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Web-based remote electronics laboratory design and implementation

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ABSTRACT

The growing deployment of mechatronics systems need a significant number of qualified engineers with a better knowledge of all theoretical and practical elements of Electronics and Electrotechnics. Building experimental laboratories at universities is costly and restricted to only students who are physically present at the campus. Setting up remote experiments is a contemporary strategy to increase access to laboratories, especially in years where on-site teaching was impossible due to the impact of the pandemic. With an ever-changing educational landscape, educators are always looking for new ways to improve their online learning process.

1. Introduction

Teaching mode and learning style have altered dramatically in the internet era. Web-based laboratories has impacted the content of courses, simplify laboratory tasks and provide open access (from anyplace and within anytime). The modern remote education has brought one of the most significant transformations which is changing from focusing on teacher and classroom into student-focused. Autonomic learning in students has become a central idea in the internet learning era. Conventional content-oriented teaching methods are giving way to student-centered ones. Students can preview experimental contents, learn the method and witness potential experimental phenomena by remote experience, using state-of-the-art Rohde & Schwarz equipment without the risk of harming real instruments. As a result, learners are the main who control the experimental class and the workload of lecturer or laboratory staff can be decreased [1].

Going with the advancement of Industry 4.0 and the enhancement of Internet of Things (IoT) is the efficient establishment of remote virtual electrotechnics laboratories. This paper first analyzes the development and necessary of remote laboratory, then explain the design tools which is LabVIEW and present the full designed and implementation of the electronics remote laboratory. All the tool kits, instruments, program structures, embedded HTML webpages and testing. The aim of this project is to build a full laboratory library that can be used immediately at the Department of Electrical Engineering and Mechatronics in the University of Debrecen and can be expanded easier without any extra cost [2]. Within this paper, an overview of implementation of the tasks as well as the knowledge about hardware and software in used will be presented. Besides, the future challenge of the increasing in both terms in the century of Industry 4.0 are included [3].

2. Basic literature and designing tool

2.1. What is a remote laboratory?

Experimentation in the laboratory is critical in engineering and

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scientific education. The nature of these laboratories is changing as a result of automation, and there is a long-running argument concerning the utility of hands-on versus virtual and remote laboratories [4]. Because traditional hands-on laboratories require equipment, space, and maintenance staff, virtual and remote laboratories are in need in addition to minimize expense. Additionally, they bring other benefits such as facilitating distant learning, boosting lab accessibility for persons with disabilities, and increasing safety for harmful experiments [5].

A remote laboratory is a teaching and learning environment that aims to develop students' hands-on experimental skills without going to a physical laboratory [6]. Virtual experiments will take place over the internet or using software designed. It allows students to do a variety of experiments without geographical restrictions.

2.2. Difference between virtual and remote laboratory

Both virtual and remote laboratories are based on the development of IoT and both providing experiments from distant. However, they still have some differences and can be categorized base on experiment environment. Remote laboratories bring access to a more realistic learning experience than software-based virtual laboratories. One can see that is especially true when taking consider of teleoperated laboratories, which allow a distant client to perform experiments in a real physical laboratory via a web browser [7] (see Fig. 1).

Remote laboratory is the combination of the benefits from traditional physical laboratory with the flexibility and convenient of simulations from virtual laboratory. Moreover, thanks to remote laboratory, experimentation engineering skills such as remote operation, diagnosis and maintenance, collaborative teleworking will be developed.

2.3. Measurement instruments

Rohde & Schwarz (R&S) is well-known for being one of the world's biggest and most reputable producers of electronic test and measurement equipment. Their goods established the standards in research, development, manufacturing, and service [9].

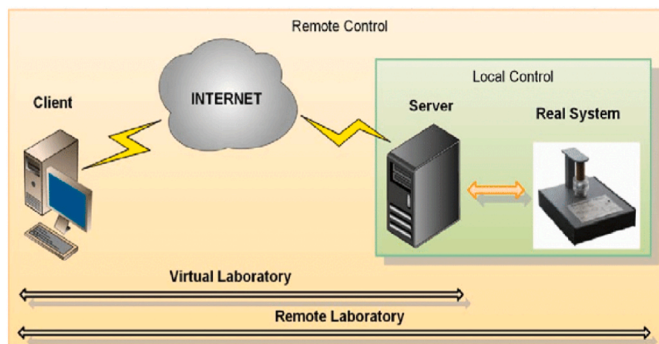


Fig. 1. Virtual and remote laboratory architecture [8].

In the following research we used R&S HMC8043 power supply and R&S RTB2002 Oscilloscope as main instruments.

2.4. Design tool

To execute these online laboratories, various software and tools are available on the market [10]. Nevertheless, the LabVIEW software environment has shown to be the most adequate for remote equipment control [11]. It provides all necessary tools for engineering automation control design [12]. Several elements of the measurement and automation business have been drastically altered by LabVIEW [13]. The title LabVIEW is a condensed version of Laboratory Virtual Instrument Engineering Workbench [14]. LabVIEW is not only a visual programming language but also a system-design platform, and development environment that was developed to allow the creation of any sort of system [14].

Choosing LabVIEW as the designing tool was based on 4 aspects: art design difficulty, programming difficulty, regarding web publishing and library. As for designing, LabVIEW is especially applicable to circuit simulation, industrial control and instrument interface design. For programming, LabVIEW has been shown that its graphical icon programming approach is a very effective learning method for many students [13].

The opportunity to publish to the internet, which is critical for the application of remote laboratories, is another consideration in the adoption of LabVIEW via the Internet Toolkit facility. Furthermore, LabVIEW have the instrument-specific drivers and libraries for both R&S measurement devices which is used for this project.

The virtual instrument (VI) front panel allows students to manage the experiment by altering the power from the power supply and the frequency generation for the oscilloscope. The remote connection capability is the following stage after the primary LabVIEW applications have been built, interfaced with the hardware, verified, and integrated.

The program for data collecting, remote monitoring, and managing specific parameters of the experiments was created with LabVIEW version 2020 and the R&S measurement device drivers. LabVIEW provides the students and researchers in the universities with the license to develop the software for this assignment. The only program necessary for the remote user to run the experiments is LabVIEW Runtime Engine, which is available for everyone to simply downloaded from the National Instruments website [15].

3. Project architecture

3.1. Remote laboratory structure

The system is shown in the figure below. Both measurement devices R&S HMC8043 and R&S RTB2002 are connected with a stream by UTP cable that will go to the server and the students or clients can access that through the Internet, see Fig. 2. High-speed networks of the gigabit class

are required for a remote laboratory which is needed to deal with high-frequency or high-speed research, as indicated [16].

For a large class with more students, only one server is needed to connect with several devices, for each device only one student can get the control but the number of students can watch it is unlimited.

3.2. Remote control process

The remote-control process is described as the flow chart above, see Fig. 3. When the client first starts the program and successfully connects from the Internet, the client can send control commands to the server. The server receives commands, sends them to the devices, and the devices will perform measurements following those commands. After that, the result from the devices will be sent back to the server, and the server will display that information on the client's computer. Clients receive the result and decide what to do next with the program. If they achieved what they need in the experiment, they can stop the remote program. If they need to do more on it, they will send more commands and the process repeats again.

3.3. Step-by-step to build the remote program

The research project was built following these steps, according to Fig. 4.:

- First, all the specifications of devices and equipment will be specified. It is also necessary to review the needs of electrical and electronic experiment learning to decide what to design.
- Second, fulfill all the requirements from hardware. Using Electronics measured instrument book, review and collect experimental data, choosing what function to be created.
- Writing the LabVIEW code to control the devices from LabVIEW software. Arrange input and output controls, specify the user interface, and create the front panel in accordance with requirements and experimental measured results, also create display of the front panel to be the same as the display of the oscilloscope.
- Create program for each class including measurement and calculation needed, table to get the data and export data to excel.
- Code debug to make sure it is working without error.
- Running simulation with the written code.
- Web-publishing program.
- Add security feature to the software.
- Test the complete program. Trying to run program with several different experiments.
- Calculate and analyze time delay.
- Making instruction for students for the online laboratory.
- Making instruction for lecturer or technician staff to prepare the laboratory for class.

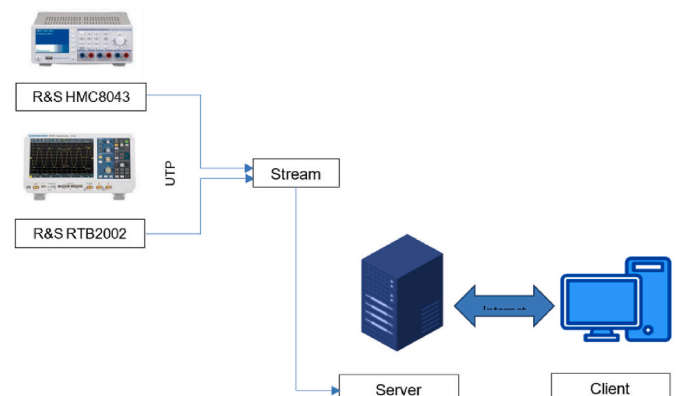


Fig. 2. Remote laboratory diagram.

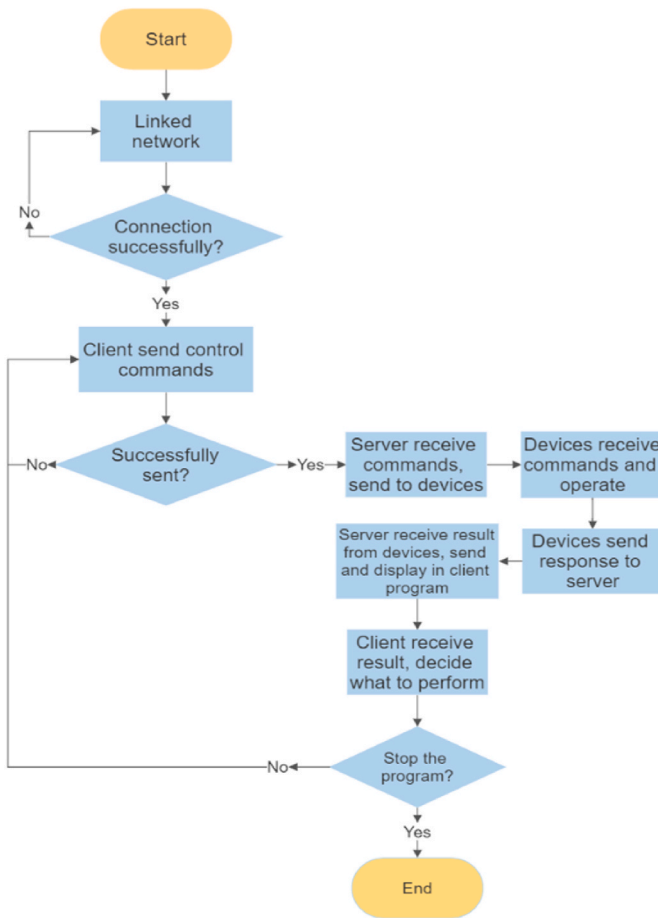


Fig. 3. Flow chart of remote control process.

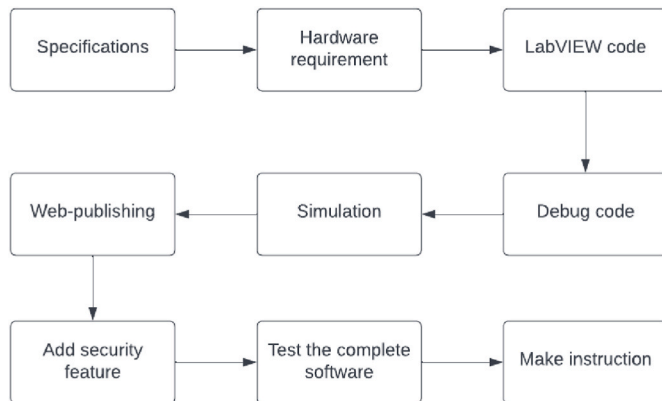


Fig. 4. Overall process of the remote laboratory.

3.4. LabVIEW program structure

The idea of LabVIEW program structure is: Entering basic value and limit of both Power supply and Oscilloscope, then filling the IP address (which can be read from the devices' ethernet parameters) of both so the system can recognize both devices, see Fig. 5.

After that, the power supply code will continue with 3 channels state function and indicators to fill their values. Those values will be read and enable into each channel.

The oscilloscope is more complicated with more step: Scan the screen and display data into the front panel, then setting autose for the graphs. Trigger and horizontal shift will be taken into consider after that.

Following is the Frequency generation.

Measuring value will be coded in another panel where students can choose what to measured, and after that they can write the different value into a table and use another function to export those data to excel.

That ends the structure of programming code. Fig. 6 shows the summary of the written code.

After finishing the program for 2 measurement devices, the first testing will be run to make sure both devices are working and provide the accurate output as well as measurements. The next step is to build the lecture which lecturer can use immediately for the Electrotechnics classes.

The front panel for each experiment will be unique, however they shared the same content that there will be literature review so they do not need to open another tab for this, some indicator to fill in values and measured value. A chart will also be prepared to write measured values in and export to excel.

4. Task performed

4.1. Installing the drivers

After reviewing several literatures and create the system structure and outline plans for the project, my first task is writing the program. LabVIEW full build 2020 32-bit is installed on my computer and in addition to the basic libraries, the instrument-specific libraries are also needed. They are public in the Rohde & Schwarz website.

After installing the two drivers, it became clear that communication with the two instruments requires two parallel running program codes, since both instruments have different commands and communication start and end. However, all two programs will be running in the same front panel as there will be some experiment need to use both of them.

4.2. The specifying basic values

The program (moving from left to right) first begins with an initialization section (see Fig. 7), in which the basic values of the instruments can be set, e.g., current-voltage limit, etc.

The static IP address must be entered for both instruments, see Fig. 8. If the program does not find the device or a communication error occurs, the program restarts. This need to be filled by the lecturer at the

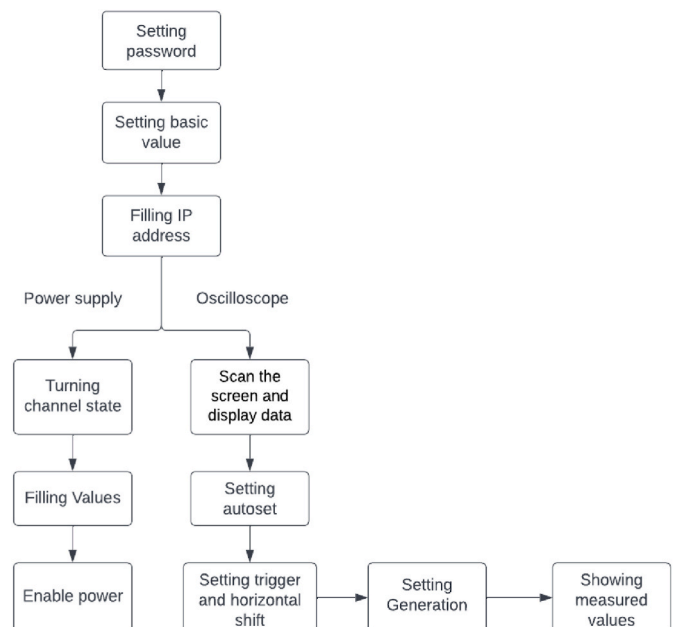


Fig. 5. LabVIEW Program structure for controlling measurement instruments.



Fig. 6. Electrotechnics class program structure.

beginning of classes.

4.3. Main runtime code structure

After setting the basic values, the entire program enters the main cycle, which is a While Loop. Within this, several machine states are specified, which are: Init, Init set, Idle, Run, Close, Reset state.

The run starts with Init, which starts the communication between the instrument and the PC. From this, the Init set enters, which sets the basic values of the instruments, such as the voltage-current limit, signal generator amplitude, etc. After this, the Idle state comes, in which the program is ready to start. Then the Run button on the user interface is activated.

Entering the Reset state occurs automatically if the program detects an error somewhere, after which the program returns to the Init state.

The SubVI is created wherever possible in the code for easier readability and overview.

4.4. Running the power supply

From left to right, the channels are enabled first, then the voltage-current limits are set as our channels. After that, the set voltage values, the absorbed current values, and the Overvoltage-Overcurrent-Overload security bit values are queried as our channels. If the while loop stops, the program automatically switches off the power supply channels. Fig. 9 shows the user interface.

The user interface displays these values:

4.5. Running the oscilloscope

The user interface of the oscilloscope can be divided into 3 parts (see Fig. 10): Display, Managing body, Measurement function.

The window that appears is an exact copy of the current oscilloscope screen. The blue waveforms are the Ch1 channel, and the red waveforms are the Ch2 channel. The signals are only visible if the channel is switched on. The time axis can be seen at the bottom, while the amplitude of the measured signal is on the right. The CH1 Div and CH2 Div columns on the left show the current value of the division per division. The Autoset button is located at the bottom, with which the oscilloscope automatically adjusts to the measured signals, see Fig. 11.

Here we can turn on, off and control the display, generate the frequency as the experiment needed.

Four separate measurement functions can be switched on, with which it is easy to find out the value of the peak-to-peak voltage of the currently measured signal, or the frequency of the signal, see Fig. 12.

4.6. LabVIEW program for electrotechnics experiments

The next step is building structure and calculation for every class which taking reference from “Electrotechnics Measuring instruction” book. The first chosen experiment is “Analysis of low-pass filter” as its

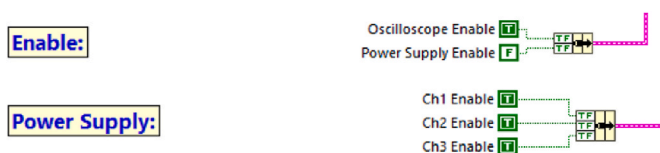


Fig. 7. Basic value of the power supply.

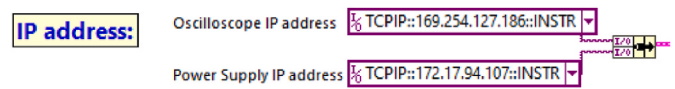


Fig. 8. IP addresses of the instruments.

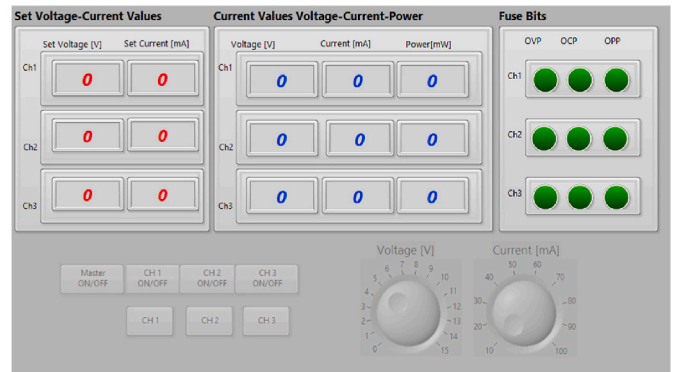


Fig. 9. Power supply interface.

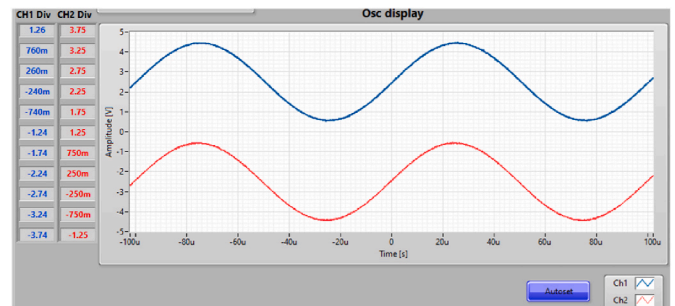


Fig. 10. Virtual display of oscilloscope.

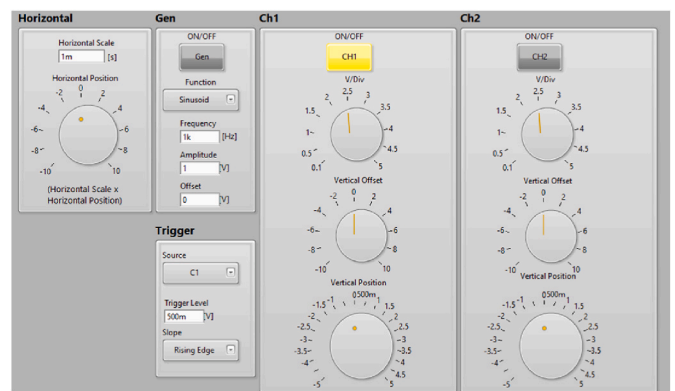


Fig. 11. Managing body of the oscilloscope.

measurements can be performed with the help of a signal generator, two oscilloscope channels and 3 power supply outputs, see Fig. 13.

The program includes all the information of the experiment which are instruction to follow, circuit diagram, calculation and report requirement, also all the data can be exported to excel to help students finish their report easily.

4.7. Web-publishing

With LabVIEW's web-publishing tool, which enables the creation, conversion, and storage of hyper-linked documents on Internet or

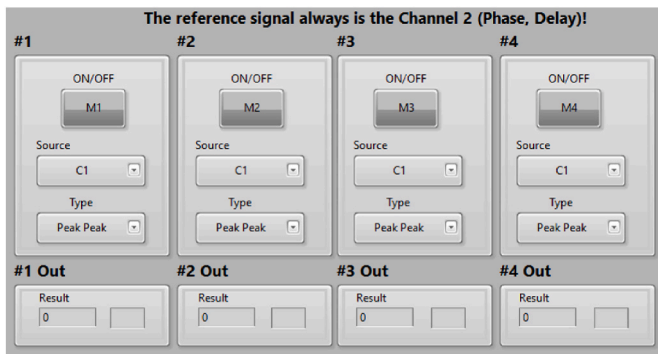


Fig. 12. Oscilloscope measurement display.

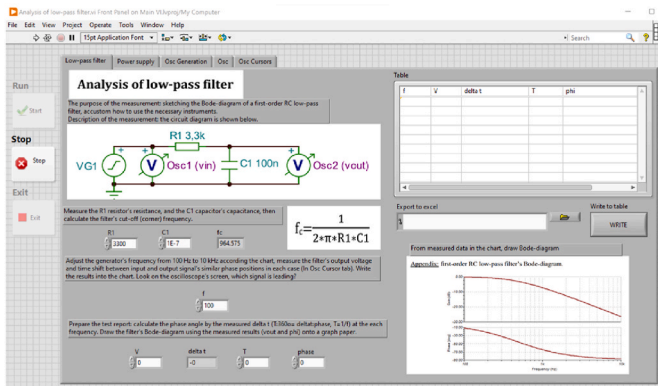


Fig. 13. Analysis of low-pass filter experiment front panel.

Intranet web servers so they can be readily shared via web browsers, real-time remote monitoring and control are made possible.

It is simple to set up and use remote panels. There are two phases to this process: On the server system, enable the LabVIEW Web Server. Then connect to and run remote panels from the client machine.

After connecting, the website will have the similar interface with the front panel.

4.8. Security feature

There is no feature in LabVIEW to create the password protective, however, we can use the prompt user for input to create a password protection for the vi, see Fig. 14. So, in case the link has lost into a stranger, they still cannot harm the process.

The program will not start until the user enters the correct password.

4.9. Testing

The testing is going along with each step of project build to make sure the program works and no confliction, also to detect error and fix in time. Below is all the testing have been made during the research.

- Running program on LabVIEW to make sure the program can control both 2 instruments.
- Running program on web server to make sure the instruments can be controlled through website.
- Running program for both control and view at the same time on web service.
- Running program for both control and view at the same time on web service for 2 groups of devices at the same time.
- Trying to finish a full experiment using the remote control, export the result file.

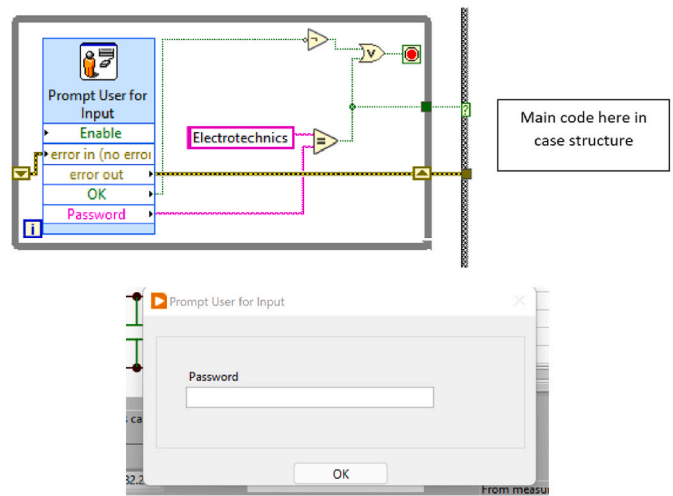


Fig. 14. Password setup for front panel.

It can be said that after several testing and fixing error, the program works well that represents exactly the same as the real instruments.

4.10. Analyse time delay

There is a small delay between the server and the real instruments when we turn on the program. The reason causing it is because the measurement devices need time to perform and send the data into server. However, the delay can be assumed as average of 3 seconds which is acceptable as this is the real remote controlling laboratory not a simulation one. The delay between real devices and server during process is around 1 second that is acceptable. The delay between server and client is negligible as less than 1 second. The remote client got all the information as soon as the server got it from real devices.

The delay time will be distributed in the following chart to see its stable. From the chart we can see the delay time is stable around average value with no dramatically change. Those small difference causing from the connection wire, network and the response from real devices varies at different time, see Fig. 15.

4.11. Preparing tutorial

After finishing all the program and testing as well as fixing every error, the next step is preparing instruction so that both lecturers and students will not have problem with the program. There will be 2 separate tutorials for student and laboratory staff to prepare and use the remote laboratory.

5. Conclusion

5.1. Achieved results

A large number of prototype experiments from basic courses were developed and successfully performed by the remote users. To sum up, it can be said that the project is working well, see Fig. 16.

5.2. Further development

Later, a laboratory information management system based on Internet of Things technologies is required which is the development trend of digital and information technology. From that the accessibility of the laboratory is controlled as well as the reservation and use of the laboratory is being recorded that can help manage the laboratory more efficiently.

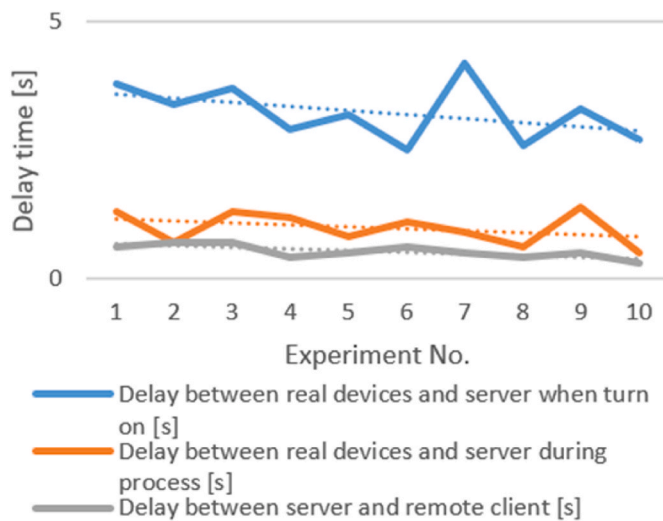


Fig. 15. Time delay of remote laboratory distributed chart.

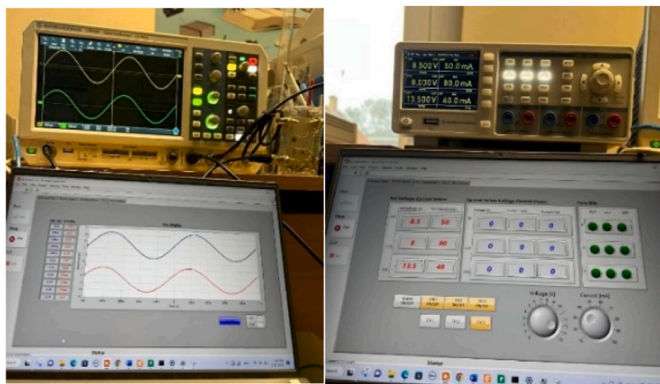


Fig. 16. Instruments controlled by LabVIEW program.

5.3. Conclusion

The main goal of this project is representing a web-based system applying for remotely controlling laboratory, create opportunity for an expanded laboratory without any additional cost. To conduct fundamental electrical engineering experiments online, a remote laboratory was set up. It was determined that the low-cost laboratory setup that was described is appropriate for conducting tests remotely.

The remote users carried out all of the prototype tests created to test the remote laboratory setting successfully. However, various restrictions with regard to the system hardware, specific experiment settings, the speed of the Internet connection, and the execution time of LabVIEW-developed applications were noted. Since in this case it is not a simulation, but access to remote devices, delays of up to 5–10 seconds may occur depending on the network load.

The project itself is expandable in a variety of ways and applying for the need of the educational field that helps students to study, makes it easier for them to connect theory and practice, broadens their perspectives, and sparks their passion in learning.

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