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Mini Hydro Electric Generator with Monitoring System

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Abstract

This project focuses on designing and developing a prototype of a mini-hydroelectric generator integrated with a real-time monitoring system using Blynk software. The system monitors key parameters such as voltage, battery level, power output, and efficiency, with data collected and displayed via an ESP32 microcontroller and a user-friendly mobile interface. A 3D-printed vertical axis turbine is used to convert the kinetic energy of flowing water into electrical energy, successfully generating approximately 5.39V DC to power basic devices like lights and fans. The project demonstrates the potential of small-scale hydroelectric systems as a sustainable and environmentally friendly energy source, especially in rural areas with limited access to electricity. Future improvements may involve using more efficient brushless DC motors, advanced microcontrollers, and optimized turbine designs, with further field testing to enhance performance and reliability. This work contributes to the development of renewable energy technologies for rural power applications.

1. Introduction

Malaysia is committed to achieving net-zero greenhouse gas (GHG) emissions by 2050, as outlined in the National Energy Transition Roadmap (NETR) [1]. One of the key goals of this roadmap is to increase the share of renewable energy in the national energy mix to 70% by 2050. Despite these ambitions, Malaysia's energy sector still relies heavily on fossil fuels, contributing significantly to carbon emissions and global climate change [2]. While large-scale renewable energy projects such as solar farms and hydroelectric dams are underway, there remains a lack of focus on small-scale, localized renewable energy solutions that can meet the diverse needs of various communities and geographical regions.

In particular, the potential of rivers, drainage systems, and small water bodies for power generation remains underutilized [3]. This represents a missed opportunity to enhance energy security, especially in rural or underserved areas where grid access is limited. Small-scale hydropower systems offer a promising solution due to their low environmental impact and flexibility in integration with existing infrastructure. Recent studies have explored innovative turbine designs and numerical analyses to improve energy efficiency in such applications [4], while other research highlights the technological advancements and challenges in small-scale water energy conversion [5]. Furthermore, industry-driven initiatives are developing practical solutions to harness water energy sustainably for real-world applications [6].

However, challenges such as site-specific design, efficient energy conversion, and cost-effective implementation continue to hinder wider adoption. This project aims to address these challenges by developing a mini hydroelectric generator system that utilizes flowing water from local rivers and drains to generate renewable energy. Unlike large-scale plants that require extensive infrastructure, this system is designed to be compact, sustainable, and adaptable to a variety of locations. The proposed solution includes a 3D-printed turbine, energy storage, and real-time monitoring using an ESP32 microcontroller and Blynk software. By demonstrating the technical feasibility and performance of a small-scale hydropower system, this project supports Malaysia's carbon reduction goals while providing a practical, low-cost energy solution for rural communities.

2. Methodology

The operational setup of the Mini Hydro-Electric Generator is shown on Fig. 1. The system begins with flowing water turning a DC motor, converting kinetic energy into mechanical energy to generate electricity. A voltage and current sensor monitor the power output to ensure accurate performance tracking. The generated power is then regulated through a charge controller, which protects the battery and electronic components from overcharging or deep discharging. A rechargeable battery cell acts as the main energy storage unit, storing excess electricity for later use and ensuring a stable backup power supply. An ESP32 microcontroller is integrated into the system and connected to Blynk software, allowing real-time monitoring of important parameters such as power output, battery level, and system performance. The stored DC power is finally converted to AC using a DC to AC inverter, making it suitable for powering basic household appliances. This setup enables efficient energy generation, storage, monitoring, and utilization.

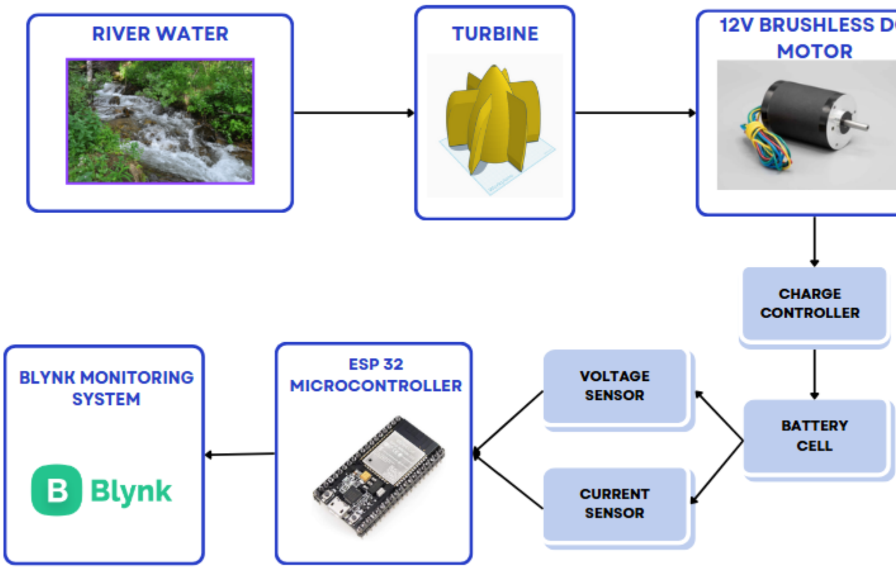

Fig. 1 *Operational block diagram*

Fig. 2 illustrates the operation of a mini hydroelectric power generation and monitoring system. The process begins with water flow detection; if no flow is detected, the system remains inactive. When water is present, it rotates the turbine, converting kinetic energy into mechanical energy, which then drives a DC motor to generate electricity. The generated power is regulated by a charge controller to maintain safe voltage and current levels, protecting system components. The regulated energy is stored in a battery cell, ensuring backup power availability. A DC-DC converter steps down the voltage from 12V to 5V to power the ESP32 microcontroller and USB module. The USB module facilitates external device communication, while the ESP32 controls system operations and processes the data. This data is transmitted to the Blynk platform, enabling users to remotely monitor energy production, battery status, and system performance in real time. The cycle is completed once all data is successfully updated in the monitoring system, ensuring continuous, efficient operation and feedback.

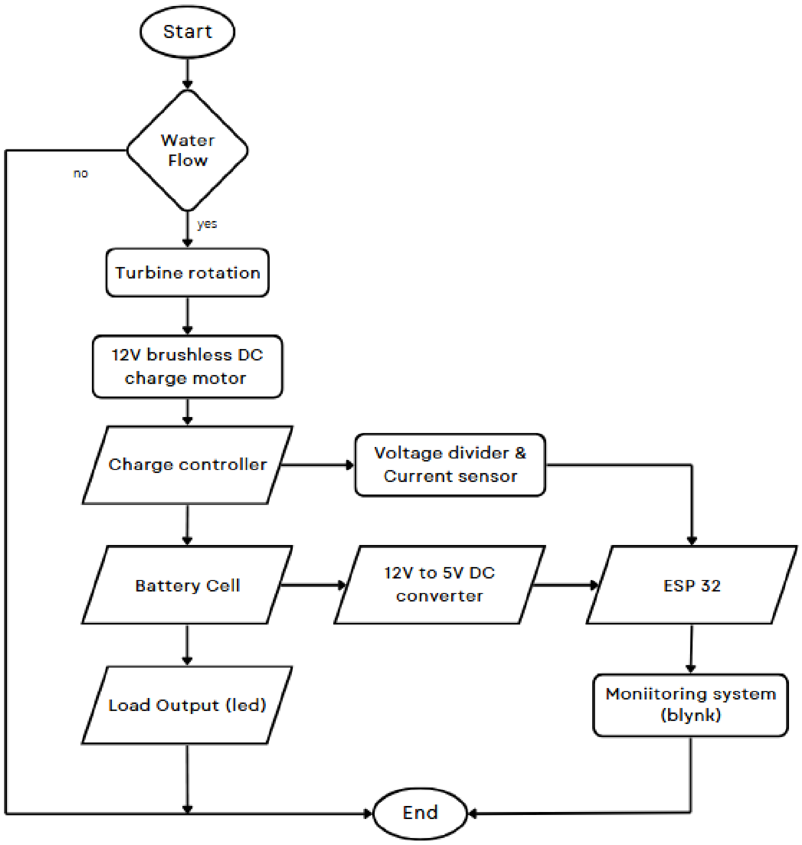

Fig. 2 *Operational flowchart*

2.1 Experimental Setup

The mini hydroelectric prototype is equipped with an integrated monitoring system that enables real-time tracking of key performance parameters such as voltage, current, and power output. An ESP32 microcontroller is used to collect data from sensors and transmit the information to a mobile application via the Blynk platform, allowing users to remotely monitor the system. Fig. 3 show the experimental setup includes a motor mounted on a shaft, functioning as a generator, which is connected to the system's electrical components. The generated data is continuously sent to the mobile app for live monitoring. This configuration ensures efficient interaction with the system and provides users with the ability to oversee and manage the operation remotely.

Fig. 3 *Experimental setup*

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3. Result and Discussion

3.1 Motor Efficiency

The efficiency of each motor can be calculated by comparing the actual voltage output to the expected voltage. The formula for calculating the efficiency (η) is:

$$Efficiency(\eta) = (\frac{Maximum\ Voltage\ Generated}{Expected\ Voltage}) \times 100 \tag{1}$$

Applying this formula to the data from Table 1:

1. DC Generator Motor Efficiency:

$$(\eta) = \left(\frac{3}{24}\right) \times 100 = 12.5\% \tag{2}$$

This shows that the DC generator motor operates at 12.5% efficiency, which indicates a substantial amount of energy is lost in the conversion process.

2. Brushless DC Motor Efficiency:

$$(\eta) = \left(\frac{9.2}{12}\right) \times 100 = 76.7\% \tag{3}$$

In comparison, the brushless DC motor operates at an efficiency of 76.7%, reflecting its superior performance in converting mechanical energy into electrical energy.

The differences in motor efficiency significantly affect the overall performance of the mini hydroelectric system. Testing showed that the brushless DC motor provided higher efficiency compared to the conventional DC generator motor. As a result, the brushless motor is more suitable for the final prototype, offering better power output and more stable energy generation. On the other hand, the lower efficiency of the DC generator suggests that further improvements are needed in the system's design. Potential enhancements include using higher-efficiency motors, refining the turbine structure for better water flow conversion, and upgrading the electrical components to minimize energy losses. These optimizations would contribute to a more effective and reliable renewable energy system.

3.2 Turbine Efficiency

The power generation in the Fig. 4 data was collected every 5 minutes over the course of 1 hour under a constant tap water flow rate. Voltage values ranged from 7.0V to 9.5V, while current varied between 0.35A and 0.58A. The system reached peak performance at the 35-minute mark, generating 5.39W of power with a voltage of 9.3V and a current of 0.58A. The power output gradually increased in the first half of the test, stabilized during peak operation, and declined slightly towards the end as water flow decreased. The results confirm the mini hydroelectric prototype’s ability to maintain a relatively stable power output under consistent flow conditions. The generated power is sufficient for basic applications, and further optimization in turbine efficiency or flow control could help increase energy output in future versions.

Table 1 *Readings for Test Conditions*

Time (min)	Voltage (V)	Current (A)	Power (W)	Notes
0	7.0	0.35	2.45	Initial water flow
5	7.3	0.40	2.92	Flow begins to stabilise
10	7.6	0.42	3.19	Slight improvement
15	8.0	0.45	3.60	Consistent output
20	8.3	0.50	4.15	Steady generation
25	8.6	0.52	4.47	Smooth performance
30	9.0	0.55	4.95	Optimal operation
35	9.3	0.58	5.39	Peak observed
40	9.5	0.56	5.32	Slight current flunctuation
45	9.2	0.53	4.88	Stable output
50	8.7	0.50	4.35	Gradual power decline
55	8.0	0.47	3.76	Flow reducing
60	7.5	0.42	3.15	Test ends, lower generation

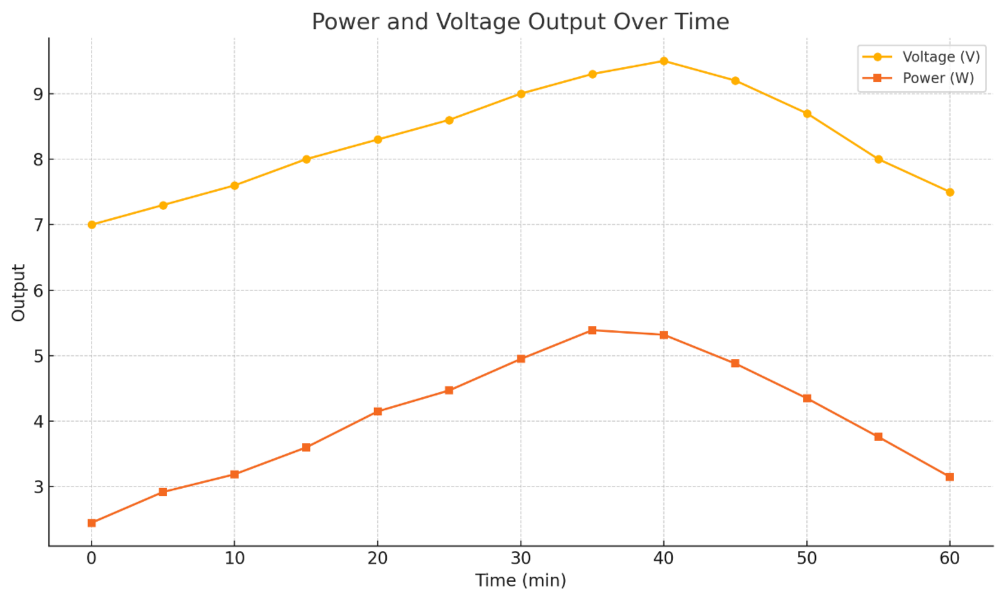

Fig. 4 *Experimental Setup.*

From Table 1 and Fig.4 the electrical power generated by the mini hydroelectric system is calculated using the basic electrical power formula:

$$P = V \times I \tag{3}$$

where:
P = Power in watts (W)
V = Voltage in volts (V)
I = Current in amperes (A)

3.3 Blynk Interface

This section presents the initial findings obtained from the experimental setup of the mini hydroelectric generator integrated with a real-time monitoring system using the ESP32 microcontroller. The results serve as a foundation for performance evaluation and highlight key operational observations from early-stage testing. These findings provide insight into the system's effectiveness, accuracy, and areas for future improvement.

One of the preliminary tests conducted involved verifying the synchronization between the DC motor output and the Blynk monitoring application. Fig. 5 and Fig. 6, the output voltage generated by the motor was successfully captured and displayed in the mobile user interface through the ESP32. This confirms that the microcontroller was able to collect sensor data and transmit it accurately to the Blynk platform in real time.

Additionally, the test was conducted to verify the functionality and accuracy of the voltage readings. The displayed values in the application were compared with direct measurements taken using a multimeter. The readings were consistent, validating that the system provides reliable real-time monitoring of power generation. This confirms that the DC motor and sensing components were functioning correctly and that the monitoring system was accurately reflecting actual system performance.

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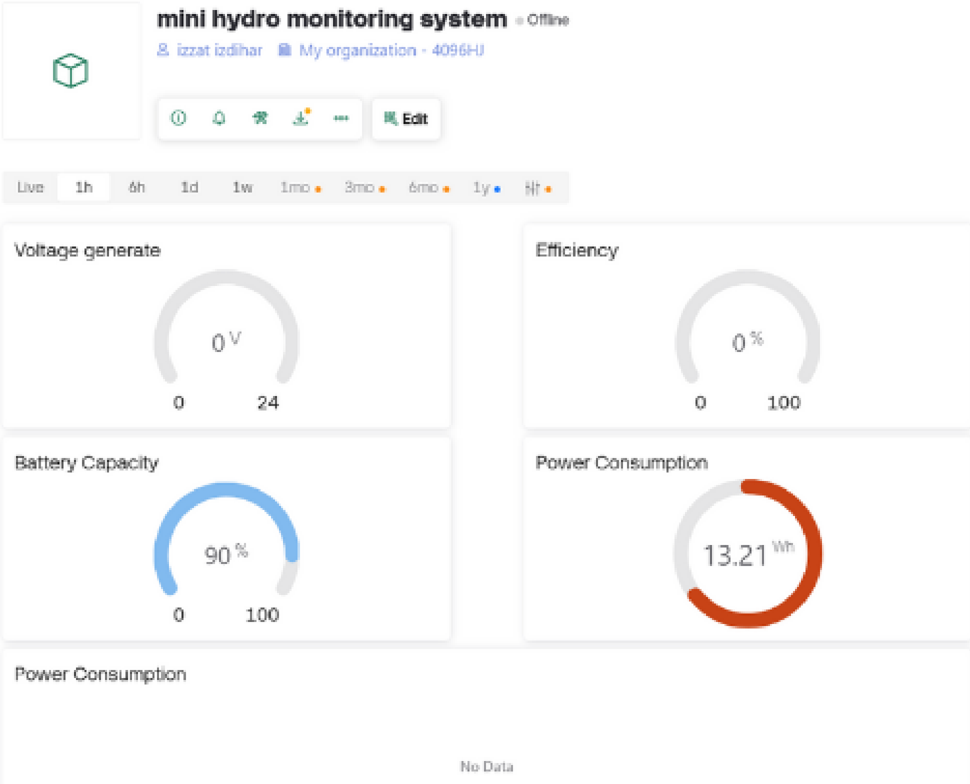

Fig. 5 *Blynk Web Interface*

Fig. 6 *Blynk Mobile Interface*

4. Conclusion

In conclusion, this project successfully achieved its core objectives by designing, developing, and evaluating a working prototype of a mini hydroelectric generator with integrated real-time monitoring. The prototype demonstrated the feasibility of harnessing small-scale water flow to generate renewable energy, making it suitable for applications in off-grid or rural areas. The system was engineered to be compact and efficient, using a 3D-printed turbine and a brushless DC motor for reliable energy conversion.

One of the project's key outcomes was the development of a user-friendly monitoring interface using the Blynk application, which worked in tandem with an ESP32 microcontroller. The system was able to transmit live data such as voltage, current, and power output, enabling users to monitor performance in real time through a mobile device. This feature significantly enhanced the usability of the system, making it accessible even to non-technical users.

Power generation data was collected at 5-minute intervals over a 1-hour period under consistent water flow conditions. The voltage output ranged between 7.0V and 9.5V, while the current varied between 0.35A and 0.58A. The system achieved peak performance at minute 35, generating approximately 5.39 watts. These results indicate that the system can produce steady energy output suitable for powering small DC loads, such as LED lights and fans. This also validates the performance of the sensing and monitoring systems, which aligned closely with multimeter readings.

Although the system showed reliable performance, it was observed that energy generation was sensitive to environmental factors, especially water flow rate. Under stable flow conditions, the generator maintained consistent output, but minor drops were seen when flow decreased. Further refinement of the turbine design and power electronics could improve system efficiency, particularly under variable flow conditions. Additionally, upgrading the sensor accuracy especially for battery monitoring could further improve the precision of data collected.

Overall, this project demonstrates the practical potential of combining renewable energy with IoT-based monitoring for sustainable energy solutions. It lays the groundwork for future developments in both hardware and software, with an emphasis on improving efficiency, scalability, and adaptability to diverse environments.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors attest to having sole responsibility for the following: planning and designing the study, data collection, analysis and interpretation of the outcomes, and paper writing.

Reference

[1] Ministry of Economy Malaysia, National Energy Transition Roadmap (NETR). Putrajaya, Malaysia: Ministry of Economy Malaysia, 2023. [Online]. Available: https://ekonomi.gov.my/sites/default/files/2023-09/National%20Energy%20Transition%20Roadmap_0.pdf [Accessed: Jan 30, 2025].

[2] Ministry of Natural Resources, Environment and Climate Change Malaysia, *National Policy on Climate Change 2.0*. Putrajaya, Malaysia: Ministry of Natural Resources, Environment and Climate Change Malaysia, 2023. [Online]. Available: https://www.nres.gov.my/ms-my/pustakamedia/Penerbitan/National%20Policy%20on%20Climate%20Change%202.0.pdf. [Accessed: Jan 28, 2025].

[3] Y. Wang, D. Wang, L. Yu, and J. Mao, "What really influences the development of renewable energy? A systematic review and meta-analysis," *Environmental Science and Pollution Research*, vol. 30, no. 22, pp. 62213–62236, 2023, doi: 10.1007/s11356-023-26286-w

[4] D. Karakaya, A. Bor, and S. Elçi, "Numerical analysis of three vertical axis turbine designs for improved water energy efficiency," *Energies*, vol. 17, no. 6, Art. no. 1398, 2024, doi: 10.3390/en17061398

[5] D. Aminov, S. Gandzha, and B. Kosimov, "Technology of using a combined excitation valve hydrogenerator as an alternative source of energy use for small rivers," in *2020 Russian Workshop on Power Engineering and Automation of Metallurgy Industry: Research & Practice (PEAMI)*, Magnitogorsk, Russia, 2020, pp. 124–127, doi: 10.1109/PEAMI49900.2020.9234384

[6] Water2Energy, "Solutions," [Online]. Available: https://water2energy.nl/solutions/. [Accessed: May 30, 2025].