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Development and Acceptability of an Industrial Motor Control System Trainer

Elmer A. Bartolome
Technical Education and Skills Development Authority, Philippines, elmerbartolome14@gmail.com

ABSTRACT

This study was conducted primarily to develop and evaluate the acceptability of an Industrial Motor Control System (IMCS) Trainer as instructional equipment for Electrical Engineering and Electrical Technology courses, Technical-Vocational Education and Training (TVET) programs in Electrical Installation and Maintenance, and skills upgrading for graduates and industry workers. The instructional device is composed of modular boards and AC induction motors. It is provided with electrical components used in motor controllers in the industry. This research study used the Project Development Method (PDM), and the Descriptive-Evaluative research design. The trainer was evaluated by three groups of respondents: the industry experts, Electrical Engineering and Electrical Technology instructors, and TVET teachers and trainers. Based on the assessment of the evaluators, the developed Trainer had a very high level of acceptability in terms of: design and construction, functionality, durability instructional applicability and safety. Hence, the developed trainer is very effective, efficient, safe and useful instructional equipment. It has the capability to perform a number of laboratory activities on motor controls. The trainer is highly recommended and very suitable for instructional and training purposes.

Key words : Development and Acceptability, Electrical Engineering, Electrical Technology, Industrial Motor Control, Instructional Equipment, Trainer.

1. INTRODUCTION

Quality education and training depends on the availability of school facilities and instructional equipment and materials in the workshops. It is through instructional equipment that students acquire maximum knowledge and skills effectively [1], [2]. Quality education builds our graduates competence in their chosen field and they must possess not only knowledge but the required technical skills aligned in the 21st Century [3]. Competency Based Training (CBT) and/or Outcome-Based Education (OBE) must be applied for a more effective teaching and learning approach that will improve students' performance. The students should be trained the technical skills needed in the industry by means of having instructional equipment to be used in the workshops [4], [5]. Research shows that active learning or learning by doing is better than passive learning. What we hear we forget but what we do we understand. Benjamin Franklin an American inventor and scientist attributed it as "Tell me and I forget, teach me and I may remember, involve me and I learn." Retention of knowledge is quite significant if there are hands-on activities performed by the students [6]. Absence or inadequate instructional materials, equipment and facilities has been a challenge of the education sector especially in the engineering, technology and technical-vocational education, not only in our country but also the rests of the developing countries. Allocated fund purchasing instructional equipment is limited, besides it is extremely expensive. The importance of instructional materials, tools and equipment are indispensable in the teaching and learning process to promote teachers' efficiency and ensure students' quality training required in the industry [7].We need more instructional equipment to keep pace with this emerging technology. We are now in the 4th Industrial revolution and we should be ready in this significant transformation in the industry. This is the current trend in automation. It will create new manufacturing jobs. Therefore, we should develop our graduates to be well equipped with current technology to secure productive employment [8]. Our graduates must be competent, efficient, and productive enough before they enter for a job. Electrical machines like motors and generators are widely used to operate manufacturing industries. These machineries must be used with a well-designed controller to benefit their maximum capacity, efficiency and safeness. A motor controller might include a manual or automatic means of starting and stopping a motor of different application [9]. Selecting the methods of starting, forward or reverse, selecting and regulating the speed, protecting against overload and electrical faults, etc. Our industry workers should be competent in the installation, tending, and operation & maintenance of the different types of motors and their controllers [10]. The primary purpose of this study was to develop and evaluate the acceptability of an Industrial Motor Control System Trainer as instructional equipment for Electrical Engineering and Electrical Technology courses, Technical-Vocational Education and Training (TVET) programs in Electrical Installation and Maintenance, and skills upgrading for graduates and industry workers. Specifically, this research study intends to: 1. design and develop an Industrial Motor Control System Trainer as instructional equipment; 2. Determine the possible laboratory activities on motor controls that can be performed in the trainer; 3. and evaluate its acceptability in terms of design and construction, functionality, durability, safety, and instructional applicability; 4. compare the evaluation of the three groups of respondents as to the general acceptability of the developed trainer. The proposed Trainer is an instructional device which can be used in the training and study of industrial motor controls, circuit designs, installation, assembly and troubleshooting of motor controllers of different applications in industrial establishments. This will eliminate the traditional method of teaching without any practical work or hands-on for the real devices of the different control circuits. Developing the required instructional equipment in Industrial Motor Controls is essential to meet industry standards and to facilitate training in the workshops. The result of this research study is beneficial to Polytechnic Colleges and Universities offering Electrical Engineering/Electrical Technology courses and TVET Institutions address the insufficiency of instructional facilities in teaching Electrical Engineering and Electrical Technology subjects, making technology visible in the workshops and classrooms; Likewise, it will help the instructors improve their teaching methods and strategies and facilitate in delivering quality technical education and right skills; and the students to strengthen their understanding of applied motor control systems and basic industrial automation; the Electrical Engineers, Electrical technologist, and industry workers enhance their skills and knowledge. They will be trained to design industrial motor control circuits, assemble, maintain and troubleshoot motor control panels for different applications. This will create careers and employment opportunities.

2. RESEARCH METHODS

The following figure 1 presents the conceptual framework of the study.

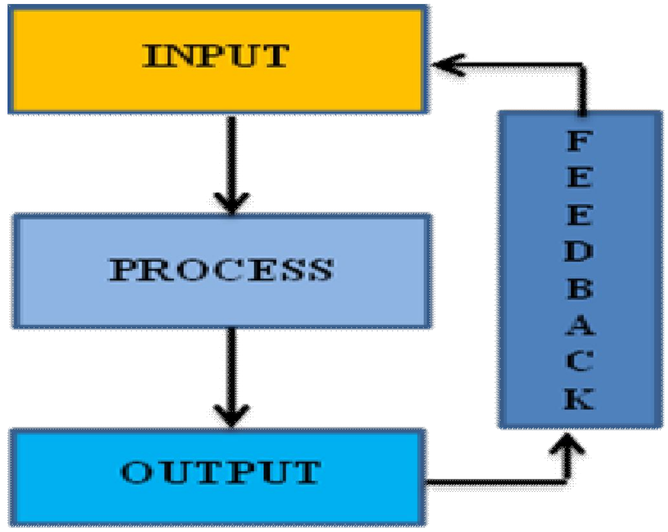

Figure 1: Conceptual Framework of the Study

Figure 1 shows the conceptual framework of the study. Based on the objectives of the study, it followed the input, process and output model. The input of this study includes ideas on the design of the project, available supplies and materials, tools and equipment and bill of materials. The process focused on the development of the trainer which includes designing, fabrication, assembly, testing, revision/modification and evaluation. Furthermore, the output of this study is the developed and accepted Industrial Motor Control System Trainer. The feedback served as reference to further improve the project.

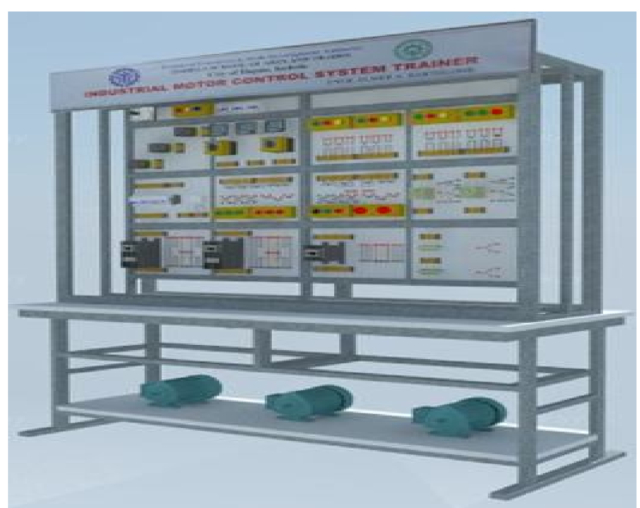

Figure 2: Perspective View of the proposed IMCS Trainer

Figure 2 shows the perspective view of the proposed Industrial Motor Control System Trainer conceptualized by the researcher with the different parts and components. The frame assembly is made up of square and rectangular steel tubing wherein the different modules and induction motors are mounted.

The trainer is an assembly of group of electrical devices that serves to govern in a predetermined manner the performance/operation of one or more electric motors. The trainer provides the skills and training requirement for installation, operation, maintenance and troubleshooting of motor controls in the industry. The trainer can be supplied by a three phase system, 220 Volts, 60 hertz source or 380 Volts for rated 380 volts industrial loads. The main circuit breaker is rated 40 Amperes.

Electrical components and control devices used in motor controllers are mounted in modular boards. The boards are made up of formica laminated sheet, acrylic glass and aluminum U-channels where the electrical components are mounted and schematic symbols were drawn. The trainer is composed of 20 different modules and three units 3-phase induction motors that are placed in the trainer which serves as the workstation. The students will select the required modules and place them in the trainer according to a given task or laboratory exercises. The trainer can accommodate up to 12 different modules. The modules are connected using standard size of wires with Y-lugs and/or stackable plugs which serves as connectors to the different modules through the PVC slotted cable trunking. A safety breaker, grounding and a low-ampere rated fuse are installed in the trainer as a safety feature. The use of this trainer will reduce/eliminate the electrical wires consumption because it has connectors with Y-lugs in both ends at predetermined lengths. It minimizes time in connecting the different control components. The materials used are available locally.

The following are the different modules used in the trainer:

1- Current Transformers
1 - Panel meters and selector switches
2 - Indicator / pilot lamps
1 - Push button switches
1 - PB with auto-manual sw. & emergency stop
1 - Circuit Breakers
1 – 2 Timer relays
1 – 4 Timer relays
3 - Magnetic Contactor & Thermal Overload relay
1 – Limit switches
1 – 4 Control relays
2 - Magnetic Contactor
1 – Floater switch
1 - Fluid level (floatless) relay
1 - Variable Frequency Drive
1 - Voltage relay
1 – 6-leads 3-phase induction motor
1 – 9-leads 3-phase induction motor
1 – 12-leads 3-phase induction motor

This research project was developed at the Technical Education and Skills Development Authority (TESDA) - Isabela School of Arts and Trades, City of Ilagan, Isabela. The trainer was evaluated by three groups of respondents: 15 Instructors from the Isabela State University, City of Ilagan campus offering B.S. Electrical Engineering and B.S. Electrical Technology. 15 TVET instructors from Technical Education and Skills Development Authority (TESDA) Training Centers, and 15 experts from the industry, like the Coca-Cola Bottlers Philippines, Inc., Isabela II Electric Cooperative, Cagayan Biomass Energy Corporation, Ilagan City Water District, and Q6 Electrical Engineering Services.

This study used the Project Development Method (PDM), and the Descriptive-Evaluative research design. The Weighted Mean was used to determine the level of acceptability of this newly developed trainer in terms of its design and construction, functionality, durability, safety and instructional applicability and interpreted the equivalent meaning of the data gathered.

The Analysis of Variance was used to determine if there are significant differences in the responses and evaluations of the respondents in terms of the identified variables. Meanwhile, the five-point Likert's rating scale as seen in Table 1 was used to determine the descriptive meaning of the indicators.

Table 1: Likert's Rating Scale.

Weight	**Mean Range**	**Qualitative Description**
5	4.20 – 5.00	Very Much Acceptable
4	3.40 – 4.19	Acceptable
3	2.60 – 3.39	Moderately Acceptable
2	1.80 - 2.59	Least Acceptable
1	1.00 – 1.79	Not Acceptable

3. RESULTS AND DISCUSSIONS

Figure 3 shows the completed IMCS trainer with 12 modules mounted. The function/operation of each control component can be demonstrated in each module, and figure 4 shows sample modules used in the trainer.

Figure 3: The developed IMCS trainer

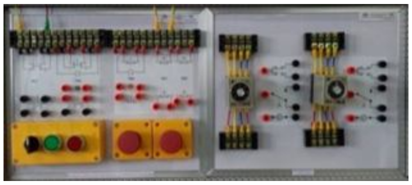

Figure 4: The Push Button Switch

The developed trainer is capable of performing the following laboratory activities on motor controls based on industrial setup.

1. Direct on Line Magnetic Starter
2. Control Logic Circuits
3. Multiple Stations Motor Control
4. Forward-Reverse Motor Control
5. Forward-Reverse with limit switches
6. Automatic forward Reverse operation
7. Wye-delta reduced voltage starter
8. Wye-Delta, Forward Reverse Starter
9. Automatic Wye-Delta, Forward Reverse
10. Three stages sequential Control
11. Automatic Sequencing
12. Start-Stop with Jog Motor Control
13. Auto-Manual Operation of Motor Controllers
14. Alternate Operation of Electric Motors
15. Troubleshooting Industrial Motor Controllers
16. Ammeter, CT's and cam switch connection for 3 phase system
17. Frequency meter connection installation to 3 phase system
18. Voltmeter and cam selector switch connection for three-phase metering
19. Connecting 3 leads, 6 leads, 9 leads, 12 leads motors in a 3-phase configuration
20. Connecting 3 phase motors for dual voltage
21. Variable Frequency Drive Connection
22. Dual Speed Connection of 3-phase motors.
23. Under/Over voltage relay connection
24. Control relays connection
25. Fluid level (floater and floatless) relay for automatic pump operation

The instructor will provide exercises/problems on industrial motor controls for actual laboratory practices. After the circuit diagrams have been checked, the students are now ready to perform the actual wiring in the IMCS Trainer. The students will connect a given control circuit using a stackable plug/connector through the banana jacks to the schematic symbols. After which, the same activity can also be performed by connecting the control devices directly through the terminal blocks. Finally, the student is now ready to assemble a 40 cm x 50 cm control panels. The following tables present the evaluation of the three groups of respondents as to the general acceptability of the electrical trainer.

Table 2: Level of Acceptability of the IMCS Trainer

Criteria	Industry Experts		EE/ET Instructors		TVET Trainers	
	Mean	Acceptability Level	Mean	Acceptability Level	Mean	Acceptability Level
1. Design and Construction	4.94	Very Much Acceptable	4.90	Very Much Acceptable	4.96	Very Much Acceptable
2. Functionality	4.98	Very Much Acceptable	4.96	Very Much Acceptable	5.00	Very Much Acceptable
3. Durability	4.94	Very Much Acceptable	4.88	Very Much Acceptable	4.92	Very Much Acceptable
4. Safety	4.94	Very Much Acceptable	4.90	Very Much Acceptable	4.98	Very Much Acceptable
5. Instructional Applicability	5.0	Very Much Acceptable	5.00	Very Much Acceptable	5.00	Very Much Acceptable
Overall Mean	4.96	Very Much Acceptable	4.93	Very Much Acceptable	4.98	Very Much Acceptable

It is revealed in table 2 that all of the criteria resulted to very much acceptable. This means that the respondents believed that the IMCS Trainer can help them in their actual laboratory activities.

Table 3: General Level of Acceptability of the IMCS Trainer

Criteria	Total Mean	Qualitative Description
Design & Construction	4.93	Very Much Acceptable
Functionality	4.98	Very Much Acceptable
Durability	4.95	Very Much Acceptable
Safety	4.94	Very Much Acceptable
Instructional Applicability	5.00	Very Much Acceptable
Grand mean	4.96	Very Much Acceptable

Table 3 provides the general level of acceptability of the trainer in terms of design and construction, functionality, durability, safety, and instructional applicability. All criteria for evaluation were rated "Very Much Acceptable" by the respondents. The grand mean of 4.96 shows that the trainer has "Very Much Acceptable" rating as to the general acceptability level. This implies that the Industrial Motor Control Trainer is highly preferred by the evaluators and is very suitable for instructional purposes. Based on the results of the evaluation among the three groups of respondents there is no statistically significant difference in the general acceptability of the Industrial Motor Control System Trainer, where $F = 2.101$, $p = 0.138 > 0.05$. This means that all the respondents agreed that the trainer is very much acceptable across all criteria and indicators.

4. CONCLUSION

An Industrial Motor Control System Trainer has been developed. Numerous laboratory activities can be performed in the trainer. The trainer is very much applicable and acceptable for instructional purposes in Electrical Engineering, Electrical Technology courses and TVET Electrical Installation and Maintenance programs. This will aid the educational and training institutions in delivering quality technical education; the instructors improve their teaching strategies; and the students in their understanding of applied industrial controls.

5. RECOMMENDATIONS

1. It is recommended that all Polytechnic Colleges and Universities and TVET Training Centers offering Electrical Engineering, Electrical Technology and Electrical Installation and Maintenance courses shall use this newly-developed Industrial Motor Control System Trainer to improve quality of instruction.
2. The trainer should be upgraded with PLC for Automation courses.
3. A similar study or innovation be conducted or made to increase the number of instructional devices in the technology area.
4. The trainer is highly recommended to be used for blended learning.

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