

Original Article

A Sustainable and Eco-Efficient Pico Hydroelectric Technology for Decentralized Power Generation in Remote Hydrological Environments

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Abstract

Background: The increasing electricity demand, driven by rapid population growth, necessitates the exploration of sustainable and alternative energy sources, particularly in remote areas. This study aims to develop and assess the performance of a portable pico-hydroelectric turbine designed to provide clean, off-grid energy for essential needs such as lighting and phone charging.

Methods: The prototype, constructed from stainless steel, includes four 6-in floats, pulleys, V-belts, a 12 V DC IC-type alternator, a 12 V battery, and a 200 W inverter (12 V DC to 220–240 V AC). Field testing was conducted in the Nagcarlan River, Liliw, Laguna, Philippines to measure voltage, frequency, and power output using a multimeter.

Results: The results indicated a steady 220–240 V AC at 57.9 Hz, generating 50 W to power two lights and a phone charger for up to 1.5 hours. Performance remained stable under varying water head conditions, demonstrating the system's reliability, portability, and suitability for basic household energy needs in rural or off-grid areas.

Conclusion: As a reliable and sustainable alternative energy source, this system demonstrates strong potential for electricity generation in remote areas with moderate to high-flow water sources, offering a practical solution for off-grid power needs and contributing to future energy management practices.

Keywords

alternative source of energy, remote areas, pico-hydroelectric turbine, IC-type alternator, electricity generation, mechanical and electrical design, sustainable energy solutions, off-grid power generation, turbine efficiency testing, renewable energy engineering

INTRODUCTION

Energy poverty remains a persistent challenge across the developing world, with rural regions experiencing the most significant disparities in access to and reliability of energy. One of the key factors exacerbating this issue is the rapid population growth. It is directly responsible for the rising electricity demand. This issue is particularly critical in remote and rural areas, where access to reliable and regular power remains difficult or impossible. Within this broader context, and given the rising energy needs, alternative and renewable energy technologies, such as hydroelectric power, have garnered significant attention over the last several years. In this broader framework, small-scale hydropower technologies have emerged as viable,

low-impact options for off-grid energy access. Recent work on floating and hydrokinetic systems (Dewatama et al., 2020; Fortaleza et al., 2018) demonstrates that water-driven generation can operate with minimal civil construction, offering environmentally gentle solutions well-suited to remote or scattered communities. Still, key gaps persist, particularly in creating portable, easy-to-deploy systems for low-head, moderate-flow sites that can meet the basic electricity needs of rural households.

To address this need, experts designed the turbine to produce 220–240 V AC within a frequency range of 60 ± 3 Hz and supply at least 50 W, which is sufficient for low-load household use. They carried out performance tests at three different head depths: 0.2 m, 0.15 m, and 0.1 m. The 0.1 m arrangement had the best average output, hitting 60.27 W at 230 V AC and 57 Hz. This output demonstrates that the system performs effectively even in shallow water. Additionally, the researchers selected the site based on factors such as flow speed, water depth, channel stability, and the amount of debris. They ensured that the system functioned effectively while causing minimal damage to the ecosystem.

This study combines earlier technical differences in pico-hydropower, which typically produces less than 5 kW and differs from micro-, mini-, and large hydro systems, as it can be easily relocated, requires minimal infrastructure, and operates in low-head streams. Prior literature highlights advantages such as simplified installation (Dewatama et al., 2020), use of existing natural flows (Fortaleza et al., 2018), adaptability for portable systems (Sarena et al., 2020), mechanical optimization (Gupta et al., 2018; Sathe et al., 2019), design refinements (Davirov et al., 2023; Khayal, 2019; Nasir, 2021), and community-level applicability (Al-Humairi et al., 2022). However, many past contributions examine mechanical performance in isolation, whether through blade refinement (Adanta et al., 2018; Masud & Suwa, 2018; Rantererung et al., 2018), power conversion approaches (Adibowo et al., 2020; Lubis & Cholish, 2019), or diagnostic analyses (Tomprowski et al., 2020), without integrating these insights into a holistic, deployable solution. Additional works in marine and riverine contexts (Doan et al., 2020; Ramadan et al., 2020) and system alignment studies (Safdar et al., 2020) expand the hydrokinetic literature but remain primarily technical.

Building on the limitations in the existing literature, this study adopts an integrated, interdisciplinary approach that encompasses mechanical design, electrical performance testing, environmental compatibility, and socio-economic usability. Environmental science informs site assessment; engineering principles guide the optimization of blade profile, inclination, and flow orientation; and community-level considerations emphasize accessibility, affordability, and minimal maintenance. This integrated framework responds directly to calls in previous literature for more design-to-deployment transitions (Masud & Suwa, 2018; Kougias et al., 2019).

The study promotes decentralized renewable energy by providing a technically proven, portable pico-hydroelectric system that aligns with sustainability, equity, and community empowerment objectives. Beyond filling immediate energy gaps in underserved regions, the findings provide a foundation for further development of portable hydro systems and their broader use in off-grid renewable energy solutions.

To address this gap, this study develops and tests a portable floating pico-hydroelectric turbine that generates electricity from naturally flowing water. Experts design the system to support basic household needs such as lighting and phone charging, with a focus on portability, easy disassembly, and straightforward transport. Building on previous work, from portability-focused designs (Sarena et al., 2020) to studies on blade and flow optimization (Davirov et al., 2023; Sathe et al., 2019) and decentralized energy models (Gupta et al., 2018), this study treats portability and modular deployment as central design priorities rather than as secondary considerations.

METHODS

The proposed project was a system used to generate electricity that is beneficial for remote areas with rivers, streams, and other bodies of water that flow nearby (moderate to high current). The floating pico-hydroelectric turbine is a device that converts energy. The rotation of a turbine generates mechanical energy due to water flow, and the rotation of the alternator, coupled by pulleys and belts, produces electrical energy that charges the battery. The battery also serves as the exciter for the alternator. A clamp meter is clamped to the battery and the positive terminal of the alternator to monitor the charging process and measure the current produced by the alternator, which connects to an inverter with a 12 V DC input and a 220–240 V AC,

60 ±3 Hz output, which converts mechanical energy to electrical energy. The output voltage, frequency, and power should be enough to provide a reliable source of electricity that people use for lighting domestic bulbs and charging phones. The project was also intended to serve as an alternative power source.

System Design

Figure 1 shows the schematic connections of the different components of the floating pico-hydroelectric turbine’s electrical box, and Figure 2 shows the actual wiring inside the electrical box. The shaft of the crossflow turbine is placed on the adjustable post. It has a harness that serves as the foundation of the floating pico-hydroelectric turbine. A casing is slightly elevated to accommodate the electrical components at the top of the harness. Furthermore, the alternator is connected in parallel to the 12V battery. The battery in the system performs several functions, including starting mechanisms, backup power, and storing added power. A DC-AC Power Inverter was connected in parallel to the battery to convert the DC power into an AC output, supplying power of 220-240 V, 60 ±3 Hz, and at least 50 W to two domestic bulbs and one mobile phone charger.

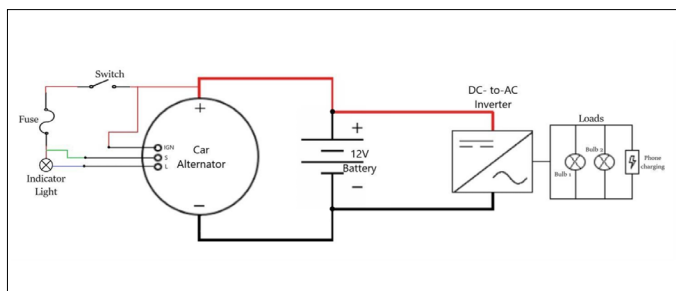


Figure 1. Schematic diagram of the electrical connections of the floating pico-hydroelectric turbine

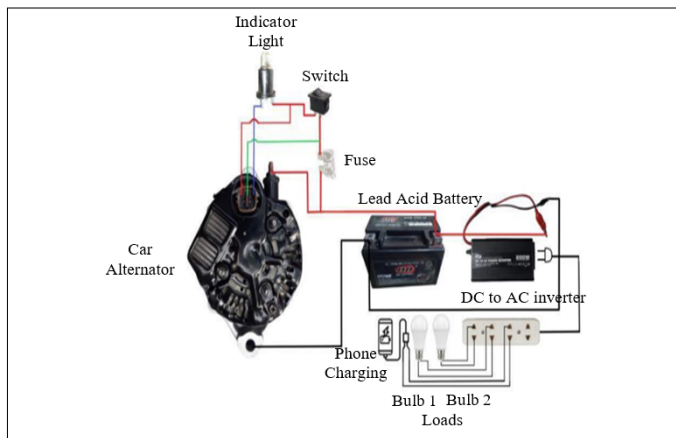


Figure 2. Internal wiring of the floating pico-hydroelectric turbine’s electrical box

System Flow Diagram

Figure 3 shows the process or flow of the proposed system of the floating portable pico-hydroelectric turbine. The prototype developed used an existing water flow from rivers or other areas with flowing bodies of water (moderate to high current). Once the water flows to the portable pico-hydroelectric turbine, the turbine rotates. The researchers chose a crossflow turbine for the prototype. When the turbine rotates consistently, the alternator generates electricity. It is wired in parallel with the battery and a connected fuse, similar to the power inverter. The researchers tested the data from the output of the DC-AC Power Inverter. The measured

output voltage of 220-240 V AC, frequency output of 60 ± 3 Hz, and the power output resulted in at least 50 W, the system was able to supply two (2) domestic bulbs and one (1) mobile charging. If the prototype did not produce a 220-240 V AC, 60 ± 3 Hz, and 50 W, it would require a significant flow of water to rotate the turbine, resulting in a higher RPM in the car alternator that generates electricity.

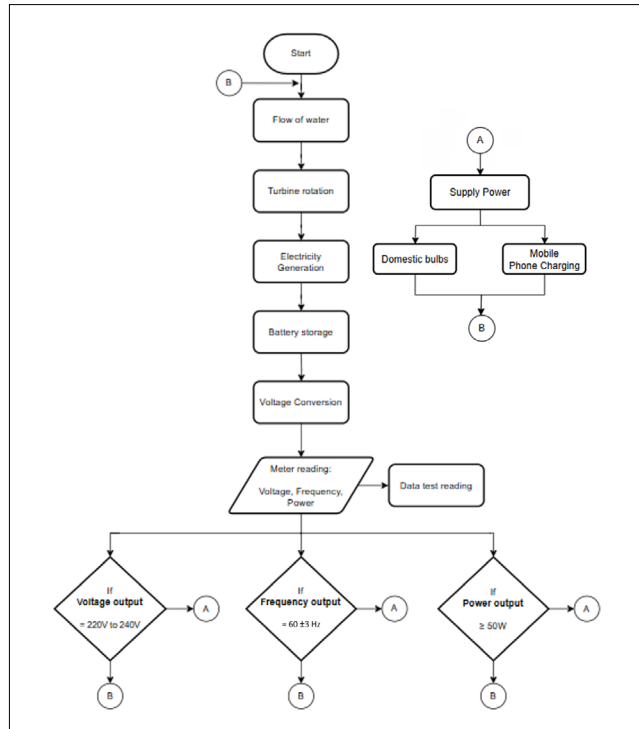


Figure 3. System Flow Diagram

Environmental Conditions for Deployment

The floating pico-hydroelectric turbine is most effective in remote, rural, or off-grid areas where conventional power sources are unavailable. Its successful operation depends on specific environmental factors that allow the system to generate a usable amount of electricity. One key requirement is a steady water flow, as the turbine requires a minimum of 1.0 meters per second (m/s) to generate sufficient kinetic energy.

This value is based on theoretical power calculations using the formula:

$$P = \frac{1}{2} \rho A v^3$$

Where: P is power, ρ is the water density (1000 kg/m^3), A is the cross-sectional area of the water hitting the turbine (0.1 m^2), and v is the water velocity.

To produce at least 50 watts of usable power (sufficient for basic lighting and charging), a flow speed of around 1.0 m/s is typically needed. The water depth must be shallow yet uniform, with a minimum of 0.1 to 0.2 meters to ensure the turbine remains submerged and steady throughout operation. The water must be reasonably clear and devoid of debris, foliage, or substantial silt that could obstruct or harm the system.

Experimental Setup and Protocol

Researchers conducted experiments in a naturally flowing body of water with a steady stream of water. Before testing, they used a calibrated flow meter to measure the flow velocity ($0.5\text{--}2.5 \text{ m/s}$) and water depth ($0.1\text{--}0.2 \text{ m}$) at the turbine placement locations, ensuring minimal interference from trash, plants, or sudden changes in water level.

They moved the turbine head using a mechanical depth gauge and floating platform risers to achieve

the desired depths of 0.1, 0.15, and 0.2 m. Active flow control was not effective in the field; therefore, the researchers utilized only stable-flow segments and conducted tests during sudden changes in flow. They conducted 30 experiments across several days. They followed the same steps for each trial: the turbine was positioned at the correct head depth, allowed to stabilize for five minutes, and then repeated three more times on different days to account for environmental changes.

They measured electrical outputs from the turbine using a RICHMETERS 102 Multimeter with 6000 Counts and Backlight for voltage, current, and frequency. They used an ANENG CM82 Digital Clamp Meter with a 600 A True RMS rating to measure current, providing complementary readings for accuracy. They recorded measurements from both instruments every 10 seconds over 15 minutes for each trial and averaged them to obtain representative values. They calibrated all instruments according to the manufacturer's instructions and continuously monitored environmental conditions to ensure accuracy of their measurements. Trials disrupted by debris or other disturbances were repeated to maintain consistency. This approach, with clearly defined instrument roles and measurement procedures, ensures reproducibility and verifiability.

Sustainability Framework for the Floating Pico-Hydroelectric Turbine

The development of a sustainability framework for a Floating Pico-Hydroelectric Turbine, as presented in Figure 4, involves integrating various sustainability principles across environmental, social, and economic dimensions. This framework outlines the key components that enable the turbine's long-term operation and lifecycle management.

These turbines generate clean, renewable energy by harnessing the power of moving water. They do not pollute or release any emissions. They are a low-impact technique for generating renewable energy and reducing the need for fossil fuels, as their design minimizes harm to aquatic environments. Floating pico-hydro systems can provide vital electricity for lighting and communication in underserved and rural regions, thereby improving the quality of life and making it easier for people to access basic services. In terms of economic sustainability, these systems are not overly expensive to set up and maintain. They can move the systems about as needed because they are durable and portable. They are a cost-effective alternative to expensive fuels or batteries. In all, this architecture ensures that floating pico-hydro turbines are a realistic, scalable, and long-term solution for generating electricity.

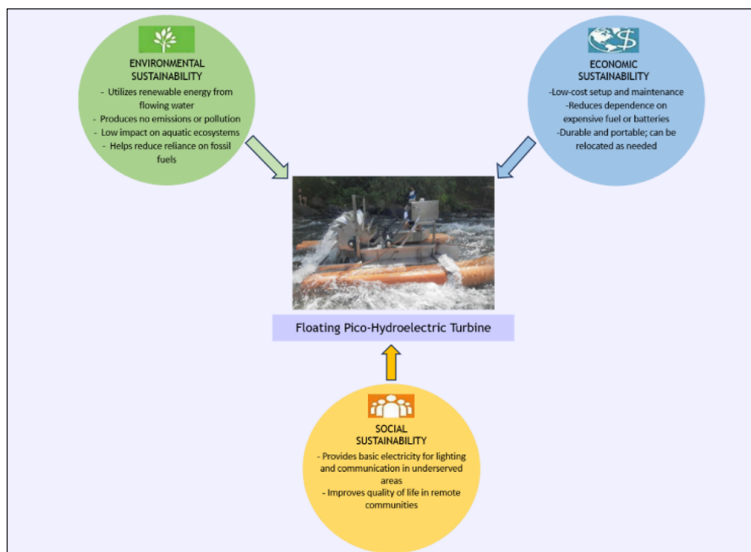


Figure 4. Sustainability Framework for the Floating Pico-Hydro Turbine

Statistical Analysis

Table 1 shows a summary of descriptive statistics for turbine power production at three different head depths. The maximum average power was measured at 0.1 m (60.3 ± 1.6 W, 95% CI: 59.7–60.8 W), followed by 0.15 m (58.4 ± 2.1 W, 95% CI: 57.6–59.1 W) and 0.2 m (57.3 ± 1.7 W, 95% CI: 56.7–57.9 W). These results show

that the turbine performs slightly better at shallower head depths, and the trials exhibit minimal variation, indicating consistent performance under controlled testing conditions.

Using Python, the researchers performed a one-way analysis of variance (ANOVA) to determine whether the variation in mean power output across the three head depths was statistically significant. They set the level of significance at $\alpha = 0.05$. The ANOVA results demonstrated a substantial effect of head depth on power output ($F(2, 87) = 20.21, p < 0.001$), indicating that mean power output varies significantly with head depth. The 0.1 m head produced more power than the 0.15 m and 0.2 m heads, showing that even minor adjustments in head depth can significantly affect turbine performance.

These differences are significant in practice: the 0.1 m head produces approximately 1.9 W more than the 0.15 m head and 3.0 W more than the 0.2 m head, indicating that shallower depths make energy conversion more efficient. In the real world, this increase may translate into significantly greater energy output over extended periods of operation. This increase demonstrates the importance of optimizing head depth to maximize both turbine efficiency and overall energy yield while maintaining system stability and reproducibility.

Table 1. Descriptive Statistics of Turbine Power Output at Different Head Depths

Head Depth (m)	Mean Power (W)	Standard Deviation (W)	95% Confidence Interval (W)
0.1	60.3	1.6	59.7-60.8
0.15	58.4	2.1	57.6-59.1
0.2	57.3	1.7	56.7-57.9

RESULTS

Efficiency Test for Turbine Head

Figure 5 presents the fitted cumulative distribution graph, depicting the frequency and cumulative probability of power outputs produced by the floating pico-hydro turbine at head depths of 0.1 m, 0.15 m, and 0.2 m. The bars represent the frequency distribution of power readings, while the overlaid lines indicate the cumulative proportion of data points below or equal to a given power value. The results show that the 0.1 m head usually produces more and higher power outputs than the other depths. This output is evident from the fact that its distribution is skewed toward higher wattage values, and its cumulative curve is steeper in the upper range. All three distributions are pretty close to each other, ranging from about 55 W to 62 W, indicating stable turbine performance with minimal variability. The 0.1 m head's steeper cumulative slope indicates that the output is concentrated at the upper end of the power range, indicating that the operating condition is more efficient. In general, the graph suggests that the turbine operates most efficiently at a head of 0.1 m, with slightly reduced outputs at depths of 0.15 m and 0.2 m.

Along with the power output, the researchers measured the electrical current of the car alternator at each depth. Depth 3 (0.1 m) again did better, with an average current of 1.77 A compared to 1.66 A at Depth 2 (0.15 m) and 1.54 A at Depth 1 (0.2 m). These data indicate that the turbine operates most efficiently at a depth of 0.1 m, where it converts the most energy in both mechanical and electrical forms.

According to the IEC 60193 standard (2016), cross-flow turbines typically operate with an efficiency range of 65% to 85%. [Kerr and Lewis \(2010\)](#) also say that these levels can be reached when the flow and system conditions are just right. This study did not calculate direct efficiency percentages; however, the steady improvements seen at Depth 3 suggest that the turbine is likely working closer to the 65–75% efficiency range. This range is not the upper limit, but it is still within the expected performance range for cross-flow turbines. These results demonstrate that the turbine design is effective and that optimizing depth is crucial for enhancing energy output in small-scale hydroelectric systems.

Voltage, Frequency, and Power Output

The voltage output distribution in Figure 6 shows that nearly all measured values are clustered around the nominal value of 230 V, indicating high voltage stability during the 30 experimental runs. Over 90% of the voltage readings fall within a tight range of approximately 229–231.5 V, as indicated by the steep rise in the cumulative curve. This output indicates that the floating pico-hydro turbine system sustains a stable electrical output despite slight variations in water flow or load conditions. The minimal dispersion suggests that voltage control is effective, which is essential for the security and dependability of connected electrical devices.

Figure 7 illustrates remarkable stability in the turbine's frequency output, with values closely grouped between 57.8 Hz and 57.94 Hz. Almost all readings are within a tiny tolerance band, as evidenced by the steep cumulative rise, which suggests minimal variation across trials. This level of frequency consistency demonstrates efficient synchronization between the turbine and generator, ensuring that the generated AC power remains within acceptable limits for typical electrical systems. The data demonstrate that the system's rotational and electromagnetic performance stays consistent despite changing operational conditions.

The power output in Figure 8 ranged from 55 W to 62.5 W, showing greater variability than the voltage and frequency. The cumulative curve's gradual slope indicates that there was only a moderate difference between the 30 trials. These fluctuations can be attributed to slight differences in head height, flow rate, and mechanical efficiency during each test. Despite the variance, the majority of values fall between 58 W and 60 W, indicating that the turbine's energy conversion efficiency is stable. The power output is consistent, indicating that the system operates reliably within the anticipated range.

These data demonstrate that a prototype turbine system with a 0.1 m turbine head operates consistently every time. When paired with efficient turbine designs and effective control mechanisms, such as Electronic Load Controllers (ELCs), small heads can still achieve a significant amount (Singh et al., 2018). The voltage and frequency stability observed are acceptable for micro-hydro systems, which are known to operate stably within the range of 220 V to 240 V and 50 Hz to 60 Hz when constructed with the proper regulatory methods (Sanampudi & Kanakasabapathy, 2021).

It is normal for the prototype output to fluctuate in power because tiny hydropower systems are generally sensitive to fluctuations in head and flow (Paish, 2002). The literature also shows similar changes, especially in systems with small-scale turbine setups, such as cross-flow, Pelton, or Turgo turbines. These turbines can keep high efficiency even at low-head settings (Khan et al., 2009; Samora et al., 2016).

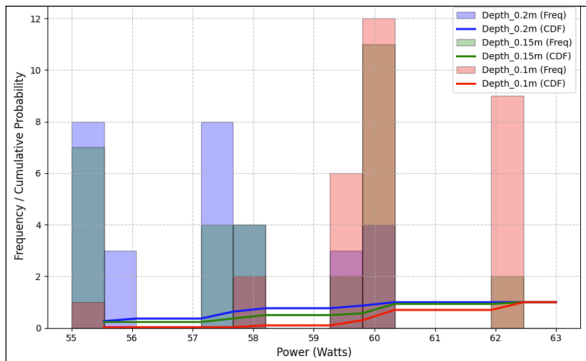


Figure 5. Power output distributions and fitted cumulative distribution curves at turbine head depths of 0.1 m, 0.15 m, and 0.2 m

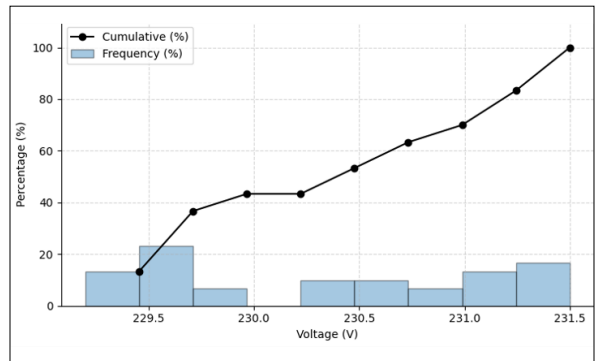


Figure 6. Voltage output stability around 230 V

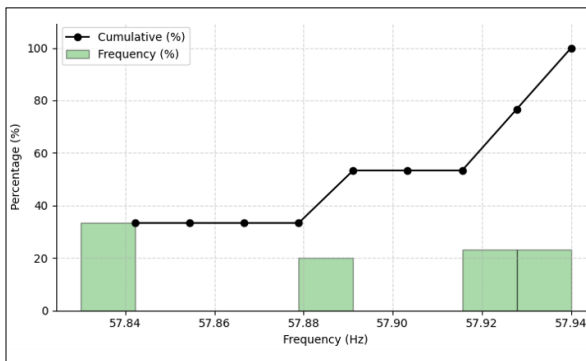


Figure 7. Frequency output consistency near 57.9 Hz

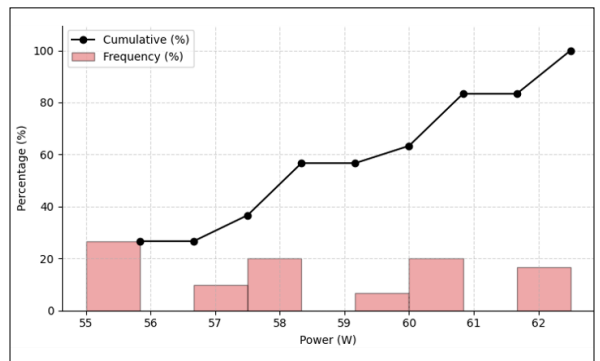


Figure 8. Power output variation between 55 and 62 W

The Operation of Loads

The method was likely a sequence of processes to ensure accurate data collection and analysis. First, the researchers carefully selected and connected the appropriate loads, verifying that they were compatible with the prototype's electrical requirements. This step was essential for preventing any potential damage to the loads or the prototype itself caused by incompatible voltage or current levels. Once the loads were connected correctly, the researchers initiated the procedure, allowing the system to run for a predetermined period of time. This time, the researchers considered additional factors, including the experimental objectives, the predicted behavior of the loads, and any specific parameters that needed to be monitored or quantified. After the specified time frame of operation had passed, the researchers would have stopped the experiment and analyzed the obtained data. This study involves observing the connected loads. The researchers plugged the loads into the convenience outlet connected to the prototype using an extension. The researchers investigate the use of domestic light bulbs and charging phones to determine their effectiveness. The loads operate for a specific period of time.

DISCUSSION

The floating pico-hydropower turbine performed best at a head depth of 0.1 m, with an average power output of 60.3 W and an average electrical current of 1.77 A. This pattern suggests that turbines perform better at shallower depths, likely because there is less turbulence and better flow interaction with the rotor. Similar patterns have been observed in low-head hydrokinetic and cross-flow turbines, where even small changes in head can significantly affect flow across the blades and overall efficiency (Kerr & Lewis, 2010; Samora et al., 2016). Power outputs varied from 55 to 62 W at all investigated depths; however, measurements at 0.1 m were not only higher on average but also more densely clustered, indicating that the conversion of mechanical energy into electrical output was more reliable at this depth.

A one-way ANOVA conducted using Python ($\alpha = 0.05$) confirmed that head depth had a significant effect on power generation. The 0.1 m head consistently produced more power than the 0.15 m and 0.2 m heads, showing that even small changes in operating depth can have a significant effect on turbine performance.

Electrical testing further demonstrates that the turbine is reliable. The voltage remained close to the nominal 230 V, while the frequency varied slightly between 57.8 and 57.94 Hz across all tests. This kind of stability is essential for small-scale hydropower systems and aligns with studies of well-regulated micro-hydro installations (Sanampudi & Kanakasabapathy, 2021; Singh et al., 2018). The alternator-turbine system kept working in sync even when the flow and load changed slightly. This system is essential for powering appliances in off-grid settlements.

The moderate power output range (55–62.5 W) indicates that the flow and head of the water change naturally, which is common in pico-hydropower systems because they are sensitive to environmental conditions (Khan et al., 2009; Paish, 2002). Still, most values ranged from 58 to 60 W, indicating that the device performed consistently and converted energy well across multiple tests. This consistency demonstrates that the turbine design effectively handles flow fluctuations, which is particularly beneficial for installations in remote areas where water conditions cannot be precisely regulated.

The results also show that, in theory, optimizing head depth is essential for low-head hydrokinetic systems. The difference in performance between 0.1 m and deeper configurations indicates that turbine efficiency is highly dependent on how the flow interacts with the blades, consistent with cross-flow turbine theory and IEC 60193 recommendations. We did not obtain exact efficiency measurements, but the 0.1 m setup likely operates at 65–75% efficiency, which is comparable to other small cross-flow turbines in low-head situations (Kerr & Lewis, 2010).

The turbine's ability to maintain a steady voltage and frequency while providing approximately 60 W of usable power demonstrates that it can be used in the home for lighting and charging devices. Because it operates all the time reliably, it could be a good choice for portable, easy-to-set-up hydropower systems in off-grid areas, especially when traditional hydropower is too expensive or inaccessible.

Limitations of the Study

Researchers should consider several key points when interpreting these results. The experiments were conducted under controlled conditions, which, although necessary for consistency, cannot fully replicate the natural variability found in rivers, such as seasonal fluctuations in flow, debris, and turbulence. Direct

measurements of turbine efficiency were also not possible because simultaneous hydraulic data, including flow rate, velocity profile, and net head, were not recorded. This limits the ability to precisely quantify energy conversion. Another consideration is that only a single turbine–alternator setup was tested, meaning that alternative rotor geometries, blade materials, or generator types might behave differently. Finally, the study was conducted over a relatively short period, so it does not account for long-term durability, turbine fatigue, or ongoing maintenance requirements that could influence the turbine's performance during extended, real-world operation.

CONCLUSION

The development and implementation of a Floating Pico-Hydroelectric Turbine presents an alternative solution to address the basic energy needs of remote areas with flowing bodies of water, generating at least 50 W of power to supply domestic light bulbs and charge phones. While the turbine battery charging cannot sustain continuous power generation, it can supply loads for more than 2 hours. The testing of the turbine head determines the most efficient depth based on the current produced by the car alternator to charge the battery. For depth 1 at 0.2 m, the current is about 1.54 A, depth 2 at 0.15 m produces about 1.66 A, and the last depth at 0.1 m produces about 1.76 A. It shows that depth 3 produces the highest current among others. In terms of average power, the three depths have a close average value of 57.3 W, 58.36 W, and 60.27 W, respectively, from depths 1 to 3. The depth number 3, at 0.1 m, with an average of 60.27 W, was the highest, and thus it is considered the most efficient among the three depths. If the power of the depth number 3, the average wattage was 58.35 W. The development of the mechanical structure of the prototype, including the turbine and floats, requires multiple tests to ensure efficient rotation and the ability of the floats to carry the prototype at medium to high currents for extended periods. Researchers face the issue of prototype weight, suggesting solutions such as using lightweight materials, redesigning for a smaller scale, employing gearboxes and chains instead of pulleys, and improving the electrical box's insulation and ventilation. Researchers recommend increasing the target power and connecting a limiter for load protection. Future improvements could involve replacing the Lead-acid battery with a Lithium-Ion one for extended runtime. Additionally, include voltage regulators to ensure consistent power delivery and state-of-charge (SoC) meters to monitor the battery's state of charge.

Author Contributions

M. C. F. Capul: Conceptualization, Writing – Reviewing and Editing, Project Administration and Supervision; **J. Loyola:** Methodology, Data Curation, Writing - Original Draft Preparation, Formal Analysis, Investigation, Validation; **K. M. Mostizo:** Methodology, Data Curation, Writing - Original Draft Preparation, Formal Analysis, Investigation, Validation; **F. D. Oida:** Data Curation, Formal Analysis, Investigation, Validation.

Funding

This research received no external funding.

Ethical Approval

Not applicable.

Competing interest

The author declares no conflicts of interest.

Data Availability

The corresponding author will make the data available upon request.

Declaration of Artificial Intelligence Use

The authors confirm that this manuscript was prepared, analyzed, and written solely by human effort, without the assistance of generative AI or AI-based technologies.

REFERENCES

- Adanta, D., Hindami, R., Budiarmo, Warjito, & Siswantara, A. I. (2018). Blade depth investigation on cross-flow turbine by numerical method. In Proceedings of the 4th International Conference on Science and Technology (ICST 2018) (pp. 1–6). IEEE. <https://doi.org/10.1109/ICSTC.2018.8528291>
- Adibowo, S., Uyun, A. S., Nur, S. M., Abdullah, K., Yandri, E., & Adiatmojo, G. D. (2020). The analyse of the automotive alternator as a generator in Picohydro system: Laboratory experiment test. *Journal of Physics Conference Series*, 1469(1), 012179. <https://doi.org/10.1088/1742-6596/1469/1/012179>
- Al-Humairi, S. N. S., Alamsyah, M. F., Daud, R. J., & Lazim, N. F. M. (2022). Development of a portable micro-hydro power generation system for rural area. In Proceedings of the 13th IEEE Control and System Graduate Research Colloquium (ICSGRC 2022) (pp. 61–65). IEEE. <https://doi.org/10.1109/ICSGRC55096.2022.9845176>
- Davirov, A., Kodirov, D., Tukhtaeva, R., Ibragimov, I., & Urokov, N. (2023). Development and testing of a laboratory model of a two-turbine small hydroelectric power plant. *IOP Conference Series: Earth and Environmental Science*, 1142(1), 012018. <https://doi.org/10.1088/1755-1315/1142/1/012018>
- Dewatama, D., Fauziah, M., Safitri, H. K., & Adhisuwignjo, S. (2020). Design and implementation: Portable floating pico-hydro. *IOP Conference Series: Materials Science and Engineering*, 732(1), Article 012049. <https://doi.org/10.1088/1757-899X/732/1/012049>
- Doan, M. N., Kai, Y., & Obi, S. (2020). Twin marine hydrokinetic cross-flow turbines in counter rotating configurations: A laboratory-scaled apparatus for power measurement. *Journal of Marine Science and Engineering*, 8(11), 918. <https://doi.org/10.3390/jmse8110918>
- Fortaleza, B. N., Juan, R. O. S., & Tolentino, L. K. S. (2018). IoT-based pico-hydro power generation system using Pelton turbine. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, 10(1-4), 189–192. <https://jtec.utm.edu.my/jtec/article/view/3615>
- Gupta, A. K., Kumar, M., Kumar, P., Panda, D., & Sahoo, R. K. (2018). Fluid flow analysis of hydroelectric turbine system for treated waste water. *International Journal of Engineering Research & Technology (IJERT)*, 6(16). <https://www.ijert.org/fluid-flow-analysis-of-hydroelectric-turbine-system-for-treated-waste-water>
- Khan, M. J., Bhuyan, G., Iqbal, M. T., & Quaicoe, J. E. (2009). Hydrokinetic energy conversion systems and assessment of horizontal and vertical axis turbines for river and tidal applications: A technology status review. *Applied Energy*, 86(10), 1823–1835. <https://doi.org/10.1016/j.apenergy.2009.02.017>
- Khayal, O. M. E. S. (2019). Hydroelectric power generation. ResearchGate. https://www.researchgate.net/publication/334415702_Hydroelectric_Power_Generation
- Kerr R.J. & Lewis R.G. (2010). *Hydraulic Turbines: Design and Application* (2nd Ed.). Springer.
- Kougias, I., Aggidis, G., Avellan, F., Deniz, S., Lundin, U., Moro, A., Muntean, S., Novara, D., Pérez-Díaz, J. I., Quaranta, E., Schild, P., & Theodossiou, N. (2019). Analysis of emerging technologies in the hydropower sector. *Renewable and Sustainable Energy Reviews*, 113, 109257. <https://doi.org/10.1016/j.rser.2019.109257>
- Lubis, S., & Cholish. (2019). Design and generating energy as a car alternator to be an alternative electricity. *IOP Conference Series: Materials Science and Engineering*, 674(1), Article 012061. <https://doi.org/10.1088/1757-899X/674/1/012061>
- Masud, I. A., & Suwa, Y. (2018). Effect of blade inclination angle on the efficiency of hydrokinetic turbine in an undershoot zero head system. *International Journal of Materials, Mechanics and Manufacturing*, 6(6), 388–391. <https://doi.org/10.18178/ijmmm.2018.6.6.413>
- Nasir, B. A. (2021). Design aspects of small-hydropower plant. *Journal of Energy Research and Reviews*, 9(2), 1–9. <https://doi.org/10.9734/jenrr/2021/v9i230226>
- Paish, O. (2002). Small hydro power: Technology and current status. *Renewable and Sustainable Energy Reviews*, 6(6), 537–556. [https://doi.org/10.1016/S1364-0321\(02\)00006-0](https://doi.org/10.1016/S1364-0321(02)00006-0)
- Ramadan, A., Nawar, M. A. A., & Mohamed, M. H. (2020). Performance evaluation of a drag hydro kinetic turbine for rivers current energy extraction: A case study. *Ocean Engineering*, 195, Article 106699. <https://doi.org/10.1016/j.oceaneng.2019.106699>
- Rantererung, C. L., Tandiseno, T., & Mallisa, M. (2018). Optimize performance of cross flow turbine with multi nozzle. *Journal of Physics: Conference Series*, 1028, 012068. <https://doi.org/10.1088/1742-6596/1028/1/012068>
- Safdar, I., Sultan, S., Raza, H. A., Umer, M., & Ali, M. (2020). Empirical analysis of turbine and generator efficiency of a pico hydro system. *Sustainable Energy Technologies and Assessments*, 37, 100605. <https://doi.org/10.1016/j.seta.2019.100605>
- Samora, I., França, M. J., Schleiss, A. J., & Ramos, H. M. (2016). Simulated annealing in optimization of energy production in a water supply network. *Water Resources Management*, 30(4), 1533–1547. <https://doi.org/10.1007/s11269-016-1238-5>
- Sarena, S. T., Purnawan, A. A., Adhitya, R. Y., Iqmalia, B. N., Herijono, B., & Sya'ın, M. (2020). Prototype of practical portable floating pico hydropower in Ngadirono River. In Proceedings of the 2020 International Conference on Pervasive Artificial Intelligence (ICPAI) (pp. 240–242). IEEE. <https://doi.org/10.1109/ICPAI51961.2020.00051>
- Sanampudi, N., & Kanakasabapathy, P. (2021). Integrated voltage control and frequency regulation for stand-alone micro-hydro power plant. *Materials Today: Proceedings*, 46, 5027–5031. <https://doi.org/10.1016/j.matpr.2020.10.403>
- Sathe, A., Shinde, P., Somavanshi, S., Sarode, S., & Raut, M. (2019). Energy generation using portable water turbine. *Journal of Emerging Technologies and Innovative Research (JETIR)*, 6(4), 197–204. <https://www.jetir.org/papers/JETIRBB06042.pdf>
- Singh, R. R., Kumar, B. A., Shruthi, D., Panda, R., & Raj, C. T. (2018). Review and experimental illustrations of electronic load controller used in standalane micro-hydro generating plants. *Engineering Science and Technology, an International Journal*, 21(5), 886–900. <https://doi.org/10.1016/j.jestch.2018.07.006>
- Tomprowski, A., Al-Zubiedy, A., Flizikowski, J., Kruszelnicka, W., Baldowska-Witos, P., & Rudnicki, J. (2019). Analysis of the project of innovative floating turbine. *Polish Maritime Research*, 26(4), 124–133. <https://doi.org/10.2478/pomr-2019-0074>

How to cite this article:

Capul, M. C. F., Loyola, J., Mostizo, K. M., & Oida, F. D. (2025). A Sustainable and Eco-Efficient Pico Hydroelectric Technology for Decentralized Power Generation in Remote Hydrological Environments. *Recoletos Multidisciplinary Research Journal* 13(2Si), 53–62. <https://doi.org/10.32871/rmjr1302si.i2502>