Design and Implementation of a Teaching Aid Inverter for 3-Phase Induction Motor

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Abstract – *Teaching aid is an important learning media to improve learning outcomes, especially teaching aids related to variable frequency drive (VFD) inverters that can communicate using LabVIEW software via serial communication protocols. This study uses an experimental method to design a structured and systematic system, and is developed by involving other supporting components, namely control with an interface on LabVIEW software via a serial communication protocol. Testing of this study was carried out in testing VFD output parameters, testing interface functions, and testing by users. Based on the test results, an average error value of 0.3% was obtained in motor rotation speed, 6.8% in the average output voltage, and 5.26% in the average current output with control using LabVIEW. Overall, the average evaluation value of this tool is 92% for the quality of the Teaching Aid Inverter that has been made. This figure is classified as very good for the use of tools as a teaching aid media.*

Keywords: *3 Phase Motor, Teaching Aid, Variable Frequency Drive*

I. Introduction

Currently, one of the formal education types, namely vocational education, has a focus and goal on improving competence and ability to be ready to work according to certain fields and majors. One of these fields is mechatronics education which includes mechanics, electricity, informatics, and control systems into one interconnected unit [1], [2]. Technology has produced media or learning resource tools that can be utilized in the teaching and learning process [4]. These media or tools can play an important role in increasing the effectiveness and efficiency of the teaching and learning process. Education continues to innovate to improve the quality of the teaching and learning process, one of which is by utilizing learning support media or teaching aids [5].

Teaching aids or teaching aids are tools used to facilitate the teaching and learning process. Teaching aids can help teachers explain the material and make it easier for students to understand the material being taught [6], [7]. Teaching aids are important learning media to improve learning outcomes, especially teaching aids related to variable frequency drive (VFD) type inverters that can communicate using LabVIEW software. These teaching aids can help students understand the material more easily and interestingly [3].

In the development of technology, Variable Frequency Drive (VFD) or commonly known as inverter can help reduce the consumption of electrical energy in controlling the rotation speed of electric motors by changing the input frequency. The input that regulates the frequency entering the motor can use the Variable Frequency Drive (VFD) control which is directly connected to the three-phase induction motor. Variable Frequency Drive (VFD) is a tool used to control the speed of AC electric motors. This control is very popular because of its ability to control motor speed [8], [9], [10], [11], [12], [13].

Previous research on Teaching aid Variable Frequency Drive (VFD) is only limited to the analysis of consumption of Variable Frequency Drive (VFD) usage that is directly connected to a 3-

Manuscript received October 2024, revised December 2024

phase induction motor [10]. In addition, there is previous research on teaching aid LabVIEW, where the use of LabVIEW functions as an interface to display response signals [20], and is used as a simple analog and digital data input control [21]. Labview as this interface is only connected to microcontroller devices such as Arduino UNO [20][21][22], while in the industrial world the use of LabVIEW connected to this microcontroller has limitations for use in applications that require high performance. In addition, many companies that produce teaching aids such as Pudak Scientific from Indonesia, and Lucas Nuelle from Germany have not yet produced and developed this teaching aid inverter, especially teaching aids that can communicate with LabVIEW. In vocational education, this teaching aid inverter is an indispensable tool, by using teaching aid inverter, students can gain a deeper understanding of the working principles, basic concepts of electricity, develop practical skills, and prepare themselves to face challenges in the world of work [1][4]. In addition, communication between LabVIEW and inverter is a very effective combination in vocational education, LabVIEW provides intuitive visualization and control in terms of interface, ease of use, strong data analysis capabilities, and development of programming skills for students. By using this combination, students can gain a deeper understanding of the working principles of inverters and develop skills that are in great demand in the industrial world [14].

Based on this, a teaching aid inverter is needed that is able to communicate with software such as LabVIEW, this teaching aid is developed with the Modbus communication protocol which has good performance in sending data that requires fast response times, monitoring output from the inverter, and processing data and more complex parameters, which will make it easier for users to learn LabVIEW as an interface for electrical devices such as inverters in controlling 3-phase induction motors.

This research is expected to be a learning medium where inverter learning requires students to not only understand the concept but also hone their skills in assembling and testing inverter circuits [23]. The output parameters of the induction motor that have been connected to the Variable Frequency Drive (VFD) and are measured properly according to the datasheet are the benchmarks in this study [18]. The test results of this teaching aid will also be used as a reference in making practical modules to improve the effectiveness of practical learning. This is because practical modules can help students to learn systematically, directed, and measurably [19].

It is hoped that with the results of this study, students can improve their knowledge and abilities in the field of electricity, which are later expected to be able to compete in the industrial world.

II. Research Method

The design of this system requires a systematic and structured process. The process of working on the system in this study uses an experimental research method. Fig 1 describes the systematic process [7].

Fig 1. System Design Flow Diagram

In this study, a Fuji Frenic Mini inverter is used as a motor speed control, and LabVIEW software is used to regulate motor speed based on its frequency input. This frequency is used as input and produces a motor output that varies according to the set frequency.

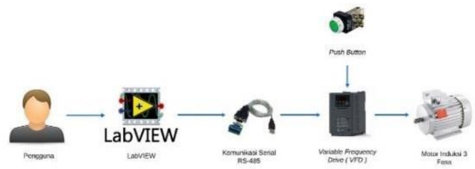

Fig 2. Overview of System Design

This study consists of mechanical, electrical, and informatic systems. The mechanical part consists of acrylic as a board, hollow iron as a holder, and a 3-phase motor as an actuator. This mechanical system will be integrated with each other in the form of a panel. The electrical part consists of wiring components with banana jacks that are also connected to the terminal block. While in the informatic part, namely the interface created in

LabVIEW software which is used to control the movement of a 3-phase induction motor.

II.1. *Mechanical Design*

The mechanical design of the prototype combines two main components consisting of a support structure (Holder) and an acrylic board (Acrylic Board). The support structure serves as a solid mounting platform for the acrylic board, ensuring its stability and resistance to mechanical vibrations. The acrylic board serves to provide a carefully designed foundation for mounting and connecting all electronic components, and efficient electrical distribution.

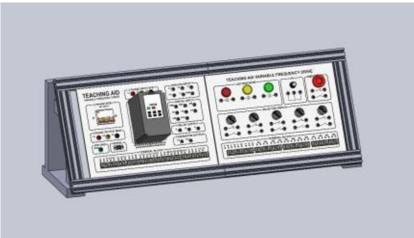

Fig 3. Assembly Teaching Aid Design

II.2. *Interface Design*

The informatics system leverages LabVIEW, a graphical software platform, to design and implement an intuitive user interface (UI). LabVIEW enables real-time visualization of data, such as current, voltage, and RPM, obtained from sensors and measurement processes. In addition, LabVIEW acts as a control system, allowing users to operate the motor through an easy-to-use interface.

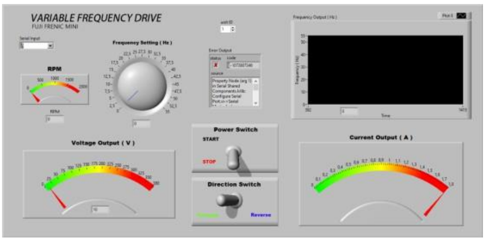

Fig 4. Interface Design

III. Results and Discussion

III.1. *Hardware Implementation*

Hardware implementation includes the process of designing, fabricating, assembling, and installing components, resulting in hardware as depicted in Figure 5.

Fig 5. Overall View of Hardware

III. 2 *Software Implementation*

LabVIEW is used as an interface to monitor motor output parameters such as motor rotation, current, and voltage. This interface can display data in real-time and allows users to monitor the inverter output. LabVIEW is also used as a motor speed controller, namely, to run the motor, change the direction of motor rotation, and adjust the motor speed based on the set frequency. After going through the design stages, the following is the result of the interface for the user.

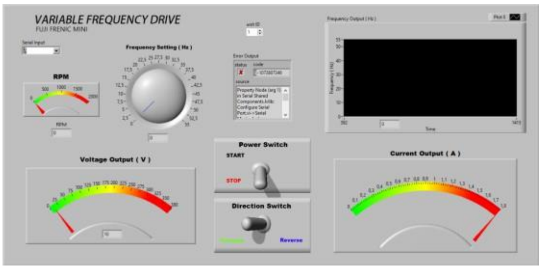

Fig 6. View of Labview Interface

On the main page display LabVIEW displays the knob that is rotated to change the input frequency input, then there is a Power Switch that functions to run and turn on the motor, and a direction switch that functions to change the direction of motor rotation. On the main page display there is also motor output monitoring, where the data taken is based on the output data processed by the Variable Frequency Drive (VFD), namely current output data, voltage, motor rotation, and frequency output.

III.3. Functional Test Result

LabVIEW functional testing is done by measuring motor performance using calibrated measuring instruments and monitoring the data through the LabVIEW interface. The implementation of communication between the VFD (Variable Frequency Drive) and the LabVIEW

Interface utilizes the RS-485 serial communication protocol. LabVIEW interface functional testing includes monitoring motor performance parameters, such as rotational speed, output voltage, and output current of the VFD (Variable Frequency Drive). In addition, control testing is carried out to evaluate the start, stop, forward, reverse, and frequency setting functions of the VFD. The jog dial method is implemented in this measurement. This method allows continuous frequency changes with a constant shift value. The frequency value tested in this test is 5Hz.

Table 1. Motor Rotation Acuracy Testing

Frequency (Hz)	Testing		Error (%)
	Tachometer	*LabVIEW*	
5 Hz	147,5	148,63	0,77 %
10 Hz	308,4	291,2	5,58 %
15 Hz	440,9	448,187	1,65 %
20 Hz	614	596,6	2,83 %
25 Hz	745,7	746,48	0,10 %
30 Hz	878,6	893	1,64 %
35 Hz	1041	1040	0,10 %
40 Hz	1196	1195	0,08 %
45 Hz	1340	1338	0,15 %
50 Hz	1483	1501	1,21 %
55 Hz	1633	1633	0,00 %
	Average		0,31 %

Based on the table 1, the tachometer frequency is observed in the range of 5 Hz to 55 Hz. The frequency distribution shows the dominance of measurements at 30 Hz, followed by 25 Hz and 40 Hz. On the other hand, the LabVIEW error value reaches a range of 5.58% to 1.65%. The best LabVIEW performance is achieved at a frequency of 55 Hz, while the lowest performance occurs at a frequency of 10 Hz. Overall, the LabVIEW error value is relatively small with an average of 0.31%. This indicates LabVIEW's ability to measure frequency with sufficient precision.

Table 2. Voltage Output Testing

Frequency (Hz)	Testing		Error (%)
	VoltMeter	*LabVIEW*	
5 Hz	60	58	3,33 %
10 Hz	95	87	8,42 %
15 Hz	125	118	5,60 %
20 Hz	160	148	7,50 %
25 Hz	185	179	3,24 %
30 Hz	225	208	7,56 %
35 Hz	255	238	6,67 %
40 Hz	285	270	5,26 %
45 Hz	300	299	0,33 %
50 Hz	330	332	0,61 %
55 Hz	350	361	3,14 %
	Average		4,02 %

The table 2 shows the operating frequency range of the motor is between 5 Hz to 55 Hz. The output voltage produced varies between 60 V to 350 V. In general, the increase in output voltage is in line with the increase in frequency in both tests. However, there are some changes. The average measurement error value is recorded at 6.8% of the measuring instrument. Overall, the performance of the LabVIEW monitor for monitored voltage is quite good.

Table 3. Current Output Testing

Frequency (Hz)	Testing		Error (%)
	AmpMeter	*LabVIEW*	
5 Hz	1,8	1,73	3,89 %
10 Hz	1,8	1,25	5,93 %
15 Hz	1,4	1,07	2,73 %
20 Hz	1,1	0,98	9,26 %
25 Hz	1	0,92	8,00 %
30 Hz	1,9	0,89	1,11 %
35 Hz	0,9	0,87	3,33 %
40 Hz	0,9	0,85	5,56 %
45 Hz	0,9	0,84	6,67 %
50 Hz	0,9	0,82	8,89 %
55 Hz	0,8	0,82	2,50 %
	Average		5,26 %

The table 3 shows the operating frequency range of the motor is between 5 Hz to 55 Hz. The output current produced varies between 0.8A to 1.8A. In general, the current value will decrease as the frequency changes. The error value increases significantly in the range of 10 Hz - 45 Hz. The average error value is 5.26% of the measuring instrument. Based on the calculated error value, the performance of the LabVIEW monitor for the monitored current is quite good.

III.4. Questionnaire Result For Users

To evaluate user experience, the EMPI method is applied. This evaluation test is carried out by users to assess the effectiveness of Teaching Aid as a tool in the learning process. The EMPI method involves assessors in using learning media and then filling out a questionnaire related to their experience with the media. This method requires a minimum of 10% of the population from the target respondent environment. The target respondents are 100 second-year Automation Engineering students. The number of respondents who filled out this evaluation questionnaire was 14 people, which is more than the minimum number required to fill out the questionnaire in this method

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[7]. The evaluation was carried out based on six criteria, namely:
• General Feeling: Assessing the overall teaching aid.
• Computer Science Quality: Assessing the technical quality of software creation.
• Usability: Assessing the ease of use of teaching aids from an ergonomic perspective.
• Multimedia Documents: Assessing the quality of multimedia components in teaching aids.
• Scenario: Assess the menu navigation structure on the interface.
• Didactical: Assess the educational design and teaching methods applied in the teaching aids.
This questionnaire uses a Likert scale assessment, where the weights are divided into 5 categories, namely:
• Weight 5 - Very Good
• Weight 4 - Good
• Weight 3 - Fair
• Weight 2 - Less Good
• Weight 1 - Very Less Good
The results are then entered into the following equation to obtain the overall final value [7].

Table 4. Voltage Output Testing

No	Overall Evaluation Items Assesed	Score
1	The whole teaching aid	97%
2	Technical quality of software creation	88%
3	Ease of use of teaching aid in terms of ergonomics	93%
4	Quality of multimedia components in teaching aid	92%
5	Structure of the menu navigation on the interface	90%
6	Teaching applied in teaching aid	93%
	Average	92%

Overall, the evaluated teaching aids received a high score, namely 92%. This score indicates that the teaching aids are considered to be quality and effective tools in helping the teaching and learning process. Based on the table 4, it shows that this teaching aid has good technical quality (score 88%), is easy to use (score 93%), and has quality multimedia components (score 92%). In addition, the menu navigation structure on the interface is clear and easy to understand (score 90%). The advantages of this teaching aid can also be seen from the effective teaching method and in accordance with user needs (score 93%).

Overall, the evaluated teaching aids can be said to be quality and effective tools in helping the teaching and learning process. The teaching aids have good technical quality, are easy to use, and have quality multimedia components. In addition, the teaching aids also apply effective teaching methods and in accordance with user needs.

IV. Conclusion

Teaching aid is designed in the form of hardware with various features, such as input and output on the VFD that make it easier for users to know the overall function of the existing inverter, serial input function to facilitate learning about communication between the VFD and software, control board to facilitate users to try external control, and banana jack input, and terminal block to facilitate users in using this teaching aid inverter. This is proven by testing by users. Overall, the teaching aid that was evaluated received a high score, which is 92%. This value shows that the teaching aid is considered a quality and effective tool in helping the teaching and learning process.

The use of the LabVIEW interface is considered quite effective because with the functions and features on the interface it can facilitate users in controlling motor rotation and monitoring the output of the VFD, where all controls and monitors from the interface function properly, with the RPM Output error value on LabVIEW being relatively small with an average of 0.31%, The average voltage measurement error value was recorded at 6.8% against the measuring instrument, and the average current output error value was 5.26% against the measuring instrument. This indicates LabVIEW's effective ability to measure frequency with sufficient precision.

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