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Outcomes-Based Trainer for Tabletop Industrial Motor Control utilizing Variable Frequency Drive and Programmable Logic Controller

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Abstract

The study focuses on the design and development of an Outcomes-Based Trainer for Tabletop Industrial Motor Control utilizing Variable Frequency Drive and Programmable Logic Controller. The instructional trainer is composed of designed for outcome based training to educate and develop student's knowledge and skills likewise integrates the instructional device's capabilities to recent technology in controls of alternating current (AC) motor in reference to the predetermined application of controllers in most industries. The trainer provides competitive learning in terms of basic and advance motor controls in conjunction with the industrial requirements. Frequency regulation to control AC motor speeds via variable frequency drive and programmable logic controller (PLC) to program specific speed level to drive the AC motor. It has the capability to operate three phase and single phase motors in performing experiments in basic and advance motor controls in line with the required theoretical topics in the courses involving motor controls. Moreover, the instructional trainer develops student's capability in setting up control components attached to magnetic casing to be placed in the metallic training board so as to demonstrate proper control setup in reference to most industrial zones. As demonstrated in the study, the training device has the capability to utilize frequency adjustment for speed control regulation, PLC programming, and modulated controls to drive three phase and single phase motors, which are currently employed in the industry. Based on the evaluation conducted, the trainer is rated positively (very good) in all criteria considered in the study in terms of functionality, safety, reliability and aesthetics.

Keywords: Variable Frequency Drive, Programmable Logic Controller, Industrial Motor Control, Outcome-Based Training

Introduction

Education in institutions of higher learning today goes beyond the traditional norms via lectures, tests for learning and training. Hence, a new learning culture emerges and a new learning model such as an outcome-based education (OBE) learning approach is favored and adopted to reform and renew education policy worldwide. This new learning approach makes teaching and learning more challenging for the academician to administer (Akir et. al. 2012). Along with this challenge is the inclusion of a comprehensive strategy to teach both knowledge and applied skills—including the "4 Cs" of critical thinking and problem solving, communication, collaboration, and creativity and innovation skills — is one that employers, educators and the public are ready to support. In addition, employers want prospective workers to acquire at least some level of industry-specific technical skills before they enter the workforce (ACTE 2010). Thus it is amendable to embed aforementioned challenges during in-school training. Students should learn in advance the required technical skill in industry by means of having industrial equipment to imitate the industrial situations.

Today's technologies come and go at an alarming rate, and the length of time in any technology, either

software or hardware, exists before being supplanted by a newer technology is growing ever shorter. For anyone working within the field of instructional technology, this rapid replacement rate of technologies can hold immense implications for both the development and delivery of educational systems (Amirault 2015).

The need of developing instructional trainers in replica of the essential industrial equipment such as controllers could somehow resemble those technologies found in industries and utilize them to facilitate instruction in the academic premise. Developing the required competencies of the industrial sector is a must in Colleges and Universities in order to produce competent graduates. This situation led to the development of numerous instructional trainers and equipment production enabling technology education to keep pace with the current industrial technological applications.

Different companies offered instructional trainers in almost all fields of engineering and technology applied in industrial setting. But most of these trainers are either limited to some capabilities in terms of skill competency or subject to technical improvements in terms of safety considerations. For instance, the AC Variable Speed Drive Trainer was developed but there were parts of the trainer that needs provision in safety to the user since the terminal connections carrying live circuits used banana jacks which is unsafe because they are exposed (AC Motor Speed Control Trainer 2012). The VLT® Micro Drive FC 51 can be set up to perform perfectly even in complex applications. It is also supported by guided programming of specific functions and the use of a PC software tool for parameterizing (Omron AC Motor Drive Trainer 2012). However the basic motor control competency in the trainer is no longer available. Despite of these deficiencies, purchase cost is still a factor to consider since most of these trainers are extraordinarily expensive.

In this study, Outcomes-Based Trainer for Tabletop Industrial Motor Control utilizing Variable Frequency Drive and Programmable Logic Controller is designed and developed as an instructional device that controls motors in reference to the common application of controllers in industries. The trainer can provide not only competitive learning in terms basic motor controls and advance motor controls in reference to industrial standards. It also has a capability to utilize frequency adjustment for speed control regulation, PLC programming, and modulated controls to drive three phase and single phase motors. These methods of controls and the combination of these control concepts are currently employed in the industry. The developed instructional device is then subjected to evaluation based on pre-determined criteria.

Objectives of the Study

The general objective of the study is to come up with an Outcomes-Based Trainer for Tabletop Industrial Motor Control utilizing Variable Frequency Drive and Programmable Logic Controller as an instructional device.

Specifically the study aims to:
1. Design an Outcomes-Based Trainer for Tabletop Industrial Motor Control utilizing Variable Frequency Drive and Programmable Logic Controller
2. Develop an Outcomes-Based Trainer for Tabletop Industrial Motor Control utilizing Variable Frequency Drive and Programmable Logic Controller
3. Identify laboratory activities based on the trainer's capability.
4. Evaluate the trainer in terms of the following criteria:
    a. Functionality
    b. Aesthetics
    c. Cost Effectiveness
    d. Safety
    e. Mobility

Significance of the Study

This study aims to come up with an Outcomes-Based Trainer for Tabletop Industrial Motor Control utilizing Variable Frequency Drive and Programmable Logic Controller substantial to facilitate and supplement instruction in the field of technology and engineering in pace with industrial aspects taking into account learning and teaching hands on manipulation as teaching resources that provide enhancement in the teaching of motor control, speed control and programming via programmable logic controls of AC electric motor.

The outcome of the study will hopefully help the instructors in enhancing their teaching methodology through actual connection of AC electric motor control, speed control and PLC programming in order to address the specific needs of the students in terms of theory and application of AC electric motor in an industrial setup. It provides student's active laboratory activity through actual manipulation by placing motor control components of their choice. Interactive laboratory activities are dependable method towards quality learning, increasing the skills and competency development in the field of ac

electric motor speed control principle of operation and other control concepts.

Conceptual Framework of the Study

In reference to the aims of the study, development of the instructional trainer is completed through significant processes determined by the conceptual framework of the study shown in Figure 1.1. It is divided into three levels; the input, the process, and the output.

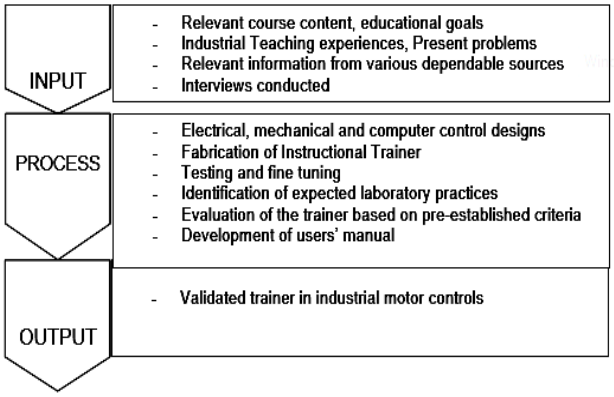

Figure 1: Conceptual Framework of the Study

The input process includes the identification of the relevant course content, the educational goals and objectives, industrial and teaching experiences, identification of problems in present status, and other related information from various dependable sources. Interviews on both instructors and students will also be considered as inputs since this pertinent information is needed to make the study applicable in educational purposes. The process will include the electrical, mechanical and computer control designing, instructional trainer development, construction, evaluation, and development of users' manual. The final output of the trainer will be the validated instructional device in industrial motor controls.

Scope and Limitations

The project prototyping was conducted within the Electrical Technology Management Area under the College of Industrial and Information Technology of the Mindanao University of Science and Technology.

Outcomes-Based Trainer for Tabletop Industrial Motor Control utilizing Variable Frequency Drive and Programmable Logic Controller was developed using low cost materials which is locally available in the market.

The frequency inverter specifications include the following parameters:

1. Single Phase or Three Phase Source
2. 220v AC source, 60 hertz
3. Nominal Power 750 watts
4. Programming Features

The instructional tool can be used as a laboratory equipment to demonstrate and simulate the principle of operation of a single phase and three phase ac electric motor, speed control, effect of overload and over current, PLC control methods and methods of protection. Incorporating the motor to any equipment as a load are limited only to 0.75 Horsepower, thus, beyond the specified limitation of the trainer, it could no longer be able handle these mechanical load and will result for over-current device tripping to protect the trainer. The evaluation of the trainer in terms of the learning impact of the students is not included in this study.

Methodology

Design and Development of the Trainer

Instructional Trainer Parts and Components Figure 2 shows the perspective view of the trainer with its parts and components. The instructional trainer is made up of 2mm thick metal sheets for 635 mm x 508 mm working table and 3.5 mm thick metal sheets for the 635 mm x 635 mm wiring board bonded to 25 mm X 25 mm aluminum frame by means of rivets. A white board measuring 635 mm x 635 mm is attached at the back of the trainer.

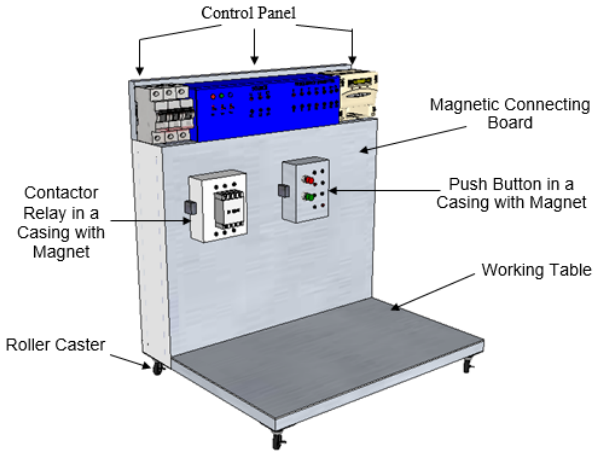

Figure 2. Perspective View of the Trainer

The Panel Board of the Trainer Figure 3 is composed of an overcurrent protection device rated 240 VAC source, three phase and 60 Amps, phase lamp indicators which are mainly used for students comprehension of the AC source troubleshooting, main control terminals which are allocated for speed control by direct to source frequency adjustment and PLC Control terminals which are used to control speed by means of Programmable Logic Control

manipulated through a computer interface operations.

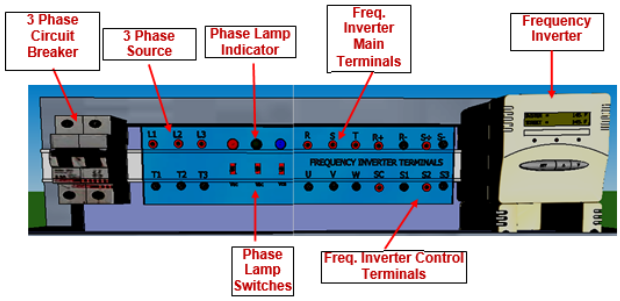

Figure 3. Panel Board of the Trainer

Wiring Connection of Circuit Breaker, Phase Lamps and Switches Terminals in Figure 4 and the Wiring Connection of Frequency Inverter Terminals in Figure 5 shows the wiring connection of circuit breaker, phase lamps frequency inverter terminals and switches terminals to their corresponding connection at the trainer's panel board.

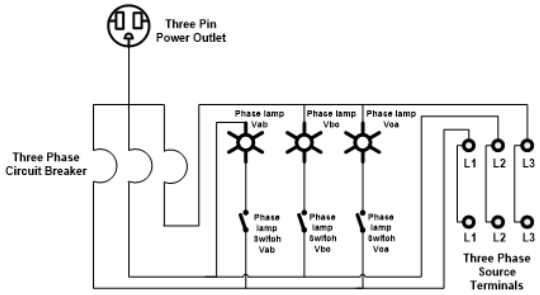

Figure 4. Wiring Connection of Circuit Breaker, Phase Lamps and Switches Terminals

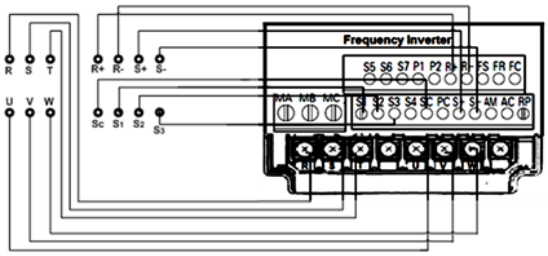

Figure 5. Wiring Connection of Frequency Inverter Terminals

The Magnetic Contactor and Push Button as shown in Figure 6 depicts the magnetic contactor and push button revealing the relay coil and contacts and its corresponding contact terminals attached to a magnetic casing. These components can be attached to the trainer through the magnetic connecting board depending on the choice of location of the user.

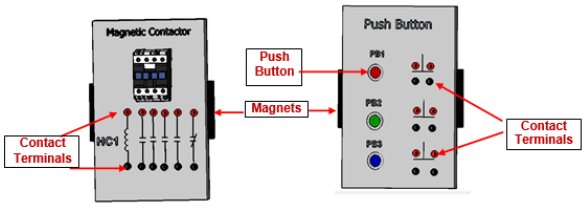

Figure 6: Magnetic Contactor and Push Button

Integration of the parts of the trainer with reference to the above stated mechanical and electrical designs are carefully undertaken while verification and testing phase justify whether the instructional trainer accomplished the expected functions and effectively satisfies the basic requirements in fulfilling the objectives of the study. Testing and trial runs are also undertaken by applying possible laboratory activities at the same.

Identification of Possible Laboratory Activities

The laboratory activities to be performed utilizing the trainer are also identified. Some of the laboratory activities that can be conducted are related to the topics on (a) Principle of electric motor operation; (b) Forward and reverse control operation of AC motor; (c) Speed control operation of AC motors and applications; and, (d) PLC controls operation and interfacing.

Evaluation of the Trainer

The evaluation and validation are the concluding steps by which the performance of the trainer's functions, characteristics and features are assessed purposely by selected evaluation participants. The evaluators are the electrical technology instructors, industry practitioners and electrical technology students who are knowledgeable to motor controls. Questionnaires were prepared based on the pre-determined criteria on functionality, cost-effectiveness, aesthetics, safety and mobility using the five point rating scale (5 as highest and 1 as lowest). Provisions for comments and suggestions were also provided in the survey instrument.

Results and Discussion

The Developed Trainer

The completed Outcomes-Based Trainer for Tabletop Industrial Motor Control utilizing Variable Frequency Drive and Programmable Logic Controller shown in Figure 8.

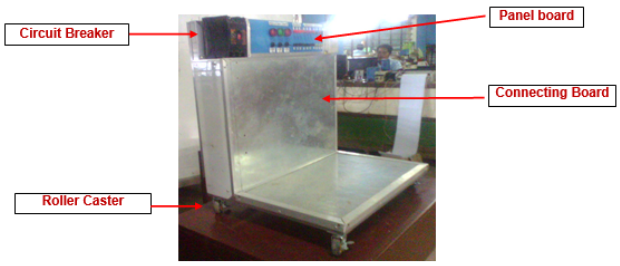

Figure 8: Completed Outcomes-Based Trainer for Tabletop Industrial Motor Control utilizing Variable Frequency Drive and Programmable Logic Controller

In Figure 9, the Metallic Wiring Board of the Trainer was so designed for maximum attraction of magnetic components to hold the attached component in a steady and tough position. The back portion of the trainer is attached to a whiteboard for lecture activities as shown in Figure 10.

Figure 9. Metallic Wiring Board of the Trainer

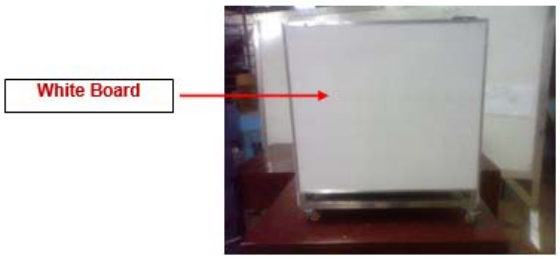

Figure 10. White board at Back Portion of the Trainer

Laboratory Activities of the Trainer

The laboratory activities are anchored on the theoretical topics in industrial motor controls. A brief line-up of some of laboratory activities identified are as follows:

1. Controlling Electric Motor using Direct-On-Line magnetic Starter (DOLMS)

a. Connecting Start and Stop Controls (DOLMS)
b. Connecting Start and Stop and Jog Controls (DOLMS)
c. Connecting Forward-Reverse Controls (DOLMS)

2. Controlling Electric Motor using Frequency Inverter

3. Motor control using PLC Programming

Results of Evaluation of the Trainer

Evaluation of the trainer is conducted utilizing the criteria on functionality, cost effectiveness, aesthetics, safety and mobility. Five (5) experienced industrial practitioners from different local companies, five (5) electrical instructors and thirty (30) electrical technology students from the university participated in the evaluation. The Evaluation Mean Rating of the Different Criteria Considered shown in Table 1 depicts the mean rating of each parameters considered in the study.

Table 1: Evaluation Mean Rating

Evaluation Criteria	Mean Rating *(5-highest; 1-lowest)*	Description
Functionality	4.3	Very Good
Cost Effectiveness	4.2	Very Good
Aesthetics	4.3	Very Good
Safety	4.4	Very Good
Mobility	4.4	Very Good

The components can be placed at any place in the wiring board which develop students ability to apply standard placement of Main Circuit and Control Circuit has a mean rating of 4.2, which means that the users of the trainer found it interesting and gave them ability to decide correct component placement of their choice, while instructors can evaluate in terms of safety and operation requirement of an industrial setup. This aspect is also rated good. Tracing motor control circuits for effective troubleshooting can be visually done because the user can conveniently replace any damage component at easily with a good mean rating of 4.2, which means that the survey participants had effectively applied troubleshooting techniques and replacement of any damaged component can be done at ease. The overall functionality rating indicated an average mean of 4.3, which means that the survey participants support the functionality of the trainer that yielded a good acceptability.

The trainer's cost is justifiable with respect to numerous training activities about motor control and motor speed control has a good mean rating of 4.3, which means that survey participants believed that the cost of the trainer compensates with the capabilities it requires to perform in relation to the numerous training outcome it can cater. Component's costs of the trainer is much cheaper than ready-made set has a good mean rating of 4.2, which means that the survey participants believed that the trainer's components would have been much expensive if they are purchased individually. The overall mean rating indicated an average mean of 4.2, which means the cost effectiveness of the trainer, has yielded good ratings.

Trainer Panel Board constructed pleasingly in terms of color and elegant design has good mean rating of 4.5, which means that the survey participants have appreciated the panel board of the trainer due to its vibrant color and pleasing to the naked eye. Metallic Wiring Board of the trainer is made up of an Alloy Steel presenting a shiny metal surface has a good mean rating of 4.1, which means the survey participants noticed that the metallic wiring board are pleasant to see and components can be easily attached and detached on the board because of its shiny surface. Trainer Frame and structure are sufficiently reinforced to hold up the entire trainer components has a good mean rating of 4.4, which means lifting and handling of the trainer are easy since it is made up of light components but are reinforced completely to hold weight of the trainer and the components attached to it. Overall mean rating in terms of indicated an average mean of 4.3, which means the survey participants found that the trainer's physical appearance and structure has yielded a good rating.

Electrical connection of components are safely placed to eliminate shock hazard Electrical connection of components are safely placed to eliminate shock hazard has a good meaning rating of 4.3, which means that the survey participants who performed sample laboratory activity experienced safe conditions during the activity with the guidance of the instructor assigned. Panel board uses sophisticated technology to detect any electric malfunctions has a good mean rating of 4.4, which means that the survey participants found out that the protective device attached to the trainer has satisfactorily performed its function during events of electric circuit troubles and malfunctions. The overall mean rating in terms of indicated a good average mean of 4.4, which means that the trainer is safe to use and applicable for laboratory activities.

The trainer can easily move in a flat surface from one place to another has a good meaning rating of 4.5, which means that the survey participants found out that the trainer can be moved in place easily by means of the roller caster and can hold its position by means of the roller caster brake. The trainer can be lifted and transferred conveniently from one place to another has a good mean rating of 4.4, which means that the survey participants found out that the trainer can be lifted and transferred without using much effort due to its lighter weight. The overall mean rating in terms of mobility indicated an average mean of 4.45, which means that the trainer has capability to be move, lifted and transferred conveniently.

Conclusion

An Outcomes-Based Trainer for Tabletop Industrial Motor Control utilizing Variable Frequency Drive and Programmable Logic Controller has been designed, developed and evaluated. Such device can control motors in reference to the common application of controllers in industries. As demonstrated in the study, the training device has the capability to utilize frequency adjustment for speed control regulation, PLC programming, and modulated controls to drive three phase and single phase motors, which are currently employed in the industry. Based on the evaluation conducted, the trainer is rated positively (very good) in all criteria considered in the study.

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