Performance of A Programmable Logic Controller Based Electrical Machine Trainer Kit

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Abstract. The objectives of this study were: (1) to develop Programmable Logic Controller (PLC) Based Electrical Machine Trainer Kit; and (2) to examine the performance of the developed trainer kit to be applied in the Electrical Engineering Practices in the Department of Electrical Engineering Education at Faculty of Engineering, Universitas Negeri Yogyakarta. The method used in this study was research and development by referring to the ADDIE model from Branch. The results of the study showed: (1) the size of the developed PLC-based Electrical Machine trainer kit for the bottom side and the back side were 44.1 cm x 100 cm and 92.7 cm x 100 cm respectively. It had a front tilt angle of 80 °, a panel board made of acrylic, a body made of aluminum plate, and an installed PLC with the brand name of Zelio SR2.201FU; and (2) the PLC-based Electrical Machine trainer kit shows satisfactory performance, indicated by all of job descriptions can function properly as planned.

1. Introduction
One of the courses in the curriculum of the Study Program of Electrical Engineering Education is Electrical Machines Practice. This course has a very strategic role in the curriculum since it underlies courses on the concentration of Industrial Control and the Industrial Electricity in the following semester, and it supports the Industrial Practices and Final Projects in the eighth semester. In addition, through this course, it is expected that students will gain the provision of practical electrical machine skills in the industry required for vocational teachers who will educate their students to enter the industry.

In the implementation of electrical engineering practice in the last five years, it is still less than ideal in increasing the achievement of the students. This was indicated by the results of individual practice tests that did not pass an average of 35% in each class and must be remedied to pass the minimum grade of B. In addition, only 10% of the students achieved the A grade. One of the reasons for this problem was inadequate types, number and quality of available equipment for electrical machine practice in the laboratory. The available equipment at the electrical machines laboratory was first procured by the World Bank Project in 1979. In that year, the main practical equipment were 3 units of Terco electric mechanical practice. Along with the age of its use, in 1999, one of them suffered a total damage so it could no longer be used. Since 1999, there were only 2 units of Terco practice machines with low quality. Moreover, with the increasing number of classes and students where each class should accommodate approximately 20 students, electrical machines practice was conducted in large groups and was not effective. In addition, the topics practiced in the Electric Machine Practice course were also limited, namely DC motors, DC generators, three-phase AC induction Motors with wound rotor, three-phase AC
induction Motors with squirrel-cage rotor, synchronous generators and synchronous motors and transformers. Other topics such as 1 phase electric motor and its application, permanent magnet DC motor, starting, rotation settings, braking in induction motor, etc., have not been practiced. On the other hand, the control of electrical machines has evolved using Programmable Logic Controllers (PLC).

Referring to these problems, it was necessary to conduct a study on the development of a PLC-based electrical engineering practice trainer kit in the study program of Electrical Engineering Education, Faculty of Engineering, Universitas Negeri Yogyakarta. In this study, the trainer kit is limited to the starting trainer kit, rotation settings, and DC motor braking, fan and mixer motor rotation settings, and 3-phase induction motor braking. The objectives of this study included: (1) producing a PLC-based electrical machine practice trainer kit; and (2) examining the performance of the trainer kit to be used for electrical machines practice.

Rauner, Maclean, Pabst, & Zimmer [1] suggested several types of learning media in terms of their forms that include real objects, model objects or artificial objects. The media of real objects or artificial objects can be realized in the form of a trainer kit. A trainer kit as a learning medium consists of tools or tangible or artificial objects, and an explanation of the use of the tools in the form of jobsheets or learning modules.

Furthermore, Rauner, Maclean, Pabst, & Zimmer explained that the use of media in learning, can influence the process of students to acquire learning experiences, as illustrated in the cone of Edgar Dale's experience. In the cone of Edgar Dale's experience, the learning experience stretches from the top to the bottom, which shows the learning experience from abstract to concrete. The learning experiences include: verbal, symbolic, visual, radio, film, television, exhibitions, field trips, demonstrations, experiences through drama, experiences through artificial objects, and direct experience. The use of learning media which is increasingly concrete will further facilitate the students’ learning. Conveyor trainer kit with a monitoring system developed in this study included the Edgar Dale cone experience, which is the experience of learning through artificial objects. This means that the conveyor kit trainer with this monitoring system can deliver a more concrete learning experience to facilitate students in mastering the determined competencies.

The existing studies related to the trainer kit, among others, were carried out by Gill, Kumar & Kumar [2] on "Design and fabrication of electro-pneumatic trainer kits", which produced electropneumatic trainer kits for learning in the Department of Mechanical Engineering, Gulzar Group of Institutes, India. Jamaluddin, Ghani, Rahman, & Deros [3] examined the "Development of training kit for learning Taguchi methods and design of experiments", which showed that the Taguchi experiment was successfully carried out through the trainer kit and the factorial design tested was in principle in accordance with information obtained from the Taguchi method. Samanol, Hamid, & Ramli [4] studied the "Development of a pneumatic trainer kit for polytechnic students", which produced pneumatic trainers for the learning of pneumatic basics for students of the Department of Engineering, Seberang Perai Polytechnic, Malaysia. Sean [5] conducted a study on "BeRobot-the robotic scientific education development kits", which produced a human-like robot trainer kit called BeRobot, to be used as a training tool for people working or interested in the robot field.

Another study was conducted by Akparibo, Appiah, & Antwi [6] entitled "Development of a programmable logic controller training platform for the industrial control of processes". The type of study used was research and development. The results showed that an interactive, cheaper and more portable PLC trainer kit was obtained for industrial process control simulations. The parts of the PLC trainer kit consisted of: PLC Delta DVP14SS2 PLC, WPLSoft software, programming devices, switches as inputs and pilot lights as outputs. The PLC trainer kit assisted the students of the Department of Electrical and Electronic Engineering in Ghana to install and program all types of inputs and outputs according to their choices. The PLC trainer kit was easily carried using a carrying case to the desired location, which accommodated the students to study the PLC comfortably anywhere. The application of the PLC trainer kit in learning could improve the students’ achievement compared to the achievement
before applying the PLC trainer kit. It was still limited since the developed product was a PLC trainer kit for simulation purposes only which was still abstract.

Other studies related to the trainer kit was conducted by Bhise & Amte [7] with the topic of "Embedded PLC trainer kit with industry application". This study was research and development. It showed that the embedded PLC trainer kit was obtained for application simulations in the industry, which had the characteristics of: safe, low cost, it had an interface with a personal computer, it met the standard, the programming language used IEC 6-1131, and it had an interface with electrical components. In the application of a trainer kit for students at MTech National Institute of Electronics and Information Technology, Auranagabad, Maharashtra, India, it revealed that the students’ learning achievement can be improved. The study is different from this study in terms of the objects and the use of the PLC trainer kit in tertiary institutions.

Studies related to other trainer kits was conducted by Eko Nugroho Nur Rohman & Sunomo [8] entitled "PLC trainer kit module with load relay safety as learning media for Wonosari Vocational School". The method used in was research and development with the ADDIE model whose research steps including: analysis, design, development, implementation, and evaluation. The results of the study showed that: (1) the performance of the PLC trainer kit module with the load relay safety operated effectively based on the results of three trials; (2) the feasibility level of the PLC trainer kit module according to the user as a whole achieved a score of 76.31%, which was categorized as good; and (3) based on the students’ learning outcomes in the trial of the PLC trainer kit in the learning of the Electronic Control System at SMK YAPPI Wonosari, the PLC trainer kit can effectively improve students’ learning outcomes. The difference between the existing study and this study lies in the developed trainer kit, namely PLC trainer kit with load relay safety, and the product of the trainer kit was used in the subject of the Electronic Control System for Vocational High School competencies in Electronic Electronics.

2. Method
This study is research and development which produce the PLC-based Electrical Machine Practice trainer kit. The development model referred to the ADDIE development model according to Robert Maribe Branch. The research steps included: Analyze, Design, Develop, Implement, and Evaluate [9]. Data collection techniques and instruments used in this study included: (1) in the needs analysis, the data were collected through observation and focus group discussions (FGD), while the instruments used were observation sheets and FGD sheets; (2) in the evaluation of the results of needs analysis and design, the data collection technique was observation, while the instruments were observation sheets; and (3) in the performance testing, the data were obtained through observation with instruments in the form of observation sheets.

To obtain instrument validity, a validity test was performed. In this study, the validity of the instruments was determined with face validity and content validity through expert judgment. To obtain the reliability of the instruments, a reliability test was performed on the instruments. The Likert scale questionnaire with the students as the respondents, , was determined through the calculation of the reliability coefficient using the Croanbach alpha formula. The instrument reliability was in the form of an observation sheet used by two observers to observe the performance of the developed product. It was determined by using the reliability of the Scot. Data obtained in the study were further analyzed descriptively.

3. Results and Discussion
During the analysis stage, observation and focus group discussion (FGD) were conducted. The results indicated that the course of Electrical Machine Practice really requires a PLC-based Electrical Machine Practice trainer kit that can be used for several practical activities, namely: (1) rotation control of DC motors; (2) rotation control of three phase induction motor; (3) rotation control of one phase induction motor; (4) starting DC motor; (5) starting 3 phase induction motor using autotransformator; (6) dynamic
DC motor braking; (7) DC motor braking by plugging; and (8) braking 3-phase induction motor by DC current injection. At the design stage, the PLC-based Electrical Machine Practice trainer kit has been produced as illustrated in Figure 1 and Figure 2.

In the development stage, the PLC-based Electrical Machine Practice trainer kit was produced. The trainer kit had the following specifications: the size of the developed PLC-based Electrical Machine
trainer kit for the bottom side and the back side were 44.1 cm x 100 cm and 92.7 cm x 100 cm respectively. It had a front tilt angle of 80 °, a panel board made of acrylic, a body made of aluminum plate, and an installed PLC with the brand name of Zelio SR2.201FU. The results of developing the electrical machines practice trainer kit are presented in Figure 3 and Figure 4.

Figure 3. The Side View of the PLC-Based Electrical Machine Practice Trainer Kit
Performance testing of the product development in the form of PLC-based Electrical Machine Practice trainer kit obtained results described in Table 1 and Table 2.

**Table 1.** Performance Testing for the Components of the PLC-Based Electrical Machine Practice Trainer Kit

| No. | Part                  | Performance Description                                      | Function | Explanation |
|-----|-----------------------|-------------------------------------------------------------|----------|-------------|
| 1.  | AC Power supply       | Voltage: Neutral Phase = 220 Volt;                          | ✓        | Good        |
|     |                       | Phases = 380 Volt.                                          |          |             |
| 2.  | DC Power supply       | Voltage: 220 Volt DC.                                       | ✓        | Good        |
|     |                       | Voltage: 0 - 220 Volt DC                                    |          |             |
| 3.  | PLC                   | Power supply 220 Volt AC, On if given a power supply.       | ✓        | Good        |
| 4.  | Input I1 - I12 Output | Running a simple Ladder diagram I1 activates Q1 dist.       | ✓        | Good        |
| 5.  | Indicator light (green)| On, if the power is being supplied to the PLC and Off, if the power is not being supplied to the PLC. | ✓        | Good        |
| 6.  | TOR Indicator light (red)| On, if there is an overload on the load and TOR trip and Off, if the load is normal | ✓        | Good        |
7. MC Indicator light (green)  
   On, if the MC coil has electric current and Off, if the MC coil has no electric current  
   √  Good

8. Source indicator light (m/k/k)  
   On, if there is a connected source and Off, if the source is not connected  
   √  Good

9. Push button  
   If it is pressed the contact is connected, if not the contact opens.  
   √  Good

10. Emergency Switch  
    NC is connected when it is normal, NC is disconnected when it is pressed, NO is disconnected when it is normal, and NO is closed when it is pressed  
    √  Good

11. Magnetic Contactor  
    If the coil has a working voltage, NO is closed and NC is open, if the coil does not have a working voltage, NO is open and NC is closed. Main contact performs like NO  
    √  Good

12. TOR  
    When in a normal state, the main contact, the auxiliary NC contact are closed and the NO contact is open. When in a overload state, the main contact and NC auxiliary contact are open, and the NO contact is closed  
    √  Good

| No. | Use of Practice                                      | Performing its function | Explanation |
|-----|------------------------------------------------------|-------------------------|-------------|
| 1.  | DC motor rotation control.                          | √                       | Good        |
| 2.  | 3-phase induction motor rotation control.           | √                       | Good        |
| 3.  | 1 phase induction motor rotation control.           | √                       | Good        |
| 4.  | DC Starting motor                                   | √                       | Good        |
| 5.  | Starting 3 phase induction motor using autotransformator. | √                     | Good        |
| 6.  | Dynamic DC braking.                                 | √                       | Good        |
| 7.  | DC motor braking by plugging.                       | √                       | Good        |
| 8.  | DC injection Braking of 3-phase induction motor     | √                       | Good        |

Table 2. Test Results of the PLC-Based Electrical Machine Practice Trainer Kit

Based on the performance testing results of the PLC-based electrical machine practice trainer in Table 1, all electrical components of the trainer kit are in good condition and can perform their functions. This means that 100% of the components can work appropriately. In addition, Table 2 shows that PLC-based Electrical Machine Practice trainer kit can be used for 8 kinds of practical experiment where the trainer kit perform its function in each experiment. These points demonstrate that the developed PLC-based electrical machine practice trainer kit has a good performance.

4. Conclusion
The PLC-based electrical machine practice trainer kit has been produced with the following specification: the size of the developed PLC-based Electrical Machine trainer kit for the bottom side and the back side were 44.1 cm x 100 cm and 92.7 cm x 100 cm respectively. It had a front tilt angle of 80°,
a panel board made of acrylic, a body made of aluminum plate, and an installed PLC with the brand name of Zelio SR2.201FU. The PLC-based electrical machine practice trainer kit has a good performance, indicated by all of the electrical components and the practical work description can function appropriately as planned.

5. References

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