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Design and Construction of Micro-Scale Magnetic Power Plants Using the Principle of Electromagnetic Induction With A Pycharm Based Monitoring System

Kamila Dinda Marsellina [1], Slamet Hariyadi[2*], Fatmawati[3], Ahmad Rossydi[4], Wiwid Suryono[5]
[1,2,3,5)]Politeknik Penerbangan Surabaya, Jl. Jemur Andayani 1 No. 73, Surabaya, Indonesia
[4)]Politeknik Penerbangan Makassar, Makassar, Indonesia
*Correspondent Author, Email : slamethariyadi396@yahoo.com

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ABSTRACT
Most power plants in Indonesia still rely on non-renewable energy sources that will run out if they continue to be used. One alternative renewable energy that can be used as a source of electricity generation is magnets. The conversion process of several neodymium magnets into electrical energy is by using a magnetic turbine and utilizing the principle of electromagnetic induction. The electrical energy produced is then connected to a monitoring system with a PZEM-004T sensor, UGN3503 sensor, Arduino ATMega 2560 microcontroller, and PyCharm programming application as a data generator. The test results show that neodymium magnets in magnetic turbines are very effective in the electricity generation process with a 15° configuration and if given a coil that is supplied with voltage to the stator.

1. INTRODUCTION

Electrical energy is a vital element in human daily life, needed for various activities. The development of power plants needs to be improved, considering that there is still a great deal of dependence on non-renewable fossil energy sources. The main challenge faced by electricity providers today is the gap in access to electricity in remote areas caused by Indonesia's vast territory. (Kurniawan & Zulkifli, 2019)

Magnets as an alternative energy source can be utilized in small-scale electricity generation, which in this case is very rarely applied and has not been developed much unlike power plants in general, which are sourced from solar, water, wind, or steam power. This power plant runs a concept using a turbine to generate electrical energy through magnetic power. The advantages of this power plant are that it does not require fuel oil, does not depend on wind, water, or solar resources, is free from noise, and is environmentally friendly. (Sumarno, 2019).

This micro-scale magnetic power plant is a power plant that applies the principle of electromagnetic induction in its application to turbines. This study aims to design a micro-scale magnetic power plant monitoring system, which is then integrated into the application by implementing one of the features in the programming application, namely PyCharm, to express data in real time in the form of numbers and graphs. The micro-generator utilizes MEMS technology combined with multilayer ceramic magnetic circuits, achieving outputs of up to 3.3 mVA at high rotational speeds (Yokozeki et al., 2014).

Turbine Integration: The air turbine, powered by compressed air, is crucial for generating electricity, with designs yielding outputs of around 1.92 µW (Iiduka et al., 2011). The monitoring system employs microcomputers for excitation control and communication, enhancing operational reliability (Yang, 2015). While the focus is on optimizing power generation and monitoring, challenges such as cogging torque in generators must also be addressed to ensure efficiency (Buana & Santoso, 2022).

2. LITERATURE REVIEW

2.1. Neodymium Magnet Turbine

A neodymium magnet turbine is a component used as the main source of electrical energy by utilizing the principle of electromagnetic induction. The rotor part of the turbine uses 20 neodymium magnets and is arranged in a circle with an N-S-N-S magnetic pole configuration. The electromagnetic stator uses 4 coil units, with each coil consisting of 2 components, namely 0.6 mm copper wire, 260 turns, and metal current.

The rotor consists of 20 neodymium magnets, strategically placed to create a strong magnetic field. The N-S-N-S arrangement maximizes the alternating magnetic field, essential for inducing current in the stator coils(Seop, 2012). The arrangement of coils around the rotor allows for effective capture of the changing magnetic flux, which is crucial for generating electricity(Li, 2010). As the rotor spins, the alternating magnetic field interacts with the stator coils, inducing electromotive force (EMF) and generating electrical current (Drayton, 2013)(Killian, 2005). This system can be integrated with additional components, such as a stabilizer system, to enhance energy output and efficiency(Drayton, 2013).

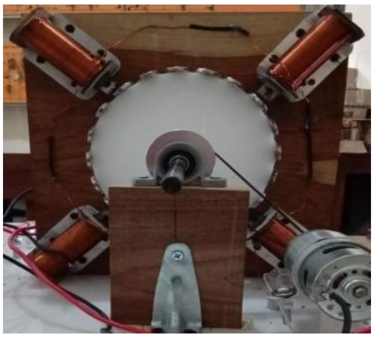

Figure 1. Neodymium Magnet Turbine

2.2. DC Generator

An electric machine is an energy conversion machine, where an electromagnetic field is used to transform energy into electrical or mechanical energy. A DC generator, or direct current generator, is a type of electric machine that uses DC voltage as its power source. This component converts mechanical rotational energy into direct current electrical energy.

Figure 2. DC Generator

2.3. Battery Charge Controller

A charge controller is an electronic circuit that is responsible for regulating the battery charging process. This device plays a role in controlling the battery voltage so that it remains within a safe power tolerance limit. For example, when the battery or battery circuit is fully charged, the AC current flow from the generator will be disconnected to prevent overcharging, which can damage the battery and extend the battery life.

Figure 3 Battery Charge Controller

Charge controllers adjust the charging voltage to match the battery's state, typically setting thresholds at 13.5 V for high voltage and 10.5 V for low voltage disconnection (Hasibuan et al., 2024) (Daud et al., 2023). Some controllers utilize pulse width modulation (PWM) to manage voltage and current during different charging phases, ensuring optimal charging conditions (Najmurrokhman et al., 2022). By preventing overcharging and maintaining appropriate voltage levels, charge controllers significantly enhance battery longevity(Shahid et al., 2023)(Pathak et al., 2022). Advanced controllers monitor thermal conditions, ensuring safe operation under varying voltage scenarios, which is crucial for battery performance(Shahid et al., 2023).

2.4. Battery

A battery is an electrochemical cell that converts chemical energy into electrical energy. When the battery is used, a chemical reaction occurs that causes deposits on the anode (reduction) and cathode (oxidation).

2.5. Inverter

An inverter is a device that functions to convert direct current (DC) voltage to alternating current (AC) voltage. The inverter output can be adjusted according to needs, either adjustable voltage or fixed voltage. This circuit is then connected to a step-up transformer to produce a perfect sinusoidal AC output voltage.

2.6. PZEM-004T Sensor

PZEM-004T is a sensor that has the ability to measure power, voltage, current, and active energy in an electric current. This sensor can be connected to an Arduino or other source platform. This module is equipped with an integrated voltage sensor and current sensor (CT), making it easy to use.

Figure 4. PZEM-004T Sensor

2.7. UGN3503 Sensor

A magnetic field, also known as a magnetic field, is a quantity that can be measured using various methods, one of which is the UGN3503 Hall effect sensor. The UGN3503 type Hall effect sensor is a magnetic field sensor that has stable measurement capabilities in a wide temperature range, from -65˚C to 150˚C.

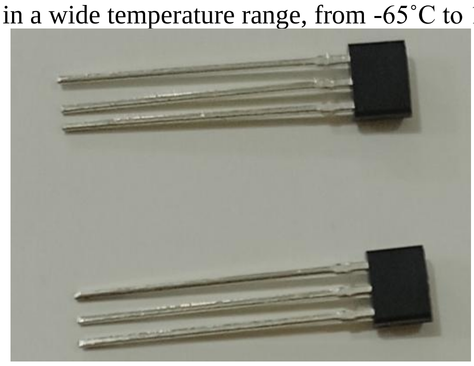

Figure 5. UGN3503 Sensor

2.8. Arduino ATMega 2560

Arduino is an open-source microcontroller device. Arduino uses its own programming language even though it uses an IC from AVR Atmel. This device has a crucial role in controlling various electronic devices, circuits, and motors.

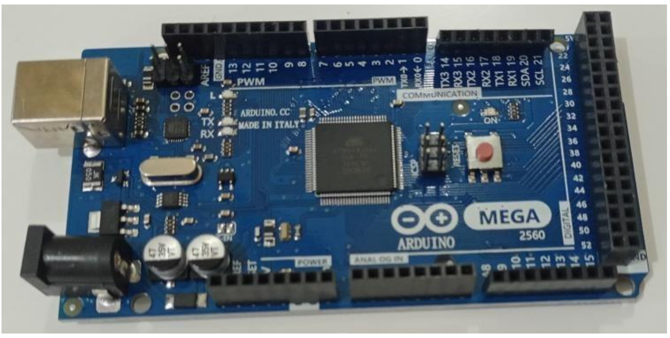

Figure 6 .Arduino ATMega 2560

2.9. Arduino IDE

Arduino IDE is software used to create programming sketches, which function as a tool for programming Arduino boards. Arduino IDE allows users to edit, create, and upload code to the desired board, and code certain programs.

2.9. PyCharm

PyCharm is an Integrated Development Environment (IDE) developed by JetBrains, specifically for the Python programming language. As an IDE, PyCharm provides a comprehensive development environment for various types of Python projects, such as web applications, data analysis, and machine learning.

3. METHODOLOGY

3.1. Research Design

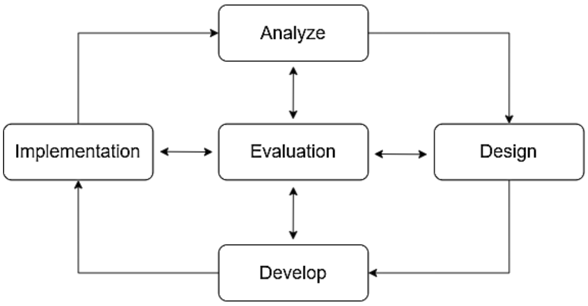

Figure 7. ADDIE Method

The method used in this study is a descriptive method with a qualitative approach that will be delivered using the ADDIE model. The ADDIE model, as the name suggests, is a model that is described in several stages of development, including:

1. Analyze
At this stage, it aims to start by analyzing the potential of the problem, which is an important initial step in developing a new product.

2. Design
At this stage, it aims to describe the product concept in detail and in detail to ensure that the resulting design is conceptual and will be the basis for the next concept development process.

3. Development
At this stage, it aims to realize the design or product plan that has been made previously into the desired product.

4. Implementation
At this stage, it aims to get a response or feedback on the product that has been developed.

5. Evaluation

At this stage, it aims to measure the extent to which the development objectives have been achieved, ensuring that the resulting product meets the needs and expectations that have been previously set.

3.2. Tool Design

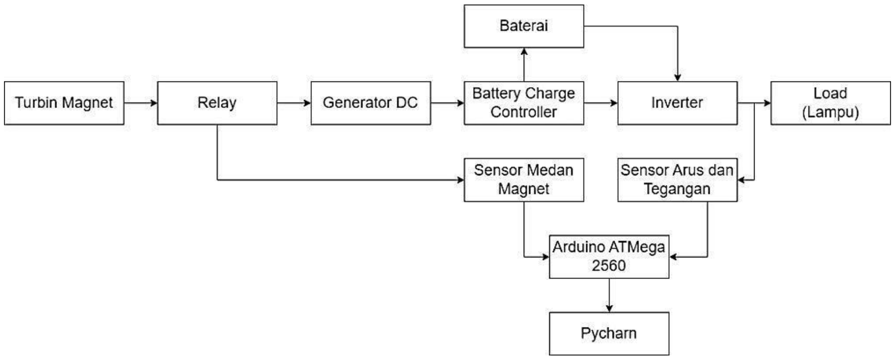

Figure 8. Block Diagram

In the block diagram, it is found that the way this tool works is that the stator part of the turbine is made using a coil that will be placed around the stator with an electric voltage flowing through it. The installation of magnets like that will create a magnetic field in the turbine and make the turbine rotate. The magnitude of the magnetic field is detected by the UGN3503 sensor. The rotation of the turbine is used as an initial drive for the DC generator to convert mechanical energy from the turbine to the DC generator through bearings, axles, and fan belts. This aims to produce a working voltage with a range of 12 VDC, which is sufficient for charging a 12V battery.

After producing electrical energy with direct current from the generator, the energy will be channeled to the charge controller. When the battery is fully charged, the DC will be directly channeled to the inverter. DC (direct) current will be converted into AC (alternating) current, and the working voltage from 12V will be increased to 220V. This allows the electrical energy to be used in electrical equipment with a standard working voltage of 220 VAC or low voltage. After that, the voltage and current will be detected by the PZEM-004T sensor. The results of the two sensors will be sent to the Arduino ATMega 2560 microcontroller, which will then be displayed in the PyCharm programming application.

4. RESEARCH RESULTS AND DISCUSSION

4.1. Analysis

At the analysis stage in the design of a micro-scale magnetic power plant using the principle of electromagnetic induction, the author has conducted an analysis and collected data and information on several relevant previous research studies. By studying the differences and shortcomings of the research, the author developed innovations in the components and design of the tools to be designed.

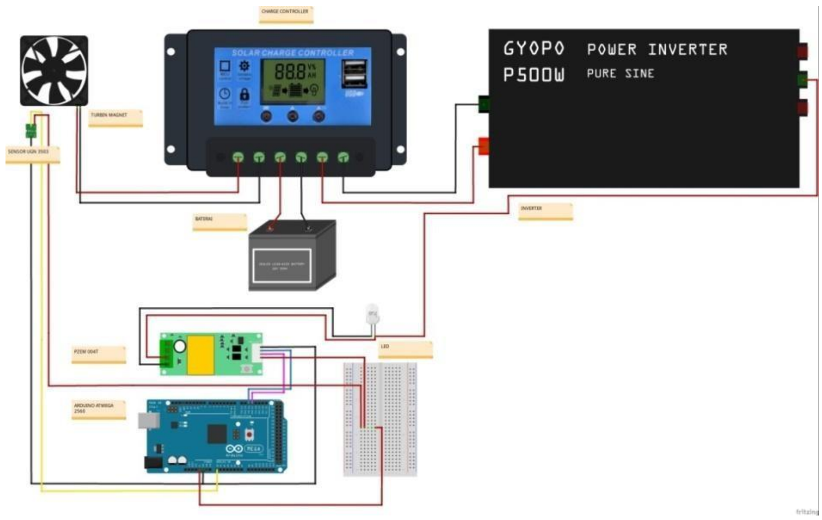

Figure 9. Generator Design Plan

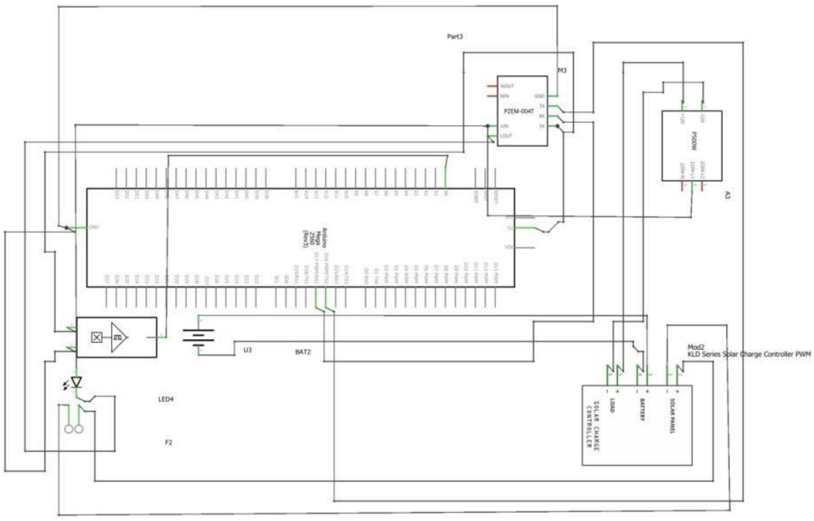

Figure 10 Generator Wiring

4.2. Development

At this stage, development is carried out by studying relevant previous studies and testing the tools that have been made.

4.2.1. Hardware Creation

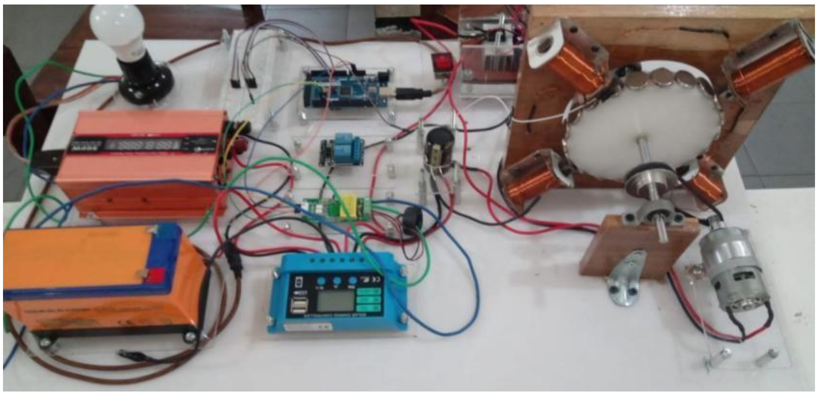

Figure 11. Hardware Creation

Description:
1. Neodymium magnet turbine
2. Relay
3. DC generator
4. Battery Charge Controller
5. Battery
6. Inverter
7. LED
8. PZEM-004T sensor
9. UGN3503 sensor
10. Arduino ATMega 2560

4.2.2. Software Creation

a. Arduino IDE

Arduino IDE (Integrated Development Environment) is a software application used to write, compile, and upload code to the Arduino microcontroller board.

b. PyCharm

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PyCharm is an application in the form of an Integrated Development Environment (IDE) used for software development with the Python programming language.

4.3. Implementation

4.3.1 Neodymium Magnet Turbine Testing

The neodymium magnet turbine is a component used as the main source of electrical energy by utilizing the principle of electromagnetic induction between several magnets with a predetermined magnetic construction. The following is the test data from the neodymium magnet turbine:

Figure 12. Magnet Turbine

Table 1 Neodymium Magnet Turbine Testing Neodymium Magnet Turbine Testing

Test	Turbine Type	Turbine Condition	Lamp Condition
1	1st Turbine	Not Rotates	Off
2	2nd Turbine	Not Rotates	Off
3	3rd Turbine	Rotates	On

Based on the test results, the first turbine with the N-S configuration could not rotate perfectly, only getting a trigger to move a little. Likewise with other rotor configurations such as N-N-S-S and N-N-N-S-S-S, the turbine still could not rotate. Then for the second turbine, as in the 1st test, it still could not rotate even though the stator part had been changed from a magnet to a coil. Meanwhile, the third turbine during the test, was able to operate and function normally after the stator part was given a voltage trigger of 5-9V.

4.3.2. DC Generator Testing

The following are the results of the DC generator test, where this component produces direct current; the voltage produced is around 12 VDC.

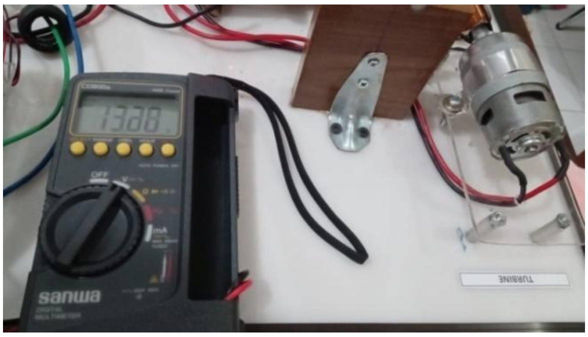

Figure 13 DC Generator Testing

Table 2. DC Generator Testing

Test	Magnetic Turbine Input Voltage	Generator Conditions	RPM	Voltage (VDC)
1	5 V	turn	1313	12,1 V
2	6 V	turn	2481	12,1 V
3	8 V	turn	6855	12,1 V
4	9 V	turn	8947	12,1 V

Based on the test results, the different voltage inputs in each test with a voltage of 5 V to 9 V, and the output produced on the generator in all four tests was 12.1 V. With these stable voltage results, this indicates that the DC generator has functioned well and optimally in producing DC voltage. In addition, the greater the turbine RPM, it will not affect the output of the DC generator.

4.3.3. **PZEM-004T Sensor Testing**

The voltage monitoring system is a system consisting of several electronic components that function to monitor the voltage and current produced by the inverter through the PZEM-004T Sensor and the results of this monitoring will be displayed in the PyCharm programming application. The following is the test result data from the voltage and current monitoring system:

Table 3 .PZEM-004T Sensor Voltage Test

Test	Voltage on PyCharm	Real-Time Voltage	*Error*
1	230,5 V	230,8 V	0,12 %
2	230,7 V	230,8 V	0,04 %
3	230,9 V	230,8 V	0.04 %
4	230 V	230,8 V	0,34 %
5	229,9 V	230,8 V	0,38 %
Error Rata-rata			0,18 %

From the test results listed above, five tests were carried out and an average error of 0.18% was produced. The difference that occurred was not too significant and in this case, showed that the monitoring process with the PyCharm programming application could operate normally and there were no obstacles during the test.

Table 4 Current Testing of PZEM-004T Sensor

Test	Current Test on PyCharm	Real-Time Curren	*Error*
1	0,09 A	0,09 A	0 %
2	0,09 A	0,09 A	0 %
3	0,09 A	0,09 A	0 %
4	0,09 A	0,09 A	0 %
5	0,08 A	0,08 A	0 %
Error Rata-rata			0 %

From the test results listed above, two test objects were carried out in the monitoring process, namely the programming application on PyCharm and direct current measurement using a multimeter. Five tests were carried out and an average error of 0% was produced. The difference that occurred was very small and in this case, showed that the monitoring process with the PyCharm programming application could operate normally and there were no obstacles during the test.

4.3.4. UGN3503 Sensor Testing

This Hall Effect sensor measures magnetic field strength with high precision, crucial for accurate monitoring(Raman et al., 2023). A Raspberry Pi serves as the main processing unit, enabling real-time data processing and analysis (Raman et al., 2023). The processed data is displayed in PyCharm, allowing users to visualize magnetic field changes effectively and make informed decisions based on real-time data (Raman et al., 2023). The system can detect irregularities in magnetic fields with a calculated error of 0.5 - 0.6% and can measure magnetic induction up to ± 58 mT (Zavorotnov et al., 2022). The magnetic field monitoring system is a system consisting of several electronic components that function to monitor the magnetic field generated by the magnetic turbine through the UGN3503 Sensor and the results of this monitoring will be displayed in the PyCharm programming application. The following is the test result data from the magnetic field monitoring system:

Table 5 .Magnetic Field Testing of the UGN3503 Sensor

Uji ke-	Magnetic Field Test on PyCharm	Magnetic Field Real Time	*Error*
1	2,97 T	2,37 T	25 %
2	2,54 T	2,31 T	9 %
3	2,7 T	2,88 T	6 %
4	2,95 T	2,63 T	12 %
5	2,56 T	2,29 T	9 %
Error Rata-rata			12,2 %

From the test results listed above, five tests were carried out and an average error of 12.2% was produced. The difference in magnetic fields occurs every time and in this case shows that the monitoring process with the PyCharm programming application can operate normally and there are no obstacles that occur during the test.

4.3.5. Arduino ATMega 2560 Testing.

Testing on the Arduino ATMega 2560 aims to ensure good connectivity between the Arduino ATMega 2560 microcontroller and the Arduino IDE software and then use the programming language to operate the tool in the final project. This process can be identified through testing between input and output voltages.

Table 6 Arduino ATMega 2560 Testing

Test	Input Voltage	Output Voltage
1	5,03 VDC	5,03 VDC
2	5,02 VDC	5,02 VDC
3	5 VDC	5,02 VDC

In this Arduino ATMega 2560 testing, the author activated this Arduino by connecting the 5 V input to a laptop/PC via USB. After that, testing was carried out and it can be concluded that the ATMega 2560 is functioning properly, as evidenced by the Arduino ATMega 2560 device test results table.

4.3.6. Overall System Testing

After a series of tests on each component were carried out, the final step was to test the overall system so that the following data was obtained:

Table 7 Overall System Testing

No	Time	Voltage (V)		Current (A)		Medan magnetic Field (T)		Lamp Condition
		PyCharm	*Real-Time*	*PyCharm*	*Real-Time*	*PyCharm*	*Real-Time*	
1	30 Sec.	230,7 V	230,8 V	0,09 A	0,09 A	2,92 T	2,37 T	On
2	1 Min.	230,7 V	230,8 V	0,09 A	0,09 A	2,72 T	2,31 T	On
3	3 Min.	230,5 V	230,8 V	0,09 A	0,09 A	2,52 T	2,88 T	On
4	5 Min.	230,4 V	230,8 V	0,09 A	0,09 A	2,58 T	2,63 T	On
5	10 Min.	229,6 V	230,8 V	0,09 A	0,09 A	2,38 T	2,29 T	On

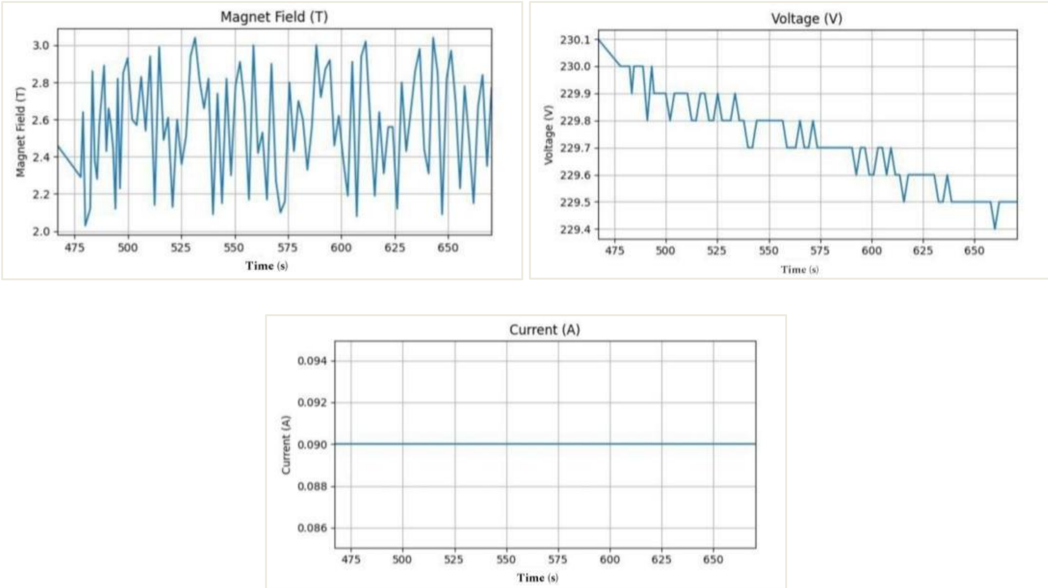

Figure 14 Overall System Test Graph

From the results of testing and simulations that have been carried out on the tool using a load in the form of one lamp with a power of 5 Watts and a battery with a capacity of 12 V / 10 Ah, it was found that this tool can operate normally. After testing for 10 minutes, there was a voltage drop on PyCharm of 1.1 V, a decrease in the magnetic field on PyCharm of 0.54 T, and on the tesla meter of 0.59 T. While the results of the current monitoring displayed on PyCharm and the multimeter have the same results without any differences.

Evaluation

The evaluation stage is the last stage with the ADDIE method. The purpose of the evaluation stage is to make revisions according to the evaluation results that have been obtained in the implementation stage for several things that do not meet the criteria for this tool.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

From all the tests that have been carried out in the study and based on the discussion in the previous chapter, several things can be concluded as follows:

1. The design of a magnetic power plant consists of two main parts: the energy generation process and the monitoring system for voltage, current, and magnetic field. This turbine design drives a generator to produce direct current (DC), which is then converted into an electric voltage of 220 V.
2. The testing of the magnetic power plant design was carried out in two stages, namely testing on the magnetic turbine and the monitoring system. The testing stage on the magnetic turbine was carried out to determine how long it would take for the turbine to reach maximum output and be in a stable condition. In addition, testing of the monitoring system was carried out to evaluate the success of the tool design that had been made, with the monitoring results displayed on PyCharm.
3. The results of testing the magnetic turbine, namely after activating the tool for 10 minutes, showed that the rotation of the neodymium magnetic turbine could drive the DC generator and could achieve a stable and constant output voltage of 230.8 VAC, and there was an error between the PyCharm application and the measuring instrument of 3%. This shows that no matter how long the turbine rotates, it will still produce constant output results.

5.2. Recommendations

1. Improve the design of this power plant by adding a control and monitoring system based on the Internet of Things (IoT) and various monitoring features to obtain more comprehensive data for further research.
2. Adding the number of coils turns according to needs, replacing the coils periodically to avoid decreasing the performance of the electromagnetic components, and adding a cooling system to the neodymium-magnet turbine.

3. Conducting tests with more accurate measuring instruments so that it can reduce the 3% error rate as previously mentioned.

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