Original Article

Design and Enhancement of Pico Hydro and Monitoring System for Generation of Electricity

Re-Ann Cristine O. Calimpusan[1], Lydelle P. Arcite[2], James Michael A. Yula[3]

[1,2,3]*Department of Electronics Engineering, College of Engineering and Geosciences, Caraga State University, Philippines.*

[1]*Corresponding Author : rcocalimpusan@carsu.edu.ph*

Abstract - Limited or nonexistent electricity access in rural areas globally adversely impacts various aspects of daily life. Pico hydro, a reliable and cost-effective form of renewable energy that harnesses the power of small streams or rivers, offers a promising solution by providing electricity for lighting and small appliances in remote communities, simultaneously mitigating greenhouse gas emissions and local pollution. The research aimed to design and enhance a Pico hydro system with a monitoring system to provide sustainable electricity for rural areas. By achieving the objectives, the power output of the Pico hydro system ranged from 150.093 W to 211.896 W, with the rotational speed determined by the water head and flow rate. The monitoring system collected data on voltage, current, power, pH level, and flow rate, revealing variations in these parameters over time. The study's findings demonstrate the successful implementation of a Pico hydro system and highlight the importance of monitoring for performance evaluation and optimization.

Keywords - Pico Hydro, Monitoring system, Turbine, Pelton Turbine, Electricity Generation.

1. Introduction

In many rural areas around the world, access to electricity is limited or nonexistent. This lack of access to electricity affects daily life, including education, healthcare, and economic growth. While there are many solutions for providing electricity, many of them are expensive or not sustainable in the long term.

One promising solution is Pico hydro, a type of hydroelectric power that harnesses the power of small streams or rivers. Pico-hydro power plants are standalone systems that generate electricity from streams and small rivers [1]. Stated that despite their small scale (generating less than 5kW), they improve the standard of living in remote areas [2]. On the other hand, monitoring the system is essential for maintaining high availability, making informed decisions, and detecting issues [3]. IoT technology plays a role in the real-time monitoring of water levels and other parameters [4-6].

This study focuses on addressing the need for a sustainable and reliable electricity solution through the design and implementation of a Pico hydro system with a monitoring system. The study aims to achieve two main objectives: first, to design and develop a turbine capable of generating a power output ranging from 100 to 300 watts by adding a pulley system to enhance its power generation, and second, to incorporate an IoT monitoring system that gathers data on the load's condition and performance.

2. Review of Related Literature

Table 1 below provides a summary of the review of related literature, specifically comparing the design and development of pico hydro and monitoring based on existing studies. The designed system encompasses several important parameters, including the pH meter, flow rate, current, voltage, power, IoT monitoring, the pico hydro system, and the Pelton turbine. By examining the literature, we can gain insights into the different aspects covered in these studies. Cañeda et al. [1] focus on monitoring current, voltage, pH, and even power.

On the other hand, Musyafiq et al. [2] also have monitoring but little power generation with the use of a Thread turbine. And we have Ginting et. al[2], who also have monitoring with current, voltage, and power. But none of the mentioned above discusses how to increase power generation. In this study, the author features an additional pulley system to improve the power generation of the pico hydro.
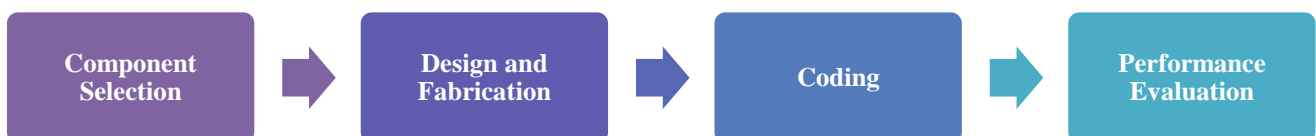

Fig. 1 System overview

Table 1. Summary of review of related literature

Parameters	[6]	[7]	[8]	This work
Monitoring				
pH meter	✓	-	-	✓
Flow Rate	✓	-	✓	✓
Current	✓	✓		✓
Voltage	✓	✓	✓	✓
Power	✓	✓	✓	✓
Turbine	Pelton Turbine	Thread Turbine	-	Pelton Turbine With Pulley System
Power	-	10W	-	150.09 W-
Generation rating	-	-	-	211.896 W

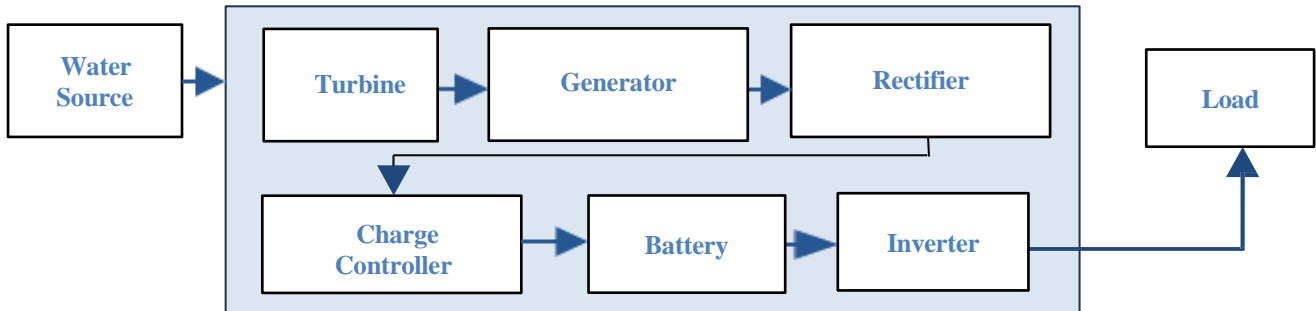-   Note specifically mention

Fig. 2 Block Diagram of the Pico Hydro System

3. Materials and Methodology

This chapter of the study focused on the proposed methodology of the researcher regarding the construction of the pico hydro and monitoring system for the generation of electricity. It also includes the system overview, system design and implementation, overall physical design and dimension of the turbine, data gathering, and statistical tools we will utilize to achieve the objectives of this study.

3.1. Pico Hydro System
3.1.1. General Framework

The overall procedural structure of the system, shown in Figure 1, starts with component selection, which entails choosing the materials and hardware components utilized in building the hardware, body, and framework of the pico-hydro generator. Next is to design and turbine structuring, which includes planning the physical structure of the whole system and creating the Pelton turbine. This procedure will cover the installation of the components to the turbine. Lastly, the researchers will evaluate the performance of the pico-hydro generation system.

3.1.2. Hardware Components

The primary hardware components used in this prototype are as follows: Generator, Three Phase Diode Bridge Rectifier, Power Inverter, Water Tank, ESP32 Microcontroller, Voltage Sensor, Current Sensor, pH sensor, and Water pipe.

3.1.3. System Overview

Figure 2 shows the block diagram of the pico hydro and monitoring system. A nozzle with pressurized water will strike directly into the turbine after the water tank's valve is opened, turning the hydroelectric generator. A single-phase diode bridge rectifier will be used to transform the producing power from the generator into square waveforms. To properly charge the 12 V battery, a PWM Charge Controller will be utilized to regulate the generator's output of voltage and current. Using a 250 W power inverter, the 12 VDC from the battery will be changed to a 220 VAC. With a 220 volts AC the system will power the house.

3.1.4. System Physical Design

Figure 3 displays both the frontal and bottom perspectives of the turbine. The frontal view showcases a 4-inch-sized pulley interlinked with the generator's pulley. On the other hand, the bottom view is intentionally left open to facilitate the discharge of water from the nozzles, subsequently returning it to the riverbank.

3.2. Monitoring System
3.2.1. System Overview

The monitoring system's block diagram is illustrated in Figure 4. Input from the INA219 sensor, water flow sensor, and pH sensor is transmitted to the ESP32 microcontroller, which in turn sends the information to the database.
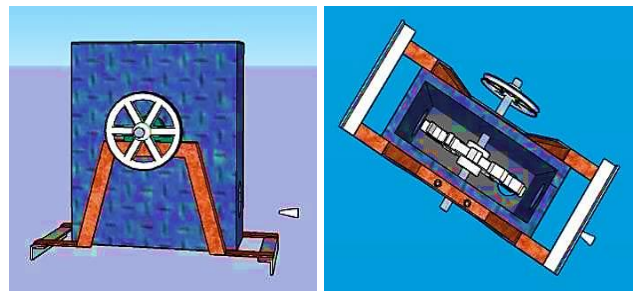

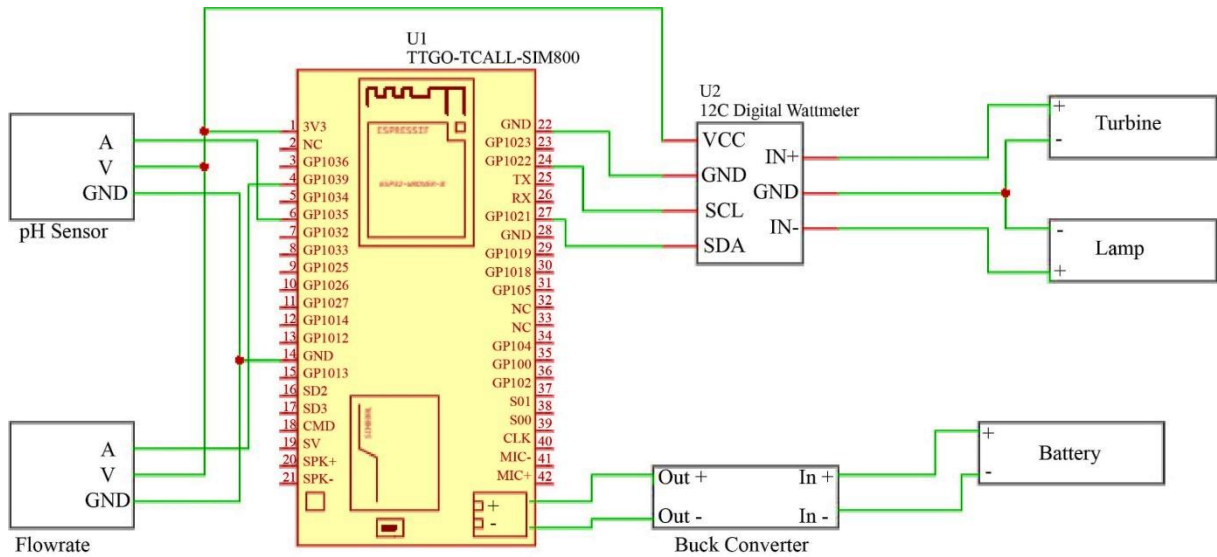**Fig. 3 Front and bottom view of the turbine**

Fig. 4 Block diagram of the monitoring system

Fig. 5 Schematic diagram of the monitoring system

3.2.2. Database

ThingSpeak was utilized as an IoT monitoring data analytics as it offers a user-friendly interface, powerful data management capabilities, real-time monitoring features, and a supportive community. Some of the key points of ThingSpeak that were considered for this study were it is open and customizable, easy data collection, data storage and visualization, real-time monitoring, and scalability and flexibility.

Figure 5 illustrates the schematic representation of the monitoring system. The pH sensor links to TTGO T-CALL GPIO35, while the SDA and SCL of the Digital Wattmeter connect to the GPIO21 and GPIO22 pins of TTGO TCALL, respectively. The battery supply not only powers the entire power system but also the central control, the TTGO T-CALL microcontroller. However, as the battery operates at 12V, a buck converter is employed to step down the voltage to 5V, providing power to the TTGO TCALL. Lastly, the lamp is connected to both the battery and the digital wattmeter for the monitoring of voltage, current, and power.

4. Results and Discussion
4.1. Pico Hydro System
4.1.1. Design and Construction of Pico Hydro Generator

The constructed actual turbine with a hydro-powered-generator is shown in Figure 6. The turbine was used and developed in the project entitled Development of Pico-Hydro System for Generation of Electricity, which was deployed in Purok 6, Barangay Taligaman Butuan City.

As seen in the figure, there are 3 brass valves fixed to adjust the pressure of the water coming out from its nozzles, which could also affect the pressure and the blade rotation. Based upon the design, there are 3 exits of the water through the nozzles, which meet at the center and hit the designed turbine blade, making it spin upon collision.

4.1.2. Power Output

The feasibility of the proposed pico-hydro system is calculated using the equation below for potential output power.

$$P_{out} = Head\ (H) \times Water\ Flow\ Rate\ (Q) \qquad (1)$$
$$\times Gravitational\ Force\ (g)$$
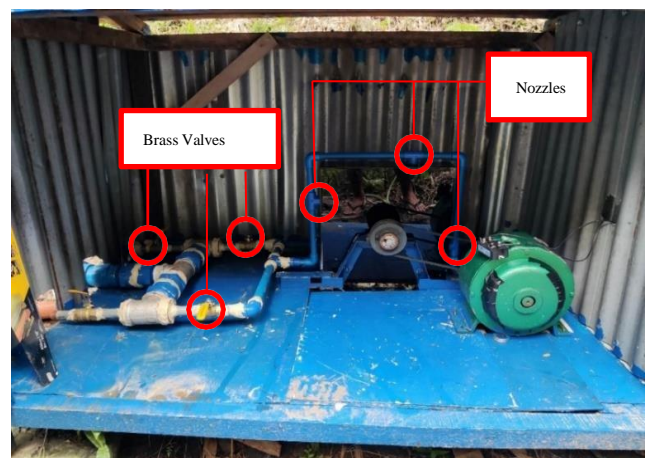$$\times Generator\ Efficiency(\eta)$$

Fig. 6 Actual Pico Hydro System

Table 2. Power generated by the generator

Head (meters)	Flow Rate (L/s)	Gravitational Force	Efficiency (%)	Power (W)	Rotational Speed (RPM)
9	3.4	9.81	50 %	150.093	169
9	3.7	9.81	50 %	163.33	193
9	4.0	9.81	50 %	176.58	229
9	4.3	9.81	50 %	189.8235	256
9	4.8	9.81	50 %	211.896	284

The power output of the Pico hydro system is the power generated by the generator. Table 2 shows the different power outputs with varying flow rate values. As seen in the table, the lowest power generated was 150.093 W, and the highest was 211.896 W. This calculation was based on Equation 1, reflected above. Thus, the first objective − to produce 100-300 W − was successfully achieved. The rotational speed, on the other hand, was taken through a contact digital tachometer. The RPM relies on the head and flow rate of the water. The greater the head and flow rate, the higher the rotational speed of the turbine.

4.1.3. Water Flow Measurement
In this study, the researchers use the bucket method to measure the flow rate of the stream. The researchers used a 16 liters bucket with a bottom diameter of 24cm, a mouth diameter of 27 cm, and a height of 32cm. After that, a stopwatch and observe when the bucket will be full. Flowrate of the stream was measured as reflected in Table 2.

4.1.4. Energy Harvested
In electrical systems, power is the rate at which electrical energy is transferred or consumed[7-10]. The formula for calculating power in electrical circuits is:

$$Power\ (P) = Voltage\ (V)\ x\ Current\ (I) \qquad (2)$$

Table 3 displays the energy transferred from the generator to the load. The voltage and current levels in the table were derived from monitoring results and grouped into five ranges from lowest to maximum. The lowest energy harvested was 0.0825 W, and the highest was 0.2058 W. These power values are generated taking into account losses and inefficiencies in the system, such as transmission losses, turbine and generator losses, electrical losses, and other factors that reduce the available power. Moreover, Equation 2 was used to compute the electrical power.

4.2. Monitoring System
The proposed system monitors the following parameters: voltage, current, power, pH level, and flow rate. The researchers originally planned to monitor the system during rainy and sunny days. However, during the conduct of monitoring, there was no time when a rainy day was monitored due to the weather recently which is super sunny. The table below shows the average sensor readings per hour to know how the system's condition is performing.

Table 4 presents data collected from a pico hydro system over time, providing insights into its performance and characteristics. The measurements were taken at hourly intervals, revealing fluctuations in voltage, current, power, pH level, and flow rate. The voltage readings varied between 3.81 V and 4.38 V, reflecting changes in the electrical potential difference within the system.

Similarly, the current values ranged from 27.80 A to 33.55 A, representing the varying flow of electric charge. These variations in voltage and current directly influenced the power output, which fluctuated between 107.22 W and 147.67 W. Furthermore, the pH level, an indicator of acidity or alkalinity, was monitored throughout the period.

Table 3. Energy is harvested by the generator to the load

Voltage	Current (mA)	Electrical Power (W)
3.3	25	0.0825
3.8	29	0.1102
4.1	33	0.1353
4.4	38	0.1672
4.9	42	0.2058

Table 4. Data Measurement of a Pico Hydro System Over Time

Time (Hr)	Voltage	Current	Power	pH Level	Flowrate
1	4.15	32.23	134.5	7.83	**4.37**
2	4.38	33.55	147.7	7.88	**4.62**
3	4.20	30.95	131.2	7.84	**4.46**
4	**3.81**	**27.80**	**107.2**	**7.57**	**4.12**

The recorded values ranged from 7.57 to 7.88, indicating a slightly acidic to a neutral environment. Monitoring pH is crucial to assess water quality and potential impacts on system components. Lastly, the flow rate, measured in cubic meters per second, showed variations between 4.12 and 4.62 cubic meters per second. This parameter is essential for evaluating the hydro system's efficiency and performance, as it directly affects the amount of energy generated.

5. Conclusion

The design and development of the Pico hydro and monitoring systems for electricity generation were conducted successfully. The system generated a maximum power output of 211.896 W and harvested a power that ranged from 0.0825 W to 0.2058 W. Moreover, the monitoring system developed in this research provides real-time data on the performance and efficiency of the Pico hydro system, enabling users to optimize power generation and reduce energy waste. In conclusion, the design and development of the pico hydro and monitoring system for electricity generation represent a significant contribution to renewable energy and sustainable development. The research conducted in this provides valuable insights into the design and optimization of Pico hydro systems and the development of monitoring systems to enhance their performance.

6. Recommendations

With the results of the research conducted, several recommendations can be made to enhance the performance and efficiency of the system. First and foremost, it is recommended to conduct a comprehensive analysis of the site-specific conditions, including the flow rate and head of the water source, to determine the optimal design of the Pico hydro system.

Secondly, it is recommended to carefully consider the turbine and motor compatibility. It is essential to ensure that the turbine and motor are adequately matched to prevent excessive energy loss or mechanical failure, which can significantly impact the system's performance. Moreover, the turbine and motor selection should also consider their availability, reliability, and cost-effectiveness to ensure a sustainable and practical solution for electricity generation. Lastly, it is recommended to continue developing monitoring systems to provide real-time data on the performance and efficiency of the Pico hydro system. This will enable users to identify areas for improvement and optimize the system to operate at its maximum efficiency.

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