

Off Grid Solar System Without Using Battery Storage (Hydro Part)

Muhammad Danial Elias¹, Mohd Fadly Abd Razak^{1*}

¹ *Department Of Electrical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, Pagoh ,84600, Muar, Johor, MALAYSIA*

*Corresponding Author: fadly@uthm.edu.my

DOI: <https://doi.org/10.30880/peat.2024.05.02.014>

Article Info

Received: 26 June 2024

Accepted: 10 July 2024

Available online: 25 November 2024

Keywords

Off Grid Solar System without using battery , solar system , Small scale hydroelectric power , Hydro electric system ,Hydro energy

Abstract

Battery storage for renewable energy like solar and water has high costs and significant environmental impacts. This project explores an alternative by combining solar and small-scale hydroelectric power. Photovoltaic panels generate electricity from sunlight, while a designed hydroelectric system uses flowing water for power generation. By creating a prototype, we demonstrate that solar and hydroelectric power together can provide a sustainable and cost-effective energy solution for homes, addressing both financial and environmental concerns. To achieve this, the project involves detailed calculations and design work to create a robust hydroelectric plant prototype includes evaluating the performance of the hydroelectric system under various conditions. This study focuses on the hydroelectric system, aiming to show its efficiency and practicality as an alternative to battery storage.

1. Introduction

Electricity is one of the important factors for the economic growth and development of a country in achieving the status of a developed country [1]. Malaysia is very dependent on three main types of fossil fuel sources, namely coal, natural gas, and fuel oil [1][2]. To reduce the dependency on fossil fuels, solar energy was introduced as a renewable source that can be used to generate electricity. In the 21st century, solar energy has developed rapidly and is expected to become a prominent renewable energy source due to its inexhaustible capacity and natural abundance [3]. The use of batteries in solar energy systems is a major concern due to their environmental impact [4]. Another alternative is needed to eliminate the reliance on batteries in renewable energy systems while maintaining effectiveness in energy generation [5]. The project will implement two different systems, namely a solar-powered water pumping system and a hydroelectric system, which are interconnected.

In terms of operating time, the two systems will operate at different times where for the solar system, it is highly dependent on the source of sunlight to enable it to generate electricity. Because of this, this solar system will be operated during the day only and it also depends on the rate of peak sunlight. For the hydroelectric system, although this system can be implemented during the day, but it will be operated at night because the load used in this system is a light bulb to show a high rate of traceability for this hydroelectric generation system to generate electrical energy through kinetic energy resulting from the flow of water sources from the upper tank in this project system [6].

The main goal is to utilise a hydropower system to produce electricity by harnessing the kinetic energy of flowing water during non-sunlight hour without battery and to develop a cost-effective hydroelectric system that can be widely adopted by individuals and communities. Main point covered this research is to conduct detailed calculations and design work to create a small-scale prototype of a hydropower system, developing the necessary components and infrastructure to support its operation, including designing and constructing water intake

structures systems to ensure efficient and reliable electricity generation and perform comprehensive testing for this prototype.

2. Literature Review

2.1 Basic Concept

Hydroelectric energy, often known as hydroelectric power or hydroelectricity, is a type of energy that uses the power of flowing water. Water travels downhill, converting potential energy into kinetic energy. The water may be utilised to move the blades of a turbine, producing energy that is supplied to the power plant's consumers. At one end of the variety, huge dams and reservoirs serve as the foundation of many hydroelectric projects [7]. Another method is Run-of-river systems, which on the other hand are a more ecologically beneficial option [8]. Hydroelectric facilities are categorized by hydraulic head difference, which affects design and efficiency [9]. For the pipeline system, mild steel and unplasticized polyvinyl chloride (uPVC) pipe which is commonly use in piping system because of their benefit as pipeline structure.

2.2 Review on Related Previous Studies

The project highlighted by Rahman [10] proposes a Portable Micro Hydro Electrical Generator utilizing a Permanent Magnet Synchronous Generator, emphasizing economic viability and reliability in harnessing continuous water flow for electricity generation. Next, project delves into the design of a floating hydro system in Indonesia is highlighted by P.Rangan [11], addressing rural challenges by employing PVC buoys and Pelton turbine-like turbines, highlighting adaptability and simplicity and it focuses on being easy to set up, needing minimal maintenance, and being able to adapt to water surfaces, which makes it beneficial to remote areas. hydro project innovatively applies a lightweight and durable PVC-based portable hydro generator for farm areas especially to supply power demonstrating a practical application of hydroelectric technology for rural agricultural settings, K.Othman [12]. A study from S.P. Adhau [13], focusing on the potential benefits of Pico-hydro power plants in rural locations, focusing on alternatives to traditional or conventional power transmission that are cheaper and take up a smaller area. A project investigates hybrid systems integrating hydro, solar, and wind to address seasonal variations in power generation in Mashhad Sarrood, Iran by Siamak Hoseinzadeh [14].

2.3 Calculation Findings Based On Related Previous Study

Theory calculation was also involved in this study where the flow rate of water for this hydro generation system was measured using the Bucket Method by Design and Development of Prototype Micro Hydro Electric System [15].

$$Q_{actual} \left(\frac{m^3}{s} \right) = \frac{\text{volume of container, } m^3}{\text{number of second, } s} \quad (1)$$

To determine the Area of the Penstock which must be used to calculated flow rate of water can be define as :

$$\text{Area, } m^2 = \frac{\pi d^2}{4} \quad (2)$$

Absolute Velocity of water is the velocity of water flowing through the sample project.

$$V = C \times \sqrt{2gh} \quad (3)$$

To determine diameter of pipe

$$\text{Diameter of pipe } D, \sqrt{\frac{4 \times Q}{\pi \times V}} \quad (4)$$

Another equation to find velocity which can be used to derive gross height h . From the value of velocity that we get , it can be used to get gross head value.

$$V = C \times \sqrt{2gh}$$

$$h = \frac{\left(\frac{V}{C} \right)^2}{2g} \quad (5)$$

Potential Power Generated as highlighted in Micro Hydropower System Design Guidelines [16] :

$$P = \frac{Ep}{t} = \frac{(\rho \times V \times g \times H_{gross})}{t} \quad (6)$$

3. Methodology

3.1 Project System Block Diagram

Figure 1 shows a basic hydroelectric system illustrating how water flows and transforms into electricity. The system starts with a set of pipes connected to a water pump. The pump sends water to an upper tank. This tank stores water at a high level to create potential energy. It's like a storage. Water flows from the upper tank to a hydroelectric generator through a series of pipes. Moving water that hit and rotate the turbine provides the generator rotational energy, which is then turned into electricity and water return into lower tank.

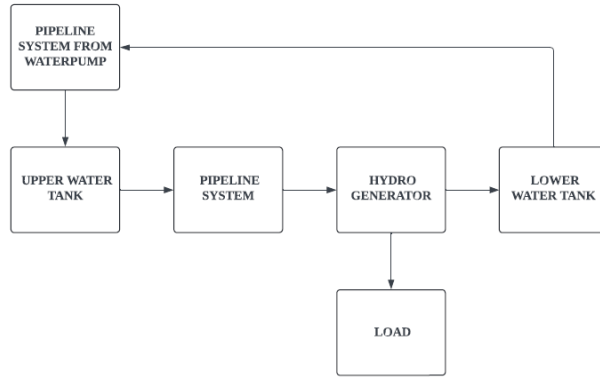


Fig. 1 Project System Block Diagram

3.2 Project Construction Process Flow Chart

Figure 2 shows project method is carefully split into three main parts to make sure that the building phase goes smoothly and on time which covered Purchasing and Preparing Equipment, Installation, and Load Testing and Finalisation. Each section is meant to cover a different part of the job, making sure that the whole thing is covered.

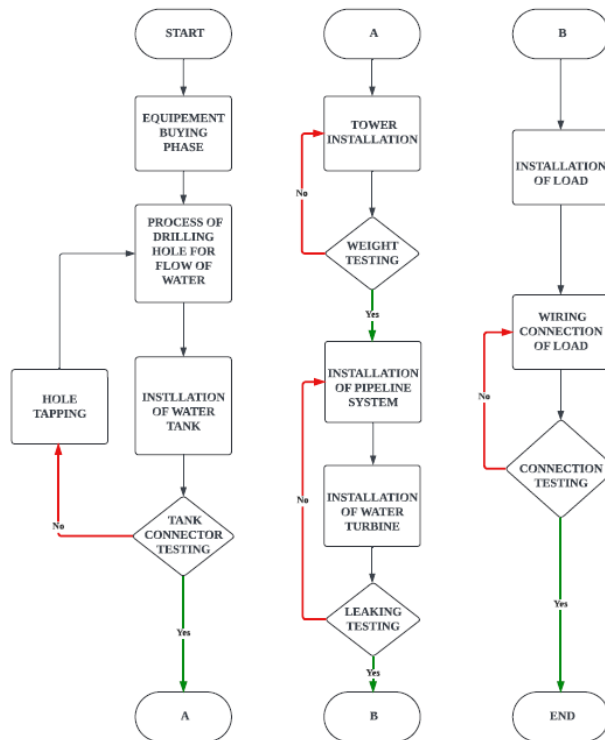


Fig. 2 Project Construction Process Flow Chart

3.3 Theoretical Calculation

Table 1 Theoretical Calculation Data

Data	Value
Volume of water for 5 minutes	125 liter
Flow rate of water	$4.1667 \times 10^{-4} Q \left(\frac{m^3}{s} \right)$
Area	$1.2667 \times 10^{-4} m^2$
Velocity	$3.289 \left(\frac{m}{s} \right)$
Gross Head	0.55 m
Potential Energy	1808.95 J
Potential Power Generate	2.25 W
Pressure output Pipeline	10.791 kPa
Output Power from pipeline	4.5 W

3.4 3D Project Concept Model

Figure 3 shows visual concept of this project which consist of two renewable energy system which is the first one is solar system, which first system is use as energy collector which is then transfer into upper water tank which function as Energy storage to create a potential energy. The energy collected is then will be converted into electricity using a second system. Second system which Hydroelectric system, consist of Upper Water as energy storage, pipeline and 12 VDC hydroelectric generator.

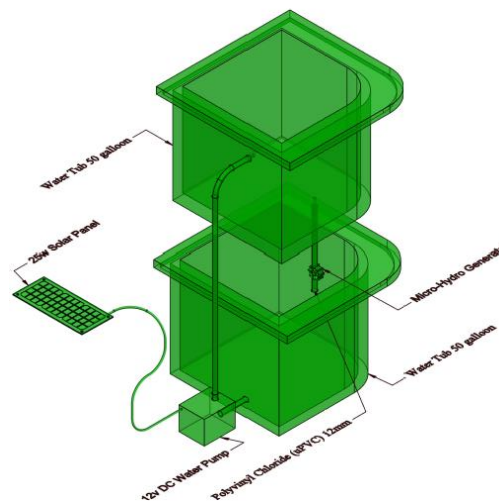


Fig. 3 3D Visualization Design of Project

3.5 Hydro System Criteria Considerations

3.5.1 Hydro Generator Selection

For the hydro generation aspect of our small-scale model, we've opted for a 12VDC water turbine hydro generator known for its reliability and efficiency. With a peak output current of 220mA at 12 volts and an expected output power of 2.7 watts, this generator is well-suited for producing electricity within our model hydro system. Its dependable specifications ensure consistent performance, making it ideal for powering small-scale applications. Moreover, the generator's inlet and outlet opening size of 1/2 inch provides valuable guidance for designing the pipeline system within our model. This specification enables us to tailor the pipeline dimensions, accordingly, ensuring optimal water flow to drive the generator and maximize electricity generation. This water turbine hydro generator also has manufacturing specifications of flow rate of 25 Liter in one minute which can help us designing capacity for water storage system.

3.5.2 Water Storage System

In this Off-Grid Solar system without battery for hydro energy system model, a water pump is integral to the operation, tasked with transferring water from a lower storage to an upper storage. The system is designed to mimic the functionality of larger-scale hydro energy systems but operates within a condensed timeframe of 5 minutes for demonstration purposes. The water pump has a specific capacity, capable of pumping up to 125 liters of water within a 5-hour period. This efficient transfer mechanism facilitates the continuous flow of water, enabling the upper reservoir to be replenished swiftly and efficiently.

3.6 Project Development

The development of a small-scale hydroelectric system prototype involves several key processes as shown in Figure 4. The first step, the Tower Installation Process (a), entails constructing a sturdy support structure using slotted angle bars for the water tank system. The structure has a square base measuring 2 feet by 2 feet and a total height of 6 feet. The slotted angle bars offer ease of assembly and versatility, with three stages of slots at heights of 3 feet, 4 feet, and 5 feet to facilitate testing different hydro head specifications. In the Weight Testing Process (b), a 50-gallon bathtub filled with water is used as the water tank, placed at the highest stage of the tower to evaluate the tower's structural integrity and stability under significant weight. The Installation of the Pipeline System and Turbine (c) involves attaching three different lengths of pipe to the tank's outflow connector, each tailored to specific head requirements. The turbine is securely positioned at the end of the pipeline to efficiently capture the water flow's kinetic energy, ensuring no leaks that could affect the flow rate. Lastly, the Installation of Load Components (d) includes using LED lamps as the primary loads, with two different specifications: one at 12V, 3W, and another at 5V, 3W. These LED lamps were chosen for their varying voltage and consistent low power consumption.

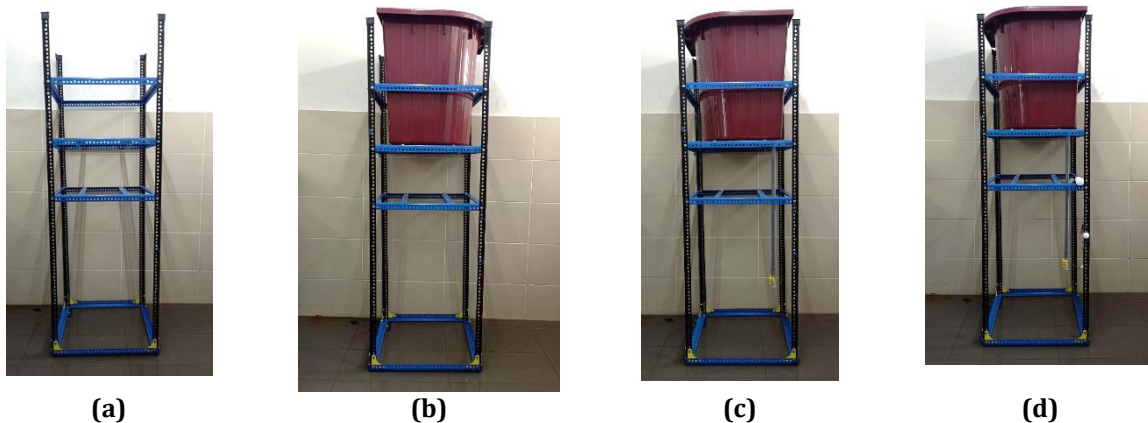


Fig. 4 Project Development (a) Tower Installation Process (b) Weight Testing Process (c) Installation of Pipeline System and Turbine (d) Installation Load Component

4. Result and Discussion

4.1 Full Setup

Figure 5 shows the full setup for hydro project which is designed with three different stages, each tailored for specific testing purposes. The setup features a sturdy tower structure that supports the entire system. At the top, there is an upper tank, while at the bottom, a lower tank which is a pool is positioned, both is crucial for water storage and flow management. Connecting these tanks with a well-organized pipeline system integrated with a hydro turbine generator, enabling efficient water movement and energy conversion. Additionally, the system includes load components to simulate different operational conditions. This comprehensive setup allows for thorough testing and analysis of hydro-related experiments, ensuring reliable and accurate results.

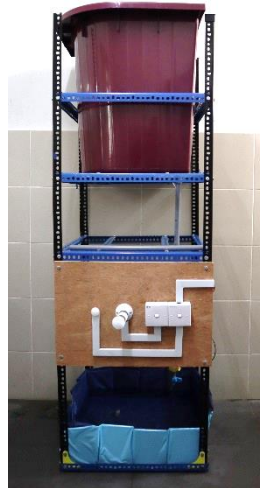


Fig. 5 Full Setup of Hydro Project

4.2 Result and Analysis Comparison

4.2.1 Flow Rate Data Comparison

The data in Table 2 shows that without a hydro generator, the flow rates of water increase with height but required short period of time as shown in Figure 6, from (4.31×10^{-4}) m³/s at 3 ft to (6.07×10^{-4}) m³/s at 5 ft, due to higher potential energy converting to kinetic energy. This results in faster emptying of the tank. With a hydro generator, the flow rates are much lower, from (4.98×10^{-5}) m³/s at 3 ft to (5.65×10^{-5}) m³/s at 5 ft, because the generator extracts energy, reducing kinetic energy and flow rate and required more time. Consequently, the tank takes significantly longer time to empty when the hydro generator is used. This highlights the trade-off between energy generation and maintaining higher flow rates for quicker tank emptying.

Table 2 Flow rate comparison for all specification

Height Of Water Tank From Ground	Without Hydro Generator (m ³ /s)	With Hydro Generator (m ³ /s)
3 ft	4.31×10^{-4}	4.98×10^{-5}
4 ft	4.70×10^{-4}	5.11×10^{-5}
5 ft	6.07×10^{-4}	5.65×10^{-5}

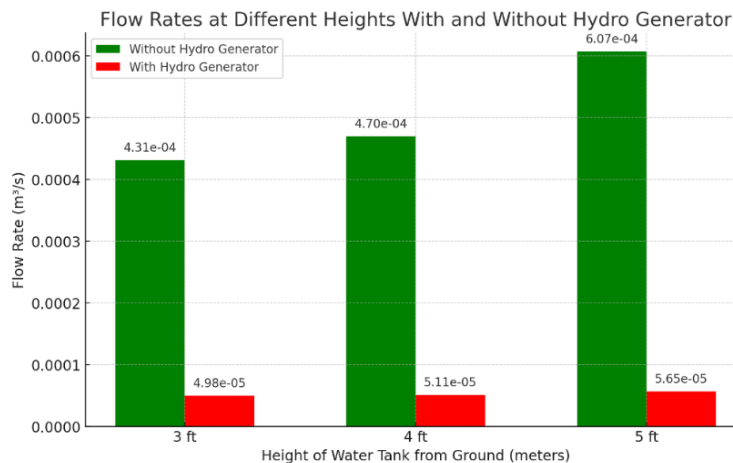


Fig. 6 Graph Flowrate comparison for all specification

4.2.2 Voltage Output Data Comparison (Without Load)

Based on the rate of voltage decrease is highest at the height of 3 feet (0.55 meters hydro head) and lowest at the height of 5 feet (0.93 meters hydro head) as shown in Table 3 and being illustrate in Figure 7. This suggests that at lower heights, the system is more sensitive to changes in the volume of water discharge , the percentage drop indicating that higher setups which is higher length of pipeline system are more efficient in harnessing higher voltage levels as water discharge volume increases.

Table 3 Without load Voltage Output Comparison for all Specifications

Height	Volume of Water discharge (Galloon)									Percentage Drop
	0	4	8	12	16	20	24	28	32	
Voltage (v)										
3 ft	6.70	6.37	6.2	5.92	5.56	5.18	4.89	4.37	3.88	42.08%
4 ft	8.62	8.47	8.25	8.01	7.75	7.44	7.11	6.76	6.29	27.03 %
5 ft	9.70	9.33	9.111	8.9	8.66	8.42	8.09	7.8	7.43	23.40 %

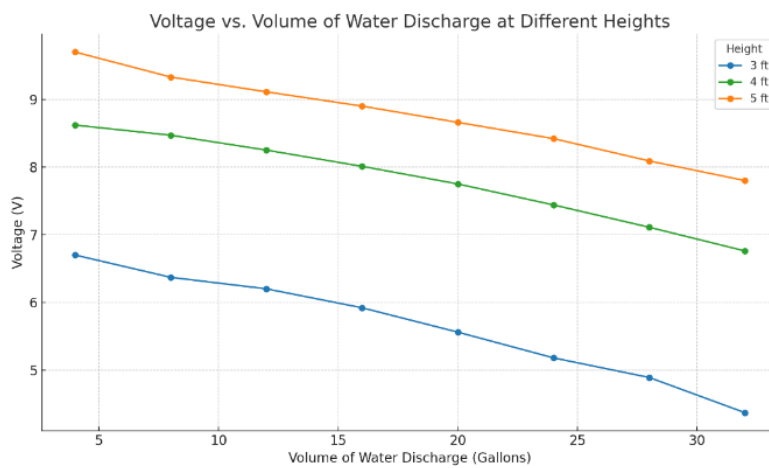


Fig. 7 Graph comparison Voltage vs Volume of water discharge for all specification

4.2.3 Voltage Output Data Comparison (With Load)

For 5V load, this data changes shown in Table 4 and illustrated in Figure 8 shows that the hydro system can handle the load effectively at all specification with minimal voltage decreases. However, higher heights along with higher length of pipeline system or head provide slightly better stability and higher regulated voltage outputs . This stability indicates that the hydro generator effectively capable to provide a consistent voltage output for with load condition of 5V, maintaining steady voltage with less voltage drop despite the increasing volume of water discharged.

Table 4 With load Voltage Output Comparison for all Specifications (5V,3W)

Height	Volume of Water discharge (Galloon)									Percentage Drop (%)
	0	4	8	12	16	20	24	28	32	
Voltage (v)										
3 ft	2.63	2.62	2.61	2.60	2.60	2.60	2.59	2.57	2.55	3.04 %
4 ft	2.68	2.67	2.67	2.67	2.66	2.65	2.64	2.63	2.62	2.24 %
5 ft	2.69	2.69	2.69	2.68	2.68	2.67	2.67	2.66	2.65	1.49 %

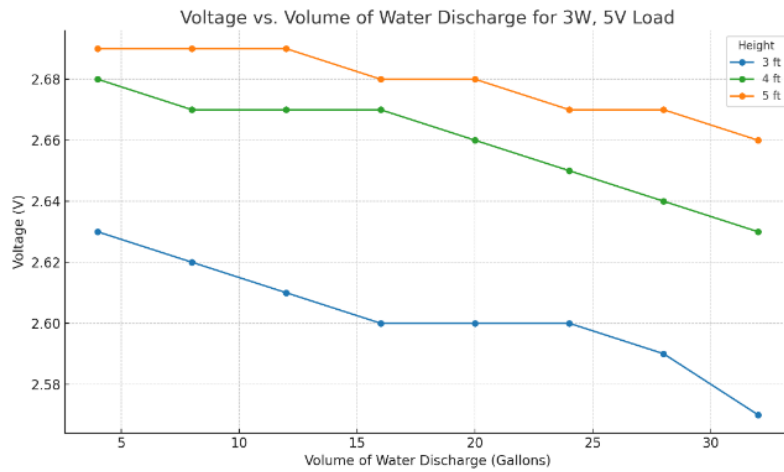


Fig. 8 5V Graph comparison Voltage vs Volume of water discharge for all specification

For 12V load , the system shows more significant voltage drops, particularly at lower heights which it has large voltage percentage drop as shown in Table 5 and graph illustration in figure 9. Higher heights with larger hydro heads are more effective in maintaining higher and more stable voltage outputs.

Table 5 With load Voltage Output Comparison for all Specifications (12V,3W)

Height	Volume of Water discharge (Galloon)									Percentage Drop
	0	4	8	12	16	20	24	28	32	
	Voltage (v)									
3 ft	6.6	6.3	6.16	5.82	5.5	5.13	4.77	4.34	3.87	41.36 %
4 ft	7.74	7.68	7.58	7.52	7.38	7.19	6.97	6.62	6.19	20.02 %
5 ft	7.8.	7.8	7.7	7.74	7.65	7.63	7.53	7.4	7.18	7.94 %

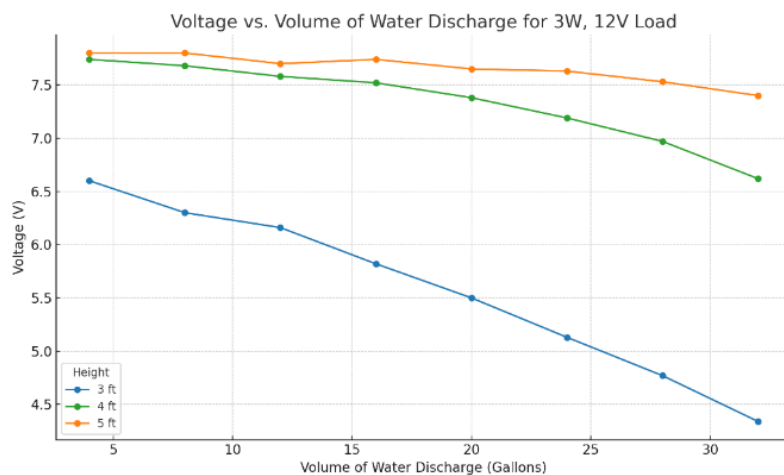


Fig. 9 12V Graph comparison Voltage vs Volume of water discharge for all specification

4.2.4 Power Output Data Comparison (With Load)

For 5V load, these trends show that higher discharge heights are more efficient in maintaining power output as shown in data in table 6 and illustration graph in Figure 10 (a) where 5ft indicates that higher discharge heights result in a slower decline in power output, where lower percentage drop reflecting higher efficiency . The load

condition remains consistently "ON" across all scenarios, indicating the system's reliability in supporting the 5V, 3W load despite variations in water discharge volume and height.

In case of 12 V load, for optimal efficiency and sustained performance, operating the system at 5 ft height is preferable compared to 4 ft. The 3 ft height is non-functional and thus unsuitable for the 12V, 3W load system which the lowest as shown in the Table 7 and arrangement of graph Figure 10 (b). This indicates that for optimal performance, the system should be operated at higher heights (preferably 5 ft)

Table 6 5V load Power Output Comparison for all Specifications

Height	Volume of water discharged (Galloon)								
	0	4	8	12	16	20	24	28	32
Power (W)									
3 ft	0.020	0.019	0.017	0.016	0.013	0.010	0.008	0.004	0.003
Percentage Power drop = 85 %									
4 ft	0.040	0.035	0.033	0.031	0.03	0.026	0.024	0.021	0.017
Percentage Power drop = 57.5 %									
5 ft	0.043	0.041	0.039	0.037	0.037	0.033	0.031	0.028	0.025
Percentage Power drop = 41.86%									

Table 7 12V load Power Output Comparison for all Specifications

Height	Volume of water discharged (Galloon)								
	0	4	8	12	16	20	24	28	32
Power (W)									
3 ft	0	0	0	0	0	0	0	0	0
Percentage Power drop = not functioning									
4 ft	0.0057	0.0053	0.0034	0.0016	0.0006	0.00022	0.00008	0.000013	0
Percentage Power drop = 100 %									
5 ft	0.015	0.013	0.010	0.009	0.005	0.004	0.001	0.0006	0.0002
Percentage Power drop = 98.7 %									

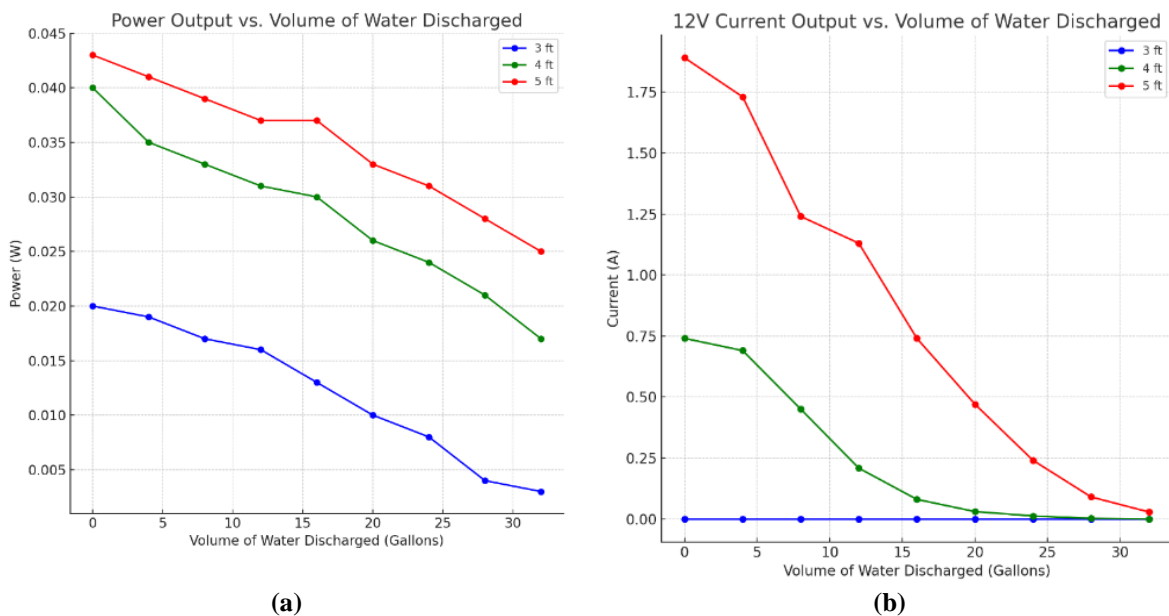


Fig. 10 (a) Graph 5V comparison Power vs Volume of water discharge for all specification (b) Graph 12V comparison Power vs Volume of water discharge for all specification

4.3 Key Parameter Finding

Based on the small-scale hydro project developed for an off-grid solar system without battery storage, in a water flow system, a hydro generator extracts energy from the water as it flows from the upper tank, which lowers the flow rate and significantly increases the time taken for the water to flow out, affecting the operation time. However, if the hydro head along with the height of water placement is increased, it can increase the flow rate of water and decrease the system's operational time. The transformation of kinetic energy into electrical energy is the cause of this decrease. Water loses some of its kinetic energy when it flows through the hydro generator's turbine where this energy is then transferred to the turbine blades and transformed into electrical energy. The significant reduction in flow rates and increasing operation time with the hydro generator highlights the trade-off between harnessing water flow for energy production

This data finding allows and very useful for the design of small-scale hydro systems that can maximize voltage output and efficiency by selecting the optimal hydro head height. The greater potential energy at increased heights converts into higher voltage outputs especially voltage produced without load connection, making setups with extended pipeline lengths and higher hydro heads more efficient. This overview allows to accurately plan and optimize the load capacity the system can sustain or support as higher hydro heads can accommodate larger loads due to their higher and more stable voltage outputs. Additionally, understanding the behaviour of voltage under varying discharge volumes helps in effective load distribution, ensuring that sections with higher heads can bear more load within the time operation. The choice of load condition should consider the specific requirements of the water discharge system, including the height and volume of water to be managed. For scenarios demanding consistent performance, the 5V, 3W load condition is preferable. However, if the system design can accommodate the variability in performance, the 12V, 3W load condition might be utilized, potentially offering benefits in other operational aspect

5. Conclusion

Based on the small scale hydro project developed for off grid solar system without battery , there is some lack of this prototype which can be used to considering the future advancement of the small-scale hydro system, where a holistic approach consists of two key components need to mark as important point which is an improvement to the pipeline system and an enhancement to the hydro turbine-generator to increase its power output. By making sure that the interiors of all water channels and pipes are smooth and do not have any water leak out from the pipeline, friction losses can be greatly decreased, enabling a larger water flow rate to reach the turbine. A good sealing to make sure no water leak must be done especially for the connection flow from tank-pipe-turbine. For turbine-generator improvement, a precise and compatible design of turbine and compatible generator can be done using the data collected to ensure maximum output is produced for small scale hydro project. Another improvement is by using a voltage regulator or DC-DC converter will help increase and maintain a consistent output.

The envisioned small scale hydro project is a physical representation of the conceptualized system, demonstrating the feasibility of harvesting hydro energy as alternatives for electricity generation without the use of batteries. By constructing this small-scale hydro project and combination system off grid solar we can collect data to maximize design for small scale hydro project a a prove if it is reliable to generate electricity. As a conclusion, this project is successfully providing important parameters such as operation time physical specification for hydro project and load compatibility for this project which can help to build a reliable small scale hydroelectric plan.

References

- [1] M. Samsudin, M. Rahman, and M. Wahid, "Akademia Baru Power Generation Sources in Malaysia: Status and Prospects for Sustainable Development," *Journal of Advanced Review on Scientific Research* ISSN, vol. 25, no. 1, pp. 11–28, 2016, Available: https://www.akademiabaru.com/doc/ARSRV25_N1_P11_28.pdf
- [2] Hadi Nabipour Afrouzi, San Chuin Liew, Chin-Leong Wooi, and Bazlul Mobin Siddiquea, "A Comprehensive Review on Available/Existing Renewable Energy Systems in Malaysia and Comparison of Their Capability of Electricity Generation in Malaysia," *ScienceDirect*, Feb. 21, 2021. <https://www.intechopen.com/chapters/75754>

- [3] S. Ashok, "Solar Energy | Description, Uses, & Facts," Encyclopædia Britannica. Feb. 08, 2019. Available: <https://www.britannica.com/science/solar-energy>
- [4] [4] franklinWH, "The Environmental Impact of Solar Batteries: Are They Truly Sustainable?," FranklinWH. <https://www.franklinwh.com/blog/the-environmental-impact-of-solar-batteries-are-they-truly-sustainable>
- [5] Girish Kumar Singh, "Solar power generation by PV (photovoltaic) technology: A review," *Energy*, vol. 53, pp. 1–13, May 2013, doi: <https://doi.org/10.1016/j.energy.2013.02.057>
- [6] Wazed, Md. Abdul and Ahmed, Shamsuddin, *Micro Hydro Energy Resources in Bangladesh: A Review* (2008). *Australian Journal of Basic and Applied Sciences*, Vol. 2, No. 4, pp. 1209-1222, 2008, Available at SSRN: <https://ssrn.com/abstract=150238>
- [7] "Hydroelectric Energy: The Power of Running Water," *Nationalgeographic.org*, 2023. <https://education.nationalgeographic.org/resource/hydroelectric-energy-power-running-water/> (accessed May 18, 2024).
- [8] Aldo, *Fundamentals of Renewable Energy Processes*. Academic Press, 2009. Accessed: May 18, 2024. [Online]. Available: <https://www-accessengineeringlibrary-com.ezproxy.uthm.edu.my/content/book/9781265079659/toc-chapter/chapter7/section/section7>
- [9] "Hydraulic head - Energy Education," *Energyeducation.ca*, 2018. https://energyeducation.ca/encyclopedia/Hydraulic_head#cite_note-RE1-2 (accessed May 18, 2024).
- [10] Siamak Hoseinzadeh, M. Ghasemi, and P. S. Heyns, "Application of hybrid systems in solution of low power generation at hot seasons for micro hydro systems," *Renewable Energy*, vol. 160, pp. 323–332, Nov. 2020, doi: <https://doi.org/10.1016/j.renene.2020.06.149>.
- [11] Rahman, M. M., Chowdhury, P., Rahman, M. N., Mowri, S. T., & Mamun, M. A. (2011). Portable micro hydro electrical generator.3.e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 6, Issue 3 (May. - Jun. 2013), PP 39-43 www.iosrjournals.org
- [12] P. Rangan, A. Stevens Karnyoto, Y. Anugerah, M. Ambabunga, and A. Rambulangi, "Design of River Flow Floating Portable Micro-Hydro," *International Journal of Engineering and Techniques*, vol. 4, 2018, Accessed: Dec. 10, 2023. [Online]. Available: <http://www.ijetjournal.org/Volume4/Issue1/IJET-V4I1P82.pdf>
- [13] K. Othman, "Portable Hydro Generator," *Multidisciplinary Applied Research and Innovation*, vol. 4, no. 2, pp. 236–241, Jan. 2023, Accessed: Dec. 03, 2023. [Online]. Available: <https://publisher.uthm.edu.my/periodicals/index.php/mari/article/view/9467>
- [14] S. P. Adhau, "A comparative study of micro hydro power schemes promoting self sustained rural areas," 2009 International Conference on Sustainable Power Generation and Supply, Nanjing, China, 2009, pp. 1-6, doi: 10.1109/SUPERGEN.2009.5348019.
- [15] jahangir baig, "Design and Development of Prototype Micro Hydro Electric System," *Academia.edu*, 2023. https://www.academia.edu/351155400/Design_and_Development_of_Prototype_Micro_Hydro_Electric_System (accessed Dec. 10, 2023).
- [16] "MICRO HYDROPOWER SYSTEM DESIGN GUIDELINES Acknowledgement." Available: <https://www.ppa.org.fj/wp-content/uploads/2020/06/Micro-Hydropwer-System-Design-Guideline-V1.pdf>