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Prototype Waterwheel Hydro Generator

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Abstract

Pests pose a major threat to agricultural crops, causing major economic losses and affecting global food security. The aim of the project is to develop effective pest management and control techniques, with a particular focus on the use of light traps to mitigate crop damage. However, ensuring the continuous power supply of these traps remains a challenge. In this study, we propose the integration of small hydropower systems into agriculture as a sustainable solution to the problem of powering light traps. Small hydroelectric plants use the energy of flowing water, such as streams or irrigation canals, to generate electricity. Installing a small hydroelectric system on a farm can create reliable renewable energy to run light traps. Additionally, small hydroelectric systems have proven to be cost-effective in the long run because of their relatively low operating costs compared to the recurring costs of other energy sources. The scalability and adaptability of small hydro systems make them suitable for different farm sizes and water resources, allowing them to be tailored to the specific needs of individual farms. However, successful implementation requires careful consideration of site-specific conditions, a feasibility assessment, and compliance with regulatory and environmental requirements. Proper system design and regular maintenance are essential to ensuring the optimum performance and durability of small hydro systems. In summary, the integration of micro-hydroelectric power generation systems into agriculture provides a sustainable and reliable power source for light traps and improves the efficiency of agricultural pest control. The solution offers advantages such as continuous power supply, environmental sustainability, cost efficiency, and scalability. By adopting mini hydro-powered light traps, farmers can effectively control pests, reduce crop losses, and contribute to sustainable agricultural practices.

1. Introduction

The sugarcane community from Five Element Technology Sdn Bhd which is located at Pertanian Moden Ayer Hitam, KM 13, Jalan Batu Pahat, Pula Kampung Batu Jalan Kluang, 86000 Kluang, Johor believes it is essential to develop a prototype of a tiny generator to power the LED light to ward off pests at night. According to the sugarcane community, this hybrid top borer kind is far worse than it was five years ago. Indonesian research on ratoon crops reveals that top borer, shoot borer, and stalk borer are the most common insect pests and have a 49.5% influence on yields and damaged percent [1]. The yield loss in India ranges between 21-37% [2]. Even with manual management, insecticides, or pest control, it is still around 30% in our affected locations, like Malaysia [3].

The primary issue with these pests is that they lay their eggs on the sugarcane buds, where the eggs hatch into larvae that consume the whole sweetness of the sugarcane. The biggest problem with these pests is that they deposit their eggs at the sugarcane shoots, develop into larvae, and then consume the entire sweetness of the sugarcane. It enlarges pores in the sugarcane as it is absorbed. The biggest damage is done to the crop between the ages of one and three months, according to data from the Malaysian sugarcane community. On the underside of leaves, females lay around 400 flat eggs in different clusters. In five days, the eggs will hatch. The larva pierces the stem above ground, enters the middle shoot, and begins feeding there. It features five violet bands with splotchy brown patterns and a soft golden tinge.

To power lights at the farm, a waterwheel generator was built. Lights can be used to attract insects, thus controlling pest from harming the crops. In essence, every farm has drainage that can aid in providing water to the plants. The waterwheel may be positioned in the drainage system, where it will spin continually to power the lights. Through this effort, we hope to help the farmers in some little way improve the standard of agricultural care. This project's objective is to design, create, and study a prototype waterwheel generator that can use farm drainage to generate electricity while also including a fin or blade design that avoids waste from being caught in it for maximum functionality and performance.

2. Materials and Methods

For decades, waterwheel generators have served as a dependable and long-lasting source of mechanical power. With an emphasis on their historical background, design principles, performance traits, and future applications, waterwheel generators are the subject of this literature review, which attempts to offer an overview of current knowledge in this area. This study seeks to offer a thorough overview of the technology and recommend areas for more research and development by synthesizing data from a variety of scholarly sources. The type of waterwheels used to generate electric power is no longer foreign to the world of farmers. This is one of the efforts to take advantage of the water channels available in their fields.

There are few commercially available waterwheels generator in the current market. Fig. 1 shows Kaplan turbine [4], research focused on enhancing a small Kaplan turbine for variable water conditions, determining optimal blade angles for improved efficiency. The turbine was a superb invention that operated at a high, practically constant efficiency throughout a wide variety of load conditions. Kaplan runners have many blades that are attached to a hub in the middle. Kaplan turbines vary from fixed propeller type turbines in that each blade may rotate inside its mounting, allowing for changeable pitch. Although up to 10 blades are feasible, Kaplan turbines typically use three to six blades. The runner's rotational speed and, thus, the quantity of potential energy that may be drawn from the moving water, can both be controlled by the changeable pitch blades.

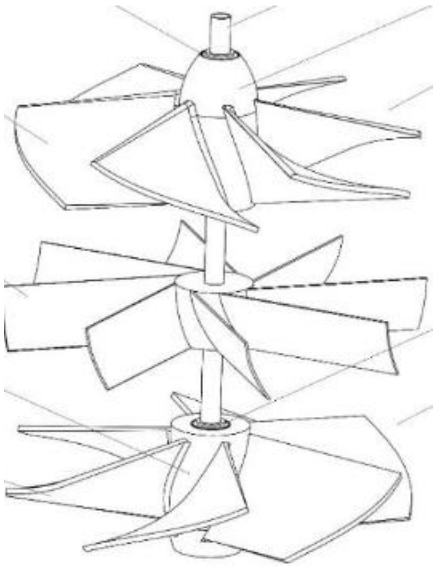

Fig. 1 *Kaplan turbine*

The crossflow turbine waterwheel [5] underwent facility adjustments, enhancements in data recording techniques, and maintenance improvements. Blade efficiency tests revealed no significant difference between J and C blade designs. Collaboration with Elgin for screen modifications is recommended. In contrast to the majority of water turbines, which feature axial or radial flows, a crossflow turbine has water flowing across the turbine blades. Like a waterwheel, the water enters the turbine at its edge. It moves outward when it enters the runner from the inside and leaves from the opposite side. Efficiency is improved by running the runner a second time.

Additionally, when the water leaves the runner, it helps to clean it of impurities and tiny particles. A low-speed device known as a crossflow turbine; it performs effectively in areas with low head but high flow.

The waterwheel generator's construction must adhere to the necessary procedures and specifications for the project's testing. A product's design must consider several crucial factors for its manufacturing to go smoothly and be user-friendly. The kind of materials and components utilised, the proper application procedure, the results of an objective analysis, and the cost of each material and component used are a few of the factors that need to be studied at.

Table 1 *Materials used to fabricate the waterwheel*

Parts	Materials
Bicycle rim	Aluminium
PVC pipe	PVC
Base	PVC
Chain	Steel
Sprocket	Steel
Steel plate (L shape)	Steel
Bolt, nut, and washer	Steel
Socket	Stainless Steel
Dynamo	Stainless Steel

Table 1 provides a clear overview of the materials selected for each part of the waterwheel fabrication. The Prototype Waterwheel Hydro Generator construction material was mainly Polyvinyl Chloride (PVC) pipes. The pipes were bought from hardwares that are in Pagoh, Johor, Malaysia and Pontian, Johor, Malaysia. Bicycle rim was obtained from bicycle shop at Panchor, Johor, Malaysia, and used as a main part for the waterwheel. PVC pipe with the largest diameter (6 inch) was cut and used as the propellers in the project. The base and the poles of project were made from smaller diameter of PVC pipes. The usage of PVC pipes was selected by the supervisor, Dr. Khairulnizam Bin Othman due to the less cost and less weight so that the project can easily be moved from one place to another. All the pipes were cut according to the measured length and were connected by PVC Elbow and PVC Tee. Bolts, washers, and nuts that were used to connect propellers to bicycle rim were bought from hardware in Pagoh, Johor, Malaysia. Chain and sprocket were obtained from bicycle workshop at Pagoh, Johor, Malaysia. They were used to connect waterwheels to the dynamo that will generate electricity to power up lights. The dynamo was bought from an electronic store located in Batu Pahat, Johor, Malaysia.

3. The Design of Prototype Waterwheel Hydro Generator

The waterwheel and the base are the two categories into which the parts of the prototype Waterwheel Hydro Generator are split. A bicycle rim and six inches of PVC pipe were used to build the waterwheel, and they were joined together with a bolt, nut, and washer. Following the measuring procedure, a 20 cm blade length is needed. Then a hole is intentionally drilled through the blade to connect at the rim. Every blade edge is smoothed off to prevent any sharp edges from endangering consumers. Mechanical fasteners are then used to join the blade at the rim since they are less expensive and easier to maintain.

PVC tubing with dimensions of 1.25 inches and 1 inch is used to construct the waterwheel's base, which is then cut to the plan drawing's specifications of 60 cm, 30 cm, and 50 cm. Due to the pole's two distinct portions, the height can be altered to correspond to the depth of the drainage. A tee joint and the elbow joint are then used to attach the PVC pipe together. All of the connectors have a PVC seal applied to them in order to lock the joint and prevent easy removal.

This waterwheel's ability to transform mechanical energy into electrical energy is essential. Power is transferred from the rotating of the waterwheel to the dynamo via chains and sprockets. There are two sprockets: one is attached to the dynamo and the other is at the rim. To keep the chain from slipping off the sprockets, the dynamo is then set on the steel plate that is sealed at one of the pole bases.

Fig. 2 shows the finalized drawing design of the prototype waterwheel hydro generator is built. This waterwheel is built in a simple way as possible to lower the cost. The waterwheel only uses a 12 V dynamo with a 66 rpm.

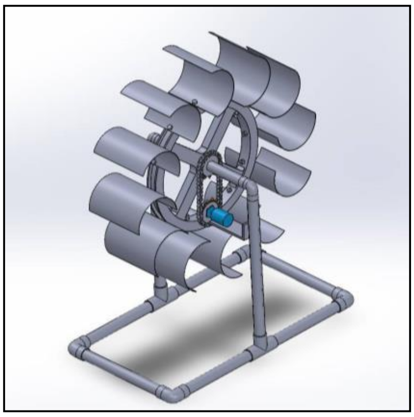

Fig. 2 *Assembly drawing of the prototype waterwheel hydro generator*

4. Cost Analysis

Table 2 *Cost to construct the waterwheel*

Component	Price Per Unit	Unit	Total Price (RM)
PVC Pipe 6' inch	RM 21 (2.4 meter)	1	21.00
PVC Pipe 1.25' inch	RM 3.90 (1 meter)	2	7.80
PVC Pipe 1' inch	RM 1.50 (1 meter)	1	1.50
PVC Joint (T) 25mm	RM 1.60	2	3.20
PVC Joint (L) 20mm	RM 0.80	2	1.60
PVC Joint (L) 25mm	RM 1.20	4	4.80
Dynamo	RM 35	1	35.00
Socket	RM 13	2	26.00
Steel plate (L)	RM 5	1	5.00
Bolt	RM 0.50	12	6.00
Nut	RM 0.30	12	3.60
Washer	RM 0.20	12	2.40
Rim	RM 15	1	15.00
Sprocket	RM 3	1	3.00
Chain	RM 4	1	4.00
	Total		RM 139.90

The development involves creating a small to medium-sized water wheel hydro system using cost-effective materials, primarily PVC pipes of varying diameters (6 inches, 1.25 inches, and 1 inch), along with PVC joints for T and L connections as listed in Table 2. A dynamo, socket, steel plate, bolts, nuts, washers, rim, sprocket, and chain are essential components for constructing the water wheel. The objective is to harness hydro energy economically by leveraging the affordability and accessibility of PVC materials, keeping costs to a minimum while ensuring the efficient generation of power through the dynamo. This design allows for a sustainable and budget-friendly approach to water wheel hydroelectric systems for small-scale applications.

5. Result and Discussion

The final product of the water wheel is shown in Fig. 3. The data was taken based on the velocity of the water stream. One of the fins at the waterwheel was marked to be used as a marker of rotation [6]. First, the number of rotations a waterwheel can make in one minute is measured. Next, the value of the electric current that can be produced by using a waterwheel is measured [7]. The average velocity of the water at the drainage is 0.2805 m/s. The same drainage has been used as a test site and data collection. The readings are taken three times before calculating the average number of rotations and the value of electric current.

The information that we got after some investigation.

Distance = 20 m
Average time = 60 seconds
Surface water velocity = 20 ÷ 60
Surface water velocity = 0.33 m/s
Average water velocity = 0.33 m/s × 0.85 (correction factor)
Average water velocity = 0.2805 m/s

Fig. 3 *Photo of Final Product*

5.1 Data of The Waterwheel Rotations for One Minute

Table 3 *Data of The Waterwheel Rotations for One Minute*

Number of Trial	Waterwheel's Rotation
1	5
2	4
3	5
4	6
5	4
6	5

Table 3 shows the readings of rotations a waterwheel can make in one minute at 0.2805 m/s of water. Based on the table below, the value of rotations is constant for every trial. This happened because the velocity of water at the drainage is constant.
Number of rotations = 5 + 4 + 5 + 6 + 4 + 5 = 29
Average rotation = 29 ÷ 6 = 4.8 ≈ 5 rotations

5.2 Data of the Electric Current Flows

Table 4 *Data of Electric Current Flows*

Number of Trial	Rotation for One Minute (rpm)	Electric Current Flows (V)
1	5	3.9
2	4	2.6
3	5	3.5
4	6	4.2
5	4	2.9
6	5	3.7

Table 4 shows the reading of electric current that can be produced by using a waterwheel. In the table below, it shows that the value of electric current is not constant. It is because of the unstable current flow that cause an unstable reading. The electric current was measured by using a voltmeter. Therefore, the average value is taken for electric current flows by using a waterwheel at velocity of water 0.2805 m/s.
Total current flows = 3.9 + 2.6 + 3.5 + 4.2 + 2.9 + 3.7 = 20.8 V
Average current flows = 20.8 ÷ 6 = 3.47 V

The stability of the water flow and the corresponding behavior of the waterwheel play crucial roles in determining the efficiency of energy generation. Since the velocity of the water at the drainage remains constant, the number of rotations per minute (RPM) of the waterwheel is consistent, as observed in Table 3. The uniformity in rotations suggests that the mechanical aspect of the system is performing optimally under these controlled conditions. A stable RPM directly correlates with a predictable mechanical output, which is essential when designing systems that depend on the rotation speed for energy generation.

However, as indicated in Table 4, the electric current generated by the waterwheel exhibits some variability, even though the mechanical rotations remain constant. This fluctuation can be attributed to several factors. One of the primary reasons for the instability in the current flow could be the inconsistencies in the electrical system, such as minor variations in resistance, wiring, or the connections in the generator. Additionally, environmental factors such as temperature changes, humidity, or the physical properties of the drainage system might affect the efficiency of the waterwheel's generator. Since the electric current was measured using a voltmeter, and voltmeters can sometimes pick up transient fluctuations, the readings may not perfectly reflect the continuous flow of current. These variations necessitate the use of average values to account for the inconsistencies, ensuring that the data provides a more accurate representation of the waterwheel's overall performance.

In future studies, improvements in the electrical measurement system could provide more stable readings. Moreover, refining the setup by using more precise instruments or installing a more robust electrical control system could help mitigate the fluctuations in current. These enhancements would lead to a more consistent energy output, making the waterwheel a more reliable source of power for applications in rural or low-flow water bodies. Additionally, further experimentation could explore how changes in water velocity, as well as different blade designs for the waterwheel, affect both the rotational consistency and the stability of the electric current generated.

5.3 Discussion

The average rotation of the waterwheel measured in Table 3 is 5 rotations per minute. The value is not constant because the velocity of the water at the drainage is uncertain. Next, the average value of electric current flows measured in Table 4 is 3.47 V. The average value was taken because of the actual value read by voltmeter is unstable. This happens because of the unstable current flow produced by using a waterwheel.

The value of voltage can be calculated by multiplying the torque by rotation per minute. Then divide by the value of current and multiply by 2π/60. The relationship between rotations per minute and electric current is the higher the voltage, the faster a motor spin. It means that the electric will show high readings if the waterwheel rotates fast in one minute.

From the information above, the value of Power can be calculated by using formula in Eq. 1. While torque can be calculated using formula in Eq. 2.

$$P = 2\pi \frac{N}{60} T \ \text{watt} \tag{1}$$

$$T = \frac{\text{Motor Output}}{2\pi \frac{N}{60}} \ \text{Nm} \tag{2}$$

6. Conclusion

In conclusion, the integration of small hydropower systems into agriculture offers a sustainable and effective solution to power light traps for pest management in crops. By harnessing the energy of flowing water, such as streams or irrigation canals, these systems provide a reliable and renewable power source, eliminating the need for mains electricity or traditional batteries. This ensures uninterrupted operation of the traps, leading to improved pest control efficiency, reduced crop losses, and increased agricultural productivity. The scalability and adaptability of small hydro systems make them suitable for farms of different sizes and water resources, allowing customization to meet specific needs. Furthermore, the long-term cost-effectiveness, environmental sustainability, and maximization of available water resources make small hydropower a viable choice for sustainable agricultural practices. Proper system design, maintenance, and compliance with regulatory and environmental requirements are crucial for optimal performance and durability. By embracing mini hydro-powered light traps, farmers can effectively combat pests, protect their crops, and contribute to a more sustainable agricultural future.

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Conflict of Interest

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

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

The authors confirm contribution to the paper as follows: ***study conception and design, data collection:*** *R Muhammad Danish Irfan, Muhammad Faqrulhadi;* ***analysis and interpretation of results:*** *Khairulnizam Othman;* ***draft manuscript preparation:*** *Muhammad Danish Irfan. All authors reviewed the results and approved the final version of the manuscript.*

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