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Design and Development of Electric Motor Controller Trainer: An Instructional Device

MANUEL A. BAJET, JR.
http://orcid.org 0000-0002-7545-971
manuelbajet@gmail.com
University of Northern Philippines
Heritage City of Vigan, Ilocos Sur, Philippines

ROGELIO C. HIDALGO
http://orcid.org 0000-0002-4917-1797
rogeliohidalgo2014@gmail.com
Ilocos Sur Polytechnic State College
Santiago Campus, Ilocos Sur

NELSON A. BAJET
http://orcid.org 0000-0001-5853-3983
nelsonbajet@gmail.com
University of Northern Philippines
Heritage City of Vigan, Ilocos Sur, Philippines

ABSTRACT

Quality education largely depends on the availability of instructional gadgets and equipment which form collectively as facilities in any learning institutions. Allocated budget in higher education is not sufficient in providing all instructional equipment like in technological courses. This triggered the researchers in developing improvised electric motor controller trainer as an instructional device similar to the commercial ones which will be utilized to reinforce laboratory shop setting. The study used project and developmental method of research; planning, designing and product development testing and revisions were implemented. The descriptive- evaluative research was employed in evaluating the level of acceptability. The newly-developed electric motor controller trainer can do the different activities as compared to the commercial ones: a) Start-Stop-Push button control; b) Start-Stop full- voltage starter with alarm silencing; c) Multiple push button stations; d) Jog motor control; e) Forward reverse motor control (electrical interlocking); f) Automatic forward and reverse motion with limit switches; g) wye-delta reduced voltage starter; and h) Two stages sequential control. The level of acceptability of the trainer is generally assessed by the respondents as very much acceptable in terms of usefulness, effectiveness, functionality, reliability, and safety. Packaging and affordability of the device should be endorsed to the Department of Education for the K-12 curriculum purposes.

Keywords – Technology Education, Performance, BSIT, R and D, project and developmental research, Ilocos Sur, Philippines

INTRODUCTION

Japan is the first country in Asia to achieve technology modernization followed by other Asian tigers such as Korea, Taiwan, Singapore, Malaysia, China, and India. All these Asian tigers exert a developmental model which is characterized by 'endogenous' modernity and economic nationalism largely driven by, long-term economic vision and strong political leadership (Jalil, 2010).

China as well, waved a school curriculum reform since 2002 (Lingbiao, 2004). A transition from knowledge delivery to student development took place. The school curriculum encouraged more inquiry learning and problem solving to change student learning from a receptive to an active way. Teachers as well, are encouraged to be more facilitative and interactive in teaching and learning process.

Thailand's chronic problems that global megatrends affect are social inequality, unsustainable country development and education separated from learners' way of life (Niramitchainont, 2013). The roles of educators in Thai social reform are to improve the new education system and develop learners to acquire global competency.

Technical and technological education as an area in the Philippine overall manpower and human resources development program, has a crucial role in providing individuals' skills to be technically equip in consonance to the requirement not just by the Philippine economy, but as well as to be globally competitive.

National development education is considered effective if it is geared towards preparing and training young individuals with the relevant knowledge, skills and right attitude embedded in their chosen academic courses. Also, it must be responsive along technical and technological advantage that would certainly contribute in accelerating productivity and countryside development.

As to statistics, it showed that as of January 2013, some 37.94 million persons were employed and classified as the labor force which comprised 92.9% of the total employment rate (National Statistics Office, 2013). Translating the above figure, it disclosed that there is a wide demand on the number of skilled workers to expanding industries in the local market alone and expectedly, the same in the global industry. Consequently, there is now a big challenge among technological institutions in the Philippines aside from the fact that they have a crucial role in moulding or developing the skills and abilities of students. This is implemented for students to not just to get a job, but to have a better job in the future. Along this line, technological institutions should provide graduates who are globally competitive. Constant revision and improvement of educational facilities are indeed necessary to be done.

Current popular criticism which hurled against technical and technological education is the mismatch of graduates to the needs of industry in terms of skills and quality of performance. Several industries and companies had claimed that school training is inadequate to their needs and that they are compelled to invest by retraining hired workers just to meet their needs and expectations.

Instructional materials used in teaching are essential in motivating students to learn effectively. Likewise, they are used to enhance the curriculum being taught. That is, the technology actually changes the way the teacher is planning or delivering information to his students (Jacks, 2004). Looking into the present trends among local industries, most equipment are driven by electric motors.

Industries and commercial establishments would cease to function without properly designed, installed, maintained and controlled electric motors because electric motors are responsible for a huge portion of commercial and industrial processes. The electric motor control system must be designed and installed to provide the correct sequence of operations for the driven equipment.

An electric motor control is a device or a group of devices that controls or governs the performance of an electric motor. It is also used for starting and stopping a motor, selecting forward and reverse rotation, selecting and regulating speed, limiting the torque and protecting against overload and faults. A motor controller can be manual or automatic in function.

For industrial plants and other industrial sites, the industrial electrician is in-charge of electrical equipment and other types of electric motor controls, from installation to repair and/ or replacement. An industrial electrician is a skilled individual who specializes installation and maintenance of electrical devices and components e.g. electric motor controls installation for manufacturing or production of factories.

For individual who wants to become a competent industrial electrician, he should be trained first at a training institution that offers electrical technology course. However, the schools must have adequate instructional materials, devices, and equipment needed in teaching. Instructional materials are important in teaching because they support student learning. For instance, a worksheet may provide a trainee with good opportunities to enhance a new skill he learned from the class. This process helps the student develop his skills through adequate exposure to instructional materials.

Students taking up Electrical Technology are criticizing the lack of sufficient laboratory instructional materials especially in electrical motor control activities. The persistent problem of non-availability or inadequacy of instructional materials, devices and equipment in teaching electrical technology program has been a great concern of a teacher/instructor. Thus, the researcher wants to design and construct a motor control trainer which will provide students with the proper information that they need in the connection of the different motor control circuits. Motor control is often taught with symbols and circuit/wiring diagrams drawn on the blackboard or a manila paper without any hands-on wiring but with this proposed motor control trainer, teachers/instructors can teach students with real devices and wirings and not merely using the imagination.

The need to innovate is paramount as innovative products from other ASEAN countries will enter the local market (Lugtu, 2013). Companies need to invest in research and development, market research, and production of new technologies.

FRAMEWORK

According Holt (2012), the use of motor control circuits is an effective way to minimize cost through the use of smaller wires and reduced-amperage devices to motor controlling. Motor control circuits are often connected to lower voltages than the motor they control for operational safety and maintenance personnel. A motor control circuit is composed of a switch (or group of switches) and a motor. Motors are often controlled by computerized control systems, solid-state logic controls, or Programmable Logic Controllers (PLCs), but basics of control systems still apply.

Hands-on learning is very important in technical and vocational courses for the actual experiences of students. A trainer is one of the instructional devices that is used in the hands-on learning or individualized learning.

Fernandez (2010) designed and developed an instructional device for the individualized trainer in auto lighting system. The trainer is helpful in providing the students the necessary knowledge in auto lighting system. The study was done through an actual research in the classroom with the experimental subjects. The quasi-experimental method using one-group pre-test and post- test design was employed given the limitation in the size of the experimental subjects. While the design may not suffice to counter all threats to internal validity, the researcher believes that any significant difference between the pre-test and post-test performance of the experimental subjects was indicative of the effectiveness of the Trainer.

Dvoracek (2006) designed an ignition coil driver which is a combination of suitable charging circuit that changes a 4uF capacitor to 380V. If the small capacitor becomes fully charged, sufficient current that flows to the gate stops, thus, preventing the SCR from remaining in the ON state if the switch is held down. A 10 mega ohms resistor is connected across the capacitor to discharge it once the switch is released. This prepares for the next firing. While the SCR is turned ON, it connects the main capacitor to the primary of the ignition coil. The voltage across the primary rises to 380V, thus, storing the energy from the capacitor as strong magnetic field. Once the capacitor is discharged, the voltage falls back to zero and this magnetic field begins collapsing. During this collapse, a reverse polarity to the initial charging current is formed, known as a fly back. This pulse is returned to the capacitor and charges it back up via a 400V Fast diode connected backward across the SCR. This fly back pulse is expected to be around 700V. While the SCR is ON state, this process continues until the energy is taken from the secondary in the form of an arc or commonly referred to as the park. This pulsed nature of the changing circuit ensures that there is always a time when no electricity is flowing, thus, allowing the SCR to switch off.

According to Shrivastava, Rawat and Agrawal (2012), regulating motion is important in industrial atomization. Various types of motors (AC, DC, SERVO or stepper) are utilized based on their applications. Among these motors, the DC motors are commonly used because of their easy control system. On the other hand, the Pulse Width Modulation (PWM) is the best among the different control methods for DC motor armature voltage control method.

Single-phase induction motors are commonly used in various applications (Singh & Giri, 2012). Any development in its performance can contribute to great savings in electrical energy consumption. A cyclo-converter fed variable frequency motor is typical example of such improvement. A cyclo-converter is a device that converts AC power at one frequency into AC power of an adjustable, but lower frequency without any direct current, or DC, stage in between. It can also be considered as a static frequency charger and typically contains silicon-controlled rectifiers.

These studies conducted are mentioned because of their similarities to some aspects as a guidepost in the conduct of the study. However, the main framework of this study is anchored on the Theory of Innovation by Sundbo (2003) which takes place in either a new element or a new combination of elements. As applied to the present study, it aimed to develop, construct and validate an instructional device. Thus, this trainer facilitates the transfer of learning process and also to assist the learning activities among students. Additionally, it helps minimize the problem of inadequate instructional device and equipment that facilitates the teaching-learning process.

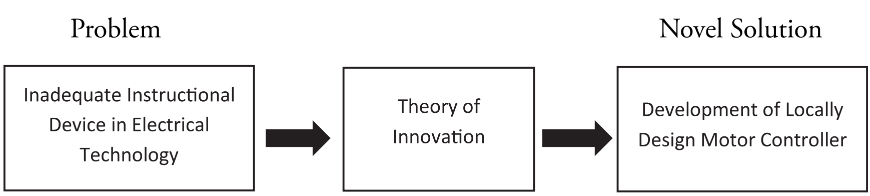

Figure 1. The paradigm

OBJECTIVES OF THE STUDY

The study aimed to design and develop a trainer of electric motor control to simulate the various motor control circuits that can be used as an instructional device to enhance the electrical technology teaching and learning process.

Specifically, it aimed to: 1) Test the different applications of the electric motor controller trainer in the following exercises: a) Start-Stop push button station,

b) Jogging, c) Reverse-Forward, d) Application limit switches, e) Application of timers, and f) Wye-delta; 2) Evaluate the respondents' level of acceptability of the proposed instructional device in terms of the following aspects: usefulness, effectiveness, functionality, and reliability; and 3) Evaluate the fabrication cost of the trainer device.

METHODOLOGY

The study used project and developmental method of research including planning and designing, gathering of materials, product development, testing and revisions. The researchers developed a functional trainer in a motor controller that can be used by students in different applications and connections of motor controls. The descriptive-evaluative type of research was also employed in evaluating the level of acceptability of the research output in terms of its usefulness, effectiveness, functionality, reliability and safety.

The questionnaires contain operations based on usefulness, effectiveness, functionality and reliability of the project. The Likert scale was also utilized in the study.

The device was assessed by 20 experts in electric motor controller coming from the different technical schools, colleges, universities, and different industries of Ilocos Sur: Tagudin Institute of Science and Technology, Ilocos Sur Polytechnic College, University of Northern Philippines, Builders Institute of Technology, Ilocos Sur Electric Cooperative, and TESDA Ilocos Sur. To comply with research ethics protocol, the researchers obtained informed consent from everyone who was interviewed on given questions to answer. They were purposively selected considering their expertise on this particular field of study. The data were gathered through their responses, and were tallied and treated statistically.

RESULTS AND DISCUSSION

Technical Description of Electric Motor Controller Trainer

The development of electric motor control trainer is a modified representation of the electric motor control trainer found or existing in the market. The newly designed electric motor control trainer has multiple functions like the commercial ones e.g. full voltage starting, reversing motors with various interlocking circuits, jogging, wye-delta starting and many other common circuits as direct ON/OFF switching, monitor lamp operation and fault indication.

The connections between the components were made by using standard wires intended for motor control which is connected to the terminal blocks. This will allow the students to make quick and precise connections.

Starting the motor is one main purpose of a motor control circuit. Several methods can be employed depending on the requirements of the circuit. The simplest method is *across-the –line* starting. This is accomplished by connecting the motor directly to the power line. In some situations, it may require the motor to start at low speed and accelerate to full speed over some period of time. In some cases, it may be necessary to limit the amount of current or torque during the starting point.

The main function of the electric motor controller is to halt the motor. The easiest way is to disconnect the motor from the power line and permit it to stop. Sometimes, it requires that the motor be stopped more quickly, or it could also happen that a brake holds load when the motor is stopped.

Meanwhile, jogging and inching are methods employed to move a motor with short jabs or power to move a motor load into some desired positions. The difference between the two is that jogging is done by momentarily connecting the motor to full line voltage while inching is done by momentarily connecting the motor to reduced voltage.

Control systems require variable speed. There are several ways to accomplish variable speed. One of the most common is with variable frequency control for alternating current motors, or by regulating the voltage applied to the armature and fields of a direct motor. Another method may involve the use of a direct current clutch.

The basic function of most control systems is to protect both the circuit components and the motor. On the other hand, fuses and circuit breakers are used for circuit protection, while for motor protection, overload relays are used.

One of the important factors being considered in many control circuits is the voltage spikes or surges produced by collapsing magnetic fields which usually happens when power to the coil of a relay or contactor is shut down. These can induce voltage spikes that are hundreds of volts which can also damage electric components linked to the power line. It is very important to consider the voltage spikes for they have a vital role in computer controlled devices such as programmable logic controllers and measuring instruments used in detecting temperature, pressure, among others. Hence, surge protection is very relevant.

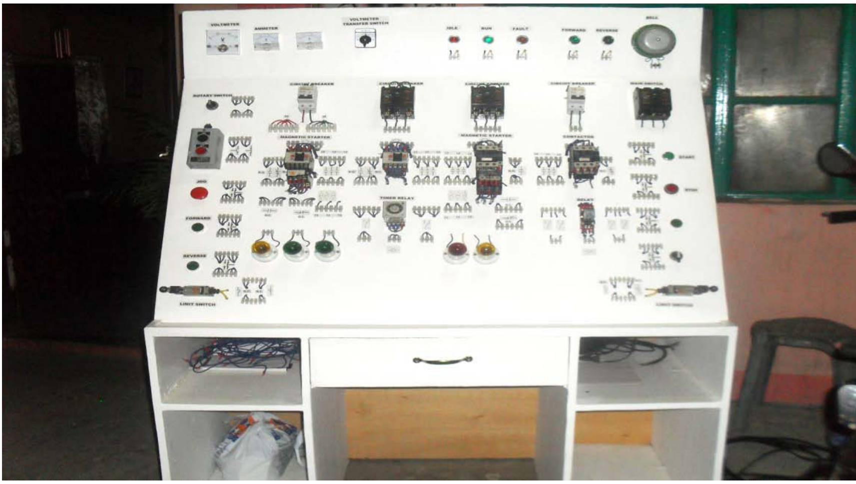

Figure 2. Electric motor controller trainer an instructional device

The newly designed motor controller can be used as an optional motor load. A simulated electric motor load can be constructed by connecting three lamps sockets to form a wye or delta connections.

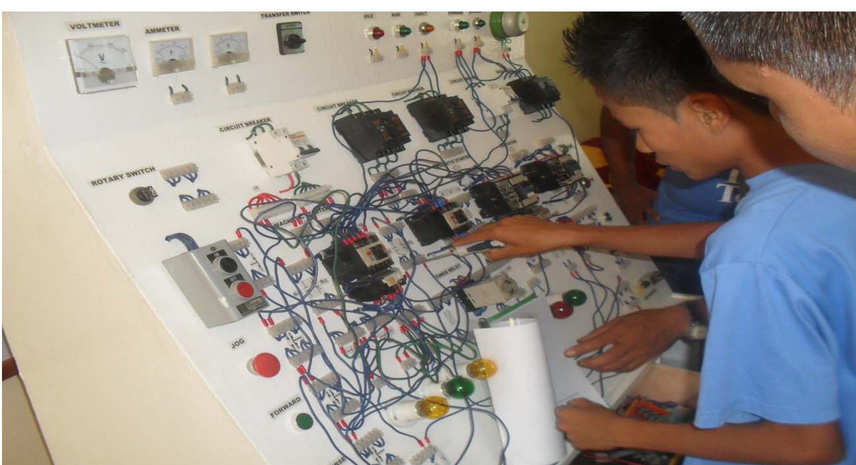

Figure 3. Student is performing "START-STOP, Full-Voltage Starter with Alarm Silencing" at the newly constructed trainer

Table 1. Level of acceptability of the electric motor controller trainer

INDICATOR		MEAN	DR
A. Indicators Along Usefulness			
AVERAGE		4.85	VMA
B. Indicators along Effectiveness			
AVERAGE		5.00	VMA
C. Indicators along Functionality			
AVERAGE		4.93	VMA
D. Indicators along reliability			
AVERAGE		4.86	VMA
E. Indicators along Safety			
AVERAGE		5.00	VMA
	OVERALL	4.93	VMA

Legend:
4.50-5.00 Very Much Acceptable (VMA)
3.50-4.49 Much Acceptable (MA)
2.50-3.49 Acceptable (A)
1.00-1.49 Not Acceptable (NA)

The overall result of the assessment made by the respondents on the acceptability of the trainer is generally interpreted as very much acceptable in all indicators with an overall weighted mean of 4.93. These findings imply that the trainer is very much acceptable as an instructional device for facilitating the process on concepts of the different activities or connections application and troubleshooting in motor controller lessons.

Fabrication cost of the trainer

The cost of fabricating the trainer is Php 25,620.00 (595 USD) and the labor cost is Php 1,500.00 (34 USD) which sums to Php 27,120.00 (630 USD). Hence, it has a greater markup selling price compared with the commercial ones from Php60, 000.00 (1395 USD) to Php 120,000.00 (2790 USD). The cost is considered as commercially competitive considering the technical and economic advantages, safety features and varied teaching-learning activities with the use of this trainer.

CONCLUSIONS

The electric motor control trainer has multiple functions such as full voltage starting, reversing motors with various interlocking circuits, jogging, wye-delta starting and many other common circuits as direct ON/OFF switching, monitor lamp operation and fault indication. The laboratory exercises are connected to full voltage, it is necessary that students must practice safety at all times in performing these exercises. The instructor should be asked each time before power is applied to the circuit. Power should be turned off each time before making changes to the circuit. The different circuits controlled by push button switches and magnetic contactors that are installed on the motor controller trainer; a) Lamp controlled by normally open (NO) push button switch, b) Lamp controlled by normally close (NC) push button switch, c) Lamp controlled by two normally open (NO) push button switch, d) Two lamps controlled by a dual acting push button switch, e)Two lamps controlled by time delay relay TR and, f) Two lamps controlled by magnetic contactors C.

The designed Electric Motor Controller Trainer can do the different exercises or activities like Start-Stop Push Button Control, Start-Stop Full- Voltage Starter with Alarm Silencing, Multiple Push Button Stations, Jog Motor Control, Forward Reverse Motor Control (Electrical Interlocking), Automatic Forward and Reverse Motion with Limit Switches, Wye-Delta Reduced Voltage Starter, and Two Stages Sequential Control.

The level of acceptability of the trainer in terms of usefulness is generally assessed by the respondents as very much acceptable in terms of usefulness, effectiveness, functionality, reliability, and safety with an average weighted mean of 4.85, 4.93, 4.86, and 5.00 respectively. Although all the parameters indicators in the usefulness are rated as very much acceptable, the highest rating is on usefulness in the field of electrical technology specifically in three phase motor lessons with a weighted mean of 5.00 and as interpreted as very much acceptable.

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