Performance of Frequency Regulation on Power in the Development of Variable Speed Drive Training Kit as a Learning Media for Motor Control Practices

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Abstract. This study develops a variable speed drive training kit for electric motor control practice media in vocational education. This is research and development with the ADDIE model. The stages of the ADDIE model carried out are Analyze, Design, Development, Implementation, and Evaluation. A Variable Speed Drive (VSD) system consists of two panels, 1) a Variable Speed Drive panel and 2) a control and metering panel. The VSD Training kit module unit using Altivar 71 is a learning medium about electric motor control systems. The VSD Training kit can work well based on trials. The test results of the training kit variable speed drive function test show that at a frequency of 20 Hz, the magnitude of the current in the R, S, and T phases get the lowest value.

Key words: Motor control, training kit, variable speed drive

1. Introduction

Vocational education is one of the formal educations to focus more on increasing the ability or competence to be ready to work in specific majors or fields. One of the fields in Vocational Education is Electricity. A quality learning process is needed to prepare graduates with reliable electrical competence to compete in the world of work. The learning process in vocational education is divided into three, namely theory, practice, and field. One of the practical electrical courses given is the Control System Practice Course. In the learning process, students will practice several types of control systems, working principles and components needed in the control system. In the industrial revolution 4.0, as it is today, the control system is an essential part. In the field of electricity, electric motor control competence is one of the mandatory things that students must be possessed.

The learning process of Control System Practice indeed cannot be separated from adequate learning facilities and infrastructure. According to the Government Regulation of the Republic of Indonesia No. 19 of 2005 concerning National Education Standards, every academic unit must have facilities, furniture, educational equipment, educational media, books and other learning resources, consumables, and other equipment. Needed to support an orderly and continuous learning process [1]. The learning process of the control system practice can be said to be of high quality. One of the indicators is the achievement of the learning objectives of the course.

To achieve the learning objectives, a media that can improve the ability of students in the learning process is needed [2]. Learning media can be used to stimulate the thoughts, feelings, and interests and willingness of students so that the learning process occurs to achieve learning objectives effectively [3]. Based on the above opinion, it can be concluded that to achieve the learning objectives of the...
control system practice in Vocational Education. It is necessary to have learning media that can stimulate the thoughts, interests and feelings of students to improve their abilities.

Based on the results of observations and interviews with lecturers in control systems courses, data is obtained if: (1) there is no learning media in the form of a training kit that makes it easier for students to assemble control systems as to electric motor speed control. (2) The need to increase the student’s motivation in the learning process of electric motor control. Increased motivation can be through media that is interesting and easily understood by students. In the practice of control systems, especially motor control competencies, there is not yet available learning media in the form of an integrated training kit, making it difficult for students in the process of assembling and retrieving measurement data according to the worksheet. That is very unfortunate because competence regarding the control of electric motors such as variable speed drives is very much needed in the era of the industrial revolution 4.0 as it is today.

In the industrial world, by using a variable speed drive, electric motors can be controlled for their performance and speed as needed. Variable speed drives (VSDs) have gained more popularity in recent years, as VSDs not only improve motor load performance but can also provide frequency support in the event of a circuit fault [4]. The development of a Variable Speed Drive Training kit for Electric Motor Control Competency Practice Media in Vocational Education is the title of the research offered to improve the quality and competence of students in learning control system practices in Vocational Education.

2. Main Theory
Learning media is a tool that can help the teaching and learning process and serves to clarify the meaning of the message conveyed so that learning objectives can be achieved properly and perfectly. Learning media can be understood as anything that can share and distribute messages from sources in a planned manner to create a conducive learning environment where the recipient can carry out the learning process efficiently and effectively [5]. Learning media is anything that can be used to channel messages from the sender to the recipient to stimulate the thoughts, feelings, and interests and willingness of students in such a way that the learning process occurs to achieve learning objectives effectively [3]. Based on the description above, it can be concluded that the notion of learning media is anything that is used to clarify the meaning of the message conveyed to stimulate the thoughts, feelings, attention, and interests and willingness of students so that learning objectives are achieved effectively and efficiently.

2.1. Learning Media Training kit
Training kit is a learning media that is included in the form of mock-ups. The Training kit is included in the original object learning media. Learning media of original objects that are not modified are actual objects as they are, without changes, except they are only moved from their original places [5]. These objects have the following characteristics: (1) can be used; (2) in standard size; and (3) known by their real names. Based on this explanation, it can be concluded that the trainer-kit is a learning media consisting of simplification of original objects according to the subject matter that serves to simulate learning activities to increase the effectiveness of learning.

2.2. Variable Speed Drive
VSD or variable frequency drive is a device used to control the speed of an electric motor (AC) by controlling the frequency of the electric power supplied to the motor [6]. VSD can control motor speed (including rotation direction) and operation with sinusoidal current and unitary power factor on the network side [7]. The advantages of VSD compared to other induction motor speed controllers are energy-saving, process optimization, smoother machine operation, and reduced maintenance [8].

The VSD training module unit using Altivar 71 is a learning medium about the Variable Speed Drive system. The entire system in the components and circuits used in this training is also adapted to the existing Variable Speed Drive system. However, so that this training is suitable and worthy as a
learning medium, this training will be designed with a modular concept. Each component is made separately with an attractive design, equipped with the name of the component, the appropriate symbol and various information about the component. Through these designs, it will be easy to use, maintain and can facilitate understanding the concept of the system and installation of the Variable Speed Drive module unit. Training kits can be installed and assembled repeatedly. A VSD system consists of two panels, namely the Variable Speed Drive panel itself and the control and metering panels. The picture of the Altivar 71 module circuit with the ATV71HU40NHZ series used is shown in Figure 1 below [9].

Figure 1. Altivar 71 Circuit.

3. Methods
This research is included in research and development (R&D) research. The purpose of this development research is to develop a Variable Speed Drive training kit as a tool or learning media in vocational education. The development model used in this research is the ADDIE approach. The ADDIE approach includes: Analyze (analyze), design (design), develop (develop), implementation (apply), and evaluate (evaluate) [10]. The implementation chart of the ADDIE model is shown in Figure 2 below.
The analysis activity identifies the problem of implementing basic motor control learning on electric motor control competencies applied to vocational education. They are looking for differences between learning objectives and the reality of the learning process that has been implemented. It is analyzing the urgency of whether or not the development of learning media is necessary and adjusted to various aspects of supporting the variable speed drive training kit. The results of the analysis show that: (1) there is no learning media in the form of a training kit that makes it easier for students to assemble a control system, especially related to electric motor speed control. (2) The need to increase the motivation of students in the learning process of electric motor control. Increased motivation can be through media that is interesting and easily understood by students. In the practice of control systems, especially motor control competencies, there is not yet available learning media in the form of an integrated training kit, making it difficult for students in the process of assembling and retrieving measurement data. That is very unfortunate because competence regarding the control of electric motors such as variable speed drives is very much needed in the era of the industrial revolution 4.0 as it is today.

The following stage designs. It is an activity to design learning media products that will be developed starting from the design of the devices needed in the variable speed drive training kit. Determine the layout of each component of the variable speed drive training kit. The design of the training frame is shown in Figure 3 below.

Figure 2. Implementation of the ADDIE Model

Figure 3. Training Frame
The third stage of development is the stage used to realize the concepts that have been prepared in the design stage into products that are ready to be implemented. At this stage, the researcher developed a variable speed drive training kit with Altivar 71 to practice electric motor control competence. The design and development is carried out by implementing the training kit design into the original training kit form. The image of making the training kit is shown in Figure 4 below.

![Figure 4. Installing Components on the Trainingboard.](image)

The next stage is implementation, which is the stage to apply the product that has been developed in actual conditions. Evaluations are the last stage. After implementing in real conditions, the developed variable speed drive training kit was evaluated to provide feedback on the following performance.

4. Results and Discussion

In the development stage, after installing the variable speed drive components to the training box and checking and adjusting the variable speed drive wiring, the next step is finishing the variable speed drive training kit. The final results of the variable speed drive training kit design are shown in Figure 5 below.

![Figure 5. Training Kit Variable Speed Drive](image)
After the variable speed drive training kit has been assembled, the next stage is a functional test. Functional testing was conducted to determine the performance of the variable speed drive training kit. The load used is a 3-phase induction motor 0.75 kW, 220/380 V, 1450 RPM, 50 Hz. Based on the test results, it is known the amount of power, Irms, and Vrms. The results of the experiment related to the effect of frequency on power on the variable speed drive training kit are shown in Table 1 below.

**Table 1. Effect of Frequency on Power**

| F  | P1  | P2  | P3  |
|----|-----|-----|-----|
| 1  | 0.034 | 0.006 | 0.004 |
| 5  | 0.099 | 0.026 | 0.004 |
| 10 | 0.007 | 0.001 | 0.006 |
| 15 | 0.019 | 0.003 | 0.003 |
| 20 | 0.515 | 3.889 | 1.734 |
| 25 | 0.018 | 0.011 | 0.002 |
| 30 | 0.001 | 0.005 | 0.001 |
| 35 | 0.002 | 0.004 | 0.002 |
| 40 | 0.035 | 0.031 | 0.038 |
| 45 | 0.222 | 0.225 | 0.230 |
| 50 | 0.028 | 0.020 | 0.057 |
| 55 | 0.192 | 0.159 | 0.196 |
| 60 | 0.007 | 0.007 | 0.003 |

Based on Table 1, it can be explained that at a frequency of 20 Hz, the required electrical power consumption is the highest compared to other frequencies. Variable Speed Drive (VSD) is used to overcome energy inefficiency in operating a 3-phase induction motor [11].

The next test stage is the effect of frequency on Vrms. In detail, the results of the frequency influence test on Vrms are shown in Table 2 below.

**Table 2. Effect of Frequency on Vrms**

| F  | VR  | VS  | VT  |
|----|-----|-----|-----|
| 1  | 229.9 | 223.6 | 224.5 |
| 5  | 230.5 | 225.2 | 224.2 |
| 10 | 229.9 | 223.5 | 224.5 |
| 15 | 229.8 | 223.8 | 224.6 |
| 20 | 231.4 | 227.4 | 226.5 |
| 25 | 231.6 | 228.9 | 227.1 |
| 30 | 232.2 | 229.7 | 227.5 |
| 35 | 231.4 | 229.1 | 227 |
| 40 | 230.5 | 227.6 | 227.9 |
| 45 | 230.7 | 227.6 | 228.5 |
| 50 | 230.7 | 227.3 | 226.7 |
| 55 | 230.1 | 226.7 | 226.9 |
| 60 | 228.9 | 225.4 | 225.7 |
Based on Table 2, it can be explained that the magnitude of \( V_{rms} \) \( V_R, V_S, V_T \) at a frequency of 1 to 60 Hz ranges from 223 V to 230 V. This means that the voltage is still in accordance with the standard.

The results of the next trial tested the effect of frequency on \( I_{rms} \). In detail, the results of the test of the effect of frequency on \( I_{rms} \) are shown in Figure 6 below.

![Figure 6. Effect of Frequency (Hz) on \( I_{rms} \) (A)](image)

Based on Figure 6, it can be seen that the magnitude of the current at a frequency of 1 Hz is the most significant current. That is because at that the motor starting current condition. Furthermore, at a frequency of 15-20 Hz, the current in each phase is at its lowest condition. After that, the current gradually increased. Based on the test results, it can be concluded that the variable speed drive training kit can work properly. In all load operation cases, the use of the VSD SW pump has a positive effect on reducing the total fuel consumption [12]. The existence of a variable speed drive can assist in operating the motor load.

5. Conclusion
Development of a VSD training kit using the ADDIE model. The stages of development carried out are Analyze, Design, Development, Implementation, and Evaluation. The VSD training kit consists of 2 panels, a VSD panel and a control and metering panel. The VSD training kit is designed using the Altivar 71 series of modules with the ATV71HU40NHZ series. The VSD Training kit can work well based on trials. The effect of frequency on \( V_{rms} \) of each phase, the voltage is between 223 V to 230 V. The training kit VSD function test show that at a frequency of 20 Hz, the magnitude of the current in the R, S, and T phases get the lowest value.

References
[1] Government Regulation of the Republic of Indonesia No. 19 of 2005 concerning National Education Standards, CHAPTER VII concerning Facilities and Infrastructure.
[2] Kartikasari. Pengaruh Media Pembelajaran Berbasis Multimedia Terhadap motivasi dan Hasil Belajar Materi System Pencernaan Manusia. Jurnal Dinamika Penelitian (63). 2016. 63-68
[3] Sukiman. Pengembangan Media Pembelajaran. Yogyakarta: PEDAGOGIA (2012)
[4] Wang, S., Ma, Y., Short, T., Tolbert, L. M., & Wang, F. Power emulator of variable speed drive with grid frequency support in multi-converter based power grid emulation system. In 2020 IEEE Energy Conversion Congress and Exposition (ECCE) (2020, October) (pp. 1694-1701). IEEE.
[5] Munadi, Yudhi. Media Pembelajaran: Sebuah Pendekatan Baru. Jakarta: Referensi Melinda. 2013.
[6] Atmam, Abrar Tanjung, & Zulfahri. Analisis Penggunaan Energi Listrik Motor Induksi Tiga Phasa Menggunakan Variable Speed Drive (VSD). Jurnal Sain, Energi, Teknologi & Industri, Vol. 2 No. 2, Juni 2018, pp. 52 – 59
[7] Machado, L., Sousa, T. J., Pedrosa, D., Monteiro, V., Pinto, J. G., & Afonso, J. L.. A three-phase bidirectional variable speed drive: an experimental validation for a three-phase induction motor. In International Conference on Sustainable Energy for Smart Cities (pp. 47-57). (2019, December). Springer, Cham.
[8] Gomgom, I. Effendi, Penerapan Variable Frequency Drive Pada Motor Fuel Screw Feeder Untuk Bahan Bakar Pada Sistem Boiler. J. Desiminasi Teknol. 2 (2014) 50–59.
[9] Manual Book DIA2ED2050104EN Altivar 71.
[10] Robert Maribe Branch. Instructional Design: The ADDIE Approach. USA. Springer Science Business Media. 2009.
[11] Sa’ban, M. A. F., Wijanarko, Y., & Pratama, D. A.. Analisis Efisiensi Energi dengan Implementasi Variable Speed Drive Pada Raw Mill Fan Fabrik Baturaja 1 PT Semen Baturaja (Persero) Tbk. In Electro National Conference (ENACO) Politeknik Negeri Sriwijaya. 2021, June. (Vol. 1, No. 1 Juni, pp. 33-48).
[12] Pariotis, E. G., Zannis, T. C., & Katsanis, J. S.. An integrated approach for the assessment of central cooling retrofit using variable speed drive pump in marine applications. Journal of Marine Science and Engineering, 2019. 7(8), 253.