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To cite this article: M Aria *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **879** 012108

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Virtual Simulation System with Various Examples and Analysis Tools for Programmable Logic Controller Training

M Aria^{1*}, J Utama², F Fauzia³, M Rizal⁴, M Fahmi⁵, M Yudha⁶

^{1,2,3,4,5,6} Electrical Engineering Department, Faculty of Engineering and Computer Science,
Universitas Komputer Indonesia, Indonesia

Email: *muhammad.aria@email.unikom.ac.id

Abstract. The purpose of this research is to design a virtual educational simulation device as a training aid for the Programmable Logic Controller. This software is equipped with an extensive library of process models to mimic the functional behavior of real factory processes, thus helping students to practice controlling various industrial processes by using various tools from PLC. The advantage of this simulator is that it provides analytical tools to get concise information about the output performance of the controlled system. The method used in this research is the Descriptive Analysis Method which consists of five stages, namely problem identification, literature study, instrument design, implementation, and testing and evaluation. The implementation of this software is based on LabVIEW (Laboratory Laboratory Workbench) on the PC. Exchange of control signals between the actual PLC (any PLC can be used) and the PC via the signal conditioning circuit and the Arduino. The results of this study are that three factory models have been made. The first factory model is a traffic light control system of two adjacent intersections. The second factory model is water level control in the tank. The third factory model is a multi elevator control system. The analysis tools for the first plant is information about the total waiting time of all vehicles passing through the intersection. The analysis tools for the second plant is a system performance graph that is equipped with maximum overshoot, settling time, and steady state error information. The analysis tools for the third plant is the total average floor displacement time of all elevator users. Therefore, this research has succeeded in making a virtual education simulation which, consists of three plant simulations and their analysis tools. The impact of this research is expected to increase students' understanding of PLC and control techniques.

1. Introduction

Programmable Logic Controller [PLC] is a processor device that is capable of controlling various types of industrial equipment [1]. Nowadays, PLC is the most commonly used controller in the industry [2]. PLCs have been widely carried out in a variety of applications, including the control of water and wastewater management [3,4], energy research [5-7], manufacturing [8-11], plant control and monitoring [12-15], and other applications [16-17]. This industrial development must be supported by a competent and reliable workforce. However, currently, there are still problems in the PLC learning process so that the graduates produced still do not meet the competencies needed by industry [18]. Moreover, it is necessary to develop learning media that are suited and applicative to the current industry so students will be ready in the industry. Guo and Chen reported that the experiment and demonstration method using the PLC in effective learning can improve teaching interaction, increase student learning interest, and enhance the whole effect of the learning process in the classroom [19].



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Indeed, there have been several studies that developed training media for PLC. In general, there are two categories of learning media for PLC, the first is based on hardware simulation and the second is based on computer software simulation. Putri made PLC training media using hardware in the form of miniature traffic light [20]. Pradana made PLC training media using hardware in the form of Bottle Filling Simulation [21]. Popa made PLC training media using hardware in the form of an industrial robotic arm [22]. Harahap made PLC training media using hardware in the form of a water filling system [23]. Sukir made PLC training media using hardware in the form of an electrical machine trainer kit [24]. While Maarif made PLC training media in the form of portable industrial automation kits [25]. However, the use of PLC training media using this hardware will require expensive costs [26]. Then as an alternative, PLC training media can be used using software on a computer. Some researchers have developed PLC learning media using computer software, but as far as we know, no one has included the analysis tool in the computer software simulator.

The purpose of this research is to design PLC training media using computer-based software that mimics the functional behavior of real system processes. In this software, there are three process models. The first process model is a traffic light control system of two adjacent intersections. The second process model is water level control in the tank. Besides, the third process model is a multi elevator control system. The method used in this research is the Descriptive Analysis Method which consists of five stages, namely problem identification, literature study, instrument design, implementation, and testing and evaluation. With the existence of a virtual simulation system with analytical tools, it is expected to help students to practice controlling various industrial processes by using various functions on the PLC so that it will improve students' understanding of PLC and control techniques.

2. Method

The method used in this research is Descriptive Analysis Method. Hence, this research will be carried out in five stages, namely: (1) problem identification, (2) study and literature survey, (3) instrument design, (4) implementation, and (5) testing and evaluation of research results. The problem identification of this research is how to design PLC training media using computer-based software that mimics the functional behavior of real system processes.

Based on studies and literature surveys, the system block diagram created is shown in Figure 1. In this system, any PLC model can be used. Virtual simulation of the processes displayed on a PC. The simulation on the PC will be controlled by the PLC. The microcontroller is used as an interface system so that the PC can receive and transmit digital signals. This system is designed to receive 36 digital input signals and can send 32 digital output signals. The system implementation is applied to the Arduino Mega microcontroller. The simulation on the PC is implemented in LabVIEW 7.0 software.

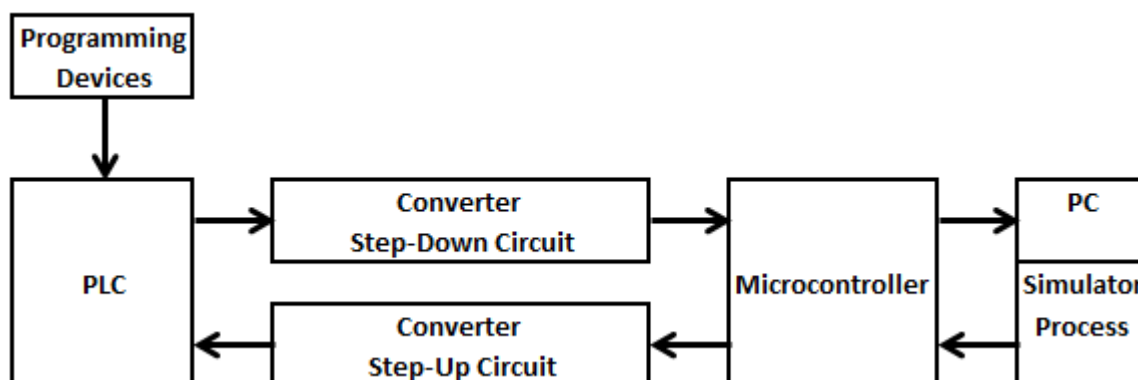


Figure 1. Block diagram of the system

3. Results and Discussion

In this design, we used the OMRON SYSMAC CPM2A PLC, the Arduino Mega 2560 microcontroller and the process simulator made on LabVIEW 7.0. Arduino Mega 2560 microcontroller was chosen to meet the design needs of 36 digital inputs and 32 digital outputs. In order for LabVIEW to be able to communicate with Arduino, we developed a library interface called LIFA 2007 because it can be operated on LabVIEW 7.0.

3.1. Circuit

In order for signals from PLC to be received by Arduino and vice versa, a step down converter circuit and a step up converter circuit have been made as shown in Figure 2. In Figure 2, the 7805 regulators will supply a constant 5 volt voltage at collector pin o 2N5551. If the PLC releases a voltage of 20 volts, the base terminal of the transistor will be active, and the Arduino pin will get a voltage of 5 volts. Meanwhile, if the PLC pin is not active, then the transistor will disconnect the collector's terminal with the emitter so that Arduino gets a voltage of 0. As for Figure 3, the Arduino pin will activate the optocoupler. If the optocoupler is active, the base terminal of the 2N5551 transistor will activate and supply a 24-volt voltage to the PLC pin. The two circuits are assembled into one hardware interface module as shown in Figure 4. The principle of this signal conditioning circuit is similar to that used by Bogdan [27] and Kayande [28].

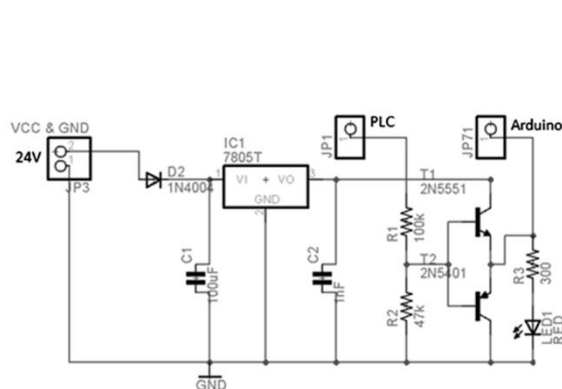


Figure 2. Converter Step Down Circuit

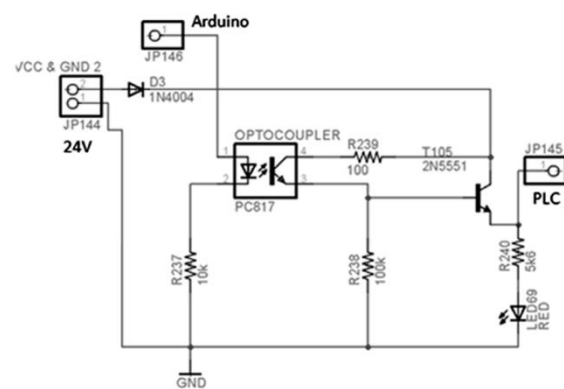


Figure 3. Converter Step Up Circuit

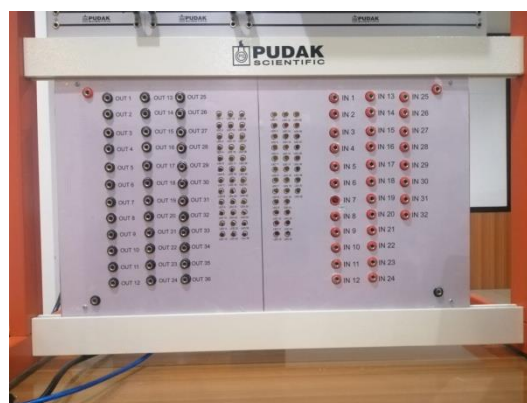


Figure 4. Hardware interface module for signal conditioning

3.2. LabVIEW Library Interface with Arduino

We have developed a library interface called LIFA 2007, so LabVIEW can communicate with Arduino. This library contains sub-programs that allow LabVIEW to access digital I/O pins or analog I/O pins on arduino. An example of using a library to access a digital output pin on Arduino is shown in Figure 5. The example of using a library to access signals from an Arduino input pin is shown in Figure 6.

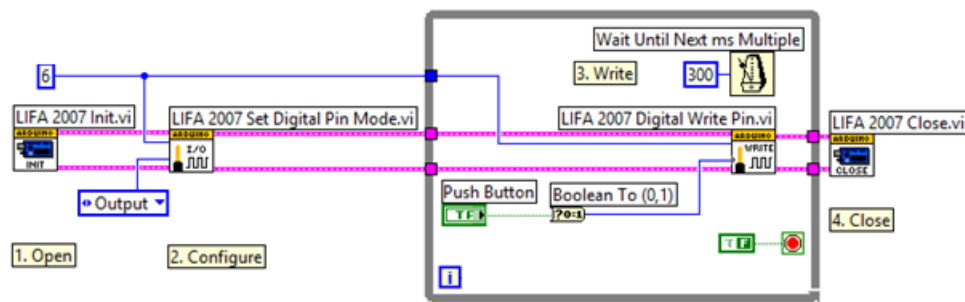


Figure 5. Example of a program controlling the output pin on Arduino

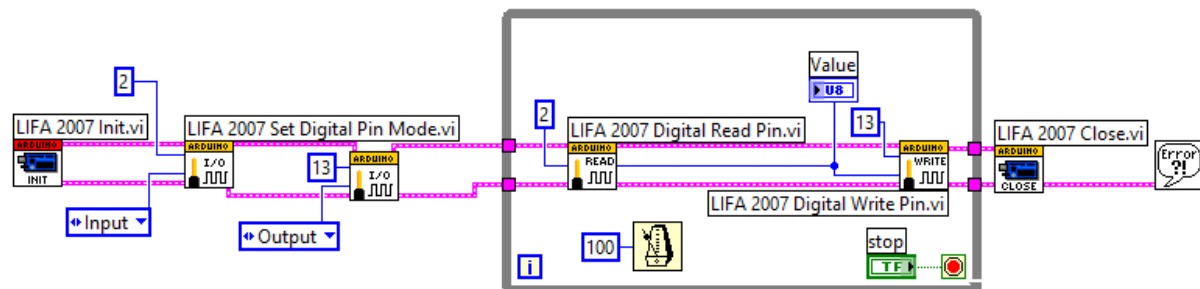


Figure 6. Example program for reading the condition of the input pins on Arduino

National Instrument does have a standard library for communicating with Arduino namely LINX [29, 30]. But based on experiments conducted by the author, the use of LINX has the disadvantage of repeating the download process on Arduino every time the program is about to be restarted. Thus, using this library has no repetition of the download process on the Arduino microcontroller.

3.3. Simulator of Real Plant Process

The process simulator is created using LabVIEW 7.0. The advantage of this simulator is the availability of analytical tools to get the output performance of the controlled system. There are three plant/process models created in this design, namely the traffic light control system simulator of two adjacent intersections, the water level controller simulator in the tank, and the multi elevator control system simulator. Dynamic parameters in each simulator can be changed by the user.

The GUI of the traffic light control system simulator of two adjacent intersections is shown in Figure 7. The analytical tool provided in this model is information about the total waiting time of all vehicles passing through the intersection. Vehicle density in this simulator can be adjusted.

The GUI of the water level controller simulator in the tank is shown in Figure 8. The analysis tool provided is a system performance graph that is equipped with maximum overshoot, settling time and steady state error information. Fluid input and output fluid in this simulator can be set, as well as the dimensions of the process tank.

The GUI of the multi elevator control system simulator is shown in Figure 9. The analysis tool provided is the total average floor displacement time of all elevator users. The number of arrivals for elevator users can be arranged. The destination floor of each user will be raised randomly.

Indeed there has been a virtual simulation system for learning PLC developed by other parties, such as that developed by Allen Bradley through LogixPro [31-33]. Although there are more plants in the LogixPro simulator, however, as far as the author knows, no one has included the analysis tool in the computer software simulator. With the existence of a virtual simulation system with analytical tools, it is hoped that it can help students to practice controlling various industrial processes by using various functions on the PLC so that it will improve students' understanding of PLC and control techniques.



Figure 7. The GUI of the traffic light control system simulator of two adjacent intersections

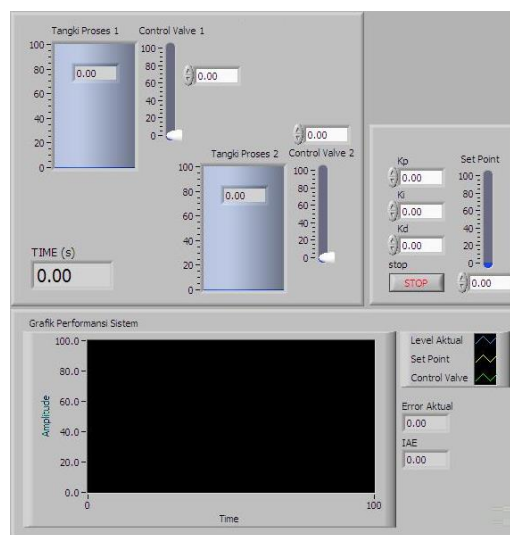


Figure 8. The GUI of the water level controller simulator in the tank

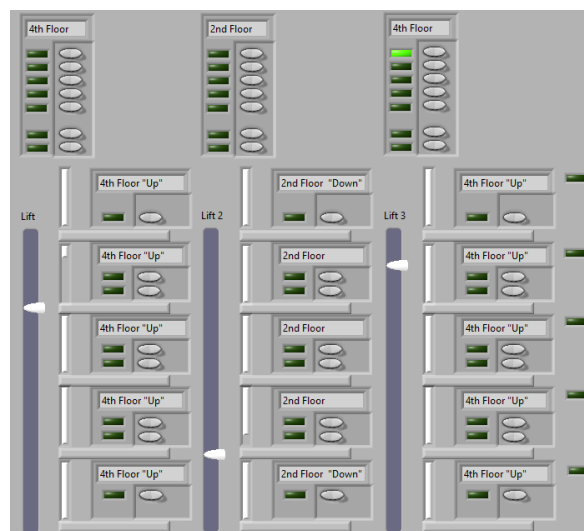


Figure 9. The GUI of the traffic light control system simulator of two adjacent intersections

4. Conclusion

In this paper, we have presented the design of a virtual simulation system with analytical tools for PLC. The advantage of this simulator is the availability of analysis tools to get compact information about the output performance of the system being controlled. This software was created using LabVIEW 7.0. Exchange of control signals between PLC and PC via a step up and step down conversion circuit and Arduino. There are three plant / process models created in this design, namely the traffic light control system simulator of two adjacent intersections, the water level controller simulator in the tank, and the multi elevator control system simulator. Dynamic parameters in each simulator can be changed by the user. With the existence of this virtual simulation system with analytical tools, it is hoped that it can help students to practice controlling various industrial processes by using various functions on the PLC so that it will improve students' understanding of PLC and control techniques.

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