Section A-Research paper
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INDUSTRIAL AUTOMATION CONTROL SYSTEM FOR ELECTRIC MOTOR:AN INSTRUCTIONAL DEVICE

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ABSTRACT

Technology education would need efficient and excellent laboratory facilities that entail manipulating educational tools. An instructional tool is a duplicate of the facilities available in the industry that give students the chance to work in the actual world to develop their skills and abilities. However, the electrical laboratory's inadequacies made it difficult for the instructors to impart to their students the skills that were required. In an effort to solve this issue, the researcher creates an instructional tool that caters the needs of electrical students. The purpose of this study was to develop and evaluate the functionality of the Industrial Automation Control System for Electric Motor: An Instructional Device and determine how effective it is as a tool for instruction. This was taking place at Bohol Island State University during the academic year 2021-2022 to enhance the quality of electrical technology instruction. The device development for this study used experimental research methodologies. A one group pre- and post-skill test was utilized to test the device effectiveness in enhancing the student's technical skills. The study's finding indicated that the device was functional and capable of operating to its full potential. Based on the device's effectiveness, the result showed that students' performance improved by 56.48% when using it. Additionally, the results demonstrated that the device is suitable for use as a tool for instruction. In order to improve the student's skills, the researcher therefore strongly suggests using the device as a tool for instruction in electrical technology laboratories.

Keywords: ***electrical technology, PLC, Human Machine Interface, instructional device, effectiveness***

Introduction

Automation is a result of technological transition. People in all nations are seeing an exciting new trend of contemporary technical growth in this modern period of life. The Programmable Logic Controller (PLC) and Human Machine Interface (HMI) are two interesting and well-known technological concepts that are at the forefront of this rapidly growing high-tech world (Chhabra, 2019). According to Barreto (2017), Programmable Logic Controller (PLC) is the major key in technology and industrial sector nowadays. PLC is a microprocessor-based controller having programmable memories that holds instructions to carry out various functions like logic, timing, counting, sequencing and arithmetic in order to operate the machines and automate the process (Anusha, 2017). Since human operator is the key player in the automation process, Human Machine Interface (HMI) is integrated. This allows communication with the PLC and input/output sensors to get and display information for operators to view, and provides platform for humans to have interaction with machines, system and other devices (Mendapara, K. 2020).

According to a study by Budimir (2020), it was emphasized that the HMI-PLC combination provides fundamental capabilities such data logging, graphing, alarm setting, and trend monitoring in addition to numerous control functions required for automated control systems in the industry. These are widely used in industry and manufacturing processes making the operation automated and allowing the operator to

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communicate with any production system (Kadam, S., et.al, 2020). Thus, great advances for the distribution of quality products are available at faster rates and reduced human error.

Programming complexity is involved in the automation industry's integration of Programmable Logic Controllers (PLC) and Human Machine Interfaces (HMI), so a skilled and technically expert individual is required to comply to the requirements. This pose a great challenge to the Philippine Higher Education for the skills development of workforce based on the industry standard. According to a research by the India-based employment solutions firm, Aspiring Minds, only one out of every three Filipino college graduates is "employable," according to the Philippine star (2017). This demonstrate the need for a significant change in the teaching methodology at the school to enhance students' foundation skills.

Bohol Island State University (BISU) is one of the leading technical institutions which aim to provide quality education which are all important in the personality development of the student skills relevant to this modern era. In spite of university's efforts, it still needs to improve its capabilities in providing training through the use of instructional devices which are in accord with the standards set in the automation industry. In response to this, the researchers were motivated to develop a device called Industrial Automation Control System for Electric Motor: An Instructional Device. It is an instructional tool integrated with HMI, PLC, electromechanical devices and industrial sensors, pilot lights and electric motors allowing students to experience the actual set up of different automated motor control operations in the modern industries.

At present, the new normal learning requires less physical contact while maintaining the substantiality of the learning mediums being used. To address such need, the device was purposely created to suit for blended learning by it being module ready and since it involves computer ladder programming, students can program virtually anywhere using the pre-installed PLC software on their personal laptops or computer making the device suitable for the old and new normal teaching and learning.

STATEMENT OF OBJECTIVES

The main goal of this study was to develop and evaluate the functionality of the Industrial Automation Motor Control System for Electric Motor: An Instructional Device, assess the device's effectiveness as a tool for instruction and determine whether there was a significant difference of the students using the instructional device's pre-and post-skill test ratings.

METHODOLOGY

The assembly of the device was done using experimental research methodologies. Its effectiveness in improving the students' technical skills was tested using a one-group pre-skill test – post-skill test method. The study was taking placed ta Bohol Island State University- Main Campus, Balilihan Campus and Calape Campus since the three campuses offered System Automation Control courses in which the industrial automation motor control is part of the topic. The researcher included 40 respondents, including 20 (twenty) fourth year of Bachelor of Science in Electrical Technology students, 12 (twelve) BISU system electrical instructors and 8 (eight) technical industry specialists.

The instruments used in the study were: Observation Guide, Pre-skill test and Post-skill test, and Scoring rubrics**.**

RESULTS AND DISCUSSION

In order to evaluate the functionality of the Industrial Automation Control System for Electric Motor: An Instructional Device and assess its effectiveness as a tool for instruction, data were gathered and calculated, which was supported by tables that show the responses. The construction of the Industrial Automation Control System for Electric Motor: An Instructional Device was based on the specified design.

The block diagram (Figure 1) of the Industrial Automation Control System for Electric Motor: An Instructional Device is a representative by blocks connected by lines showing the relationships of the components.

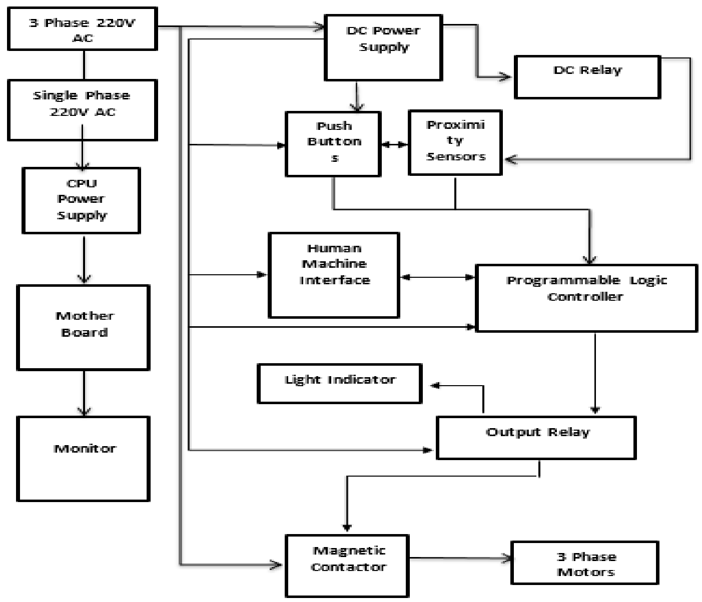


Figure 1. Block Diagram of Industrial Automation Control System for Electric Motor: An Instructional Device

The Pictorial Diagram (Figure 2) of the Industrial Automation Motor Control System for Electric Motor: An Instructional Device shows the connections and arrangement in which the components were connected.

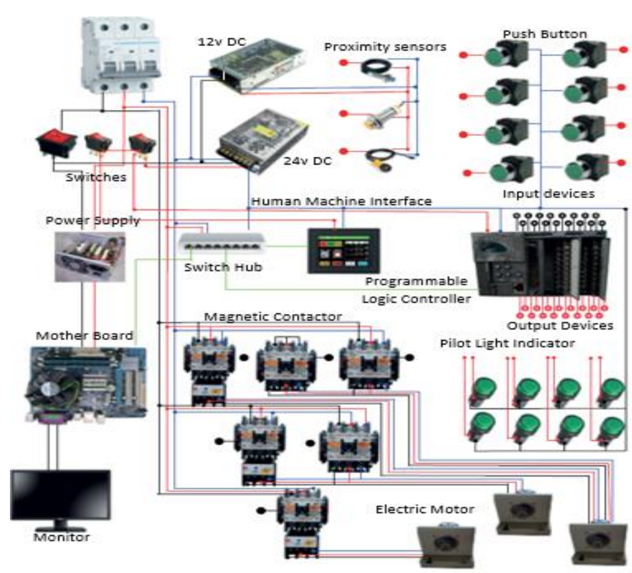
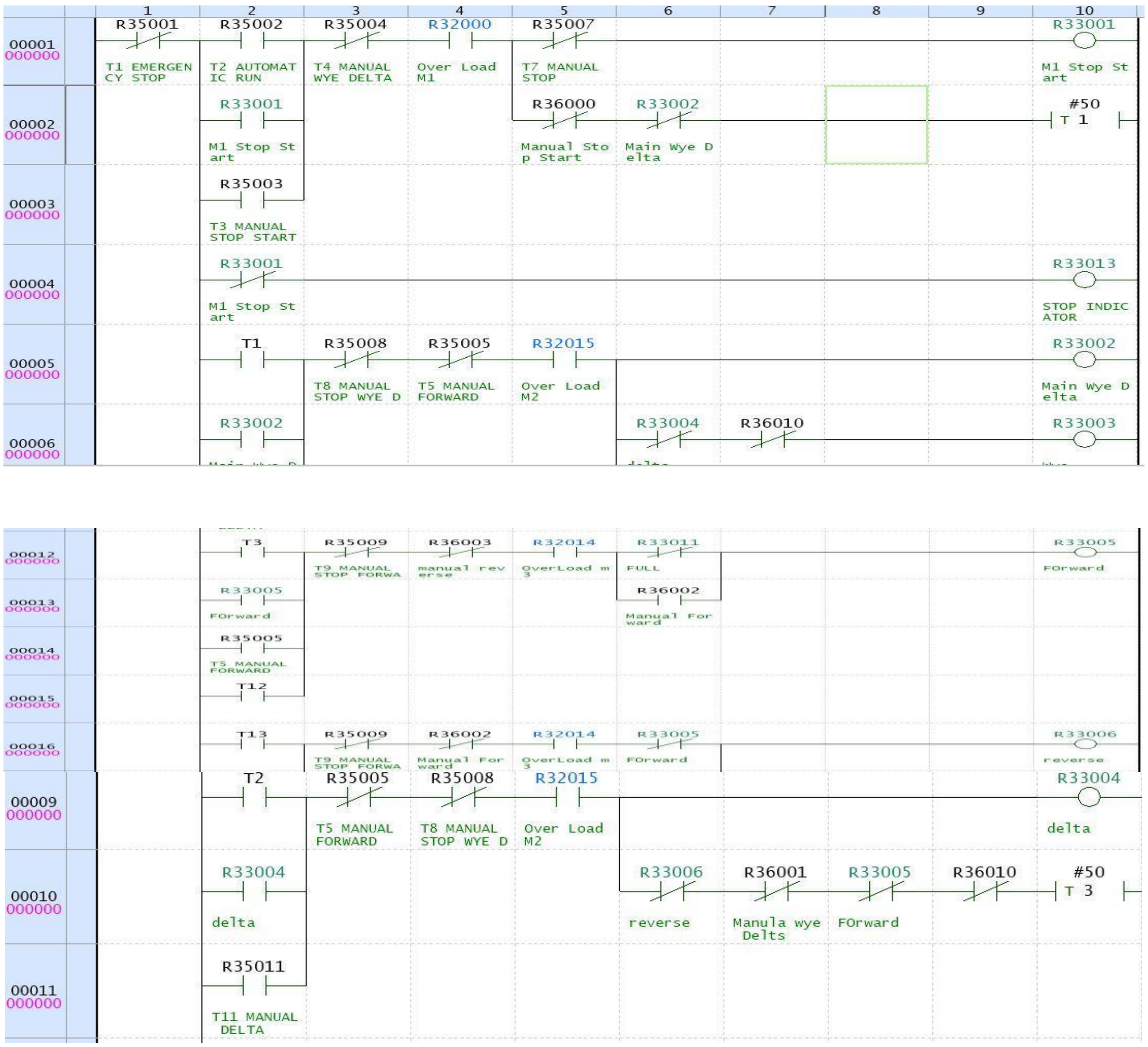


Figure 2. Pictorial Diagram of Industrial Automation Motor Control System for Electric Motor: An Instructional Device

ISSN 2063-5346

Ladder diagram (Figure 3) of the Industrial Automation Motor Control System for Electric Motor: An Instructional Device is the representation of the visual connection of the components using the PLC and HMI software.



ISSN 2063-5346

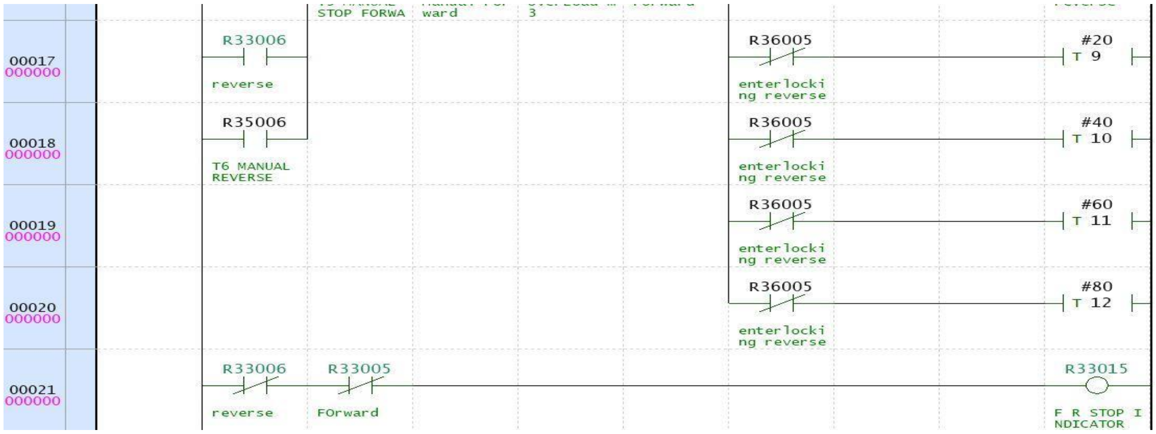


Figure 3. Ladder Diagram of the Industrial Automation Motor Control System for Electric Motor: An Instrucional Device

Table 1-Functionality of the Industrial Automation Control System for Electric Motor in terms of Sequential Control Simulation

Process	Control	Mode of Control	Operation	Result	Interpretation
Belt Conveyor	Touch Panel	Manual	Pressed start control button in HMI panel, manual contact close provides interlocking	Magnetic contactor energized, pilot light indicator illuminated and electric motor 1 energized, low level indicator energized.	Functional
		Automatic	Pressed the automatic button on HMI panel for automatic control	Magnetic contactor, timer coil 1 energized, pilot light indicator, HMI indicator illuminated and electric motor 1 energized	Functional
	Push Button	Manual	Pressed the start push button 1, manual contact close provides interlocking	Magnetic contactor energized, pilot light indicator illuminated and electric motor 1 energized.	Functional
		Automatic	Pressed start push button 1, contact closed	Magnetic contactor, timer coil 1 energized, pilot light indicator illuminated and electric motor 1 energized	Functional
Miller	Touch Panel	Manual	Pressed wye control button in HMI, the contact triggered to close, manual contact close provide interlocking	Main and wye contactor energize, motor 2 energize, pilot light indicator illuminated HMI Indicator Illumined, after 5 second, change to delta connection and delta light indicator illuminated,	Functional
		Automatic	Timer contacts 1 closed, main and wye contact closed after 5 second timer 2 contact closed, wye contact open and delta contact close	After 5 seconds main magnetic contactor and wye connection energized, wye pilot light indicator illuminated, after 5 second wye connection de-energized and change to delta connection, delta indicator illuminated	Functional
	Push Button	Manual	Pressed wye push button, the contact triggered to close, manual contact close provide interlocking	Main magnetic contactor and wye magnetic contactor energized; pilot light indicator energized after 5 second wye delta	Functional
		Automatic	Timer contacts 1 closed, main and wye contact closed after 5 second timer 2 contact closed, wye contact open and delta contact close	After 5 seconds main magnetic contactor and wye connection energized, wye pilot light indicator illuminated, after 5 second wye connection de-energized and change to delta connection, delta indicator illuminated time coil 3 energized	Functional
Bucket Elevator	Touch Panel	Manual	Pressed forward control button in HMI, Pressing reverse control button in HMI,	Contact close, forward magnetic contactor and motor 3 energized. HMI indicator illuminated; Light indicator energizes in sequence full indicator illuminated; reverse magnetic contactor energized	Functional
		Automatic	Timer 3 contact closed, forward maintaining contact closed and coil energized	Forward magnetic contactor energized, pilot light indicator illuminated in upward direction, full indicator energized reversed magnetic contactor	Functional

				energize	
	Push buttons	Manual	Pressed forward push button in HMI, Pressing reverse push button in HMI,	Contact close, forward magnetic contactor and motor 3 energized. Light indicator energizes in sequence full indicator illuminated; reverse magnetic contactor energized	Functiona l
		Automatic	Timer 3 contact closed, forward maintaining contact closed and coil energized	Forward magnetic contactor energized, pilot light indicator illuminated in upward direction, full indicator energized reversed magnetic contactor energize	Functiona l

Table 1 shows the result of the functionality of the device in terms of its Sequential Control Simulation. The operation involves mini-rice mill process which includes belt conveyor, miller and bucket elevator. The simulation of belt conveyor, miller and bucket elevator was done using push buttons or HMI touch panel. During the operation, it had two options either using manual or automatic. For the manual operation, it was observed that the user can controlled each of the process involved in the operation of rice mill by pressing the corresponding control either in the HMI touch panel or using push button, pressing the manual control allow interlocking connection to avoid the contact of timer to energized.

Sequential operation control begins by pressing the start push button whether in HMI or Push buttons. It triggers the contact to closed and energized relay coil and timer coil. After 5 second the timer contacts closed allowing the main and wye connection to energized and its pilot light indicator illuminated after 5 second the operation switch to delta, wye connection was now open to avoid short circuit, another timer was energized. The timer contacts close allowing the relays coil of the forward operation to energize, the light indicator started to turn on sequence for forward operation.

It started until it reached the full indicator allowing the reverse operation to take over and open the contact of forward operation. While the reverse operation was energized, the pilot light indictor was slowly de-energized after the last pilot light indicator for reverse operation was performed all the operation of rice mill will stop allowing for another set of operation to be performed.

The performance of the device in terms of sequential control simulation was found functional which means it performed the program without any error that occurred.

Table 2-Functionality of the Industrial Automation Control System for Electric Motor in terms of Motor Control Operation

Program	Contr ol	Trial	Operation	Result	Interpr etation
Stop Start	HMI	1	Create and upload program to HMI, Pressed the start and stop button in the Touch panel	Motor 1 energized, pilot light indicator illuminated, and HMI panel indicator energized	Functio nal
		2			
		3			
	PLC	1	Create and upload program PLC, Pressed Push Button no. 1 for start and push button 2 for stop	Motor 1 energized, pilot light indicator illuminated	Functio nal
		2			
		3			

Double Stop Start	HMI	1	Create and upload program to HMI, Pressed the double start and stop button in the Touch panel	Motor 1 energized, pilot light indicator illuminated, and HMI panel indicator energized	Functio nal
		2			
		3			
	PLC	1	Create and upload program to PLC, Pressed the start and stop push button 1,2 and 3, 4	Motor 1 energized, pilot light indicator illuminated,	Functio nal
		2			
		3			
Forward reverse	HMI	1	Create and upload program to HMI, Pressed forward button and reverse button in Touch Panel	Motor 3 energized, pilot light indicator illuminated, and HMI panel indicator energized	Functio nal
		2			
		3			
	PLC	1	Create and upload program to PLC Pressed push button 1 for Forward, 2 for reverse, 3 for stop.	Motor 3 energized, pilot light indicator illuminated,	Functio nal
		2			
		3			
Automati c Forward Reverse	HMI	1	Create and upload program to HMI, set timer on delay to 5s pressed forward button in Touch panel	Motor 3 energized, pilot light indicator illuminated, and HMI panel indicator energized	Functio nal
		2			
		3			
	PLC	1	Create and upload program to PLC, set timer on delay to 5s and Pressed forward push button	Motor 3 energized, pilot light indicator illuminated,	Functio nal
		2			
		3			
Wye delta	HMI	1	Create and upload program to HMI pressed wye button and Delta in Touch panel	Motor 2 energized, pilot light indicator illuminated, and HMI panel indicator energized	Functio nal
		2			
		3			
	PLC	1	Create and upload program to PLC, pressed wye push button and delta push button	Motor 2 energized, pilot light indicator illuminated,	Functio nal
		2			
		3			
Automati c Wye Delta	HMI	1	Create and upload program to HMI set timer on delay 5s and pressed wye button in Touch panel	Motor 2 energized, pilot light indicator illuminated, and HMI panel indicator energized	Functio nal
		2			
		3			

ISSN 2063-5346

	PLC	1	Create and upload program to PLC, set timer on delay 5s and pressed wye push button	Motor 2 energized, pilot light indicator illuminated,	Functio nal
		2			
		3			

Table 2 shows the simulation of motor control operation. The program created were the stop-start, double stop-start, forward-reverse, automatic forward-reverse, wye-delta and automatic wye-delta. The means of controls was the use of HMI and PLC and tested in 3 different trials. For the stop start and double stop start, the program was created and uploaded in HMI and PLC and then the push button and control button in HMI was pressed which energized the magnetic contactor coil and electric motor and the pilot light indication illuminated.

For forward reverse and automatic forward reverse the program was created and uploaded in HMI and PLC and then the push button for forward was pressed and in HMI control which resulted to energized the forward magnetic contactor coil which energized the electric motor to forward direction and when the reverse push button was pressed, the reverse magnetic contact was energize the operation of the electric motor was change in reverse direction. For the automatic forward reverse the forward push button was pressed and HMI control was also actuated, after 5 second it changes to reverse direction.

The wye delta and automatic wye delta, program was created and uploaded in HMI and PLC and then the push button and control button in HMI were pressed which energized the magnetic contactor coil in wye connection and then the delta control was pressed which interchanged the connection from wye to delta operation and electric motor was energized. For automatic wye delta, it takes 5 seconds to reverse the change the connection from wye to delta operation.

After 3 consecutive trials in different motor control operations, it was observed that no error occurred and successfully simulated the operation which was interpreted as functional.

Table 3-Functionality of the Industrial Automation Control System for Electric Motor in terms of Motor Overloading Protection and Alarm Devices

Item	Parts	Operation	Trial	Result	Interpretation
1	Overload relay stop start	Modify the trip button from clo to open	1	Motor 1 (Belt conveyor motor) operation would stop and the buzzer rang.	Functional
			2	Motor 1 (Belt conveyor motor) operation would stop and the buzzer rang.	Functional
			3	Motor 1 (Belt conveyor motor) operation would stop and the buzzer rang.	Functional
2	Overload relay Forward reverse	Modify the trip button from clo to open	1	Motor 2 (Miller motor) operation would stop and the buzzer rang.	Functional
			2	Motor 2 (Miller motor) operation would stop and the buzzer rang.	Functional
			3	Motor 2 (Miller motor) operation would stop and the buzzer rang.	Functional
3	Overload relay Wye Delta	Modify the trip button from clo to open	1	Motor 3 (bucket elevator motor) operation would stop and the buzzer rang.	Functional
			2	Motor 3 (bucket elevator motor) operation would stop and the buzzer rang.	Functional
			3	Motor 3 (bucket elevator motor) operation would stop and the buzzer rang.	Functional

Table 3 shows the functionality of Industrial Automation Control System for Electric Motor: An Instructional Device in terms of Motor Overloading Protection and Alarm device.

In trials 1, 2 and 3, the overloads relay (OL) and the buzzer were tested for its functionality. During trial 1 the trip button of Overload Relay1 (OL1) has pulled out to trip resulting to the stoppage of the bucket elevator motor (motor 1) operation and the buzzer rang.

During trial 2, the Overload Relay 2 (OL2) trip button has been pulled out to trip and it still resulted to the stoppage on miller motor (motor 2) and the buzzer also rang. Lastly, in trial 3 as the Overload Relay 3 (OL3) trip button pulled to trip, also resulted to stop the belt conveyor (motor 3) operation and the buzzer rang.

The results of the trials showed that when overloading was experienced, the operation of each motor would stop and the buzzer rang to alarm the operator of the fault. The Overload Relays cut the passage of electric current going to the magnetic contactor coil causes the de-energization of induction motor. This in turn closes the circuit of the buzzer which cause to ring. It means that Overload Relays and buzzer installed in the device were functional at 100 percent.

According to the 2008 National Electrical Code, Article 110.9, states that "Equipment intended to interrupt current at fault levels shall have an interrupting rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment. Equipment intended to interrupt current at other than fault levels shall have an interrupting rating at nominal circuit voltage sufficient for the current that must be interrupted" (Murphy, 2012). This article emphasizes to install protective devices on the circuit with the interrupting rating sufficient to cut the circuit when excess current on the line detected. The device has been equipped with overload relay that will cut the circuit when the induction motor experienced overloading.

The Effectiveness Level of the Industrial Automation Control System for Electric Motor: An Instructional Device

Table 4- Pre-Skill Test and Post-Skill Test Result of the Students
N = 20

Range	Description	Pre skill Test			Post Skill Test		
		f	%	Rank	f	%	Rank
3.25 – 4.00	Excellent	0	00.00%		12	60.00%	1
2.50 – 3.24	Very Good	0	00.00%		8	40.00%	2
1.75 – 2.49	Good	4	20.00%	2	0	00.00%	
1.00 – 1.74	Needs Improvement	16	80.00%	1	0	00.00%	
Average Rating		**1.51 Needs Improvement**			**3.47 Excellent**		

The frequency and percentage of the students' performance on the Industrial Automation Control System for Electric Motor: An Instructional device's pre-skill test and post-skill test are displayed in the table. The average rating on the pre-skill test was 1.51, indicating that is needed improvement, but the average score on the post-skill test was 3.47, indicating excellent performance. The outcome showed that the device is a useful tool for acquiring learning competencies in electrical laboratories and crucial for developing students' skills.

Table 5 - Difference on the Performance of the Students under Pre-Skill Test and Post-Skill Test Results of the Students.

Difference	t computed value	t tabular value	Description	Interpretati on
	at 0.05 level of significance, df = 19			
Pre-skill test and Post-skill test	-25.597	±2.09302	Significant	Reject Null Hypothesis

The difference between the students' pre-skill test and post-skill test is shown in Table 5. The data showed that students performed better on the post-skill test than the pre-skill test. At a significance level of 0.05, the calculated t-value was -25.597, with an absolute tabular value of 2.093. The null hypothesis was rejected since it revealed a substantial difference between the students' performances in the pre-and post-skill test. This demonstrated the importance of using the Industrial Automation Control System for Electric Motor: An Instructional Device tor enhancing student skills and knowledge retention.

According to Franklin and Peat (2005), working hands-on delivers a more interesting and realistic experience of the content, which leads to positive motivating effects (Holstermann and Grube, 2010). With the aid of the Programmable Logic Control (PLC) and Human Machine Interface (HMI), the device gave the students hands-on experience on designing, installing and debugging motor controls, helping them to retain their knowledge and advance their technical skills. Additionally, it strengthens students' enthusiasm in the subject and boosts their self-confidence, causing them to actively participate in laboratory activities and industrial studies (Erdal, et al. 2008)

CONCLUSIONS

Based on the study's findings, the following conclusions were drawn:

The Industrial Automation Control System for Electric Motor: An Instructional Device is useful tool for delivering instruction in electrical laboratories which gives students a thorough understanding of the automated control system of industrial automation suing the Programmable Logic Controller (PLC) and Human Machine Interface (HMI). In addition, the device can function at its peak efficiency while yet guaranteeing the students' safety.

RECOMMENDATIONS

The following recommendations are made in accordance with the data and findings:

Use the Industrial Automation Control System for Electric Motor: An Instructional Device in delivering the instruction on system automation course; construct additional automated control system instructional device that can imitate the actual functions in the industry; and endorse the study to be protected by a patent.

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