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Inverter Practical Module Design for Power Electronics Course in Electrical Engineering Education Study Program

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Abstract— Inverter material is one of the essential materials in power electronics courses. An inverter is an electronic device that converts direct current (DC) into alternating current (AC). This concept is the foundation of electronics. Because the power electronics course is a practicum course, a practicum module is required as an intermediary teaching medium; this practical module discusses 3-phase inverter material, which uses the pulse width modulation (PWM) and sinusoidal pulse width modulation inverter (SPWM) switching methods. Through Tinkercad software, the circuit is assembled, and the output wave results from the two methods used are seen in designing the 3-phase inverter practical module using the Research and Development method. This research uses media and material validation sheet instruments to determine the feasibility of the 3-phase inverter practicum module. The research results showed that the percentage of media experts was 94%, material experts were 81%, and language experts were 84%. Hence, the 3-phase inverter practicum module is very suitable for use and can make it easier for students to understand inverters. Thus, developing a 3-phase inverter practicum module can effectively increase students' understanding of inverter material and interest in learning. It can also be an alternative for lecturers in teaching.

Keywords: power electronics, SPWM, PWM, practical module.

I. INTRODUCTION

Power electronics is an electrical course that often does practical work to understand various electronic components, such as current, voltage, frequency, control systems, and others, in converting electricity so that the electric current can be distributed and used. Students can use various teaching materials to understand power electronics broadly and deeply, one of which is inverter material. An inverter is an electronic device that converts direct voltage (DC) to alternating current (AC) (Apriani & Barlian, 2018; Can, 2022; Mundus et al., 2019; Ruman et al., 2019; Sangi & Mamahit, 2024; Zeng et al., 2018).

Inverters with sinusoidal techniques usually go through two switching methods: Sinusoidal Pulse-Width Modulation (SPWM) (Albert et al., 2023; Hidayat et al., 2022; Mahto & Mishra, 2020; Ruman et al., 2019), which is one of the switching techniques that produces an inverter output waveform with characteristics approaching sinusoidal with this technique, the output voltage cannot reach its maximum value and produces higher harmonic distortion. Pulse width modulation (PWM) is a way to manipulate the width of a signal expressed by a pulse over some time to obtain a different average voltage. Pulse width modulation is obtained with the help of a square wave, where the wave's duty cycle can be changed to obtain a varying output voltage, which is the average value of the wave (Gao et al., 2020; Jiang et al., 2021; Jiménez-Castillo et al., 2019; Saripurna et al., 2019; Veerabathini et al., 2018).

Usually, students doing practicums only understand the various teaching tools available in the laboratory, even though, with the development of sophisticated technology, these tools are already available in the form of software that can be accessed on laptops wherever and whenever they want. Many electrical software programs support students' understanding of power electronics, one of which is Tinkercad.

From the observation results of researchers in the Electrical Engineering Education Study Program in direct interviews with expert lecturers in the field of electricity, a teaching module is needed for the Power Electronics course so that students can understand various electrical components widely whenever they want in the form of software. Therefore, researchers are interested in conducting a study entitled Design of a Practical Module for a Power Electronics Course in the Electrical

Engineering Education Study program. This study aims to determine the preparation of a 3-phase inverter practical module in the power electronics course. Moreover, to determine the results of testing the 3-phase inverter practical module by the validator.

II. METHOD

The researcher uses the Research and Development (R&D) method. R&D is a type of research that aims to develop a new and valuable product or innovation (Audretsch & Belitski, 2020; Bustinza et al., 2019; Dwiansyah Putra et al., 2020; Fatirul & Walujo, 2022; Gustiani, 2019; Oei et al., 2024; Rayanto & Sugianti, 2020). To design an inverter practicum module in the power electronics course, researchers must go through several stages to become teaching materials.

In this study, the researcher simplified the product development stages into several more straightforward stages. Guided by the stages of research and development of Sugiyono's Research & Development (Sugiyono, 2021), the researcher only needed several stages to design a 3-phase inverter practical module according to the researcher's needs, as seen in Figure 1.

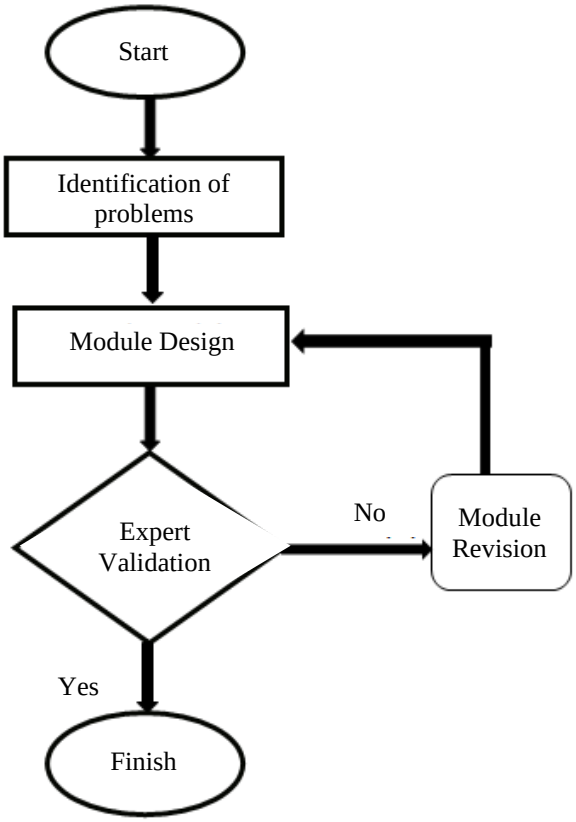


Figure 1. Research flow diagram

In this study, the instrument used is the media and material expert validation sheet. The media and material expert validation sheet is used to measure the validity and feasibility of this study's media, material, and language (Saski & Sudarwanto, 2021). The data collection technique in this study is a validation sheet, which provides a validation sheet to each validator in terms of media experts carried out by Hari Anna Lastya, M.T., / Hadi Kurniawan, M.Si. At the same time, the material expert is carried out by Sadrina, S.T., M.Sc. / Raihan Islamadina, S.T., M.T. For language experts, it is carried out by Mrs. Rahmayanti, M.Pd. / Juniar Afrida, M.Pd. This activity seeks expert validators' input, criticism, and suggestions on the 3-phase inverter practicum module.

After the data has been successfully collected through validation sheets from media, material, and language experts, it will be processed through analysis techniques. This study used quantitative data analysis. Quantitative data analysis begins using data obtained from interviews, observations, and expert input in words, responses, suggestions, and criticisms. The data obtained is used as a guide in improving product development.

III. RESULTS AND DISCUSSIONS

A. Design of Practical Module

This study aims to design an inverter practical module for the power electronics course in the electrical engineering education study program and to determine the feasibility results of the practical module based on expert validators from media, materials, and language.

1. Programming Code

In the initial stage, the researcher used the C++ language for the pulse width modulation (PWM) switching method and the sinusoidal pulse width modulation (SPWM) method. Programming is the most crucial part of the design stage of a 3-phase inverter practical module. If the programming code is wrong, the results of the two switching method circuits will be in error and will not produce the output waveform desired by the researcher. Students can set the desired output waveform by changing the value at int a = 1000 or 100 to see the PWM waveform change and the int value with d and t.

2. Designing the Circuit

The 3-phase inverter circuit is simulated using electrical software, namely Tinkercad, which can

produce output waves resembling an oscilloscope. The software is run on a laptop and uses a stable internet network. The PWM and SPWM programming codes are inputted, and then the circuit is made as in Figures 2 and 3.

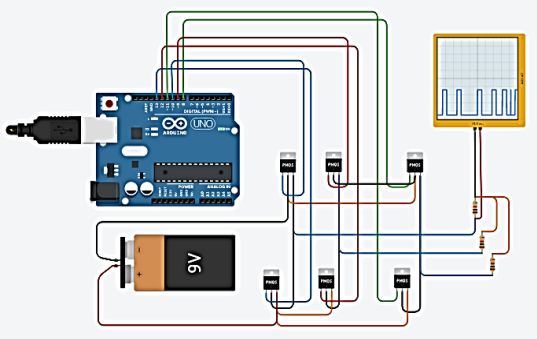


Figure 2. PWM circuit and waveform

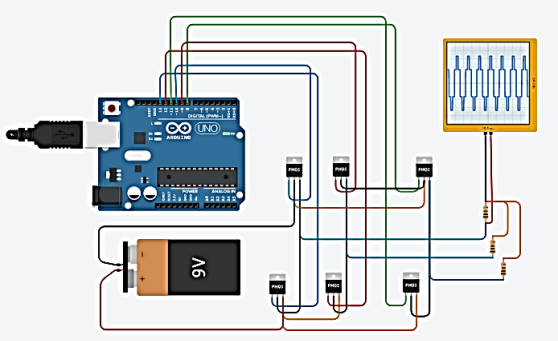


Figure 3. SPWM circuit and waveform

3. Module Design

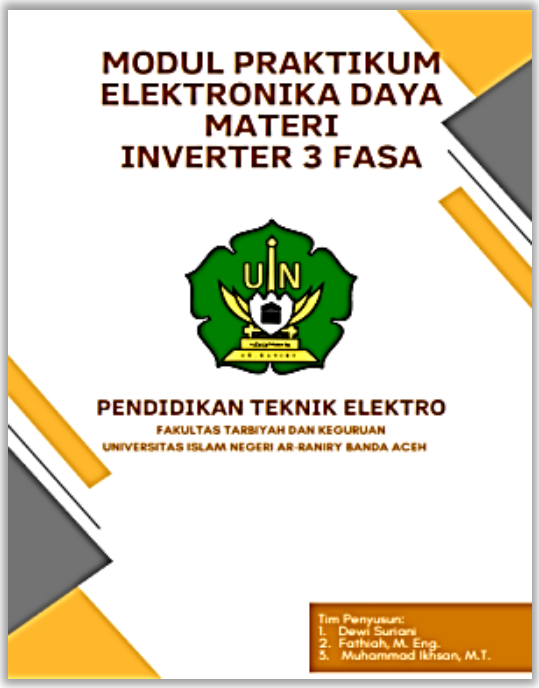
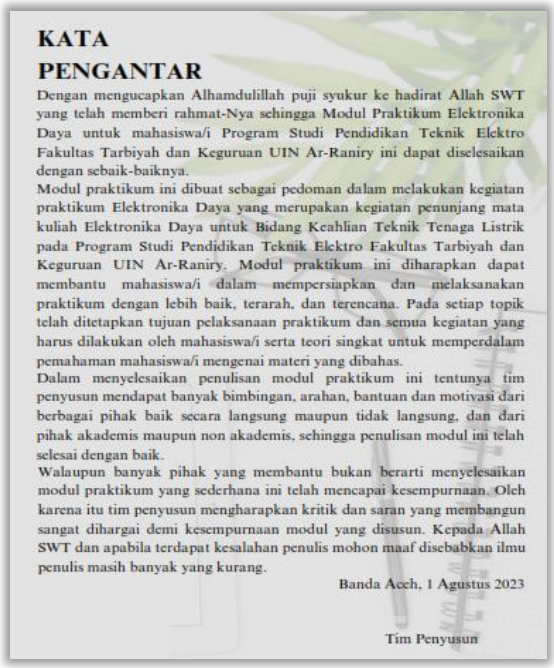


Figure 4. Practical module cover design

The module introduction, which is part of a module containing praise, gratitude, and the introduction of the module, is on the cover page (Figure 4). The module introduction can be seen in Figure 5.



KATA PENGANTAR

Dengan mengucapkan Alhamdulillah puji syukur ke hadirat Allah SWT yang telah memberi rahmat-Nya sehingga Modul Praktikum Elektronika Daya untuk mahasiswa/i Program Studi Pendidikan Teknik Elektro Fakultas Tarbiyah dan Keguruan UIN Ar-Raniry ini dapat diselesaikan dengan sebaik-baiknya.

Modul praktikum ini dibuat sebagai pedoman dalam melakukan kegiatan praktikum Elektronika Daya yang merupakan kegiatan penunjang mata kuliah Elektronika Daya untuk Bidang Keahlian Teknik Tenaga Listrik pada Program Studi Pendidikan Teknik Elektro Fakultas Tarbiyah dan Keguruan UIN Ar-Raniry. Modul praktikum ini diharapkan dapat membantu mahasiswa/i dalam mempersiapkan dan melaksanakan praktikum dengan lebih baik, terarah, dan terencana. Pada setiap topik telah ditetapkan tujuan pelaksanaan praktikum dan semua kegiatan yang harus dilakukan oleh mahasiswa/i serta teori singkat untuk memperdalam pemahaman mahasiswa/i mengenai materi yang dibahas.

Dalam menyelesaikan penulisan modul praktikum ini tentunya tim penyusun mendapat banyak bimbingan, arahan, bantuan dan motivasi dari berbagai pihak baik secara langsung maupun tidak langsung, dan dari pihak akademis maupun non akademis, sehingga penulisan modul ini telah selesai dengan baik.

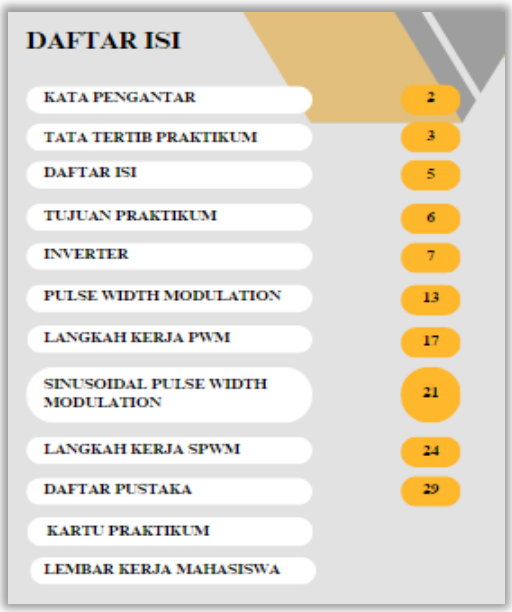
Walaupun banyak pihak yang membantu bukan berarti menyelesaikan modul praktikum yang sederhana ini telah mencapai kesempurnaan. Oleh karena itu tim penyusun mengharapkan kritik dan saran yang membangun sangat dihargai demi kesempurnaan modul yang disusun. Kepada Allah SWT dan apabila terdapat kesalahan penulis mohon maaf disebabkan ilmu penulis masih banyak yang kurang.

Banda Aceh, 1 Agustus 2023

Tim Penyusun

Figure 5. Module introduction

The table of contents page contains a short list of the main titles or sections contained in the module, accompanied by page numbers or serial numbers that refer to the location where the sections are found in the module so that it is easy for readers to find the page they want to read. The module table of contents can be seen in Figure 6.



DAFTAR ISI

Figure 6. Table of contents of the practical module

The rules page contains rules that students must obey and directions from lecturers that must be applied in the practicum environment or to regulate the behavior of practicum participants. This includes safety regulations and instructions during the practicum. The rules can be seen in Figure 7.

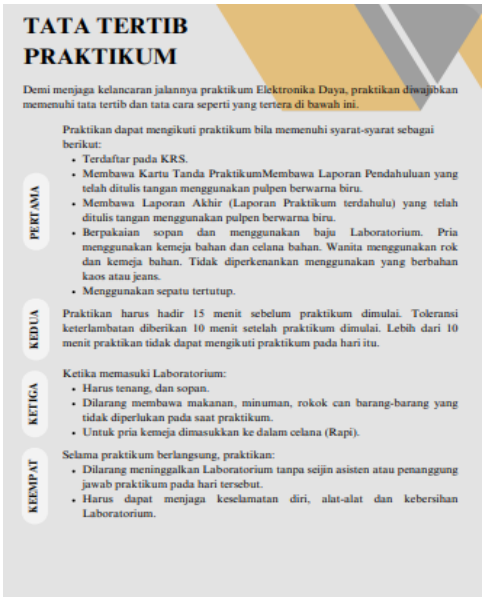


Figure 7. Practical module rules and regulations

The practicum objective page contains initial instructions for students to know the objectives of conducting practicum on 3-phase inverter material, and the most important thing is that students can find out the equipment they must provide, which can be seen on this page. After conducting the practicum, students are expected to understand the theoretical concepts studied in the module and those applied in real situations or practiced directly during the practicum to achieve the expected ability goals. The practicum objective page can be seen in Figure 8.

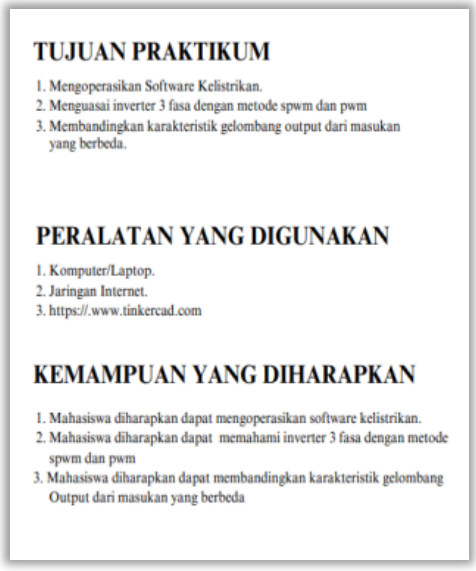


Figure 8. Initial instructions for the practicum

The inverter page explains the material regarding the inverter that can change direct current (DC) voltage into alternating current (AC) output voltage, as well as how it works accompanied by a circuit from the inverter to the resulting output waveform. The inverter page can be seen in Figure 9.

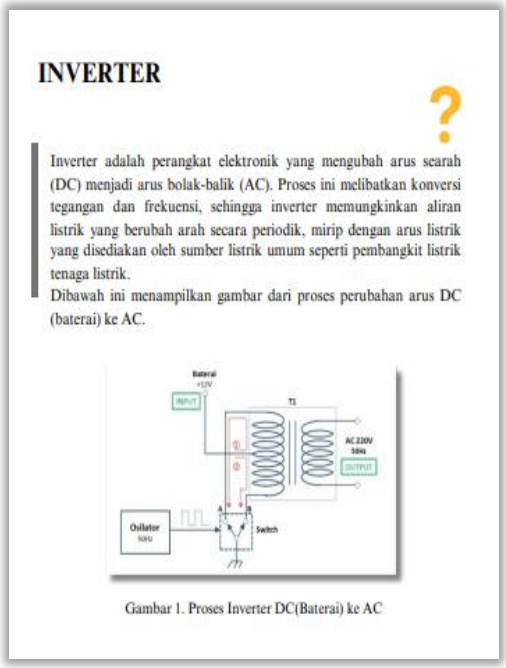


Figure 9. Inverter material

This page explains the material regarding Pulse width modulation and sinusoidal pulse width modulation, which are methods used in running this 3-phase inverter module. The method page can be seen in Figure 10.

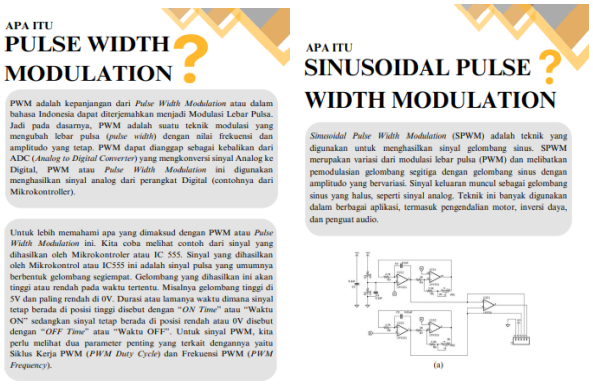


Figure 10. PWM and SPWM method materials

This page contains an explanation of the material regarding the work steps, which describes the instructions regarding each practical procedure that is practiced sequentially so that students in carrying out the practical follow each direction listed and produce directed learning that is clear. The experimental procedure page can be seen in Figure 11.

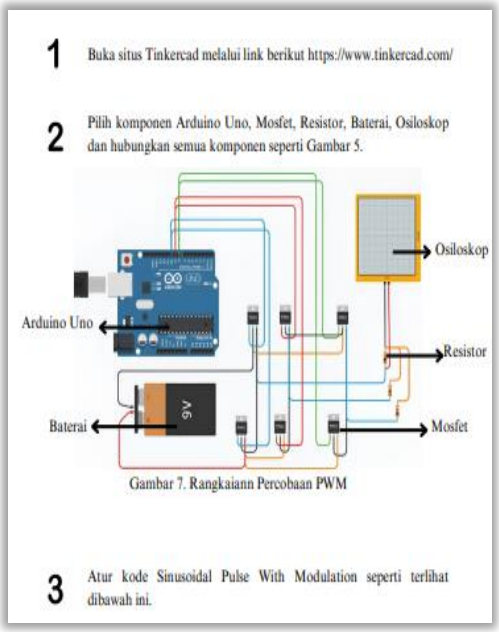


Figure 11. Experimental procedure

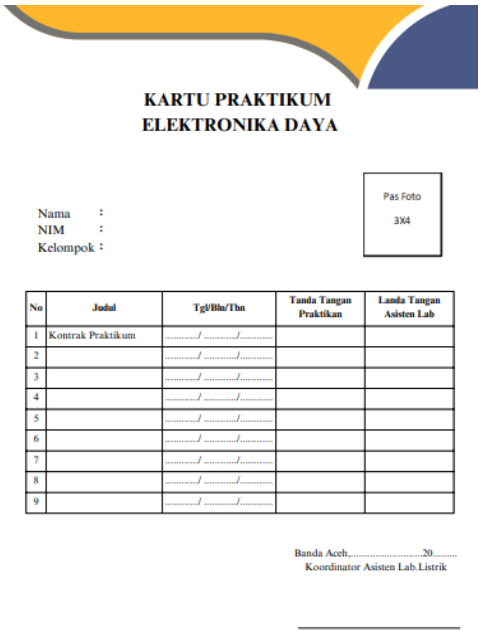
This page contains the programming code used in the 3-phase inverter module. The programming code is implemented in the Tinkercad software to run the circuit so that the inverter circuit produces an output wave with pulse width modulation (PWM) and sinusoidal pulse width modulation (SPWM). The programming code page can be seen in Figure 12.

```
int a=100;  //coba diubah nilai a ini nanti frekuensi berubah

void setup()
{
pinMode(8, OUTPUT);
pinMode(9, OUTPUT);
pinMode(10, OUTPUT);
}

void loop()
{
digitalWrite(8, HIGH);
digitalWrite(9, LOW);
digitalWrite(10, HIGH);
delayMicroseconds(100+a);
digitalWrite(10, LOW);
delayMicroseconds(100+a);
digitalWrite(9, HIGH);
delayMicroseconds(100+a);
digitalWrite(8, LOW);
delayMicroseconds(100+a);
digitalWrite(10, HIGH);
delayMicroseconds(100+a);
digitalWrite(9, LOW);
delayMicroseconds(100+a);
}
```

```
int t=0;
int d=0;

// By Swagatam (my first Arduino Code)
void setup(){
pinMode(8, OUTPUT);
pinMode(9, OUTPUT);
}
void loop(){
digitalWrite(8, HIGH);
delayMicroseconds(500+t-d);
digitalWrite(8, LOW);
delayMicroseconds(500+t-d);
digitalWrite(8, HIGH);
delayMicroseconds(750+t-d);
digitalWrite(8, LOW);
delayMicroseconds(500+t-d);
digitalWrite(8, HIGH);
delayMicroseconds(1250+t-d);
digitalWrite(8, LOW);
delayMicroseconds(500+t-d);
digitalWrite(8, HIGH);
delayMicroseconds(2000+t-d);
digitalWrite(8, LOW);
delayMicroseconds(500+t-d);
digitalWrite(8, HIGH);
delayMicroseconds(1250+t-d);
digitalWrite(8, LOW);
delayMicroseconds(500+t-d);
digitalWrite(8, HIGH);
delayMicroseconds(750+t-d);
digitalWrite(8, LOW);
//.......
```

Figure 12. Programming code input into the inverter circuit

This page contains an explanation of the practicum card and a practicum attendance sheet used as a document to record the attendance of practicum participants in a particular practicum session. The practicum card contains information such as the participant's name, practicum date, participant's signature, and the laboratory assistant or teacher's signature as proof of attendance. The laboratory assistant/teacher uses the practicum attendance sheet to monitor participant attendance and manage attendance records. The practicum card page can be seen in Figure 13.



KARTU PRAKTIKUM
ELEKTRONIKA DAYA

Nama :
NIM :
Kelompok :

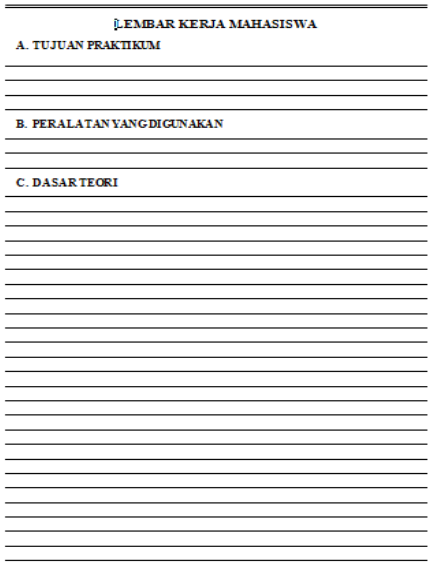
Pas Foto 3X4

No	Judul	Tgl/Bln/Thn	Tanda Tangan Praktikan	Landa Tangan Asisten Lab
1	Kontrak Praktikum	...../...../.....		
2		...../...../.....		
3		...../...../.....		
4		...../...../.....		
5		...../...../.....		
6		...../...../.....		
7		...../...../.....		
8		...../...../.....		
9		...../...../.....		

Banda Aceh,.....20.....
Koordinator Asisten Lab.Listrik

Figure 13. Student attendance sheet

This page contains an explanation of the student worksheet, which is a record of reports during the practicum in the laboratory room; this sheet makes students remember and implement all activities during the practicum according to the instructions in filling out the worksheet that has been listed, also on the student worksheet there is an evaluation or exercise that the teacher expects for students to be able to understand the inverter material well. The student worksheet page can be seen in Figure 14.



LEMBAR KERJA MAHASISWA

A. TUJUAN PRAKTIKUM

B. PERALATAN YANG DIGUNAKAN

C. DASAR TEORI

Figure 14. Practical report sheet

B. Validation results

1. Media Expert

Media validation was conducted at the Faculty of Tarbiyah in the electrical engineering education study program room. Conducting media validation by providing a validation sheet to the validator, Mrs. Sadrina, S.T., M.Sc. During validation, the researcher only provided the module and validation sheet without any face-to-face meeting when filling out the validation sheet and suggestions and input on the inverter practicum module to be revised in terms of font usage, layout, coherence and colors that are too much/ striking so that the impression is not appropriate and not beautiful to look at by students and filling out the validation sheet for the second time after the researcher revised. In the second validator, Mrs. Rahmayanti, M.Pd., the researcher provided a validation sheet and met face-to-face when providing an assessment with the validation results can be used with revisions and did not re-validate.

2. Material Expert

While the material expert validator conducted by Mrs. Hari Anna Lastya, S.T., M.T. Validation was conducted at the Faculty of Tarbiyah in the electrical engineering education study program room face-to-face so the researcher received suggestions and input on improving the 3-phase inverter practical module material and conducted a second validation after the researcher revised the material section by adding circuit images to each sub-material and on the student worksheets made like LKPD so that students can easily understand and do the assignments directed at the practical module. Material validation was also conducted in order to obtain suggestions and input from Mr. Hadi Kurniawan, M.Sc., in the validator's workroom in the 2nd-floor multi-function building; during the assessment, the researcher provided a validation sheet and took it back according to the day promised by the validator, the results obtained in the first validation were to make improvements/revisions to the experimental procedure stages by redesigning the stages so that students clearly understood the module instructions and could practice, after the researcher revised the validator's input the researcher re-validated so that the final result of the assessment given by the material expert validator was that it was suitable for use without revision.

3. Linguist

Language validation was conducted at the Faculty of Tarbiyah in the information technology education study program room with two validators; the first one conducting validation with Mrs. Raihan Islamadina, S.T, M.T. the researcher met the validator and the validator filled out the validation sheet directly so that the researcher received suggestions and input directly with the assessment given by the validator being suitable for use with revision. The second validator was Mrs. Juniar, M.Pd. The researcher met the validator by providing a face-to-face validation sheet and taking the results of filling in the values on the promised day; the assessment results given were suitable for use with revision.

C. Discussions

This research was conducted to design teaching materials in the form of inverter practicum modules using the Research and Development (R&D) research module. This inverter practicum module helps students understand inverters more efficiently and effectively through Tinkercad electrical software. This module discusses a 3-phase inverter with the Pulse Width Modulation (PWM) Sinusoidal Pulse-Width Modulation (SPWM) switching method.

For the practical module to be functional for students of the electrical engineering education study program, the researcher asked for criticism and suggestions from expert lecturers in electricity to assess the suitability of the media, materials, and language (Malado & Habibu, 2023; Saseno et al., 2023).

Validator assessment on each question item only gives an assessment based on five categories, namely: (1) Not feasible, (2) Less feasible, (3) Quite feasible, (4) Eligible, and (5) Very feasible. The validation assessment on media experts contains 12 questions with a value category of 1-5 for each answer that assesses aspects of media eligibility, such as module size, module cover design, and module content design. From the first validator on each question item, a score of 57 was obtained with a percentage of 95%; from the second validator, a score of 56 was obtained with a percentage of 93%. Then, the percentage results from the two validators in the field of media experts were added together so that the final result for giving a value from the media aspect was 94%.

In the aspects assessed by the validation of the material regarding learning objectives, materials, time, and benefits (Moonik et al., 2022; Sawenduling et al., 2022), The expert assessment aspect of the material contains 9 questions that obtained results in validation with the first validator 37 with a percentage of 82%. In the second validator, a score of 36 was obtained, and a percentage result of 80% was obtained. Then, the percentage results from the two validators in the field of media experts were added up

between the two, and the final result for giving a value from the media aspect was 81%.

Meanwhile, in the assessment of language experts, there are 10 questions about language rules, spelling accuracy, symbols, and use of terms in the practical module. The validation results with the first validator were 41, with a percentage of 82%. At the same time, the second validator got a score of 43 with a percentage of 86%. Then, the percentage results from the two validators in the field of media experts were added together so that the final result for giving a value from the media aspect was 84%. Based on the validity calculation formula and the validity category of the 3-phase inverter practical module, it can be stated as "Very Eligible".

IV. CONCLUSIONS

The compilation of the 3-phase inverter practical module is designed using Sugiyono's Research and Development (R&D) method with several stages to suit the needs of researchers. The material discussed in the module is a 3-phase inverter through Tinkercad software using the Pulse Width Modulation (PWM) Sinusoidal Pulse-Width Modulation (SPWM) method.

The results of the 3-phase inverter practical module testing were carried out on 6 validators, each aspect of which was divided into 2 people: the media expert validator obtained an average percentage of 94%, 2 material expert validators obtained an average percentage of 81%, and 2 people in the language expert validator obtained an average percentage of 84%. Based on the validation of media and material experts on the inverter practical module, it received the category "Very Eligible" to be applied to the Power Electronics course.

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