Development of Power Electronic Practicum Units for Vocational Education

E Prianto¹, Sunomo² and T H T Maryadi³

¹,²,³ Department of Electrical Engineering Education, Universitas Negeri Yogyakarta

Email: ¹eko_prianto@uny.ac.id

Abstract. The purpose of this research is to develop a Power Electronics practicum unit in the Department of Electrical Engineering Education, Faculty of Engineering, YSU, so that it is suitable and feasible to be applied in vocational education learning by considering the safety aspects of the components and their users. The development includes a three-phase AC source voltage drop from 45 volts to 24 volts per phase, load replacement, the use of up and down voltage converters with greater current capability, and a direct voltage power supply without a transformer switching model. The method used is research & development with technical tests for each part of the module according to the purpose of setting up the practicum unit. The research results were obtained; the power supply with a 24 volt AC source is able to supply a current of 3.63 amperes at a direct voltage of 20 volts with a voltage drop of 0.5 volts, a direct voltage lowering converter is able to change the voltage from 15 volts to 6 volts at a current of 3.66 amperes, with a voltage drop of 0.13 volts. A direct voltage booster converter is able to convert a voltage of 15 volts from 1.78 amperes to 25 volts with a voltage drop of 0.1 volts. The four-pole three-phase motor can be controlled via the TRIAC from zero rotation to maximum rotation, the protection system is capable of breaking the fuse instantaneously in the event of a faulty connection from phase-neutral to phase, followed by disconnection of the 24-volt three-phase AC power source within one second.

1. Introduction

The development of the electronics industry is developing very rapidly, the electrical engineering expertise vocational program must meet the needs of learning media to support the learning process [1]. Power electronics, according to [2] and [3], is a science related to the use of electronic devices to control and convert large electrical power, including the realm of control (control system). Power electronics is the application of solid-state electronics to control and convert one form of electrical power to another form such as converting between AC and DC or changing the magnitude and phase of voltage and current or frequency or combination of these [4]. Some experts determine that Power Electronics is a multidisciplinary subject while for some other experts consider it an interdisciplinary subject. From the student's point of view, no matter which side Power Electronics was on, they always saw it as a difficult subject. Most of the vocational engineering (TVET) students might consider this course more of a burden [5]. The power electronics laboratory should have a manual. The laboratory should be an integral component of the power electronics and electrical machinery curriculum. Students must understand not only the conversion system but also more advanced concepts such as
control theory, speed, and position sensing, switching signal generation, gate drive isolation, circuit layout, and other critical issues [6]. The power electronics practicum unit (trainer) in the Electrical Engineering Education Department uses the German Standard with a three-phase voltage of 45 volts per phase so that its technical feasibility is inadequate due to the use of a 50Hz ballast transformer as an inductor in the switching system and converter system, both lowering and an increase in voltage and is only an open loop with an electric current of 100mA.

This research was carried out by developing the power electronics lab unit by reducing the voltage source from three-phase 45 volts to 24 volts per phase and developed it so that it is technically feasible to be used as a practical unit for vocational education. The converter is made with open-loop and closed-loop systems using the TL 494 control IC produced by Texas Instruments. A new load in the form of a 24/41 volt three-phase motor is used as practical equipment on the topic of three-phase system phase control with TRIAC. Reference to the specifications of the practicum unit was adopted from Purdue University (Indiana, USA) and the University of Illinois at Urbana. The purpose of this study is to develop a Power Electronics practicum unit in the Department of Electrical Engineering Education, Faculty of Engineering, YSU, so that it is suitable and feasible to be applied in vocational education learning by considering the safety aspects of the components and their users. The safety aspect of the power electronics lab unit can be seen from the speed of disconnecting the electronic fuse to protect the practicum unit with a current cutoff limit of 5 amperes in the event of a phase-neutral 24 (volt) to phase-to-phase (41 volt) fault.

Figure 1. Previously used Power Electronics module specifications

2. Method
The method used in this research is research and development (R & D). The development model carried out refers to the ADDIE model. The ADDIE model stands for Analysis, Design, Development, Implementation and Evaluation developed by Dick and Carrey. The stages in the ADDIE model can be seen in Figure 2 as reported by [7]. ADDIE is carried out with the aim of redesigning the practicum unit and providing additional electronic protection in the form of a Fuse Destroyer and Phase Failure which works on 24 volts back and forth, testing all loads and evaluating the technical specifications. Evaluation of the technical specifications of the converter includes current capability, voltage drop and work resistance.
Figure 2. ADDIE Model

2.1. Analysis
The analysis starts from the availability of electronic components on the market, the security level of the module unit to be made, in terms of possible connection errors (connection) made by the practitioner.

2.2. Design
The design process is carried out by designing power electronics practicum units. The master module unit system frame design uses the previous module unit design. Changes made in the form of replacement of the acrylic design and the source voltage circuit.

2.3. Development
Development is carried out by assembling a power electronics practice unit to realize the design. The development is carried out on the sub-unit module, apart from the front panel in the acrylic section which contains the safety system, voltage terminals, and power switches. Sub-module units, namely units that can be removed and installed (plug and play) on the main module in accordance with the topic being studied are the parts that will be developed. The sub-module units developed include; load module unit, direct voltage converter module unit in the form of a boost converter, open and closed-loop systems, buck converter, open and closed systems, 24-volt three-phase motor load unit, and supply, power by using transformerless switching technology.

2.4. Implementation
The implementation process is carried out by means of technical tests for each part of the module according to the purpose of setting up the practicum unit. This process is carried out in three stages, the first stage is the functional test of each module unit which includes the main module unit test and the sub-unit module test. The first stage of the test is to test each type of load. On the lamp load by observing whether it is too bright and hot, or vice versa. The light of the flame is reset to make it comfortable on the eyes by inserting a series resistor. The second stage of the test is the stability value of the converter output voltage at no-load conditions to full load with a current above one ampere. The third stage test is testing the AC drive, this test is carried out on the motor speed regulation, can it be adjusted from the motor to a stop until the motor is fully rotated.

2.5. Evaluation
The evaluation stage is carried out to correct deficiencies in the practicum unit. After testing, the deficiencies obtained from the technical specifications of the practicum module unit are fixed. Improvements can be made from re-analyzing, redesigning, to redeveloping the practicum module to get the best specifications.
The data to be searched is in the form of the value of the source voltage and current capability at the output of the main module, the ability to work on each sub-module unit, and the technical feasibility of the unit as a whole including the resulting current capability, the output voltage drop in the output current being tested and a description of the motor speed range. The data analysis method is carried out by descriptive data analysis, which will describe the performance of each sub-unit module and the main module as a whole through the feasibility of its technical specifications, namely its ability to disconnect the fuse and disconnect the three-phase source automatically in the event of a break in one of the melting guards. The specification of the feasibility of the converter module is in the form of voltage drop technique data when loaded with large currents in accordance with the resistive character of the lamp load. Analysis of three-phase motor speed control disrupts the condition of the motor that is able to adjust the speed from idle or not rotating until it reaches full rotation when it gets a three-phase voltage supply in sine form.

3. Result and Discussion
The development was carried out by replacing the 220-volt alternating voltage for L1, L2, and L3 in the previous module which was removed and replaced with a 24-volt system. The development of the step-up and down-voltage converters includes schematic drawings made in accordance with the standard form of the step-down and voltage-stepping converter technique in the module unit with elements in the form of source voltage, inductor, switcher, and PWM, while the previous form uses direct electronic component images.

![Figure 3. The practicum unit that has been developed](image)

For lamp loads, the result of the development is the replacement of a 220V / 100Watt incandescent lamp into a dual filament motorcycle incandescent lamp. The light intensity of load lamps is convenient to use in practical implementation. The development of the module is carried out by adding electronic protection for automatic fuse breakers and phase loss detectors as shown in Figure 4.
Test the performance of the step-down and step-up converter circuit using a resistor or lamp load, not a resistor that can be adjusted, resulting in incorrect current values. This is not a problem, because in the implementation of the practicum later, the teacher can use a resistive load whose resistance value can be adjusted so that students get the right current data.

Table 1. Test Results of the Converter and Power Supply.

| Test Type         | Input | Output | Load Type                        |
|-------------------|-------|--------|----------------------------------|
| Voltage Increaser (boost converter) | | | |
| Without Load      | 15    | 0,03   | 25                               |
| Loaded            | 15    | 2,17   | 24,9                             |
| Loaded            | 15    | 3,39   | 24,9                             |
| 6 (decrease/drop) | > 5   |        | 1,12                            |
| Voltage Decreaser (buck converter) | | | |
| Without Load      | 15    | 2,01   | 6,87                            |
| Loaded            | 15    | 3,86   | 19,5                            |
| Power Supply (AC to DC Converter) | | | |
| Without Load      | 25    | 0      | 20                              |
| Loaded            | 25    | 3,86   | 19,5                            |
| Without Load      | 25    | 0      | 9                               |
| Loaded            | 25    | 1,61   | 8,7                             |

From the functional test results obtained, the automatic fuse breaker system works when the input voltage to each unit exceeds 2 volts from the peak voltage value. This system works to protect CMOS and MOSFET ICs which have a maximum absolute voltage of 20 volts. The phase loss protection system will react due to a break in the melt safety.

The results of the functional test of the power supply and converter (increasing or decreasing the voltage) obtained a maximum current value that is not round. This is due to the test using a lamp load, both a 24-volt lamp is connected in series with a 12.5 ohm 40-watt resistor, or a 24-volt lamp without a row of resistors to test voltages below 10 volts, and a 1-ohm resistor. To produce around value one must use a large power variable load resistor. Compared to previous up-and-down converters which were only capable of producing load currents below 10 milliAmpere, the converter results of the
development show much better performance and can be measured using measuring instruments available in the laboratory so that in the calculation of practical results, students will get a theoretical calculation value close to the value of practical results.

4. Conclusion

In the power electronics practicum unit being developed; The electronic fuse breaker that is made able to work to protect the module unit by breaking the 5-ampere fuse safety in the event of a phase-neutral or phase-in connection, the 24/41 volt three-phase power source automatically shuts off after a break of the melting safety of one of the phases due to a wrong connection. or loads that exceed 5 amperes in one second. With this kind of module units: the student of vocational education more safely (using very low working voltage), cheap, reliable, durable, easy to be repaired (the unit constructed with common electronics component).

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