



REMOTE LABORATORY: CONDUCTING LABORATORY EXPERIMENTS OVER THE INTERNET

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Abstract: The scope for Internet of Things (IoTs) has been growing exponentially due to its rapid evolution of computers, cell phones, and the internet. E-learning has become more and more popular as a result of the increased possible options for distance learning. Remote laboratories have been one of the options being examined as a serious replacement to traditional laboratories. The main objective of the work is to provide access to Programmable Logic Controller (PLC) laboratory from distant location. So, that it will contribute to the fields like “Distance learning”, “Remote laboratories”, “Virtual learning environments” etc. In distance education, the students may not always be physically present at an institution. However, theory classes are being conducted online but laboratory tasks are not yet been conducted over the internet. Hence scope for remote laboratory has been increasing rapidly. Remote laboratory is the use of embedded systems and IoTs to establish a connection with the real laboratory experiments at the distant location. The rapid development of processors and internet gives IOT enabled devices much more flexibility. Also, remote laboratories enable intensive use of university facility. The work focused on converting the PLC universal simulator experiments into remote control online laboratory. The development of remote laboratory for a PLC Universal Simulator helps the students to carry out laboratory experiments at any time from any location. With the help of IOT Platform and Blynk Mobile application, accessing the PLC Universal Simulator inputs/outputs are carried.

Keywords: Universal Simulator, Programmable Logic Controller, Distance Learning, Remote Laboratory, E- learning.

1. INTRODUCTION

The drastic development in the field of Computers, Smartphone's, and Internet the scope for IoTs has been increasing rapidly. E-learning has become more and more popular as a result of the increased possible options for distance learning. Remote control laboratories have been one of the options being examined as a serious replacement to traditional laboratories. However, we cannot control all the labs from remote location but we can do some of them. A remote PLC laboratory design and realization has been discussed which is mainly uses the Local area network connected computers to accomplish the task [1]. A manufacturing cell has been deployed for a distance PLC programming course [2] employing a remote laboratory. Lab equipment in PLC lab has been operated through Smartphone [3]. An industry equipment has been automated [4] using Lab View and IoT. A virtual tool has been developed to program PLC from distant location [5] without spatial-temporal constrain. The electrical drives laboratory has been converted to PLC based remote laboratory [6]. An automatic lab has been provided to operate remotely [7] by which the students interact with the physical system over the internet. The setups available are D.C motor, magnetic levitation system, a water tank, helicopter simulator and a LEGO mobile robot. Two computers are being used in order to program PLC laboratory for manufacturing an engineering process [8]. In which one computer working as a system controller and another as a system supporter. A robotic laboratory has been made to access remotely so that it can be utilized by many students at the same time, the main goal of this paper [9] is to access the performance of the e-laboratory scenarios in terms of efficacy of the training provided to students. Remote laboratories have been one of the options being examined as a serious replacement to traditional laboratories. Automation professional players are focusing solely on remote access to the regulated process these days. The Department of Instrumentation and Control Engineering is also working on this, which could provide remote access



to laboratory equipment. Students also get greater interest in their rapidly evolving field of these types of labs. The programming procedure and information about how to use mobile application are the most significant aspects of the experiments. As a result, a new hardware controller circuit is interfaced between the PLC and the Universal Simulator in addition to enhancing the functionality of the current Universal Simulator. However, the simulator's control remains completely under the control of the remote user, and also the simulator can be operated on-site. The hardware controller has been designed for PLC with Universal Simulator. The development and improvement in automation has been going on continuously in the present world. But most of us don't give much preference towards the educational institutions and their improvements in their modes of teaching. The present PLC laboratory does not have flexibility which means we need to go to the location in order to access the equipment's in the lab. As we have seen from 2019 due to Covid-19 pandemic encouragement to distance learning, e-learning and remote laboratories has been increased drastically because all the educational institution has been shut down for several months. Although theory classes have been conducted online but almost all the practical class and laboratory are closed due to lack of flexibility. Automation professional players are focusing solely on remote access to the regulated process these days. The Department of Instrumentation and Control Engineering is also working on this, which could provide remote access to laboratory equipment. Students also get greater interest in their rapidly evolving field of these types of Lab's. The programming procedure and information about how to use mobile application are the most significant aspects of the experiments. As a result, a new hardware controller circuit is interfaced between the PLC and the Universal Simulator in addition to enhancing the functionality of the current Universal Simulator. However, the simulator's control remains completely under the control of the remote user, and also the simulator can be operated on-site. The hardware controller has been designed for PLC with Universal Simulator.

2. SYSTEM IMPLEMENTATION

The system architecture is shown in Figure 1. The remote laboratory System developed for the Bosch lab is shown in Figure 2.



Figure 1: System Architecture

2.1 Experimental Platform

The main intention of this proposed work is to provide access to the existing PLC Laboratory from remote location at any given time. So, in case of any emergencies as we have seen from past two years, students cannot able to attend practical classes due to lack of flexibility in laboratories. If we provide access to the laboratories from remote location students can remotely access and practice different experiments available in the proposed remote laboratory. The different station of the system shown in Figure 2.

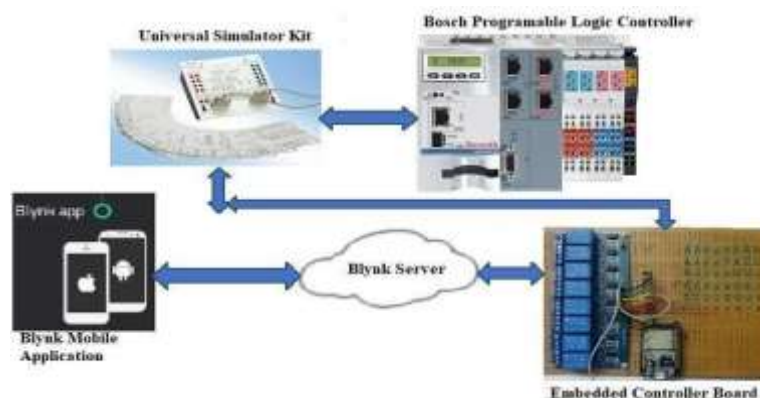


Figure 2: Remote Laboratory System



There are many applications and requirements that can be done through PLC, among those a popular application is being converted as tile so that one can program for that tile and test the program with the help of Universal Simulator the experimental platform is shown in Figure 3.

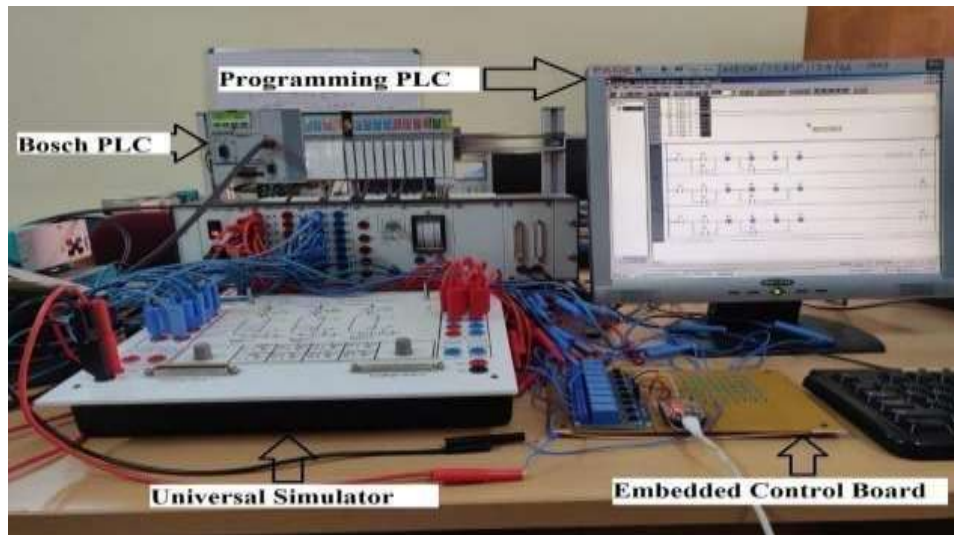


Figure 3: Experimental Platform

2.2 Embedded System

From the Blynk libraries we can control many controllers remotely only criteria are that the controller should be programmed properly for the required application. We are now controlling universal simulator so we need eight control inputs and we are monitoring eight outputs. For our application we are using ESP32 which has built in Wi-Fi and there are thirty general purpose input and output pins. ESP32 is a fully integrated Wi-Fi and Bluetooth IoT solution one which consists of roughly 20 components in relay every one of the eight common terminals are shorted so we can utilize normally open contact at whatever point we need. The Switches in the Universal Simulator S1 to S8 are associated with the normally open terminals of the eight relays. So, when we send signal from the Blynk mobile application the Controller will send trigger signal to the relays so the typically common contact will shift to normally open contact so the individual signal is applied to the PLC. The output voltage from the Programmable Logic Controller is 24 Volts which we can't straight forwardly interface with the controller pins, in the event that we do as such, the controller will be damaged. The necessary voltage for the controller is 3.3 volts, so a regulator circuit is designed shown in Figure 4 for Maximum input voltage of 24 volts and least voltage of 20 volts for load current of 30mA. The obtained opposition esteem is 414 ohms subsequently absolute of 500 ohms obstruction of every one of 100 ohms is utilized.

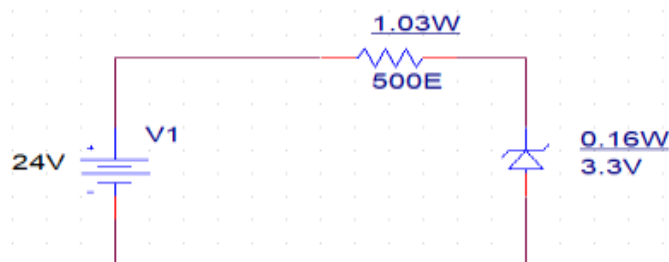


Figure 4: Regulator Circuit

There are eight outputs from the Programmable Logic Controller thus for each output the regulator circuit is associated then from the Zener diode terminal the pins are connected with the controller output. The entire Embedded Controller board Architecture and layout is shown in Figure 5 and 6. The board is interfaced between the Programmable Logic Controller and the PLC universal simulator.

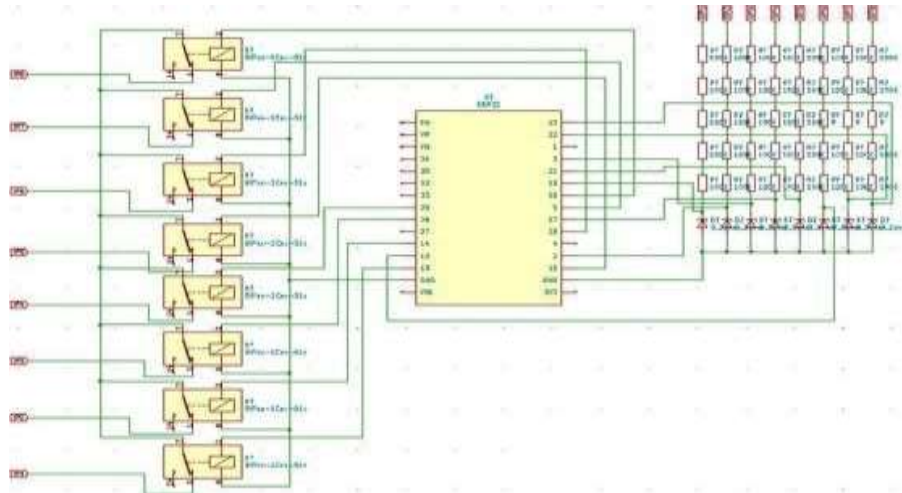


Figure 5 : Embedded Controller Architecture

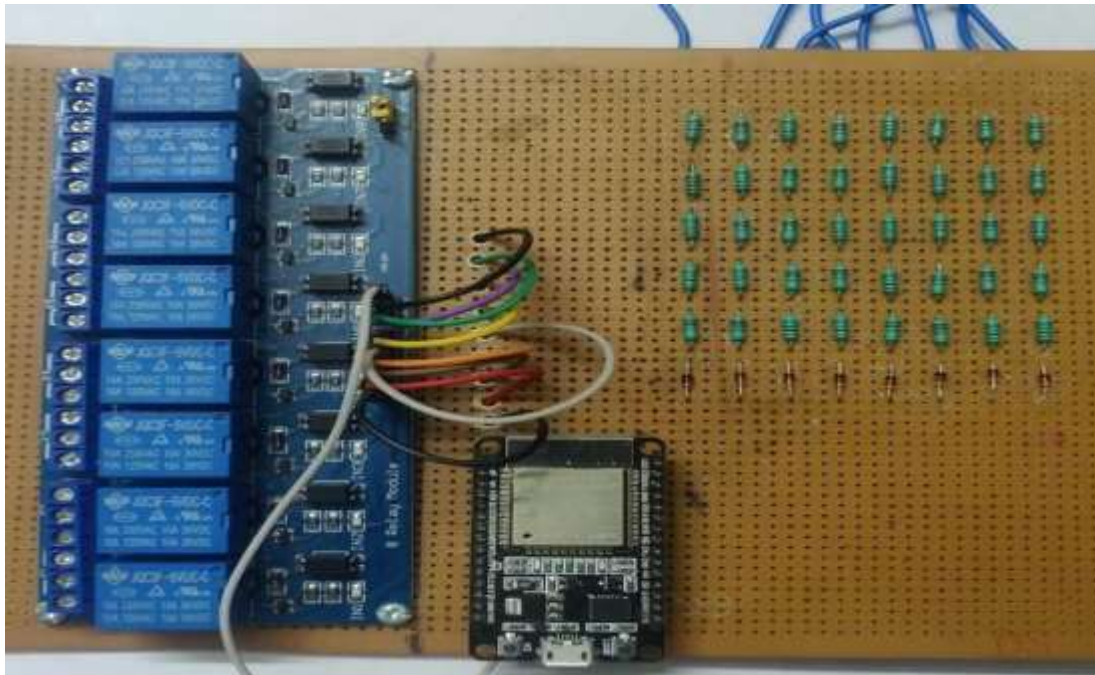


Figure 6 : Embedded Controller Schematic

2.3 Example Template:

Tank Filling Device Simulator For illustration purpose a tank filling device simulator is taken shown in Figure 7, consists of 3 tanks that are equipped with signal encoders.

The tank filling device simulator is switched on using the S1 pushbutton “Start”. For switching the device simulator off, the S2 pushbutton “Stop” is used. For the "Max" (full) notifications, the signal encoders S3, S5 and S7 are used.

For the "Min"(empty) notifications, the signal encoders S4, S6 and S8 are used. The storage tanks can be arbitrarily filled and emptied by hand. For the filling, the valves Y1, Y2 and Y3 are used.

A control is to secure that after an "Min"(empty) notification occurred, only 1 tank can be filled. The filling of the tank continues until the corresponding "Max" (full) notification has occurred.

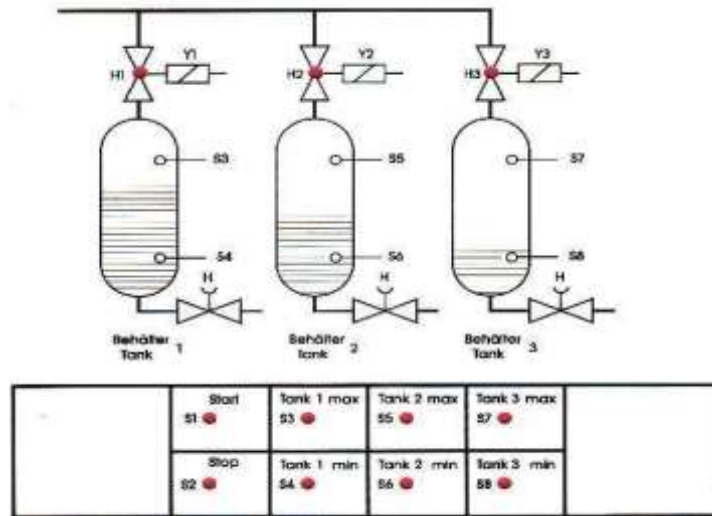


Figure 7 : Tank Filling Device Simulator

2.4 Graphical User Interface

In order to interact with the system, we are using a mobile application called Blynk. From this app only we are controlling the inputs and monitoring the output simultaneously. This app is basically an app editor which allows user to create multiple projects, which has graphical widgets such as buttons, sliders, virtual LED's etc. shown in Figure 8. There are several libraries through we can control and monitor many controllers directly from the application. Once the project is created and programmed successfully it can be shared with other users as it is and also, they have the authority to modify the program as per their requirements.



Figure 8 : User Interface

3. SYSTEM PROGRAMMING AND OPERATION

In the wake of amassing the framework, what remains is to notice its activity and effectiveness. This should be possible by programming PLC in a way that it's inputs and outputs are programmed in particular way that for every experiment all the inputs and outputs address are maintained same. Wi-Fi connection should be same as per the program in the controller. Both sensing and sending the output and input happens simultaneously. We go over the signals acquired and sent when we get proper Wi-Fi connection. We additionally attempt to legitimize how a framework as straightforward as possible contends with those accessible in the actual location.



3.1 PLC Programming Instructions

In order to interact with the simulator remotely we need to follow some rules while programming for any application. While programming for any particular application we can use any logic or strategy but while assigning input and output address for the controls we must follow same address for all the applications which are given in the below Table 1.

TABLE 1: Input Address

Serial Number	Inputs	Address
1	S1	Port 0 IX0.0
2	S2	Port0 IX0.1
3	S3	Port0 IX0.2
4	S4	Port0 IX0.3
5	S5	Port0 IX0.4
6	S6	Port0 IX0.5
7	S7	Port0 IX0.6
8	S8	Port0 IX0.7

3.2 ESP32 Programming Instructions

In order to get proper control over the inputs to the PLC we need to program the controller in such a way that it does not turn ON any of the inputs in any of the conditions such as during booting. In order to achieve this, we can use pull-up or pull down registers which are built-in in our case. Look at the instructions properly and program as per the input and output pins which are being used. While Programming for inputs use pull down resistors commands so that at the time booting the controller will not send any signals to the PLC otherwise it will send High signal to all the eight inputs.

4. EXPERIMENTAL FRAMEWORK AND RESULTS

Steps to be followed for initialization of the system are given below:

- i. Connect all the Inputs and Outputs to the PLC from the Universal Simulator.
- ii. Place the programmed tile over the simulator.
- iii. Power ON both Simulator and the controller circuit.
- iv. Wait for three to six seconds so that controller will connect to the programmed Wi-Fi connection.
- v. Then from your Blynk mobile application connect to the Blynk server.
- vi. Provide inputs to the PLC as per the requirement.
- vii. Simultaneously observe the outputs in the application itself.

The primary objective of the Tank Filling Device Simulator experiment is to maintain that at any given time, at least one of the three tanks are filled. When the tank minimum signal is given by any of the switches S4, S6, S8 corresponding tanks valve will be opened indicated by H1, H2, H3. The valves will close only when the tank full signal is given by their respective switches S3, S5, S7. S1 and S2 are the Start and Stop buttons given for the emergency controls. In this example tank 3 minimum signal is given hence H3 valve is opened as shown in Figure 9.

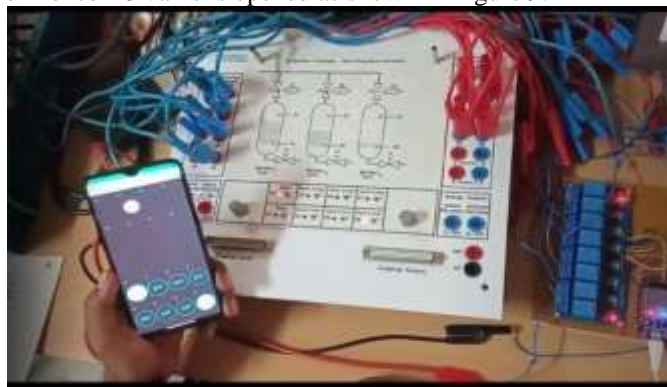


Figure 9: Tank Filling Simulator



5. CONCLUSION

The work introduces an experimental evaluation of remote laboratory in the distance learning area. The work makes students/user to gain access to the laboratory equipment's from the remote location in the real time. The work focuses on implementing concepts and approaches created in the research area of distance education, e-learning, and exploring the integration of remote laboratory settings from a technology standpoint. The system developed for the PLC universal simulator have been presented, which makes the students to acquire basic knowledge in field of PLC and automation. The availability of the high-speed internet connection for the remote laboratory is crucial part. There are many enhancements that can be realized for future work, some of them are Learning management system (LMS) can be developed, Remote laboratory concept can be applied to develop other laboratories such as Power Electronics, Control System, Electrical Measurements.

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