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A Tabletop Industrial Motor Control Trainer with Frequency Inverter and PLC Controls

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Abstract
The study focuses on the design and development of a tabletop industrial motor control trainer with frequency inverter and PLC controls. The instructional trainer is designed to innovate and integrate an instructional device that controls alternating current (AC) motor in reference to the common application of controllers in industries. It has the capability to integrate and utilize frequency adjustment for speed control regulation through the frequency inverter and provides option to use programmable logic controller (PLC) to program speed, sequence, and modulation into the motor drive. Further, the trainer has the capability to test three phase and single phase motors following a carefully designed experiments based on theoretical topics stipulated in the course content of motor controls course. Evaluation results show a positive outcome in terms of its functionality, safety, reliability and aesthetics.
Keywords*: Frequency Inverter, Programmable Logic Controller, Motor Controls, Instructional Device, Competency*

1.0 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[1]. 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[2]. 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[3]. 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[4]. 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[5]. 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, a Tabletop Industrial Motor Control Trainer with Frequency Inverter and PLC Controls 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 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.

2.0 METHODOLOGY

2.1 Design and Development of the Trainer

Figure 1 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, and roller caster is attached to the trainer for mobility purposes.

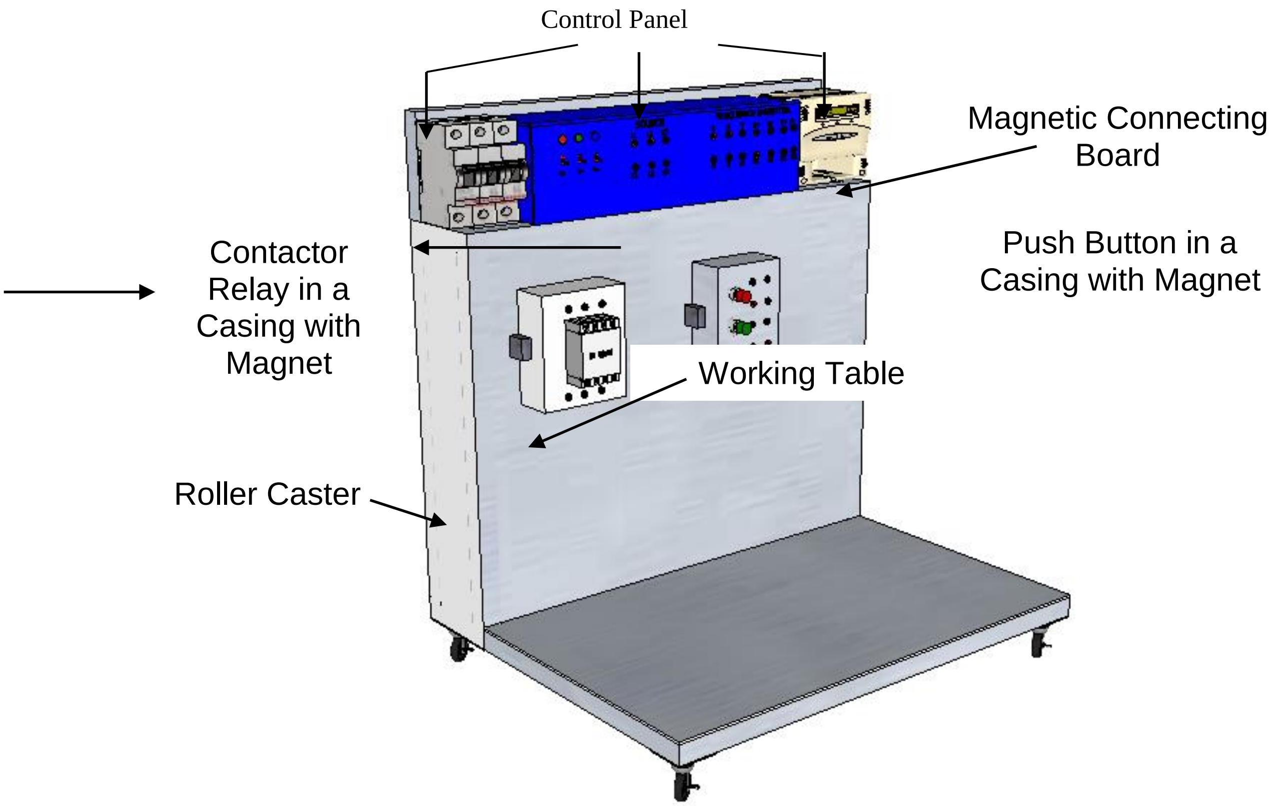

Figure 1. Instructional Trainer Parts and Components

In Figure 2, the panel board of the trainer is shown. It 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.

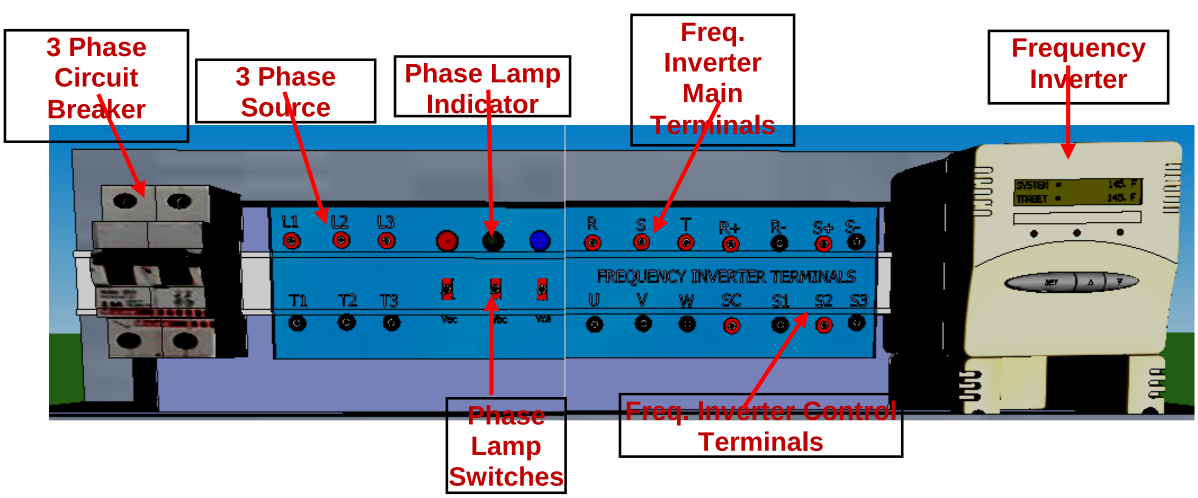

Figure 2. Panel board of the trainer

Figure 3 shows the wiring connection of circuit breaker, phase lamps and switches terminals to their corresponding connection at the trainer's panel board and in Figure 4, the wiring connection of frequency inverter terminals is shown.

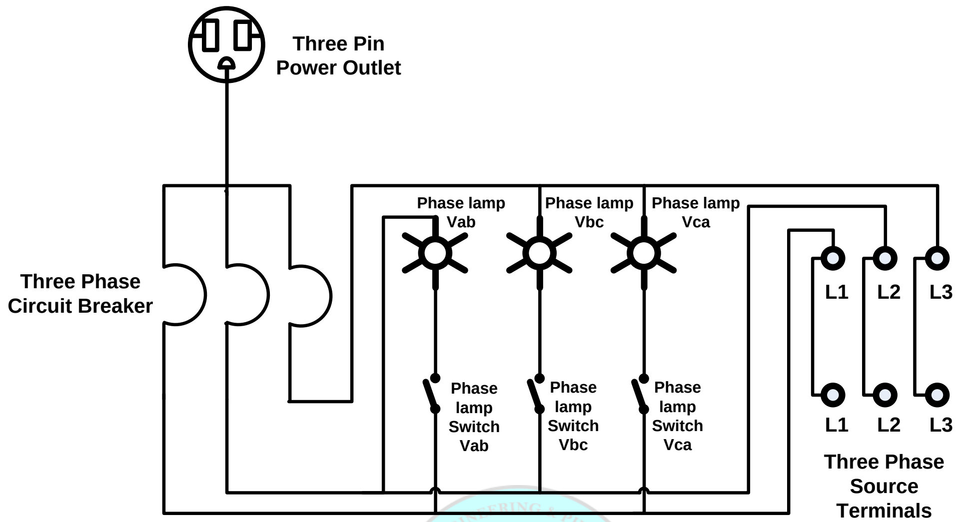

Fig. 2. Wiring Connection of Circuit Breaker, Phase Lamps and Switches Terminals

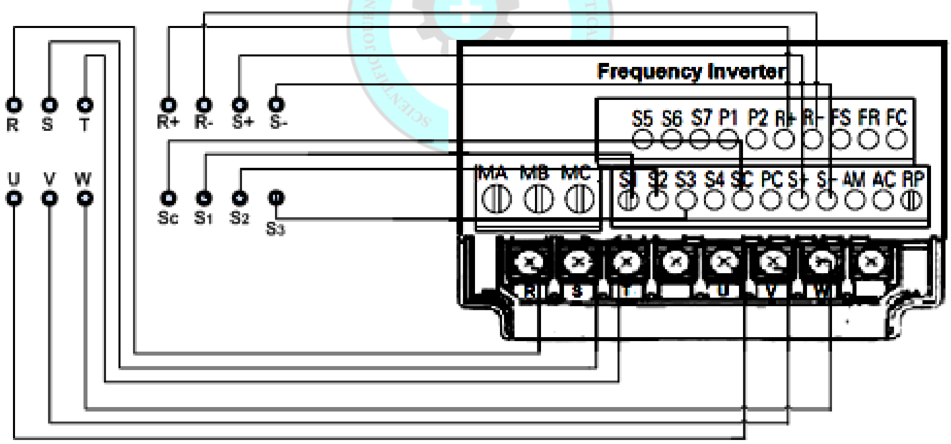

Figure 4. Wiring Connection of Frequency Inverter Terminals

Figure 5 shows 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.

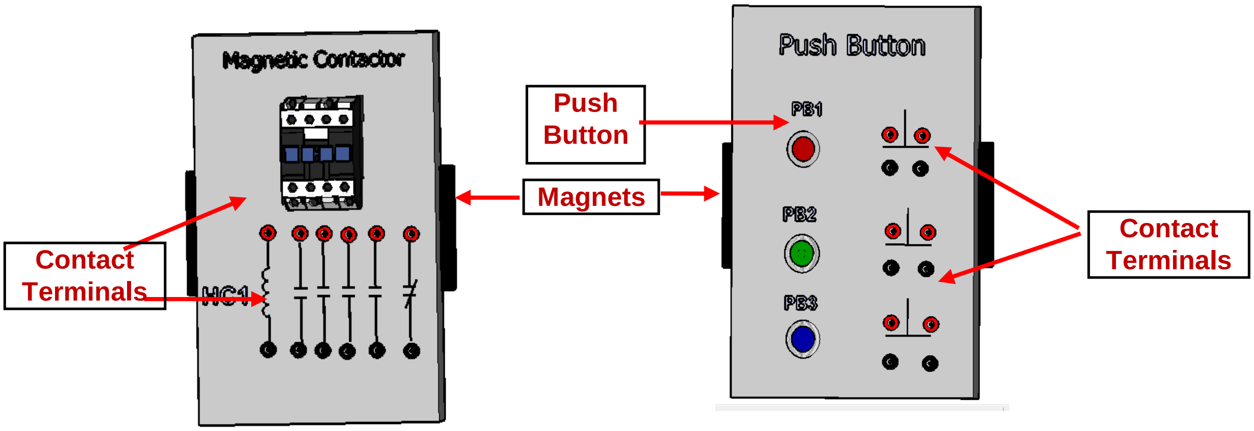

Figure 5. Magnetic Contactor and Push Button

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.

2.3 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.

2.4 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.

3. RESULTS AND DISCUSSION

3.1 The Developed Trainer

Figure 7 shows the completed tabletop AC motor control trainer with frequency inverter and PLC controls. The metallic wiring board was made up of 2.0 mm thick alloy steel plate attached to rectangular aluminum frame fixed by means of blind rivets. The metallic board was so designed for maximum attraction of magnetic components to hold the attached component in a steady and tough position as shown in Figure 8. The back portion of the trainer is attached to a whiteboard for lecture activities as shown in Figure 9.

Figure 7: The Tabletop Industrial Motor Control Trainer

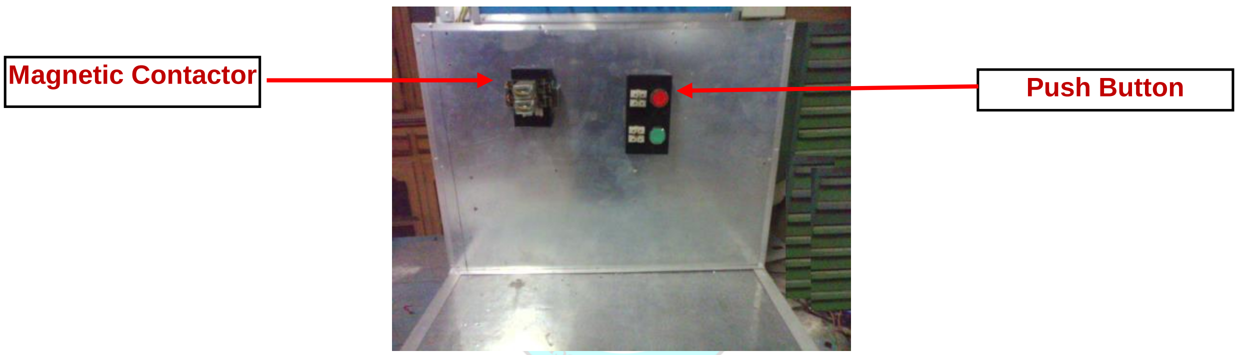

Figure 8: The Metallic Wiring Board of the Trainer

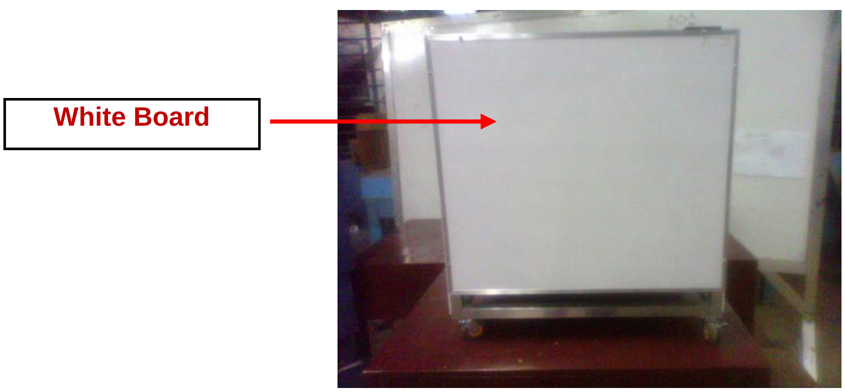

Figure 9: White board at Back Portion of the Trainer

3.2 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:

- 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)

- Controlling Electric Motor using Frequency Inverter
- Motor control using PLC Programming

3.3 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. Table 1 shows the mean rating of each parameters considered in the study. Based on the evaluation results, the respondents rated the trainer positively in terms of its functionality, cost effectiveness, aesthetics, safety and mobility

Table 1: Mean Rating of the Different Criteria Considered

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

4.0 CONCLUSION

An innovative tabletop industrial motor control instructional training device with frequency inverter and PLC Controls 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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