PLC Based Remote Accessible Refrigeration Training Unit

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ABSTRACT
Since the Covid-19 pandemic occurred, teaching and learning activities must be held remotely. Learning is done online. Students and lecturers carry out WFH (work from home). In principle, online learning is not expected to reduce the knowledge transfer process. However, in terms of learning that requires tools or practicum activities, it is still necessary to get a breakthrough to replace these activities with WFH. In this regard, research is proposed to develop and build a prototype of a basic refrigeration system training unit that students can access online at their respective places using a computer, tablet, or smartphone. Students can do practical work on the refrigeration system through this device, starting from how the system works, instrumentation, control, and online operation on equipment placed in the laboratory. With the development of a device system that can be accessed remotely, it was found that direct learning activities can be replaced online, although not completely. The steps taken started from designing the refrigeration system, instrumentation, control and supporting software for online or remote access learning systems, web servers, building a refrigeration system training unit, and system integration. Remote access is built with a web server in LOGO PLC. The result can be presented in the form of Ms. Excel files. The condition of the refrigeration system can be set remotely. The system can be monitored from the user interface which displays system data and state. The average value of COP and the refrigeration system's efficiency is 3.9 and 76% respectively.

Keywords *Covid-19, Teaching, Refrigeration, Remote Accessible.*

1. INTRODUCTION

Teaching and learning activities can simply be divided into two delivery processes, namely the delivery of theoretical and practical materials that involve the ability to do something operational and innovative related to equipment. The delivery of knowledge is not problematic if it is conveyed indirectly or not dealing directly between teachers and students. However, the knowledge that requires action on a demonstrative means of delivery is indispensable. This, when delivered non-demonstratively directly with the equipment, does not provide the desired learning outcomes. Self-study for students requires greater effort than learning with the help of a teacher.

An e-learning system can provide online learning assistance. Advanced e-learning systems have also provided simulators to help understand a process, including equipment. In fact, practical learning activities can be done anywhere as long as the equipment used is available. A problem arises if you want to have online learning that involves operating a piece of equipment. A piece of equipment can be operated remotely or online, but it does not always work without building a system. Not all existing equipment is equipped with an online system. One of the equipment that is practically studied in the refrigeration and air conditioning engineering study program at Politeknik Negeri Bandung is the refrigeration system.

In a pandemic situation, practical activities for learning about these tools must be carried out online, but to implement them, a system that can be meet the targeted learning objectives is needed. Related to the provision of an online learning system for the equipment, research activities for the Development of Electrical and Instrument Laboratories are needed with the specific aim of developing an online learning system for the refrigeration system. This activity can also produce online learning materials for related subjects including refrigeration systems, instrumentation, automatic control, control applications, RHVAC electricity, automation, basic programming and applications, electronics and where final project students can be involved in these activities.

The urgency of this research is the need to build a system to support online practicum activities. The special specification of the applied scheme is that it can generate data from real plants.

1.1. Related Works

The use of information technology is an important thing in learning and is not something to be said as a luxury [1] especially in the era of a pandemic. As with tablet computer support in learning, the use of the cloud is very intense by students and teachers [2], as is e-learning in learning. On the other hand, the interactive features of e-learning can increase learning motivation [3] and many universities have used the open-source Moodle platform to help deliver learning materials to students, including Polban. e-Learning has become a global educational phenomenon that is of interest to educational researchers worldwide, especially because of the effects of the COVID-19 pandemic on the education system [4]. In using e-learning, students need adjustments because this is different from the habit of using social media that they often use [5].

In addition to e-learning, distance learning is also called a virtual laboratory (VL). Practical activities that are usually carried out directly can be done with VL. On the other hand, e-learning and VL can be combined [6]. The virtual laboratory presents data or experimental situations with data obtained from mathematical models of the virtualized system. Real data can be obtained by a system called a remote laboratory (RL).

A complete RL will involve an automation system so that the implementation of the practicum can be controlled remotely and can be observed visually on the practitioner’s computer. An overview of the completeness of RL is discussed in Practical Online Learning and Laboratories, for Engineering, Science and Technology: Apply the new online technologies to create brilliant hands-on, interactive education and training for professionals and students of engineering and technology written by Steve Mackay and Darrell Fisher [7].

Accessing the laboratory online has the possibility of increasing students’ understanding of what is learned from lectures and books [8]. In the internet era, RL can be built based on embedded systems and IoT [9].

The latest Web Editor for PLC LOGO development has been launched so that its access can be done globally [10] without adding many supporting components. Thus, PLC LOGO has supported IoT. Local web server access [11] can be developed into global access.

A refrigeration system works based on a control system, so it is possible to build a remote access system to support online practicum activities using this device.

1.2. Our Contribution

The contribution of this paper is to combine Arduino as a low-cost device with an industrial PLC to build remote access to the refrigeration system to support the implementation of remote practicum learning to be more effective.

1.3. Paper Structure

The rest of the paper is organized as follows. Section 2 Explains the importance of studying real systems rather than just simulations. Section 3 reveals how to design and build a refrigeration system trainer unit that can be accessed remotely simultaneously. Section 4 discusses the results obtained and concluded in section 5.

2. BACKGROUND

The refrigeration system is a nonlinear plant system. Therefore, studying the refrigeration system is inadequate to present it in the form of a simulation. In studying this system, it is inadequate to measure only one or two quantities. As the refrigeration system consists of several main components, namely compressor, condenser, expansion valve, and evaporator, where each component state and its combination are conditions that must be observed in studying the system as a whole, therefore it is necessary to measure the condition data of the components of the actual system such as temperature, pressure, current and voltage.

Even though the combination of the above main components that the refrigeration system is primarily designed to work as needed, various situations from the system conditions need to be controlled as needed for that controller components are added.

As the goal to be achieved in realizing the system, the resulting system built can be used to study both the refrigeration system and the control system. The design carried out starts from designing the refrigeration system, which is formed into a training unit.

The control system applied is designed to use a controller that is no longer just a thermostat but a device called a PLC.

The system building realized is expected to support distance learning more comprehensively than laboratory equipment operated directly.

3. METHODOLOGY

This research was carried out with the steps shown in the diagram in Figure 1.

As shown in the diagram below, the initial stages have been carried out in previous studies that have succeeded in building a simulator plant in PLC that can be accessed from several types of computers and smartphones.

As explained in the above section, studying the system can not only study the simulation, but also must have the actual system. In this regard, this study aims to build a refrigeration plant system that aims to facilitate distance learning objectives.

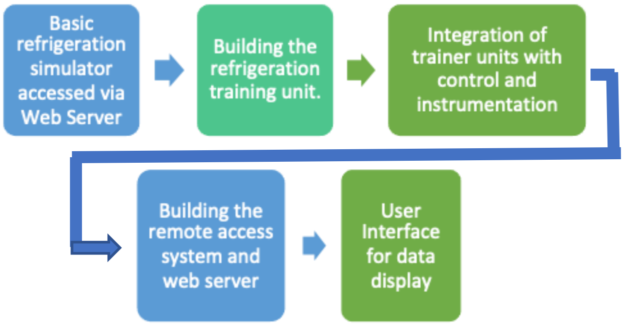

Figure 1 Diagram of the research stages

3.1. Design of Refrigeration Training Unit

A refrigeration system built is designed based on the standard system and in the form of a standard training unit as it is usually used in direct learning in the classroom. However, in this research, a PLC is applied to control the system, which can be accessed remotely at the same time.

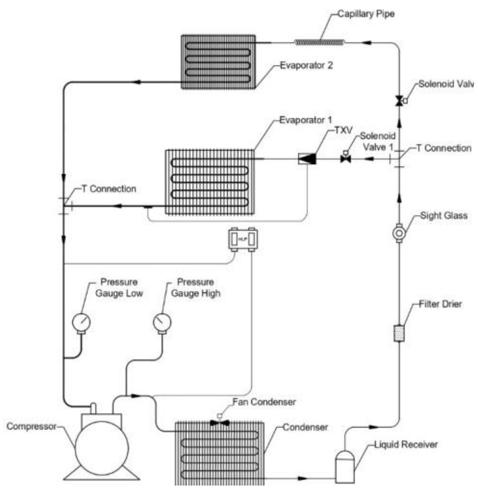

Figure 2 Diagram of refrigeration system designed

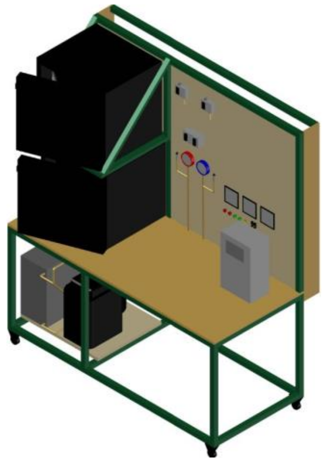

Figure 3 Visual in 3D of the unit trainer

The refrigeration training unit is designed to include one compressor, one condenser, and two evaporators. The two evaporators use different expansion devices: a TXV (Thermostat Expansion Valve) and a capillary tube. Several stages in the design are determining the dimensions of the cabin, the load of the product to be cooled, calculating the cooling load, determining the capacity of the cooling machine, planning the layout of components and the shape of the unit, and finally designing hardware and software to measure and control the system. The picture in Figure 2 is the diagram of the refrigeration system designed, and Figure 3 is the 3D visualization of the design refrigeration training unit.

3.2. Remote Access Instrumentation

To achieve the remote access goal, several detailed design stages are needed, namely:

1. Integration PLC with the refrigeration system.
2. Data acquisition system development
3. Representing Logic controlling strategy to PLC Software

In this project, a remote access system is designed to apply PLC LOGO (Figure 4) to control the refrigeration system. The web server-based access facility from the PLC to communicate remotely between the user and the refrigeration system. With LOGO software Web Editor (LWE), it is also possible to create customizable websites tailored to the needs of controlling and monitoring the integrated system.

Figure 4 PLC LOGO 8 kit module

One important step, to integrate a PLC as a controller is to connect one or more sensors whose function is to measure the state variables of the system plant to the PLC. For the refrigeration system here, several following experimental sensor devices are chosen.

All temperature in the system is measured using a DS18B20 sensor. For pressure, the SKU237545 sensor is selected to measure the pressure value of a liquid or gas that has non-corrosive properties. Those sensors are shown in Figure 5.

Figure 5 Temperature and pressure sensors

The other two sensors are for measuring the current and voltage of the system. The current sensor selected is ACS712 and to measure the voltage is the ZMPT101B sensor respectively shown in Figure 6.

The selected temperature sensor cannot be directly connected to the PLC, but a popular microcontroller in learning course is selected through an intermediary, namely Arduino Mega. Sensor data is sent from Arduino Mega to PLC by implementing Modbus communication.

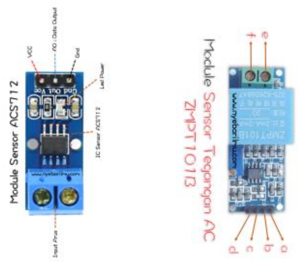

Figure 6 Current and voltage sensor

In addition, the PLC is also connected to actuators such as solenoid valves which will later function to regulate the opening and closing of the solenoid valve.

3.3. System Integration

The integration of the designed system can briefly be explained that the refrigeration system runs with PLC-based control based on the temperature, pressure, current and voltage quantities of the system measured using sensors where the value is sent to the PLC via Arduino with Modbus communication. Integration like this has guaranteed the system can run well.

The final design is to design the system so that it can be accessed remotely. Through web-based programming, the PLC user interface (UI) can facilitate users' access and control of the system.

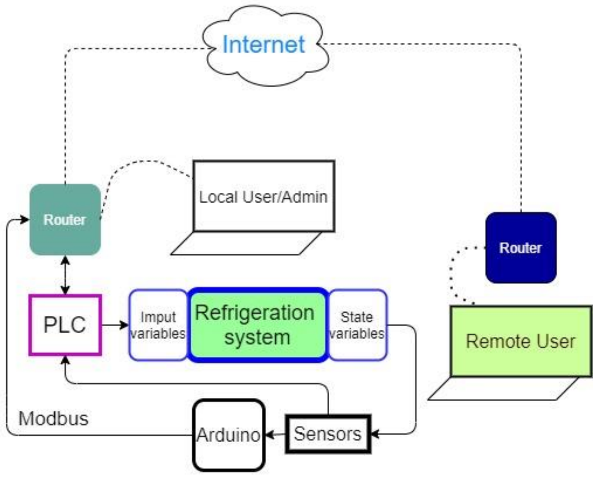

Figure 7 Integrated system designed

The measurement value obtained from the PLC sensor will be input to the web server to view or monitor the data value via the web server. Then the refrigeration system can be controlled using remote access on the web server connected to the internet. Therefore, users/students can access the web server anywhere when online practicum learning is carried out. Figure 7 shows the diagram of the integrated system as designed and discussed.

Tests are carried out on the system made to find out whether the system has worked well and collected data from the system for analysis.

4. RESULT AND DISCUSSION

According to the design, the refrigeration training unit system has been built as depicted in Figure 8.

Figure 8 Remote accessible refrigeration trainer

The value of the trainer system variables can also be accessed and displayed with the application that has been developed.

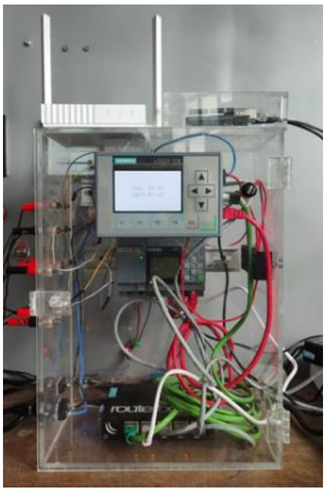

Figure 9 Remote accessible box

Remote access to the trainer system above is facilitated using a web server enabled from the PLC LOGO which is used as a controller (Figure 9).

About eight variable values including temperature, pressure, voltage, and current are displayed in the UI. The operating temperature setting of the system can also be set remotely. Limited access to settings on one device by many users is set so that the setting values will be operated alternately according to the time allotted for each user.

Trivially the system can be accessed simultaneously by only two users. This will both be scrambling to give the setting. Access by more than two users causes access cannot be done with a 'forbidden' message to keep the system working normally. The user interface for accessing the system is depicted in Figure 10.

Figure 10 PLC Logo UI system access

By choosing the 'customize site' after login, the UI will view the navigation system section for the parameters setting and control for the system (Figure 11). To program the PLC user should log in without choosing the "customize site."

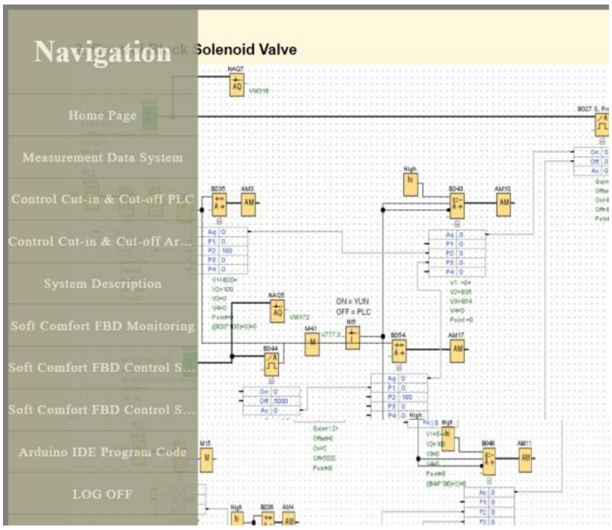

Figure 11 Navigation menu of the UI

When users access this system, some practical things can be learned, for example, related to PLC programming, because once they get permission to access the system, the program can be changed online. The control logic applied in the system is one of the applications of the electrical control learning subject.

Another practical aspect is in the field of instrumentation and measurement. Using the system that was built, it can be studied in detail how the implementation of the electronic system learned in class can be implemented. This system also provides additional learning about remote access itself. Figure 11 shows an information button to view all about the system.

Figure 12 below is the page view to set the system temperature and pressure when the user chooses "cut in and cut off" navigation.

Figure 12 Page for the cut in and cut off setting

After the remote access session ends, the result data can be saved or downloaded in the form of Ms. Excel file and chart (Figure 13 and Figure 14), ready to be processed and analyzed as a series of teaching and learning activities.

D	E	F	G	H
Time (menute)	Discharge Temp.	Suction Temp	Out Condensor Temp.	uctTemperature in Cabin 1
0	25,5	24,93	25,22	24,31
5	31,43	16,87	28,62	23,68
10	38,87	-3,43	30,13	22,31
15	41,25	-4,52	30,18	21,5
20	42,62	-4,87	30,31	20,5
25	43,68	-5,68	30,25	19,12
30	44,12	-5,25	30,31	18,37
35	44,56	-5,31	30,43	17,68
40	45,06	-5,37	30,43	16,56
45	45,31	-5,43	30,62	16
50	45,56	-5,68	30,93	15,31
55	45,87	-5,93	30,93	14,5
60	45,93	-6,05	30,81	13,93
65	46,06	-6,25	30,87	13,37
70	46,06	-6,25	30,87	12,87
75	46,06	-6,25	30,87	12,12

Figure 13 Ms. Excel file system data

The performance of the refrigeration trainer that was built can be checked from the data. The data (shown in graph of Figure 14) used the standard method of COP and efficiency calculation gives results as shown in Figure 15.

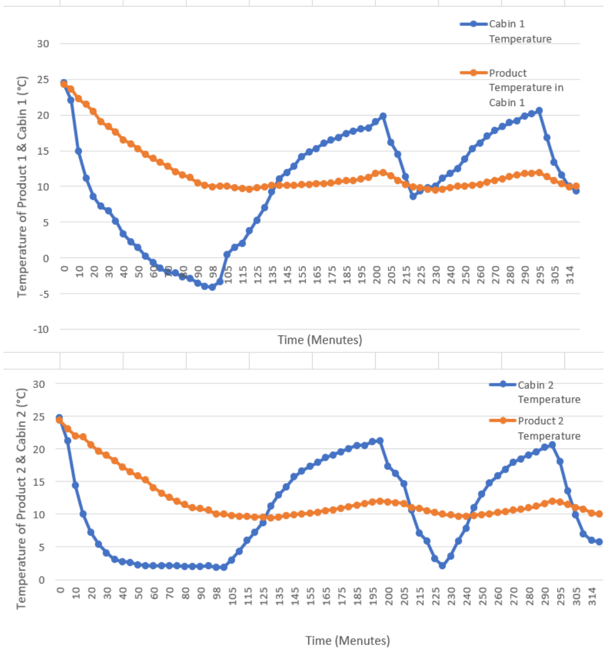

Figure 14 Product and cabin temperature

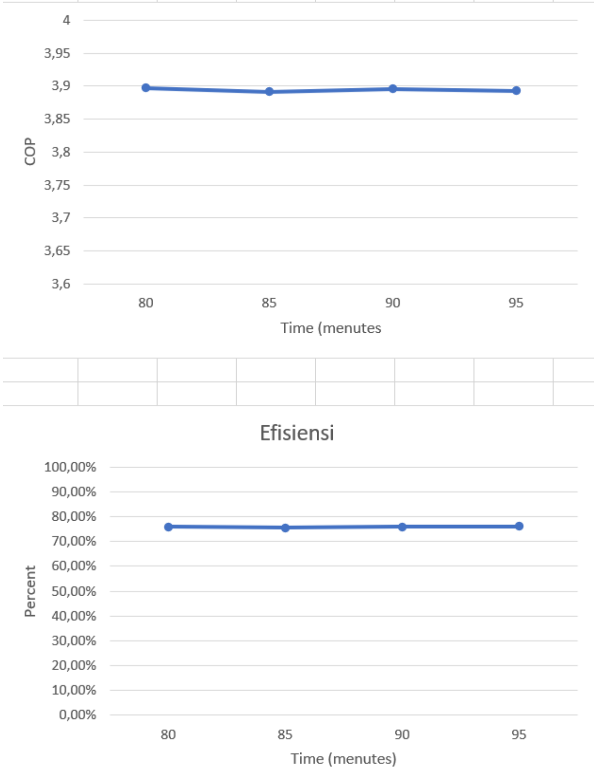

Figure 15 COP and efficiency

Average value of COP and the efficiency is 3.9 and 76% respectively.

5. CONCLUSION

The results of this study can be summarized in the following outline:

1. The designed system is successfully built and tested.
2. The refrigeration system built can be controlled by PLC.
3. Sensor data is read using Arduino Mega as an interface, while Arduino and PLC communicate using Modbus communication.
4. Remote access built with web server from LOGO PLC using public IP.
5. Result data can be presented in the form of Ms. Excel files.
6. The condition of the refrigeration system can be set remotely.
7. The system can be monitored from the user interface that displays data and system conditions.
8. The average value of COP and the efficiency of the refrigeration system built is 3.9 and 76% respectively.

AUTHORS' CONTRIBUTIONS

P., M.A.F., M.A.: Conceived and designed the analysis; Collected the data; A.B., M.R.A.: Contributed data or analysis tools; P., M.A.: Performed the analysis; Wrote the paper.

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