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HARNESSING CAMPUS WATER FLOW: A CASE STUDY ON MINI HYDRO GENERATOR VOLTAGE OUTPUT AT POLYTECHNIC UNGKU OMAR

Adi Firdaus Hat[1], Mohd Saiful Saleh[2] and Aida Tukiran[3]

[1] *Department of Mechanical Engineering, Polytechnic Ungku Omar, Ipoh, Malaysia*
[*] adifirdaushat@gmail.com

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ABSTRACT

This case study investigates the potential of utilizing a mini hydro generator system within a Polytechnic campus to generate electrical energy, with a primary focus on voltage output. As global concerns over sustainable energy sources continue to rise, exploring alternative and environmentally friendly power solutions has become increasingly relevant, particularly in educational institutions. The objective of this project is to evaluate the performance of a small-scale hydroelectric system in producing usable voltage output using natural or existing water flow within the campus environment. A mini hydro prototype was designed and installed at a location with continuous water movement, such as a drainage channel or an artificial stream. The system includes a water turbine connected to a DC generator. Voltage output data were collected under varying flow rates and environmental conditions to determine the reliability and stability of the generated electricity. The results demonstrated that the system could produce a voltage output ranging from 1V to 3V, depending on water velocity and turbine efficiency. Although the generated voltage is modest, it is adequate to serve as an initial input for voltage boosting circuits, enabling broader electrical applications to support small-scale applications such as powering LED lighting, mobile device charging, and basic electronic equipment. These findings indicate that mini hydro systems have potential as a supplementary renewable energy source on campus while offering hands-on learning opportunities for students in the fields of electrical engineering, environmental studies, and sustainable technology. Furthermore, this project highlights the practical implications of using low-cost and low-maintenance technologies to harness naturally available energy. In conclusion, the implementation of a mini hydro generator not only supports energy sustainability goals but also enriches the Polytechnic's role in promoting green innovation through real-world applications.

1.0 Introduction

The global demand for sustainable and renewable energy solutions continues to grow as concerns over environmental degradation and fossil fuel dependency intensify. Among the various renewable energy sources, hydropower remains one of the most reliable and widely utilized options. While large-scale hydroelectric plants are well established, small-scale or mini hydro systems are gaining attention for their ability to generate electricity in localized settings with minimal environmental impact.

Educational institutions such as polytechnics offer a unique opportunity to implement and study renewable energy systems on a manageable scale. These environments not only provide suitable physical spaces, such as campus drainage systems and streams, but also serve as platforms for applied research and student engagement. A study conducted by (Raveendra, 2022) on a rural campus demonstrated the practicality of deploying micro hydro turbines at main water tanks and farm ponds, effectively reducing grid dependency and harnessing onsite water flows. By integrating practical projects into the learning environment, students can gain hands-on experience in energy generation technologies and sustainability practices.

Recent advances in mini hydro systems have demonstrated significant improvements in voltage output and efficiency when combined with power enhancement technologies. For instance, integrating current boosters into mini hydro systems has been shown to improve voltage output by 43% and overall system efficiency by over 300%, enabling faster battery charging and more consistent power delivery (Ismail et al., 2024). Additionally, research indicates that the height of the water source and flow discharge rate play critical roles in determining the electrical output, with greater values resulting in higher voltage and power generation (Ariani & Gumay, 2021).

This paper presents a case study on the design and implementation of a mini hydro generator at a Polytechnic campus, focusing specifically on the voltage output produced under varying water flow conditions. The aim is to evaluate the potential of such a system as a supplementary energy source and its effectiveness in producing a stable initial voltage that can be further boosted for practical use. Solutions like inverter-based voltage control systems have been developed to maintain stable output despite fluctuating loads (Lukutin et al., 2023). Furthermore, the use of multi-converter DC-DC topologies allows for boosting low voltages produced by mini turbines to usable levels, making these systems more adaptable to varying flow conditions and application requirements (Ahmad et al., 2022). The findings contribute to the growing body of research on micro-renewable energy systems, particularly in educational and small-scale contexts, where cost-effectiveness, simplicity, and educational value are key considerations.

2.0 Methodology

The development of a mini screw turbine with an integrated floating device and platform begins by designing a stable buoyant structure that can support the turbine system on water surfaces. A screw turbine is mounted in such a way that water flow drives its rotation, while the floating platform provides stability and ease of deployment in varying water levels. On this platform, a

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motor generator is securely installed to convert the mechanical energy from the turbine into electrical energy. The connection between the turbine shaft and the generator is achieved using a chain mechanism combined with different sprocket settings, which allows for adjustment of rotational speed and torque to match the generator's requirements. This design ensures flexibility, efficient energy transfer, and adaptability for small-scale or off-grid hydropower applications, especially in low-head water conditions. Complete construction of the screw turbine setup is shown in Figure 2.1.

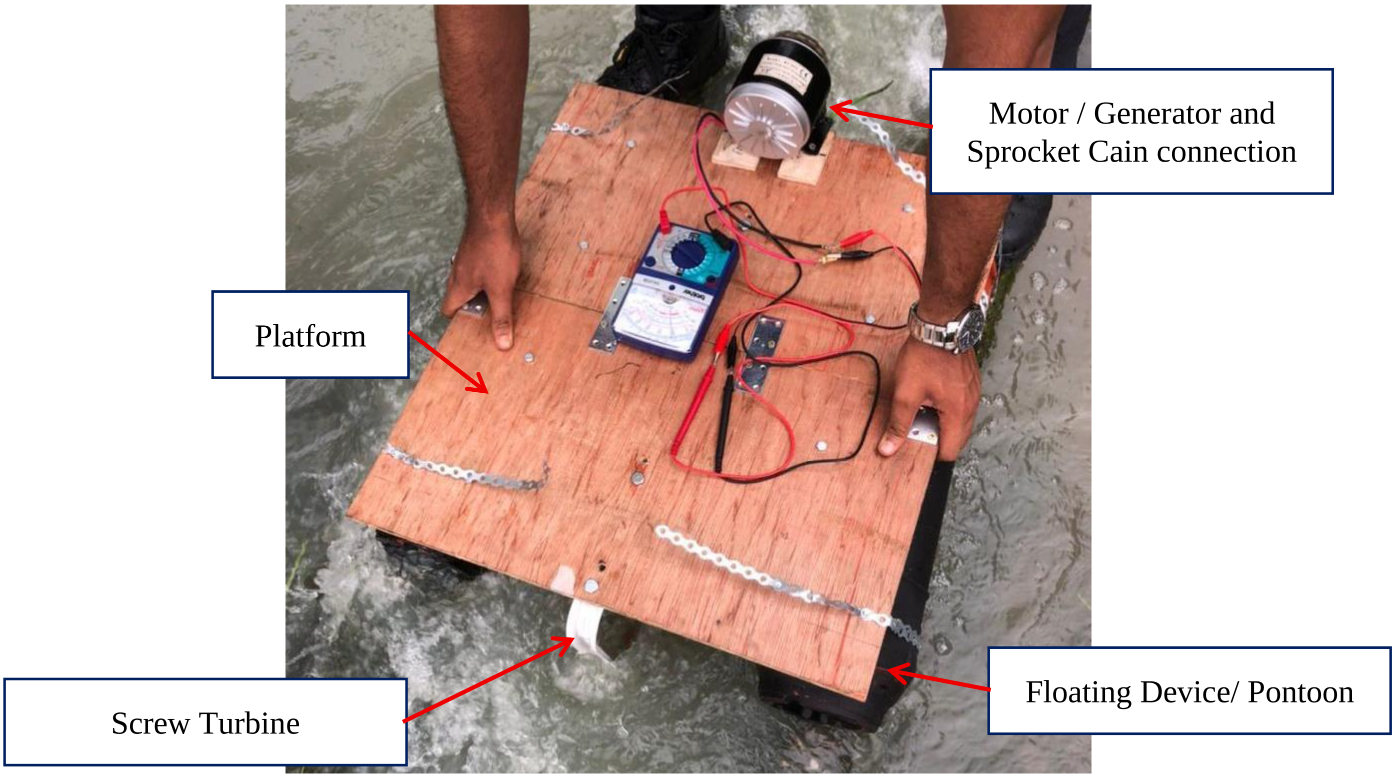

Figure 2.1: Setup of the Mini Hydro Generator.

The success of the mini hydro generator system largely depends on selecting an appropriate site with consistent and sufficient water flow. To ensure this, a comprehensive assessment was conducted across various locations within the Polytechnic campus. Key criteria included the availability of continuous water flow, which is essential for the turbine to operate effectively.

Measurements of water velocity and head height were taken using simple methods like the float technique and measuring tape to assess the potential energy available. In addition to hydraulic factors, accessibility and safety were important considerations. The chosen site needed to be easily accessible for installation, monitoring, and maintenance, while also posing minimal safety risks, avoiding areas with deep water or fast currents. Structural suitability was also evaluated to ensure the site could support the mounting of the hydro system securely, including the presence of stable ground or concrete banks.
After assessing several options, three sites of the campus drainage system were selected as shown in Figure 2.2. This location offered steady water flow and a gentle slope to provide

usable head. The careful selection of this site was crucial to maximizing the system's performance and reliability, while also providing a practical and safe environment for students to engage with renewable energy technology.

Figure 2.2: Locations Selected for the Experiment.

Location A: Situated at the junction of two drainage channels

Location B: Wider part of the drainage system

Location C: Newly constructed drainage site that has undergone recent modifications, yielding a more regular and uniform layout

Each site had a different water flow profile and head height to allow comparison of performance.

The design of the mini hydro generator system was focused on simplicity, efficiency, and suitability for educational use within a Polytechnic setting. The system was intended to convert the kinetic and potential energy of flowing water into electrical energy through mechanical rotation. A screw-type water turbine, also known as an Archimedes screw turbine, was selected for this project due to its ability to operate effectively under low-head and low-flow conditions, which matched the characteristics of the selected site. This type of turbine is known for its reliability, ease of maintenance, and ability to function with debris-laden or variable water flows making it ideal for small-scale applications in campus environments. Research by Erinofiardi et al. (2017) demonstrated that these turbines can achieve efficiencies up to 49% at an inclination angle of 22°, highlighting their potential for energy generation even with ultra-low heads. Another manufacturing research by Indriani and Hendra (2014) also supports the feasibility of screw turbines for small-scale power generation, showing successful fabrication and electricity production from such systems.

The screw turbine was connected directly to a low-speed, permanent magnet direct current (DC) generator, which was chosen for its ability to produce voltage output efficiently at low rotational speeds. PMDC generators are widely used in micro-hydro systems because they produce usable electrical output even at relatively low input torque (Kumar & Tiwari, 2016). The mechanical energy generated by the turning screw was transferred through a chain mechanism to the generator, which then produced the electrical output. The system was mounted on a stable frame to ensure proper alignment and structural integrity during operation. Voltage output from the generator was measured using a calibrated digital multimeter. In educational applications, this setup is ideal for demonstrating renewable energy principles in a hands-on, practical manner (Al Mamun et al., 2020).

Overall, the system design emphasized practicality and adaptability, allowing for real-time experimentation and observation. The integration of a screw-type turbine demonstrated the effectiveness of using unconventional but efficient turbine designs in micro-hydropower applications, particularly in low-resource environments like educational institutions.

The system was installed at each location one at a time. For consistency, the same turbine-generator setup was used at all three locations. For each location data was taken in three consecutive days. The water flow was directed from the source to the turbine, and the generator was connected to a voltmeter. Figure 2.3 and 2.4 shows the process of installation on difference site locations.

Figure 2.3: Installation of the turbine on site B.

Figure 2.4: installation process on site C

Voltage output was measured using a digital voltmeter during a 60-minute test at each location. Readings were taken every 10 minute and recorded. The average voltage output from each site was then compared to determine which location provided the highest and most stable voltage output.

3.0 Results

The performance of the mini hydro generator was evaluated by measuring the voltage output over three consecutive days. Readings were taken at 10-minute intervals over a one-hour period each day to observe consistency and changes in system behaviour. The data focused on the generator's voltage output as an indicator of energy conversion efficiency from the screw-type turbine setup. This section outlines the recorded values and provides insight into how the system responded to real-world conditions on-site.

First data collection was conducted on site A. As mentioned before the site was situated at the junction of two drainage channels. Adjustment was made to make sure the hydro generator can operate on optimum performance. Table 3.1 show the data collected in site 1 based on 1 hour running time on 3 consecutive days.

Table 3.1: Data Collected on Site A.

Time Interval	Day 1 (V)	Day 2 (V)	Day 3 (V)
10th Minute	1.26	1.48	1.52
20th Minute	1.23	1.50	1.32
30th Minute	1.13	1.26	1.45
40th Minute	1.26	1.34	1.66
50th Minute	1.56	1.33	1.78
60th Minute	1.62	1.67	1.82

The voltage output data collected shows a clear trend of increasing and stabilizing electrical generation performance from the mini hydro system. On Day 1, the voltage readings were relatively low, ranging from 1.13 V to 1.62 V, with noticeable fluctuations. This variation may be attributed to initial inefficiencies in system alignment, water flow inconsistency, or turbine-generator coupling that had not yet been fully optimized. By Day 2, the system demonstrated improved performance, with voltage values rising to a range of 1.26 V to 1.67 V. The increase in average voltage output indicates better water flow interaction with the screw-type turbine and possibly minor mechanical adjustments or cleaning of the waterway that improved efficiency.

On Day 3, the voltage readings were the most stable and highest overall, ranging from 1.32 V to 1.82 V, with the peak value recorded at the 60th minute. This suggests that the system reached a relatively optimal operating condition. The improvements across the three days may also reflect environmental consistency, such as increased water volume or flow rate due to rainfall or reduced debris.

Following the initial testing at Site A, the next step in this case study involves conducting a similar data collection process at Site B as shown in table 3.2.

Table 3.2: Data Collected on Site B.

Time Interval	Day 4 (V)	Day 5 (V)	Day 6 (V)
10th Minute	1.55	1.97	2.03
20th Minute	1.67	2.02	2.52
30th Minute	1.98	2.06	2.56
40th Minute	1.83	2.24	2.50
50th Minute	1.89	2.23	2.61
60th Minute	1.90	2.01	2.47

The voltage output recorded at Site B across Days 4 to 6 demonstrates a clear improvement in the performance of the mini hydro generator compared to Site A. On Day 4, the voltage ranged from **1.55 V to 1.90 V**, showing a moderate increase from earlier tests. However, by Day 5 and especially Day 6, the system displayed a notable surge in output, peaking at **2.61 V** on Day 6 at the 50th minute. Overall, Site B maintained voltage levels consistently above **2.0 V** on most intervals during Days 5 and 6, indicating better efficiency and water flow conditions.

These improvements suggest that Site B offers a more favourable environment for micro-hydro power generation, likely due to higher water velocity, improved head pressure, or reduced obstruction in the water channel. Additionally, the screw-type turbine appeared to perform more optimally at this location, converting kinetic energy into electrical output more effectively. The consistent performance indicates that the mini hydro system is better suited for this site and could potentially be scaled for higher output with voltage boosting techniques.

Table 3.3: Data Collection on Site C.

Time Interval	Day 7	Day 8	Day 9
10th Minute	1.98	2.56	2.88
20th Minute	1.93	2.78	2.54
30th Minute	1.85	2.22	2.22
40th Minute	1.75	2.81	2.45
50th Minute	1.99	2.45	2.45
60th Minute	2.21	2.53	2.77

Data collection on Site C revealed a progressive improvement in voltage output, suggesting that the location is highly favourable for mini hydroelectric generation. On Day 7, the system produced a relatively moderate output ranging from 1.75 V to 2.21 V, indicating initial stability and functionality of the screw-type turbine setup. However, on Day 8, the voltage readings significantly improved, peaking at 2.81 V and maintaining values above 2.2 V throughout the measurement period. The trend continued Day 9, where voltage output remained strong and consistent, with a high of 2.88 V, the highest recorded across all sites.

The sustained increase in voltage over the three days suggests that Site C benefits from superior water flow characteristics, such as consistent head pressure and velocity, which enhance the turbine's ability to convert kinetic energy into electrical energy effectively. Overall, Site C demonstrated the most promising results, with voltage levels consistently suitable for direct application in low-power systems or for use as a reliable input to voltage-boosting circuits. This makes Site C a most suitable site for long-term implementation and further development of micro-hydro power solutions.

The case study conducted at three different sites within the Polytechnic campus successfully demonstrated the viability of a mini hydro generator system for producing low-voltage electrical output from natural water flow. Site A, serving as the baseline, showed moderate voltage output ranging from 1.13 V to 1.82 V, indicating functional performance under minimal flow conditions. Site B exhibited improved results, with voltages reaching up to 2.61 V, suggesting that better water flow dynamics and site conditions contribute to greater system efficiency. Site C yielded the highest voltage values, peaking at 2.88 V, and maintained consistently high readings across all three days of testing, proving to be the most suitable location among the three.

The consistent voltage levels above 2.0 V at Site B and C further affirm that these outputs are sufficient for basic applications or as initial voltage inputs for boost converters. These findings align with existing studies which highlight the practicality of mini and micro-hydro systems in low-head environments, especially for off-grid or rural electrification (Kaunda et al., 2012; Paish, 2002). The results also reinforce the potential for campus-based renewable energy installations, supporting sustainable energy goals (Fong et al., 2010). Based on this case study, it is evident that there is substantial potential to further develop mini hydro power generation systems at selected sites within the campus, leveraging existing water resources for sustainable and scalable energy solutions.

4.0 Discussion

The voltage output data across the three sites reveals a clear trend of performance improvement from Site A to Site C. Site A, which served as the initial test location, produced the lowest voltage values, ranging between 1.13 V and 1.82 V, indicating limited water flow or suboptimal turbine performance. Despite its stability, the system at this site lacked the sufficient energy levels required for broader application without additional voltage boosting. In contrast, Site B showed a significant improvement, with voltages ranging from 1.55 V to 2.61 V, reflecting enhanced water flow dynamics and better energy conversion. This makes Site B viable for powering basic electronic devices or as a source input for DC-DC converters. Site C demonstrated the best performance overall, with voltage outputs ranging from 1.75 V to 2.88 V, consistently exceeding 2.5 V in later testing intervals.

These results confirm that Site C has superior hydraulic conditions, including greater flow velocity or volume, and optimal turbine interaction. The increasing voltage trend across the three sites indicates that the system’s performance is highly dependent on environmental and site-specific factors, supporting the study’s objective to evaluate small-scale hydroelectric systems using existing water flows within a campus setting.

These findings align with prior research affirming the feasibility of using natural streams for decentralized power generation in institutional or rural areas (Bansal et al., 2011; Kishore & Bhandari, 2017; Lee et al., 2020). The results also highlight how even minimal elevation and moderate water sources can generate usable energy when appropriate turbine technologies, such as screw-type turbines, are employed (Paish, 2002; Kaunda et al., 2012; Williams & Simpson, 2009).

5.0 Conclusion

This study aimed to evaluate the performance of a small-scale hydroelectric system in generating usable voltage output using natural or existing water flows within the campus environment. The results from three selected test sites demonstrated that the mini hydro generator system can produce consistent and measurable electrical output. Site A, with the lowest flow conditions, generated voltage levels between 1.13 V and 1.82 V, proving system functionality under minimal conditions. Site B showed improved performance with voltages ranging from 1.55 V to 2.61 V, indicating the positive impact of better water flow and site suitability. Site C produced the highest and most stable voltage output, reaching up to 2.88 V, highlighting its strong potential for future development. These findings confirm that natural water sources within the campus can be effectively utilized to support micro-hydro power systems for low-power applications or as inputs to voltage-boosting circuits. The study successfully met its objective by demonstrating that, with proper site selection and turbine design specifically the use of a screw-type turbine mini hydro systems can deliver reliable output even in small-scale and low-head environments. This supports the broader potential for integrating renewable energy systems into campus infrastructure to promote sustainability and energy independence.

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