desktop application for the authentication system and management of remote users. Moodle will send PartnerID and password to connect to TeamViewer. It has been examined that the laboratory requirement, time and flexibility restrictions constitute a significant obstacle facing traditional students desiring to finish the course. A remote access laboratory can be eliminating time and flexibility restrictions. The preliminary study of RLab usability proved that such system is adequate to give the learners a distance practical work environment.

1. Introduction

Laboratories are the most important facilities for engineering students to do a useful practical work. Therefore, universities should provide the appropriate environment for practical work. Hence, an industrial automation laboratory will offer students experience with educational PLC kits. A Programmable Logic Controller (PLC) is a type of industrial controller that could be used to control machinery which industrial productivity is an essential role. The PLC can be controlled using Ladder Diagram, Function Block Diagram, and Structured Text, which is easy to learn and to use. However, this sophisticated facility is high cost. Thus, a university should be eager to provide it.

The invention of internet technology took effect as an accelerator to implement new teaching methods. One of the benefits of the internet on the laboratory is the emergence of the concept of the remote laboratory. The concept of the remote laboratory can be an alternative solution for remote measurement, supervision or control. In the education, this concept can be used as a supporting tool for distance learning. Thus, this concept allows students to operate the laboratory remotely. The concept of the remote laboratory has been used in many universities around the world. The use of a remote laboratory is an urgent need with consideration of the ratio cost, benefits and the time. Remote labs are



a smart and useful solution, although local laboratories will always be necessary [1]. One of the most significant contributions of the remote laboratory is the improvement of self-study for learners [2].

Practical work in industrial automation course is often inadequate to get much knowledge of various PLC applications. To answer the problems, an accessible remote-control software is adopted for realizing RLab which would provide the real experiment environment [3]. However, equipment of laboratories and its maintenance require a considerable investment. It was appeared because of the lack of laboratory budget. On the other hand, available resources insufficient some time inappropriate due to the limitation of the flexibility of schedules and time to access the laboratories, and too many learners in the queue to carry out a practical work activity. To cope these problems, virtual instrumentation and the internet capability are being introduced to implement sharing the resources among different institutions. It can be helping to reduce costs and to provide greater flexibility of practical work schedules, thus giving the opportunity to a more significant number of students to perform experiments in their style, at any time and from anywhere [4]. It can be done using the resources among different institution are sharing through remote labs. Therefore, the experiment is designed to stay on and available for 24 hours a day and seven days a week. Thus the learner can use this experiment tool anytime. To be further developed, all experiments are designed in such a way. With RLab, then the teacher can improve the quality of learning without extra time of teaching and learning [5].

2. Model of The Remote Lab

The Remote Laboratory (RLab) utilized the CE111 and CE123 industrial automation kits produced by TQ. It is to provide practical experience of PLC to sense and to control the flow rate and the level of water in a two-tank system. Each tank included in two internal reflection types optical level sensors. It was to sense the maximum and minimum water levels. A variable-speed pump was to transfer water from a reservoir located in the unit base into the upper tank. It was also equipped with an in-line flow sensor providing a pulsed output for flow rate and volumetric monitoring. Solenoid operated valves to be separately closed or opened to control the flow path of the water from the upper tank back to the sump via the lower tank. Diagram of this model is shown in figure 1. The Rlab model can be described into following formulas.

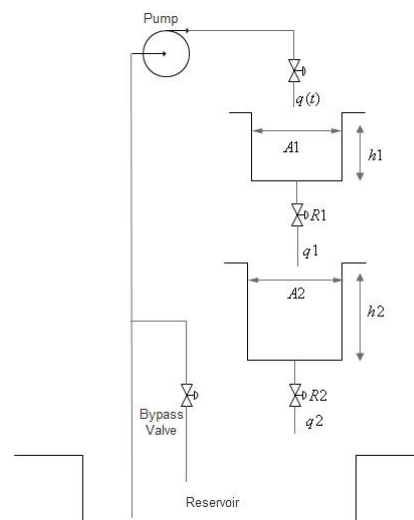


Figure 1: Noninteracting tank system

From figure 1, we can write mass balance at tank1 as:

$$q - q1 = A1 \left(\frac{dh1}{dt} \right) \quad (1)$$

A mass balance at tank two is given as

$$q1 - q2 = A2 \left(\frac{dh2}{dt} \right) \quad (2)$$

The expressions give the flow head relationships for the two linear resistances in the non-interacting system.

$$q1 = \left(\frac{h1}{R1} \right) \quad (3)$$

$$q2 = \left(\frac{h2}{R2} \right) \quad (4)$$

combining (1) and (3)

$q - \left(\frac{h1}{R1} \right) = A1 \left(\frac{dh1}{dt} \right) = R1 \cdot A1 \left(\frac{dh1}{dt} \right) = R1 \cdot q$ Taking the Laplace transforms of both sides of Equation, assuming the zero initial condition, we obtain $(R1 \cdot A1s + 1)H1(s) = R1 \cdot Q(s)$

$$\frac{H1(s)}{Q(s)} = \frac{R1}{R1 \cdot A1s + 1} = \frac{R1}{\tau_1 s + 1} \quad (5)$$

$$\frac{Q1(s)}{Q(s)} = \frac{1}{\tau_1 s + 1} \quad (6)$$

combining (2) and (4), using the same steps as above, we obtain:

$$\frac{H2(s)}{Q1(s)} = \frac{R2}{R2 \cdot A2s + 1} = \frac{R2}{\tau_2 s + 1} \quad (7)$$

Therefore the overall transfer function is determined as

$$\frac{H2(s)}{Q(s)} = \frac{1}{(\tau_1 s + 1)} \frac{R2}{(\tau_2 s + 1)} = \frac{R2}{(\tau_1 s + 1)(\tau_2 s + 1)} \quad (8)$$

Table 1. The variable for the PLC system

| Variable | Address on PLC | Function |
|-----------------|----------------|-----------------------------------|
| Fluid-level, L1 | X1 | Tank 2 LOW-level switch |
| Fluid-level, L2 | X2 | Tank 2 HIGH-level switch |
| Fluid-level, L3 | X3 | Tank 1 LOW-level switch |
| Fluid-level, L4 | X4 | Tank 1 HIGH-level switch |
| Fluid-level, L5 | X5 | Tank 2 LOW-level switch |
| Valve, V1 | Y1 | Reservoir LOW level float switch |
| Valve, V2 | Y2 | Pump to reservoir valve (by-pass) |
| Valve, V3 | Y3 | Tank 1 feed valve |
| Valve, V4 | Y4 | Tank 1 drain valve |
| Pump, P1 | Y0 | Pump |
| Flowmeter, F1 | X0 | Flowmeter |

The variables of input and output in these kits could be seen in Table 1. The wiring diagram is kept in offering the manual instructions. Remotely, the learners could not change the wiring diagram that has been set to a fixed configuration. However, the learners could do some experiments for this configuration.

A simple set of the sequence for RLab might be as follows:

1. Open V2, and then close V3, and set P1 ON (this is to start filling tank 1).
2. Wait until L4 is set and P1 OFF (this is to stop the process of filling Tank 1 when it is full).
3. Wait for 10 seconds.
4. Open V3, then close V4 (this is to start emptying the Tank 1 and flowing the content into Tank 2).
5. Wait a minute until L3 is set and close V3
6. Repeat the sequence from step 1 indefinitely.

3. Design and Development of The Remote Lab

This section describes the design and development of RLab. The RLab system consists of remote user client installed on notebook or desktop computer. The RLab server provides the ability to access distance learning system using Moodle. On the remote lab, a desktop computer connected to the PLC equipped by a web camera that can provide a real-time view of the lab environment. The construction of RLab could be seen in Figure 2.

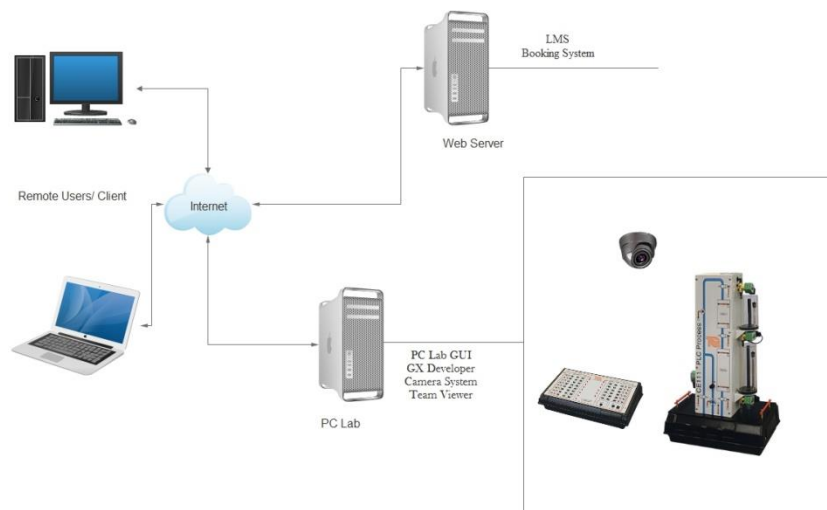


Figure 2: Construction of RLab

In general, three methods for granting remote access to RLab with resources are as follows. (1) the direct access through the standalone authentication system of single laboratory instance. (2) the access provided by the supervisory and management system like LMS or CMS. (3) Access provided by platforms for interconnection and laboratory sharing [6]. RLab using a combination of access provided by the supervisory and management system of Moodle. The learners access provided by platforms for interconnection and laboratory sharing using TeamViewer.

The learners can use a browser installed on their computer or laptop to connect with RLab with a proper internet connection. Also, the learner should install the TeamViewer on his computer. To start the experiment, the learners should log in through Moodle website stored on the web server. Hence, they could also access the available instructions of using RLab, job sheet, and booking facility.

After logging on the Moodle website, learners could book a schedule to use the remote lab. Learners could select the desired day and time slot. Each slot has 30 minutes, and each learner can only use three slots in a day. When the booking time has arrived, the learner will get a partner ID and password from a particular link. The partner ID and password are then used in the TeamViewer application.

At this stage, the learner is already connected with the RLab. However, the security of these protocols can become a problem. While SSH and Remote Desktop protocols are considered secure by design,

VNC is not secure by default [7]. To solve this problem, RLab's GUI is designed to protect the target PC. Hence, the learners could only access specific applications. Furthermore, avoidable applications will not be accessible to prevent the system vulnerability. The RLab's GUI is shown in figure 3.

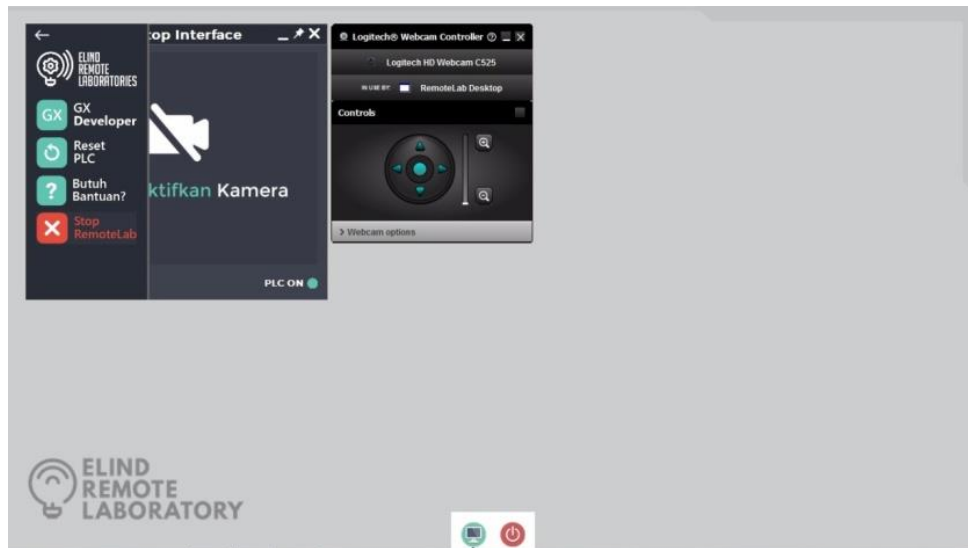


Figure 3: RLab's GUI

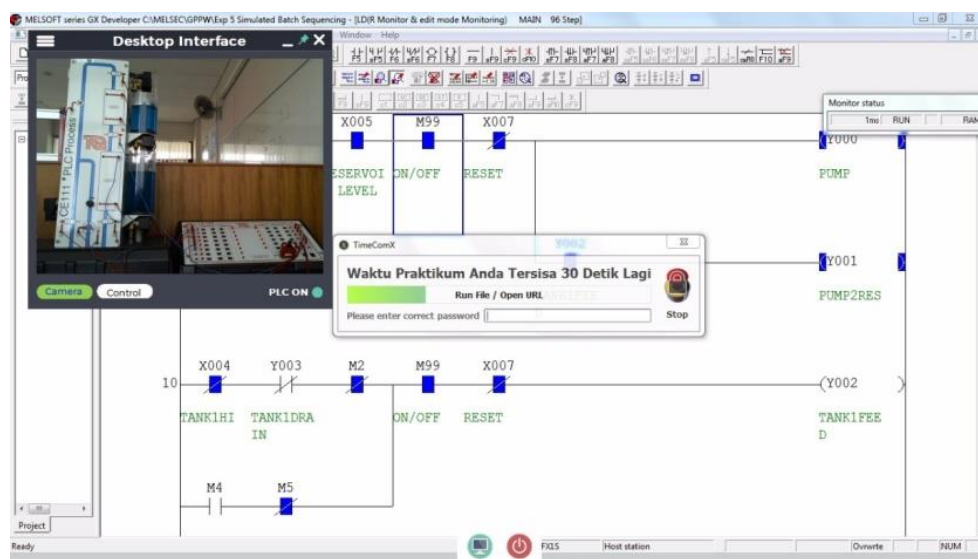


Figure 4: The learner side of the remote lab.

4. Preliminary Examination

To assess the early development of RLab, we conducted the usability examination. The examination involved expert and potential learners, i.e., students of electrical engineering education. The participants asked to log in to the Moodle website study the desired experiment provided on the job sheet. They asked to draw diagram ladder provided by the job sheet and then uploading the compiled program to target PLC. After that, the learner can operate and see directly the experimental tools that are operated. They can monitor the experiment progress in a real-time view through webcam installed in the target PC. The available time for each participant to use RLab for one session is 30 minutes. When the experiment time is almost over, a notice will appear that can be used to store the experiment results in

RLab. The system will automatically close the RLab when the 30-minute time is up. Screenshot of this stage is shown in figure 4.

5. Conclusion and Future Work

Setting up and implementing RLab can be successful and practical. The research success is evidenced by the fact that the learners in the remote client can connect and operate both RLab from a remote location.

Further examination in improving the remote laboratory can deliver of the RLab more flexible, more accessible and increase a rapidity in practical. A pedagogical study and examination also benefit to assess the learner's interest, along with investigating specific equipment that needed in deciding of the scale of application.

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