PROTOTYPE OF MICRO HYDRO POWER PLANT USING TESLA TURBINE BASED ON PROPORTIONAL INTEGRAL DERIVATIVE(PID) AND INTERNET OF THINGS

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ABSTRACT
In this era of technological development, electrical energy plays an important role in human life. Mostof the electrical energy comes from coal, which is a conventional power plant. However, conventional powerplants have a negative impact on the environment. As an alternative, renewable energy is a solution in an effort to achieve sustainable development. Microhydro Power Plant is an alternative energy small-scale power plant that converts water potential energy into mechanical energy. One of the innovative technologies that can improve the performance of MHP is the use of tesla turbine. Therefore, this research design aims to develop a prototype of the MHP and also optimize the output voltage of the MHP with a series of buck boost converters equipped with a Proportional Integral Derivative (PID) control system. The research methods used include the design and manufacture of tesla turbine prototypes, implementation of PID control to optimize and stabilize the voltage output at the generator, and integration of the Internet of Thing system for remote monitoring and control. The average voltage obtained is 8.73 V without load, and 5 V using a load. Based on the test, the buckconverter functions to reduce the voltage to 5 V for ESP32 power. In the buck boost converter, the output voltage from the generator ranges from 4 V to 5 V, which is then stabilized to 13 V. This can be seen by measuring the voltage and can be monitored using the LCD and also the Ubidots Web. This can be known by measuring the voltage and can be monitored using LCD and also Ubidots Web. The test results show thatthe prototype can generate electricity with high stability thanks to the application of PID control.

Keywords: Buck Boost Converter, Microhydro, Tesla Turbine, Proportional Integral Derivative, Internet of Things

A. INTRODUCTION

The progress of human civilization in this era is inseparable from the vital role of energy. Electrical energy is an essential requirement for modern life. However, conventional power plants such as PLTU and PLTB that are widely used today have a negative impact on the environment. The limitations and negative impacts of using fossil fuels encourage the need to find sustainable alternative energy sources.

One of the renewable energy sources with great potential is water energy, which can be utilized through Microhydro Power Plants (MHP). MHP is a small-scale power plant that converts the potential energy of water into mechanical energy by rotating the turbine shaft, which is then converted into electrical energy by a generator. The electrical power generated ranges from 5 to 100 kW. Microhydro power plants are suitable for application in areas far from PLN sources. One of the innovative technologies that can improve the performance of MHPs is the use of tesla turbines. Tesla Turbine has the ability to convert energy with higher efficiency than conventional turbines, so it can produce more electrical energy with the same amount of water. Tesla turbines have a simpler and more compact design, making them easier to install and maintain.

The thing that needs to be considered is also the MHP traveler, with the condition of the MHP location far away, it will hamper the technician in carrying out maintenance and monitoring conditions on the MHP. This research aims to maximize the performance of the MHP by increasing the output voltage of the generator to match the predetermined set point, which is 14v, using a buck boost converter circuit that is stabilized through Proportional Integral Derivative (PID) control. Meanwhile, to maximize maintenance, the MHP is equipped with monitoring and load control using the ubidots web server in real time. In previous studies, there was no PID control as an output voltage stabilizer and also a monitoring and control system from the load.

Based on the background of the above problems, the author proposes a Final Project with the title

"PROTOTYPE OF MICRO HYDRO POWER PLANT USING TESLA TURBINE BASED ON

PROPORTIONAL INTEGRAL DERIVATIVE (PID) AND INTERNET OF THINGS".

B. METHODOLOGY

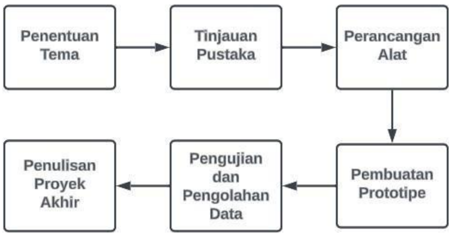

Figure 1 Research Methods

This research begins with determining the problem and determining what theme will be raised. The next stage is to review supporting journals as a literature study of tool design. The next stage is the design and manufacture of tools. The design of the tool is in the form of a prototype of a power plant where the scale of the tool is small. The testing stage as a measurement and validation feasibility test of the tool whether it functions as expected.

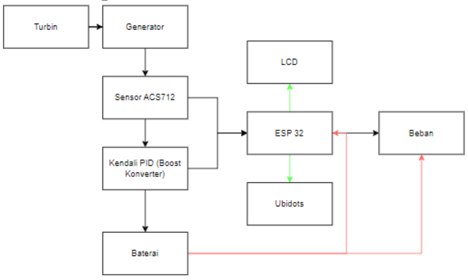

Figure 2 Tool Design Diagram

The design diagram of the device has 3 parts, namely the data sender, data receiver, and data display. The data sender comes from the ACS712 sensor which will read the voltage produced by the generator then forwarded to Esp32. Esp32 receives data from the sensor then processes from analog to digital data. Lcd and web will display digital data that has been processed and forwarded by Esp32 as a microcontroller.

Hardware components:

1. Tesla Turbine

The Tesla turbine, invented by Nikola Tesla in 1913, is a bladeless fluid turbine that uses a hollow metal disk that rotates due to the bernoulli effect of high-velocity water flowing through a nozzle creating mechanical energy, which is further converted into electrical energy by a generator connected to the turbine shaft.

2. Generator

The generator in the prototype micro hydro power plant functions as a vital component that converts mechanical energy from water flow into electrical energy. This system utilizes water sucked up by a pump to rotate a turbine, which then drives a generator with 24 volt specifications to produce electricity on a small scale.

3. Buck Boost Converter Circuit

Buck Boost converter circuit in micro hydro system plays an important role to increase or decrease the generator output voltage. This circuit focuses more on increasing the voltage to a level higher than the input voltage produced by the generator.

4. Esp 32

The Esp32 is an open source microcontroller with built-in WiFi and Bluetooth, which connects devices wirelessly. The ESP32 synchronizes hardware and software with the C++ programming language via a USB port and only requires a 5V supply. The ESP32 functions to receive and send voltage and current data, display information on the LCD and Ubidots platform via WiFi, and regulate the stability of the output voltage and turbine speed using the PID method.

5. Solar Charge Controller

Solar Charger Controller (SCC) is an electronic device that regulates the flow of power from the generator to the battery, functioning as a voltage booster and power regulator to maintain battery conditions. In this design, the SCC used is 10 Ampere.

6. ACS712 Current Sensor

The ACS712 sensor module measures electric current using the Hall effect. With three pins (VCC, GND, OUT), this module detects DC and AC currents, generating an analog signal on the OUT pin that is proportional to the current. This sensor is useful for monitoring current, detecting overcurrent, and measuring power consumption.

7. Battery

A battery is a device that stores chemical energy and converts it into electrical energy, which has positive and negative poles. In this prototype, a 12V 5 Ampere dry battery is used to store energy from the generator and distribute electricity to the load when the generator is not operating.

8. Pump

The pump in this prototype sucks water from the reservoir and flows it into the pipe that sprays water on the turbine. The pump used is Db Moswell 125 with 220 V input voltage specifications, 30 liters/minute capacity, and 125 watts output power.

9. 16x2 LCD

LCD (Liquid Crystal Display) is a type of screen that uses liquid crystals to display data. In this circuit, the LCD functions as a monitoring display, output parameters of voltage and current produced by the generator, with the data processed by the microcontroller.

Software components:

1. Arduino IDE

The Arduino IDE is open-source software for programming Arduino and ESP32 microcontrollers, available for Windows, Mac OS, and Linux. To use the Arduino IDE with ESP32, install the ESP32 Library and select the ESP32 port. The Arduino IDE uses the C programming language, which is easy to learn and almost similar to human language.

2. Proportional Integral Derivative (PID)

A PID (Proportional Integral Derivative) program is a control algorithm that maintains balance and achieves a desired value by calculating the error (the difference between the desired value and the actual value) and using three components:

a. Proportional (P): Responds to the current error signal; the larger the error, the larger the control signal.

b. Integral (I): Responds to the accumulation of error over time; the longer the error lasts, the larger the control signal.

c. Derivative (D): Responds to changes in error; the faster the error changes, the larger the control signal.

PID is used in various systems, including micro-hydro power plants (MHPs), to keep the output voltage and frequency stable, and optimally regulate the water flow to the turbine to increase efficiency.

3. Web Ubidots

Ubidots is a web-based IoT platform for collecting, visualizing, analyzing, and managing data. It collects data from sensors and IoT devices in real-time and stores it in the cloud, and provides customizable dashboards and graphs for data visualization.

The Tool Works

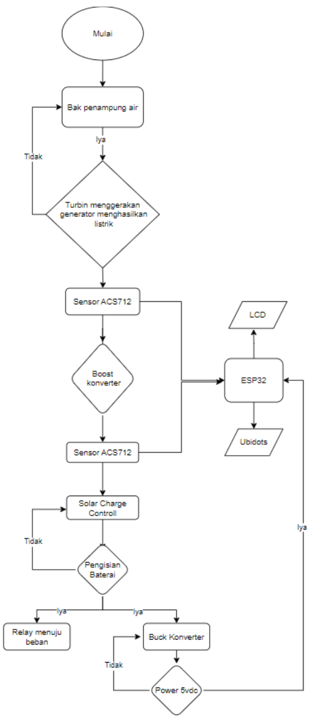

Figure 3 Tool Work Flowchart

In the tool design block diagram above it can be explained, when the tool starts, from the reservoir water will flow water through the pipe with the help of a pump to suck water from the reservoir. Water flows into the pipe and there is a water tap and noozle as a water sprayer to the tesla turbine. The turbine will rotate due to fluid motion and will automatically drive a generator that produces electrical energy. The electrical energy produced will be read by the ACS712 sensor, after which it enters the boost converter with a PID control system. PID here functions to keep the generator output voltage stable, PID commands the expected set point on the PWM signal, then transfers it to the mosfet to adjust the voltage on the boost converter. PID helps maintain the generator output voltage at the desired level, despite changes in the load to be stabilized and will be forwarded to the SCC to control the charging voltage so as not to overload the battery. Before the SCC there is also an ACS712 sensor to determine the output voltage that has been set based on PID control. The battery functions as a storage of electrical energy. After being stored in the battery, the voltage will be branched into 2 power supplies, the first for 12vdc lamp load power, and the other voltage goes to the buck converter to reduce the voltage to 5vdc as microcontroller power. This generator is equipped with a monitoring system that will monitor the current voltage output from the generator before and after stabilizing the PID control, as well as control the load which will be processed by the ESP 32 microcontroller and displayed via LCD. In addition, the results of monitoring and PID control will be visualized on the Internet of things platform, Ubidots, which can be accessed anywhere.

C. RESULTS AND DISCUSSION

This chapter discusses testing the system design of the device to evaluate the performance of each component and the entire system. This test ensures that the system can function optimally.

1. Generator Output Testing with Load and Without Load

In this final project, the author will test the turbine and generator with two conditions, namely using a load and no load. This test is to obtain comparative data between the voltage generated by the generator using a load and the voltage generated without using a load.

Figure 4 No-load Generator Measurement

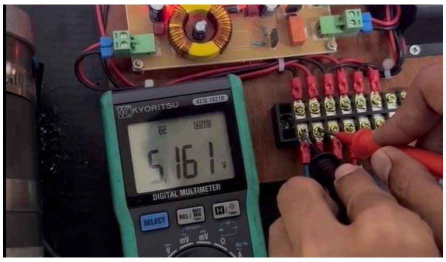

Figure 5 Generator Measurement Using a Load

In the table below are the test results using load and no load using an avometer to measure the current voltage value, and also a tachometer to measure the turbine rotation value.

Table 1 Generator Testing

Experiment	RPM	No Load		Using Load	
		Voltage	Current	Voltage	Current
1.	9.0	8.74 V	-	5.12 V	0.21 A
2.	8.8	8.80 V	-	5.16 V	0.19 A
3.	9.2	8.71 V	-	4.95 V	0.20 A
4	8.8	8.61 V	-	4.80 V	0.20 A
5.	8.9	8.80 V	-	5.15 V	0.18 A

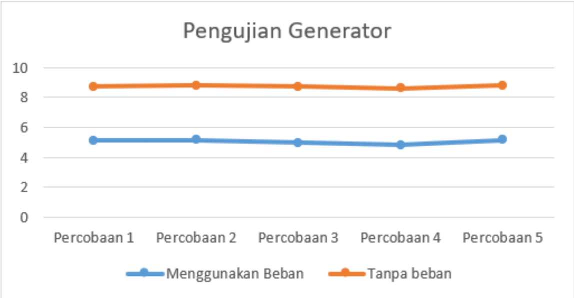

Figure 6 Generator Testing Chart

Analysis results obtained:

In this experiment, measurements were taken using an avometer to measure voltage and current. Voltage measurements using an avometer showed that the generator tested had an average voltage of 8.732 V without load and 5.036 V with load. The significant decrease in voltage when a load is applied indicates a large influence of the load on the voltage generated. In this experiment, it is concluded that the voltage when using a load will be smaller in value and the current will be larger, compared to no load. The average current flowing when a load is applied is 0.196 A. This shows that the load consumes a relatively constant current despite variations in voltage. Then a tachometer was used to measure the rotation value of the turbine and an average of 8.94 Rpm was obtained.

2. Buck Boost Converter Circuit Testing

Testing the buck boost converter circuit is carried out to evaluate the performance of the circuit, with a focus on observing the increase in voltage that will be used as a power source for the load. Tests are carried out using avometer tools and measured at the input port of the boost converter and also at the output port of the boost converter. The following are the measurement results of the buck boost converter circuit.

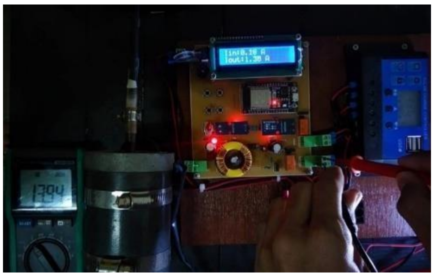
Figure 7 Boost Converter Measurement

Based on Figure 7, the test is carried out by measuring the output of the *buck boost* converter using an avometer, and data is obtained as shown in the table.

Table 2 Buck Boost Converter Testing

Experiment	PWM	V Input	V Out Buck Boost Converter
1.	223	5.12 V	13.80 V
2.	212	5.16 V	13.76 V
3.	212	4.95 V	13.78 V
4.	212	4.80 V	13.90 V
5.	223	5.15 V	13.94 V

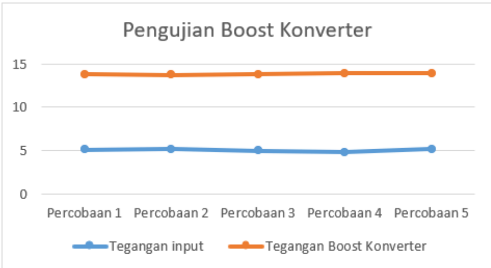

Figure 8 Boost Converter Testing Chart

Analysis results obtained:

In the boost converter circuit, the voltage enters through mosffets, inductors, capacitors, diodes and resistors and produces a voltage 2-3 times greater than the original voltage. Testing the buck boost converter circuit shows that this converter is able to produce a stable and higher output voltage than the varying input voltage, with the output voltage ranging from 13.76 V to 13.94 V when the input voltage fluctuates between 4.80 V to 5.16 V. The graph also shows that the voltage produced by the boost converter is more stable. This shows that the converter is effective in maintaining stability and performing voltage conversion well under different test conditions.

3. Current and Voltage Difference Testing on Avometer, LCD, Web

In testing comparing the voltage and current values produced by the generator using avometer, LCD and ubidots applications to compare different measurement results on one circuit. This test can be done with a tool in the form of an avometer and can be compared by looking at the sensor data results that have been displayed on the LCD screen and also the ubidots web. There are several parameters displayed on the LCD and also ubidots such as input voltage, output and input and output currents.

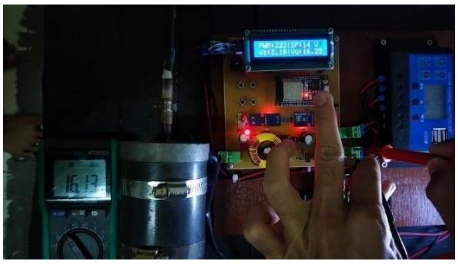

Figure 9 Voltage Output Measurement Using an Avometer

Figure 10 LCD Screen Display

Table 3 Comparison of Voltage Measurements

Experiment	Avometer		LCD Display		Web Server	
	Vout	Iout	Vout	Iout	Vout	Iout
1.	15.79 V	1.3 A	12.65 V	1.20 A	12.63 V	1.20 A
2.	15.56 V	1.25 A	14.63 V	1.22 A	14.65 V	1.22 A
3.	14.56 V	1.1 A	14.29 V	1.05 A	14.29 V	1.05 A
4.	16.12 V	1.22 A	14.75 V	1.35 A	14.75 V	1.35 A
5.	14.91 V	1.26 A	14.55 V	1.08 A	14.50 V	1.08 A

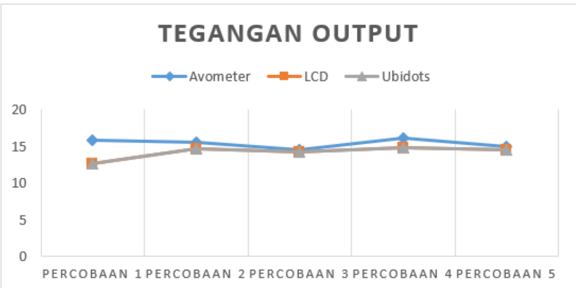

Figure 11 Output Voltage Comparison Chart

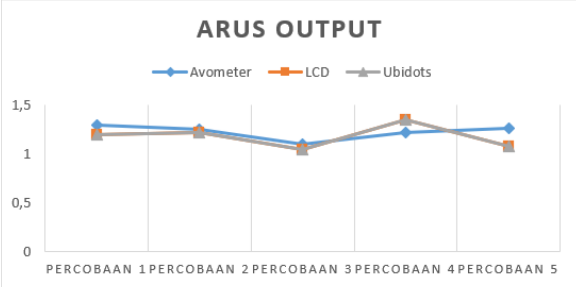

Figure 12 Output Current Comparison Chart

In this experiment, measurements were taken with the help of an avometer to measure the voltage and current values. The measurement results show that there is a significant difference in the input and output voltage between the avometer and LCD and also ubidots, with the avometer showing a higher value of about 1.21 V. In contrast, the output current measurement shows a smaller difference of 0.05 A. So, in the table above, it can be concluded that the voltage and current values when measured using the avometer and on the LCD screen have a slight difference, while on the LCD screen and ubidots web, the value is the same. The difference in voltage measured using the avometer and sensor can be caused by inaccurate calibration of the avometer, plus the sensor has a lower input impedance so that it can affect the measured voltage because they draw a larger current than the avometer.

4. Buck Converter Testing

Buck converter testing is done to determine whether the buck converter can function properly when reducing the 12V voltage from the battery to 5V for the Arduino Nano, ESP32 as a microcontroller, and LCD as a voltage and current value displayer. The following is a table of test results.

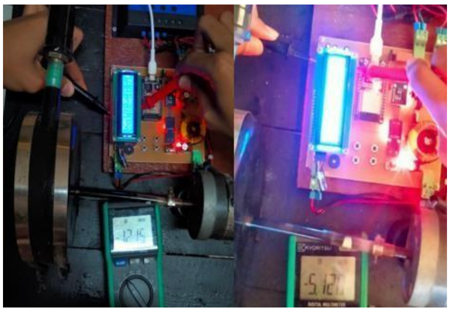

Figure 13 Buck Converter Voltage Measurement

Measurements were taken at the output of the buck converter to determine the voltage value. The measurement process involves connecting the red pole to the positive terminal of the buck converter and the black pole to the negative side using an avometer, as shown in Figure 13.

Table 4 Buck Converter Testing

Experiment	Input Voltage	Output Voltage
1	12,15 V	5,12 V
2	12,18 V	5,09 V
3	12,15 V	5,11 V
4	12,15 V	5,12 V
5	12,13 V	5,09 V

Analyzed results:

Based on the measurement data, the input voltage from the battery of 12V is reduced to 5V using a buck converter, which is set to supply the ESP32 and Arduino Nano. From the measurement table that was done five times, an output voltage of 5V was obtained. This proves that the buck converter is functioning properly.

Advantages and Disadvantages of the tool

Advantages

1. Micro hydro power plant as an alternative environmentally friendly power plant. This micro hydro power plant prototype uses tesla turbines, as a separate innovation from various types of turbines on micro hydro.
2. This tool is equipped with a buck boost converter circuit that can increase or decrease the voltage and can also stabilize the voltage from the generator voltage source, where the voltage from the generator tends to change due to the water discharge factor that flows the turbine.
3. This prototype is equipped with a PID (Proportional Integral Derrivative) approach method as an automatic voltage stabilizer, so that the output voltage results obtained tend to be more accurate.
4. The prototype of the micro hydro power plant has been equipped with an ESP32-based microcontroller-based monitoring system that can not only be monitored using an LCD, but has also been integrated with wifi so that it can be connected and can be monitored via a web server in real time and also remotely.

Disadvantages

1. The design of this tool still uses tesla turbines and generators on a small scale.
2. The water discharge and pressure generated must be large in order to rotate the turbine.
3. Application-based remote monitoring depends on a stable internet connection. If it is in a situation without wifi, it cannot be connected.

CONCLUSION

Based on the experiment and discussion, it can be concluded that ::

1. In this final project, the voltage can be adjusted using a buck boost converter with the PWM method with a predetermined set point through PID. This makes the generator output voltage which is initially small will be increased to 2-3 times greater than the original voltage, and the fluctuating voltage will become stable, thus extending the battery life when charging.
2. Based on the experiments conducted, the rotation of the turbine is averaged at 8.94 rpm with the output voltage of the generator without load with a maximum output of 8.80 V and a minimum of 8.61 V, then the output voltage of the generator with a load produces an output of 5.16 V and a minimum of 4.80 V, with a maximum current of 0.21 A and a minimum current of 0.18 A. As well as testing the buck boost converter circuit produces a maximum output voltage of the buck boost converter generated 13.94 V and a minimum of 13.76 V where the voltage is made fixed around 13 V.
3. In the design of this tool, parameters such as voltage, current and control of the lamp load can be monitored using the ubidots web server which has been integrated with the LCD. Monitoring results can also be retrieved database in excel form as data reporting.

Reccomendations

In the process of making this final project, the author realizes that this tool still has shortcomings and is not completely perfect. So, the author suggests several things that can be utilized for future development in order to be better and can be developed. The suggestions, namely:

1. For larger scale research, it should be done by increasing the capacity of the battery, generator and turbine to be used.
2. Additional research is needed when the MHP utilizes water directly from rivers or other watercourses, so that we can compare the accuracy of the output produced.
3. The utilization of MHP can be a useful learning tool for the community and students, because MHP utilizes energy from the flow of water around the environment to meet electricity needs.

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REFERENCES

[1] Abidin, M., & Radani, M. T. (2022). Design of Prototype Micro Hydro Power Plant (Pltmh) Cross-Flow Turbine Type (Doctoral Dissertation, Politeknik Negeri Ujung Pandang).

[2] Alfatich, W. A., & Tindyo Prasetyo, S. T. (2021). Design of Vortex Microhydro Power Plant Prototype Using Permanent Magnet Syncronous Generator (Pmsg) as Street Lighting (Doctoral Dissertation, Universitas Muhammadiyah Surakarta).

[3] Basri, M. W. H. (2022). Design of Buck-Boost Converter in Microhydro Power Generation System Using Pid. Science Electro, 14(2).

[4] Solihat, I. (2020). Design of Microhydro Power Plant Prototype (Pltmh). J. Inov. Knowledge Science. And Technol, 2, 22.

[5] Rante, H. A. (2022). Design of Tesla Turbine Prototype as Water Turbine (Doctoral Dissertation, Politeknik Negeri Ujung Pandang).

[6] Riyanto, A., Mulyanto, A., & Sutanto, R. (2017). EFFECT OF VARIATION OF DISK SPACING ON TESLA TURBINS (Doctoral dissertation, UPT. Unram Library).

[7] Rizaldi, D. (2015). Design of Tesla Turbine as a Water Turbine and Comparative Analysis of Variations in the Number of Disks and Distance Between Disks. Department of Mechanical Engineering, Faculty of Engineering, University of North Sumatra, Medan

[8] Rohman, M., Sulaksono, D. H., & Yuliastuti, G. E. (2021, June). Utilization of Water Flow for Current and Voltage Monitoring System in Web- Based Microhydro Generator. In Proceedings of the National Seminar on Electrical Engineering, Information Systems, and Informatics Engineering (Snestik) (Vol. 1, No. 1, Pp. 269-274).

[9] Saraswati, S. D. (2023). Design of Micro Hydro Power Plant Simulation Tool (Pltmh) (Doctoral Dissertation, Politeknik Negeri Ujung Pandang).

[10] Wiranata, I. P. A., Janardana, I. G. N., Wijaya, I. W. A., Elektro, T., Teknik, F., & Udayana, U. (2020). Design of Micro Hydro Power Plant Prototype Using Cross-Flow Turbine. Spektrum Journal, 7(4).