World Journal of Engineering Research and Technology
WJERT
www.wjert.org
Impact Factor Value: 5.924

AUTOMATION CONTROLLER USING PROGRAMMABLE LOGIC CONTROLLER AND ARDUINO: AN INSTRUCTIONAL DEVICE

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Article Received on 21/02/2021 **Article Revised on 12/03/2021** **Article Accepted on 31/03/2021**

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ABSTRACT

The main goal of this study was to design, assemble and assess the functionality of the Automation Controller using Programmable Logic Controller and Arduino. The device was used to assist the teachers in imparting lessons on topics including; electric motor control, industrial automation, and servo robotic system. This study was conducted in Bohol Island State University – Main Campus, Tagbilaran City in School Year 2019-2020. It made use of the experimental design using one group pre skill test – post skill test method in gathering data to test the effectiveness of the device. The result of the study revealed that the students' average rating in the pre skill test and post skill test were 1.64 and 3.36, respectively. This further shows that the students performed better in the post skill test than in the pre skill test. It is evident that the students learned more in the demonstration having hands-on performance in the device than in the discussion alone. The Automation Controller using Programmable Logic Controller and Arduino: An Instructional Device is an effective tool for instruction in BS Electrical Technology.

KEYWORDS; instructional device, functionality, programmable logic controller, arduino, industry 4.0.

INTRODUCTION

The advent of the 4th Industrial Revolution or Industry 4.0 is expected to have magnanimous implications for the Philippines' skills development. According to the International Labor

Organization (ILO) on its published article "ASEAN in Transformation: How Technology is Changing Jobs and Enterprises in 2016,[1] states that 49% of Philippine Industries are at a high risk of automation over the next 20 years, and 80% of those affected will come from the Business Process Outsourcing (BPO) and the Electronics and Electrical Products Sectors.

The fourth industrial revolution – also named as Industry 4.0 – is one of the most trending topics in both professional and academic fields (Chiarello et al., 2018, Liao et al., 2017).[2] This concept has Smart Manufacturing as its central element. It also considers the factory's integration with the entire product lifecycle and supply chain activities, changing even the way people work (Stock et al., 2018).[3] Industry 4.0 relies on the adoption of digital technologies to gather data in real-time and to analyze it, providing useful information to the manufacturing system.

In a nationally published newspaper, Manila Bulletin, an article issued last August 26 of 2017,[4] TESDA Director Guiling Mamonding said " Technical Education and Skills Development Authority (TESDA) is facing very serious problems with the lack of trainers, assessors, equipment, and budget which, if not addressed as soon as possible, could lead to the collapse of the agency. He further disclosed, "We have a problem on trainers and assessors. We don't have enough of them. This is a national problem as far as TESDA is concerned." In conjunction with this, another nationally published newspaper PhilStar Global issued an article last May 9 of 2019.[5] that TESDA needs more training equipment. TESDA Director-General Isidro Lapeña stressed this during the 18th Regional Skills Competition at the Pangasinan Training and Development Center.

With this developing an instructional device is the goal of the researcher. The device is designed to impart knowledge to the students effectively and cope with the gap between the industry and the academe for the revolution of the industry 4.0. The success in the skill and knowledge acquisition in an instructional situation depends on the suitability of the instructional material, adequacy, and effective utilization of the available materials. The lack of instructional materials in a learning area is one of the learning institutions' problems. Effective teaching and learning involve seeing, handling, and manipulating real objects and materials. The knowledge that learners attain in classrooms would be ineffectual unless they observe the process and understand the relationship between action and reaction.

In this study, the researcher's main objective was to design and develop a Automation Controller using Programmable Logic Controller and Arduino to enhance students' learning, especially in the area of Electric Motor Control, Industrial Automation, and Servo Robotics System.

METHODOLOGY

Design

The study utilized the experimental research design in the assembly of the device. Various trials and errors were done until the device was 100% functional. To test the effectiveness of the device in enhancing the technical skills of the students, one group pre skill test – post skill test was used. This design sought to determine if there are changes in the performance of the respondents after having been exposed to the use of the device. A pre skill test was administered to the students before the discussion. After the pre skill test, a discussion on the motor control and industrial automation was discussed with actual manipulation of the Automation Controller using Programmable Logic Controller and Arduino. Then, the post skill test was administered to the respondents.

RESULT AND DISCUSSION

The Functionality Level of the Automation Controller using Programmable Logic Controller and Arduino.

Table 1 shows the functionality level of the Automation Controller using Programmable Logic Controller and Arduino in terms of relay logic control.

The researcher designed a Stop-Start Motor Control diagram using relay logic. Wirings were done, and all the input and output devices were connected into their designated terminals. When the researcher pressed the start button, the motor started to run continuously, and when the researcher pushed the stop button, the motor stopped. The researcher did it thrice to make sure the operation went smoothly. During the three trials, all the operations were successful without any problems.

The Stop-Forward-Reverse Control was then tested. After the hardwiring was done, the researcher repeated the same steps in the previous operation. After completing all the steps, the researcher pressed the forward button. The electric motor started to rotate its shaft

clockwise, and when the researcher pressed the reverse button, the electric motor also reversed its direction. This indicated that the operation was fully functional.

Stop-Wye-Delta motor control was also performed. After pressing the start button, the motor ran in wye operation. After several seconds, the wye contactor disconnected and turned to delta operation. The researcher designed and uploaded sequential motor control. Motor 1 first turned on, followed by motor 2, then motor 3. All the electric motor designs functioned adequately from the first up to the last design. Hence, it was all rated 100% functional.

Table 1: The Functionality Level of the Automation Controller using Programmable Logic Controller and Arduino in terms of Relay Logic Motor Control.

Item	Type of relay logic control	Operation	Trial	Response	Description
1	Stop-Start Control	Hardwired and configure the electromechanical devices for stop-start operation	1	Pressing the start button, the motor will turn on while pressing the stop button, the motor will stop	100 % functional
			2	Pressing the start button, the motor will turn on while pressing the stop button, the motor will stop	100 % functional
			3	Pressing the start button, the motor will turn on while pressing the stop button, the motor will stop	100 % functional
2	Forward-Reverse Control	Hardwired and configure the electromechanical devices for forward-reverse operation	1	Pressing forward button, the motor will rotate clockwise while pressing reverse button the motor will rotate counterclockwise.	100 % functional
			2	Pressing forward button, the motor will rotate clockwise while pressing reverse button the motor will rotate counterclockwise.	100 % functional
			3	Pressing forward button, the motor will rotate clockwise while pressing reverse button the motor will rotate counterclockwise.	100 % functional
3	Wye-Delta Control	Hardwired and configure the electromechanical devices for wye-delta operation	1	Pressing start button, the motor will run through wye configuration and change to delta configuration after several seconds	100 % functional
			2	Pressing start button, the motor will run through wye configuration and change to delta configuration after several seconds	100 % functional
			3	Pressing start button, the motor will run through wye configuration and change to delta configuration after	100 % functional

				several seconds	
4	Sequencial Control	Hardwired and configure the electromechanical devices for sequencial operation	1	Pressing start button, the motor 1, motor 2 and motor 3 will turn on with an interval of 5 seconds respectively	100 % functional
			2	Pressing start button, the motor 1, motor 2 and motor 3 will turn on with an interval of 5 seconds respectively	100 % functional
			3	Pressing start button, the motor 1, motor 2 and motor 3 will turn on with an interval of 5 seconds respectively	100 % functional

Table 2 shows the functionality level of the Automation Controller using Programmable Logic Controller and Arduino in terms of PLC-based motor control. The Law of Electromagnetic Induction states that when a conductor is placed in a changing magnetic field (or a conductor moving through a stationary magnetic field), it causes a voltage across the conductor, causing the motor to turn on or rotate. The device was tested as to its functions and desired operation. All outputs were found to be 100 percent functional because in digital programming the logic programmed to the PLC can only be functional or not. Iqbal S. in "Workhorse of Industrial Automation" states that the programming software allows the entry and editing of the ladder-style logic. The researcher entered a set of instructions to the software and the program ran without any bugs. The researcher also managed to change the addresses. During the simulation, input and output statuses changed which indicated that the program was functional.

The researcher designed a Stop-Start Motor Control diagram and uploaded it to the PLC. Wirings were done, and all the input and output devices were connected in the PLC at their designated terminals used in the program. When the researcher pressed the start button, the motor started to run continuously, and when the researcher pushed the stop button, the motor stopped. The researcher did it thrice to make sure the operation would go smoothly. During the three trials, all the operations were successful without any problems.

The Stop-Forward-Reverse Control was then tested. After the program was uploaded to the PLC, the researcher repeated the same steps in the previous operation. After completing all the steps, the researcher pressed the forward button. The electric motor started to rotate its shaft clockwise, and when the researcher pressed the reverse button, the electric motor also reversed its direction. This indicated that the operation was fully functional.

Stop-Wye-Delta motor control was also performed. After pressing the start button, the motor ran in wye operation. After several seconds, the wye contactor disconnected and turned to delta operation. The researcher designed and uploaded sequential motor control. Motor 1 first turned on, followed by motor 2, then motor 3. All the electric motor designs functioned adequately from the first up to the last design. Hence, it was all rated 100% functional.

Table 2: The Functionality Level of the Automation Controller using Programmable Logic Controller and Arduino in terms of Programmable Logic Control (PLC)-Based Motor Control.

Item	Type of relay logic control	Operation	Trial	Response	Description
1	Stop-Start Control	Designed and upload a stop-start control program to the PLC and hardwired the electrical devices for stop-start operation	1	Pressing the start button, the motor will turn on while pressing the stop button, the motor will stop	100 % functional
			2	Pressing the start button, the motor will turn on while pressing the stop button, the motor will stop	100 % functional
			3	Pressing the start button, the motor will turn on while pressing the stop button, the motor will stop	100 % functional
2	Forward-Reverse Control	Designed and upload a forward-reverse control program to the PLC and hardwired the electrical devices for forward-reverse operation	1	Pressing forward button, the motor will rotate clockwise while pressing reverse button the motor will rotate counterclockwise.	100 % functional
			2	Pressing forward button, the motor will rotate clockwise while pressing reverse button the motor will rotate counterclockwise.	100 % functional
			3	Pressing forward button, the motor will rotate clockwise while pressing reverse button the motor will rotate counterclockwise.	100 % functional
3	Wye-Delta Control	Designed and upload a wye - delta control program to the PLC and hardwired the electrical devices for wye-delta operation	1	Pressing start button, the motor will run through wye configuration and change to delta configuration after several seconds	100 % functional
			2	Pressing start button, the motor will run through wye configuration and change to delta configuration after several seconds	100 % functional
			3	Pressing start button, the motor will run through wye configuration and change to delta configuration after several seconds	100 % functional
4	Sequencial	Designed and	1	Pressing start button, the motor 1,	100 % functional

	Control	upload a sequencial control program to the PLC and hardwired the electrical devices for sequencial operation		motor 2 and motor 3 will turn on with an interval of 5 seconds respectively	
			2	Pressing start button, the motor 1, motor 2 and motor 3 will turn on with an interval of 5 seconds respectively	100 % functional
			3	Pressing start button, the motor 1, motor 2 and motor 3 will turn on with an interval of 5 seconds respectively	100 % functional

Table 3 shows the functionality level of the Automation Controller using Programmable Logic Controller and Arduino in terms of Arduino – based motor control. The researcher designed a Stop-Start Motor Control diagram and uploaded to the arduino. Wirings were done and all the input and output devices were connected in the arduino at their designated terminals used in the program. When the researcher pressed the start button, the motor started to run continuously and when the researcher pushed the stop button the motor stopped. The researcher did it thrice just to make sure the operation would go smoothly. During the three trials, all the operations were successful without any problems.

The Stop-Forward-Reverse Control was then tested. After the program was uploaded to the arduino, the researcher repeated the same steps in the previous operation. After completing all the steps, the researcher pressed the forward button. The electric motor started to rotate its shaft clockwise and when the researcher pressed the reverse button, the electric motor also reversed its direction. This indicated that the operation was fully functional.

Stop-Wye-Delta motor control was also performed. After pressing the start button the motor ran in wye operation. After several seconds, the wye contactor disconnected and turned to delta operation. The researcher designed and uploaded the sequential motor control. Motor 1 first turned on, followed by motor 2, then motor 3. All the electric motor designs functioned properly from the first up to the last design. Hence, it was all rated 100% functional.

Table 3: The Functionality Level of the Automation Controller using Programmable Logic Controller and Arduino in terms of Arduino-based Motor Control.

Item	Type of relay logic control	Operation	Trial	Response	Description
1	Stop-Start Control	Designed and upload a stop-start control	1	Pressing the start button, the motor will turn on while pressing the stop button, the	100 % functional

		program to the Arduino and hardwired the electrical devices for stop-start operation		motor will stop	
			2	Pressing the start button, the motor will turn on while pressing the stop button, the motor will stop	100 % functional
			3	Pressing the start button, the motor will turn on while pressing the stop button, the motor will stop	100 % functional
2	Forward-Reverse Control	Designed and upload a forward-reverse control program to the Arduino and hardwired the electrical devices for forward-reverse operation	1	Pressing forward button, the motor will rotate clockwise while pressing reverse button the motor will rotate counterclockwise.	100 % functional
			2	Pressing forward button, the motor will rotate clockwise while pressing reverse button the motor will rotate counterclockwise.	100 % functional
			3	Pressing forward button, the motor will rotate clockwise while pressing reverse button the motor will rotate counterclockwise.	100 % functional
3	Wye-Delta Control	Designed and upload a wye - delta control program to the Arduino and hardwired the electrical devices for wye-delta operation	1	Pressing start button, the motor will run through wye configuration and change to delta configuration after several seconds	100 % functional
			2	Pressing start button, the motor will run through wye configuration and change to delta configuration after several seconds	100 % functional
			3	Pressing start button, the motor will run through wye configuration and change to delta configuration after several seconds	100 % functional
4	Sequencial Control	Designed and upload a sequencial control program to the Arduino and hardwired the electrical devices for sequencial operation	1	Pressing start button, the motor 1, motor 2 and motor 3 will turn on with an interval of 5 seconds respectively	100 % functional
			2	Pressing start button, the motor 1, motor 2 and motor 3 will turn on with an interval of 5 seconds respectively	100 % functional
			3	Pressing start button, the motor 1, motor 2 and motor 3 will turn on with an interval of 5 seconds	100 % functional

				respectively	
5	Robotic Arm System	Designed and upload a robotic arm program to arduino	1	Pressing Set button, the arduino will record the position of the arm while pressing Play/Pause button will let the robotic arm continuously move each position saved.	100 % functional
			2	Pressing Set button, the arduino will record the position of the arm while pressing Play/Pause button will let the robotic arm continuously move each position saved. coordinate saved.	100 % functional
			3	Pressing Set button, the arduino will record the position of the arm while pressing Play/Pause button will let the robotic arm continuously move each position saved.	100 % functional

The Level of the Effectiveness of the Automation Controller using Programmable Logic Controller and Arduino

To determine the degree of effectiveness of the Automation Controller using Programmable Logic Controller and Arduino as an instructional device, a pre-skill test and post-skill test was administered to fifteen (15) students.

A rubric is simply a scoring tool that identifies the various criteria relevant to an assignment or a learning outcome and explicitly states the possible levels of achievement along a continuum. Rubrics was used by the researcher to identify the learning outcomes of the respondents and explicitly state the level of achievement of each respondent from poor to very good.

"The training environment is the working environment itself or a replica of the working environment" (Colley, 2003).[6] The table above shows the improvement of the average rating of the students after using the device. This addresses the inadequacy of learning of the students using Automation Controller using Programmable Logic Controller and Arduino.

Table 4: Pre-skill Test and Post-Skill Test Results of the Students using Automation Controller using Programmable Logic Controller and Arduino.

N = 16

Score	Description	Pre skill Test	Post Skill Test

		f	%	Rank	f	%	Rank
3.25-4.00	Very Good	0	00.00%		10	62.50%	1
2.50-3.24	Good	0	00.00%		6	37.50%	2
1.75-2.49	Fair	4	25.00%	2	0	00.00%	
1.00-1.74	Poor	12	75.00%	1	0	00.00%	
Average Rating		**1.64 Poor**			**3.36 Very Good**		

Table 4 shows the frequencies and percentages of the students' performance before and after the lecture and demonstration using the Automation Controller using Programmable Logic Controller and Arduino. It shows that 12 out of 16 or 75.00% of the students' pre-skill test performance was described as "poor." Four (4) students or 25.00% of the total respondents described it as "fair." No one from the respondents described as "Very Good" and "Good." The average rating of this group is 1.64, described as "poor".

After the treatment was employed, a post-skill test was conducted. The respondents got higher results compared to their pre-skill test. Ten (10) out of sixteen (16) or 62.50% of the respondents' performance was rated "Very Good" and were ranked first in the group. Six (6) out of sixteen (16) or 37.50% of the respondents rated "Good". The students had a total average rating of 3.35, which was interpreted as "Very Good". Clearly, it was found that in the post-skill test of the students who used the Automation Controller using Programmable Logic Controller and Arduino they got higher scores. Hence, it is effective for improving the learning competencies of students through actual and hands-on demonstration.

CONCLUSION

Based on the findings, the following conclusions were drawn:

The Automation Controller using Programmable Logic Controller and Arduino: An Instructional Device is an effective tool for instruction in BS Electrical Technology and BS Electrical Engineering students. The device was rated high in the effectiveness level and performed well in the automation control system. It enhances the skill competency of the students and improves the quality of instruction in the workshop environment.

RECOMMENDATION

Based on the data and findings, the researcher offers the following recommendations:

1. The researcher recommends the output of the study to be submitted to the Intellectual Property Office – Philippines (IPOPHIL) for patent application and to ensure the protection of the device.
2. The shop instructors may use the Automation Controller using Programmable Logic Controller and Arduino for BS Electrical Engineering and BS Electrical Technology

courses to assist the learning of the students. It will be used particularly in the curriculum-related with industrial system automation.

3. Electrical teachers and instructors have to undergo training on PLC-based and Arduino-based technology to broaden their competencies in control automation.
4. School administrators may encourage their instructors to develop 3D animated instructional videos to deliver course information that can be extremely helpful in the class.

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