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Implementation of a Floating Archimedes Screw Pikohydro System for Ultra-Low Head Irrigation Channels

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Abstract

Irrigation canals with ultra-low head conditions have the potential as a source of renewable energy, but they have not been optimally utilized due to the limitations of conventional hydropower plants. This study aims to design, implement, and evaluate the performance of the Archimedes Screw turbine-based floating Picohydro Power Plant (PLTPH) in the Tukad Ayung Mambal irrigation canal. The design was carried out based on the results of hydraulic characteristics measurements, then validated using Computational Fluid Dynamics (CFD) simulations on ANSYS before being implemented in the field. The measurement results showed a water discharge of 0.53 m³/s and a flow speed of 0.30 m/s, with a theoretical power potential of 23.85 W. The turbine designed has a diameter of 0.12 m, a length of 0.50 m, four threads, and a thread angle of 8°, with an estimated power of 21.94 W. Simulations show a low pressure drop, namely 16.2 Pa in the turbine and 1.97 Pa in the floating PLTPH system. Field tests yielded an average of 0.91 W of electrical power or 21.84 Wh of daily energy, with a system efficiency of 4.14% of the theoretical power. The results of the study show that the Archimedes Screw turbine based floating PLTPH has the potential to be a solution for the use of renewable energy in irrigation canals with ultra-low head conditions.

Keywords: Archimedes Screw; Floating PLTPH; Ultra-low head; Irrigation canals; Renewable energy; CFD.

1. Introduction

Picohydro Power Plant (PLTPH) systems are one of the renewable energy technologies that utilize water flow to produce electrical energy on a small scale. Most conventional hydropower generation technologies require a sufficient difference in water height so that it is not suitable for application to water lines with ultra low head conditions. The Archimedes Screw turbine is one of the alternatives that can operate in ultra low head conditions because it has a simple construction and is easy to implement in open channels [1], [2]. The Tukad Ayung Mambal waterway in Sibangkaja Village, has an average discharge of about 0.75 m3/s that flows throughout the year, but has a very low elevation difference [3]. This condition provides an opportunity to apply an archimedes screw turbine with a floating system without the need to build a dam on the waterway. Several previous studies have developed Archimedes Screw turbines for picohydro power plants and demonstrated good performance in low head conditions [2], [4]. However, the research generally focuses on laboratory testing and analysis of turbine characteristics. Based on these conditions, this study aims to design, build, and implement a floating Archimedes Screw turbine as a picohydro power plant on waterways with ultra low head conditions.

2. Literature Review

2.1 Pikohydropower

The operating principle of a pikohydropower system is based on utilizing the available hydraulic head, the kinetic energy of water flow, and the discharge of water in irrigation channels, rivers, or waterfalls. The system can generate electrical power even under low-flow conditions of approximately 1 L/s and a hydraulic head as low as 1 m [1].

2.2 Water discharge

The discharge or magnitude of a river flow is the volume of water that passes through a transverse cross-section in a unit of time, which is generally expressed in m^3/second. Meanwhile, flow is the movement of water masses along the channel of a river. Thus, discharge measurement includes the activities of measuring and calculating flow speed, depth, river width, and wet cross-sectional area, all of which are necessary in determining discharge and water level [5].

The flow rate can be obtained through direct measurements in the field or calculated using the following equations [5]:

$$V = \frac{m}{s} \quad (1)$$

The equation of water discharge is as follows:

$$Q = V \,.\, A \quad (2)$$

Description:

V : Water flow rate(m/s)
m : Distance (m)
s : Time(s)
Q : Debit (m^3/s)
A : Water flow cross-section area (m^2)

2.3 Ultra Low Head Water Flow Conditions

Ultra-low head condition is a power plant condition with a difference in height (head) of less than 3 m or close to 0 m, so that water flow energy is utilized continuously and comes more from the discharge and speed of water flow than the difference in elevation. This condition is generally found in irrigation canals, canals, or rivers with relatively flat flows, making it suitable for the application of floating power plants [6].

2.4 Hydrolysis Power and Efficiency

Hydrolytic power is the power produced by water flowing from a certain height. The amount of potential power of a water source is influenced by the height of the fall (head) and the flow discharge. The potential energy of the water flowing and falling on the wheel will be converted into power, which can be calculated using the following equation [4].

$$P = \rho \,.\, Q \,.\, g \,.\, H \quad (3)$$

Description:

P : Power (watts)

r	:	Water density (1000 kg/m^3)
Q	:	Debit (m^3/s)
G	:	Earth's gravity (m/s^2)
H	:	Head or water drop height (m)

If the application of the archimedes turbine there is no head falling but on the flowing water channel without a head. So the formula of energy potential does not apply, but uses the formula of kinetic energy, namely. So it becomes [4]:$Ep = m \times g \times hEk = \frac{1}{2} \times m \times V^2$

$$P = \frac{1}{2} \times \rho \times Q \times V^2 \quad (4)$$

Description:

P	:	Power (watts)
r	:	Water density (1000 kg/m^3)
V	:	Water acceleration (m/s)
A	:	Water flow cross-section area (m^2)

System efficiency (Ƞ PLTPH) is the ability of generating equipment to convert kinetic energy from flowing water into electrical energy. To calculate efficiency, the following equations can be used [4]:

$$\eta_{PLTPH} = \frac{P_G}{P_H} \times 100\% \quad (5)$$

Description:

η_{PLTPH}	:	Efficiency of the PLTPH system
P_G	:	Daya Generator (W)
P_H	:	Daya Hydrolysis (W)

2.5 Archimedes Screw Water Turbine

The archimedes screw turbine utilizes the flow of water to generate torque in the helical plane so that the screw shaft rotates and drives the generator to generate electrical energy. This technology is a development of the Archimedes screw pump and began to be applied as a power plant since the 1990s. Archimedes screw turbines are known as renewable energy technologies that are environmentally friendly, have a simple construction, and are safe for aquatic ecosystems, so they have been implemented in hundreds of power plant installations [2]. The construction of the archimedes screw turbine on a hydroelectric power plant system is shown in Figure 1.

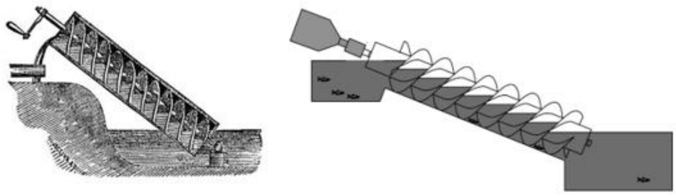


Figure 1: Schematics of the Archimedes Screw Turbine [2].

2.5.1 Blade or Spoon Diameter (D)

The blade diameter is the outer diameter of the turbine thread that captures the kinetic energy of the water flow. The larger the diameter of the blade, the greater the volume of water that is stored so that the torque increases. However, larger diameters also increase the mass and hydrodynamic load, so they must be adjusted to the strength of the material and the condition of the waterway [7].

The diameter of the spoon is searched based on water discharge, turbine rotation, and turbine constant as in the following formula [7]:

$$D = \sqrt[3]{\frac{Q}{k.n}} \tag{6}$$

Description:

D	:	Turbine spoon diameter (m)
Q	:	Debit air (m^3/s)
k	:	Turbine constant
n	:	Turbine rotation (rpm)

The constant value of the archimedes screw turbine is obtained through the thread constant table as shown in Table 1 below. The turbine rotation (n) is selected from Table 2 of the archimedes screw turbine operating rotation. The rotation of the archimedes screw turbine consists of slow, medium, and fast categories [7].

Table 1: Constant Value of Archimedes Screw Turbines [7]

d/D	22°		26°			30°	
	1.0 D	1.2 D	0.8 D	1.0 D	1.2 D	0.8 D	1.0 D
0,3	0,331	0,335	0,274	0,287	0,286	0,246	0,245
0,4	0,35	0,378	0,285	0,317	0,323	0,262	0,271
0,5	0,345	0,38	0,281	0,317	0,343	0,319	0,287
0,6	0,315	0,351	-	0,3	0,327	-	0,273

Table 2: Turbine Operating Rounds [7]

Speed	Turbin revolution per minute (rpm)
Slow	20 - 23
Medium	25 - 26
Almost	29 - 31

2.5.2 Turbine Shaft Diameter (d)

The diameter of the turbine shaft is the diameter of the central rod that supports the threaded blade and transmits torque. The diameter of the shaft should be strong enough to withstand twisting and bending loads, but not too large so as not to reduce the effective volume of water and turbine efficiency [7]. To find the diameter of the turbine shaft, you can use the ratio of the diameter of the turbine shaft (d) to the diameter of the turbine blade (D) as shown in table 1 above. If you want a comparison between the diameter of the turbine shaft and the diameter of the turbine blade of 0.4, then [7]:

$$\frac{d}{D} = 0{,}4 \tag{7}$$

Description:

D	:	Turbine spoon diameter (m)
d	:	Turbine shaft diameter (m)

2.5.3 Turbine Length Dimensions (L)

The dimensions of the length of the archimedes screw turbine can be obtained by the height of the water fall (head) and the inclination of the turbine that is (β) desired or adjusted to the conditions in the field, so that an equation [7] is obtained:

$$\sin \beta = \frac{H}{L} \tag{8}$$

Description:

b	:	Turbine tilt (°)
H	:	Height of the water drop or *head* (m)
L	:	Turbine length (m)

2.5.4 Turbine Pitch (S)

The pitch of the turbine is designed by taking a stipulation, i.e. by first determining the angle of the turbine thread (a) [7].

If the turbine angle ≤ 30° then S = 1.2 D

If the turbine angle = 30° then S = 1.0 D

If the turbine angle ≥ 30° then S = 0.8 D

2.5.5 Number of Threaded Spoons (Z)

The number of threaded blades indicates the number of helices (flights) found along the turbine shaft. These parameters affect the continuity of water flow and the rotation stability of the turbine. A larger number of threaded spoons will increase the number of water buckets so that the flow becomes more stable and vibrations are reduced. However, too many tablespoons can increase fluid friction and energy loss [7]. The number of threaded blades is calculated based on the known length of the turbine and then compared to the pitch distance of the turbine, resulting in the following equation [7]:

$$Z = \frac{L}{S} \tag{9}$$

Description:

Z	:	Number of threads
L	:	Turbine length (m)
S	:	Pitch spacing (m)

2.5.6 Thread Angle (α)

The thread angle is the angle of inclination of the turbine shaft to the horizontal plane. This parameter plays an important role in determining the hydraulic efficiency of the turbine, as it affects the gravitational force and the water flow velocity components acting on the threaded blade. Scientifically, a thread angle that is too small causes water to spill back easily, while an angle that is too large increases energy loss due to friction [7]. The angle of the thread can be searched by previously calculating some of the following equations [7]:

$$X = \frac{1}{Z} . S \tag{10}$$

So:

$$\Delta h = X.\sin\beta \quad (1)$$

Thus, the thread angle (α) can be found using equation [7]:

$$\alpha = \frac{h_o}{\Delta h} \quad (2)$$

Description:

h_o : Pitch distance or S (m)

2.5.7 Turbine Efficiency

The efficiency of the archimedes screw turbine obtained from the design of the PLTPH turbine design can be obtained using the following equation [7]:

$$\eta = \left(\frac{2\,.\,\alpha + 1}{2\,.\,\alpha + 2}\right).\left(1 - \frac{0{,}01125\,.\,D^2}{Q}\right) \quad (3)$$

Description:

η : Turbine efficiency
α : Archimedes screw turbine blade angle
D : Turbine blade diameter
Q : Water discharge (m^3/s)

3. Method

3.1 Water Discharge Measurement

The measurement of the water line is carried out to determine the area of the wet cross-section, which is used for the calculation of water discharge and the potential of the electricity produced. The cross-sectional shape of the observed waterway shows the characteristics resembling the isosceles trapezoid shown in Figure 2. The measured waterway dimensions are shown in Figure 3.

Figure 2: Measurement of Tukad Ayung Mambal Waterway.

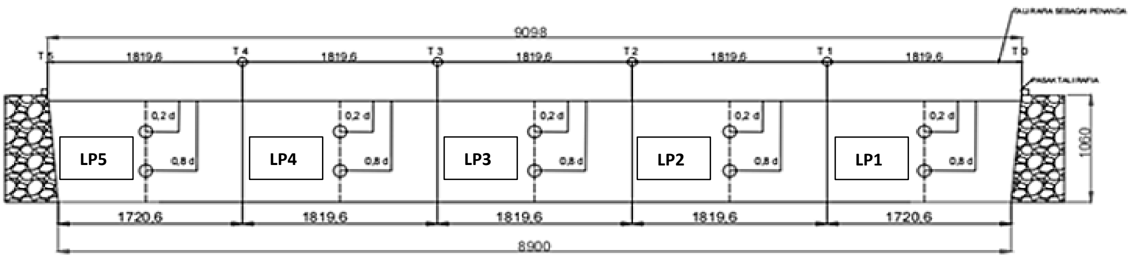


Figure 3: Measurement Results of Tukad Ayung Mambal Waterway Size.

The measurement of the water flow speed of Tukad Ayung Mambal was measured using a flowmeter measuring device. Data collection of water flow speed data is carried out by two methods, namely by monitoring and hanging methods. Measurements by the monitoring method were carried out at five cross-sectional points of the waterway at a depth of 0.2d and 0.8d, respectively. The following is a documentation of measurements using the monitoring method. The results of the measurement of the water flow speed of the monitoring method are shown in Table 3.

Table 3: Results of Water Flow Velocity Measurement Using the Monitoring Method.

No	Cross-section section	Depth Point	
		0.2 d	0.8 d
1	T0 to T1 (LP1)	(0,3 m/s)	(0,3 m/s)
2	T1 to T2 (LP2)	(0,30 m/s)	(0,20 m/s)
3	T2 to T3 (LP3)	(0,20 m/s)	(0,20 m/s)
4	T3 to T4 (LP4)	(0,20 m/s)	(0,10 m/s)
5	T4 to T5 (LP5)	(0,10 m/s)	(0,10 m/s)

The second method uses the hanging method, measurements with the hanging method are also carried out at five cross-sectional points of the waterway at a depth of 0.2d and 0.8d, respectively. The results of the flow speed measurement of the hanging method are shown in Table 4.

Table 4: Results of Water Flow Velocity Measurement Using the Hanging Method.

No	Cross-section section	Depth Point	
		0.2 d	0.8 d
1	T0 to T1 (LP1)	(0,30 m/s)	(0,30 m/s)
2	T1 to T2 (LP2)	(0,30 m/s)	(0,30 m/s)
3	T2 to T3 (LP3)	(0.30 m/s)	(0.10 m/s)
4	T3 to T4 (LP4)	(0.10 m/s)	(0.10 m/s)
5	T4 to T5 (LP5)	(0.10 m/s)	(0.10 m/s)

3.2 Calculation of the design of the Archimedes Screw turbine

In this study, the first cross-sectional area (LP1) was used for the implementation of floating PLTPH because the location has faster water flow than other cross-sectional areas, and the ease of the tool testing process. LP1 has a water discharge of 0.53 m^3/s, so the estimated power produced by the turbine can be calculated as an equation (4):

$$P = \frac{1}{2} \times 1000 \text{ kg}/m^3 \times 0{,}53\ m^3/s \times (0{,}3\ m/s)^2 = 23{,}85\ W$$

It was obtained for the potential electrical power in the application of the prototype at the LP1 location, which was 23.85 W.

3.2.1 Blade Diameter (D)

The D parameter in table 1 is a comparison of the diameter of the turbine shaft (d) to the diameter of the turbine blade (D) with the angle of the blade thread (α), which is 22°, 26°, 30°. While 0.8 D; 1.0 D; and 1.2 D is the pitch distance of the turbine (S). Followed by equation (6):

$$D = \sqrt[3]{\frac{0{,}014\ m^3/s}{0{,}245\ .\ 30\ rpm}} = 0{,}12\ m$$

3.2.2 Turbine Shaft Diameter

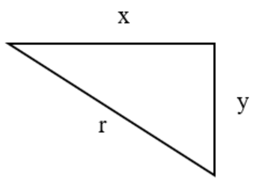
The dimensions of the turbine shaft diameter are obtained by calculating using equation (7). The ratio between the turbine shaft diameter (d) and the turbine blade diameter (D) selected is 0.3, so that:

$$\frac{d}{0{,}12\ m} = 0{,}3$$

$$d = 0{,}3\ .\ 0{,}12\ m = 0{,}036\ m \approx 0{,}04\ m$$

3.2.3 Turbine Length Dimensions

The turbine length is calculated based on the depth of turbine entry into the water which is 0.3 m, with the angle from the previous study being 30 degrees [4] using equation (8):



$$tan\ \alpha = \frac{y}{x}$$

$$tan\ 30° = \frac{0{,}3\ m}{x}$$

$$x = \frac{0{,}3\ m}{tan\ 30°}$$

$$x = \frac{0{,}3\ m}{\frac{1}{3}\sqrt{3}}$$

$$x = 0{,}5\ m$$

3.2.4 Turbine Pitch

The pitch of the turbine is designed by taking a stipulation from Rores, i.e. by first determining the angle of the turbine thread (a), i.e. the turbine angle of 30° so that by using equation (8):

$$S = 1{,}0\ .\ 0{,}12\ m = 0{,}12\ m$$

3.2.5 Number of Threaded Spoons

The number of threaded spoons on a turbine is obtained by calculating using equation (9):

$$Z = \frac{0{,}5\ m}{0{,}12m} = 4{,}16 \approx 4\ ulir$$

3.2.6 Thread Angle

The size of the thread angle can be obtained by calculating several equations (10), (11) and (12):

$$X = \frac{1}{Z} . S$$

$$X = \frac{1}{4} .\ 0{,}12 = 0{,}03$$

$$\Delta h = X. \sin 30°$$

$$\Delta h = 0{,}03. \sin 30°$$

$$\Delta h = 0{,}03 . 0{,}5 = 0{,}0015$$

So that the thread angle is obtained

$$\alpha = \frac{h_0}{\Delta h}$$

$$\alpha = \frac{0{,}12}{0{,}015} = 8°$$

3.2.7 Turbine Efficiency

The efficiency of an archimedes screw turbine is calculated by equation (13):

$$\eta = \left(\frac{2 . \alpha + 1}{2 . \alpha + 2}\right) . \left(1 - \frac{0{,}01125 . D^2}{Q}\right)$$

$$\eta = \left(\frac{2 . 8 + 1}{2 . 8 + 2}\right) . \left(1 - \frac{0{,}01125 . 0{,}12^2}{0{,}014}\right)$$

$$\eta = \left(\frac{17}{18}\right) . (1 - 0{,}01157)$$

$$\eta = 0{,}94 . 0{,}98 = 92\%$$

3.2.8 Theoretical Electrical Power Estimation

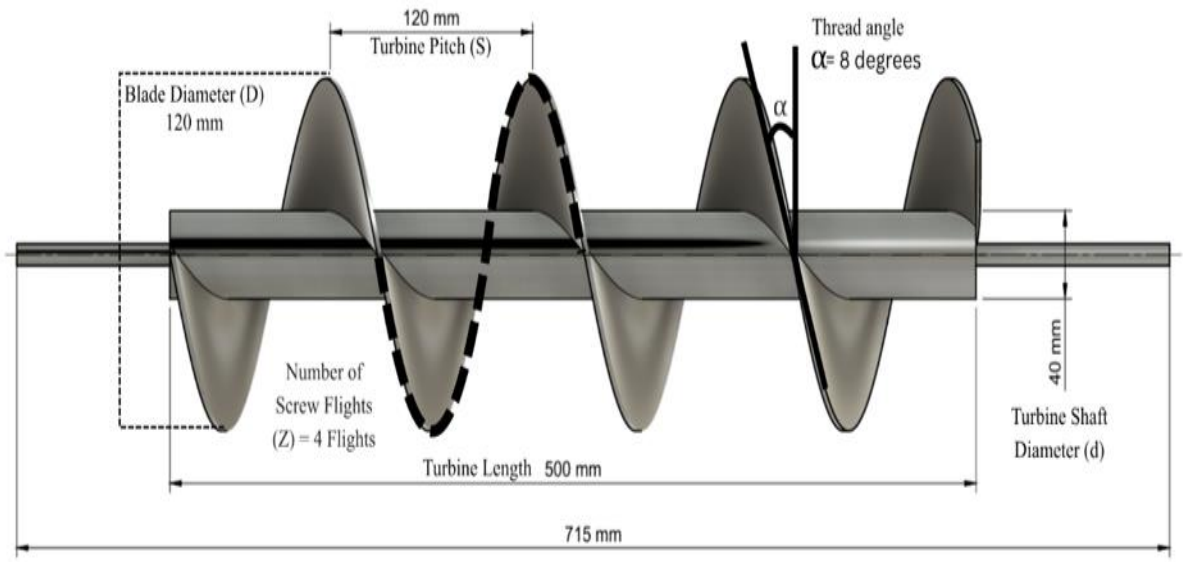
After knowing the efficiency of the design made, the estimated power generated by the turbine can be calculated using a discharge potential of 0.53 m³/s using the equation (14):

$$P_{turbin} = \frac{1}{2} \times 1000\ \text{kg}/m^3 \times 0{,}53\ m^3/s \times (0{,}3\ m/s)^2 \times 0{,}92 \\ = 21{,}94\ W \quad (14)$$

3.3 Design

3.3.1 Archimedes Screw Turbine Design

Based on the calculation results that have been obtained, the next process is carried out by designing a turbine model using Fusion 360 software according to the specifications of the calculation results.

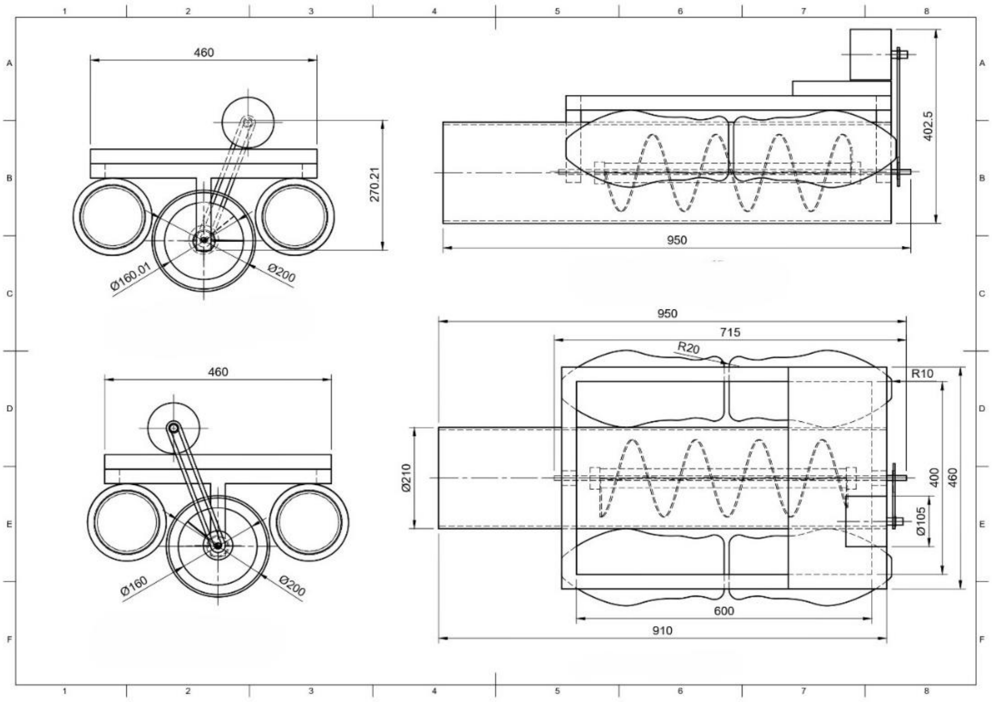


The resulting turbine model is shown in Figure 4.

Figure 4: 3-Dimensional Design of Archimedes Screw Turbine.

3.3.2 Picohydro Design

The plant design is developed based on the dimensions of the turbine designed and integrated with the buoyancy system to adjust the characteristics of the water line which has ultra-low head conditions.



The two-dimensional and three-dimensional prototype designs are shown in Figures 5 and 6, respectively.

Figure 5: 2-Dimensional Design of Protitipe Piko Hydro Float.

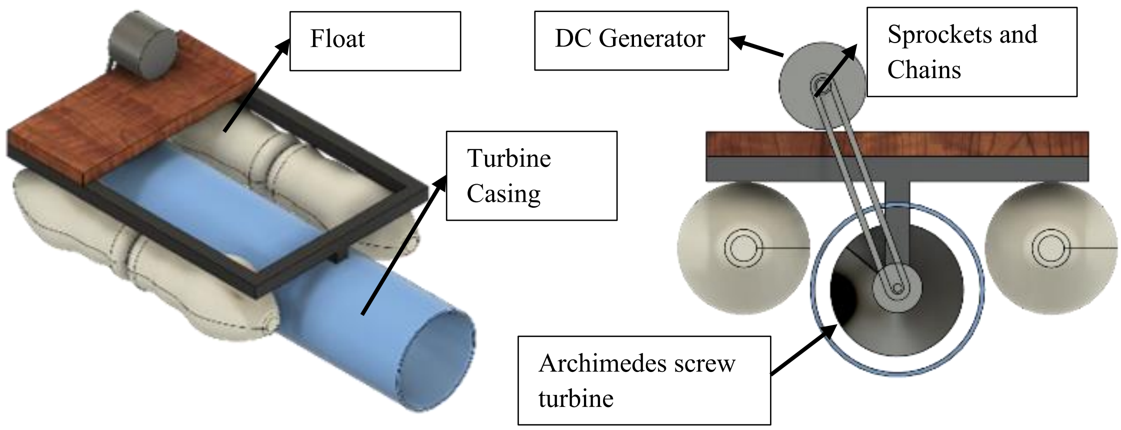


Figure 6: 3-Dimensional Design of Floating PLTPH With Archimedes Screw Turbine.

3.4. Computational Fluid Dynamics (CFD) Simulation Design with ANSYS

This simulation aims to determine the mechanical response and flow behavior to the planned design, so that the potential for structural failures and design inconsistencies can be minimized. ANSYS software is used as a simulation aid because it is able to represent the operating conditions of the system in close proximity to real conditions.

3.4.1 Fluid Flow Simulation of the Archimedes Screw Turbine Prototype

The results of the CFD simulation of fluid flow shown in Figure 7 using ANSYS Discovery software, the flow of water with an inlet speed of about 0.3 m/s forms a spiral pattern that follows the threaded blade of the turbine archimedes screw, showing the conversion of the kinetic energy of water into the rotational motion of the shaft. The velocity distribution shows the high-velocity zone in the free-flow and the low-velocity zone in the space between the spoons due to the interaction of the structural fluid, with a maximum velocity of about 0.456 m/s and the formation of a local vortex indicating energy transfer. Pressure analysis showed pressure drop along the flow with a maximum pressure drop of about 16.2 Pa which is relatively small, so the flow resistance is low and the turbine design is suitable for low head applications. Overall, the simulation results prove that the archimedes screw turbine design is feasible for use in floating PLTPH systems because it is able to utilize water flow effectively and efficiently.

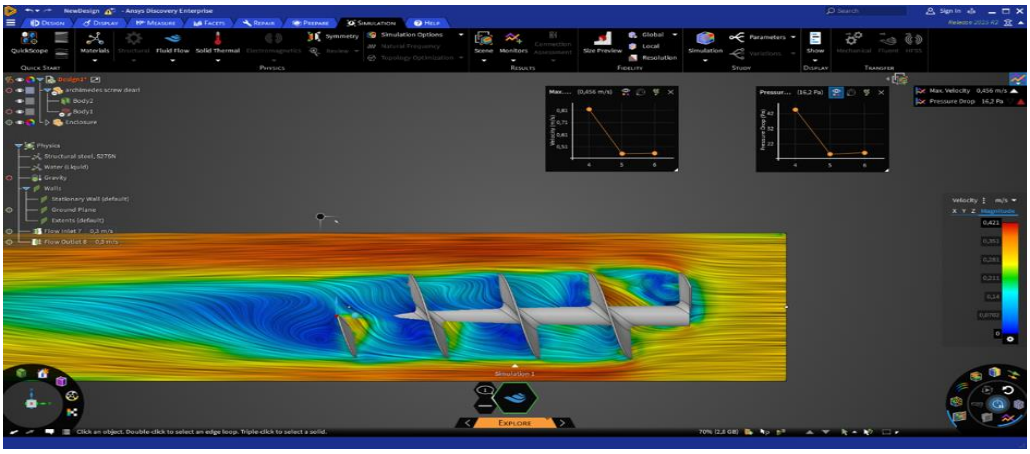


Figure 7: Fluid Flow Simulation of the Archimedes Screw Turbine.

3.4.2 ANSYS Contour of Static Pressure Simulation of Archimedes Screw Turbine Prototype

The results of the ANSYS contour of static pressure simulation of the archimedes screw turbine prototype shown in Figure 8 show the distribution of static pressure in the archimedes screw turbine, where the high pressure on the side of the blade receiving the water flow plays a role in generating torque on the turbine shaft. The decrease in pressure along the direction of the flow output indicates that the water energy is converted into mechanical energy gradually. The relatively even pressure distribution on each blade signifies stable and efficient turbine performance, and is suitable for low head applications with a small risk of cavitation.

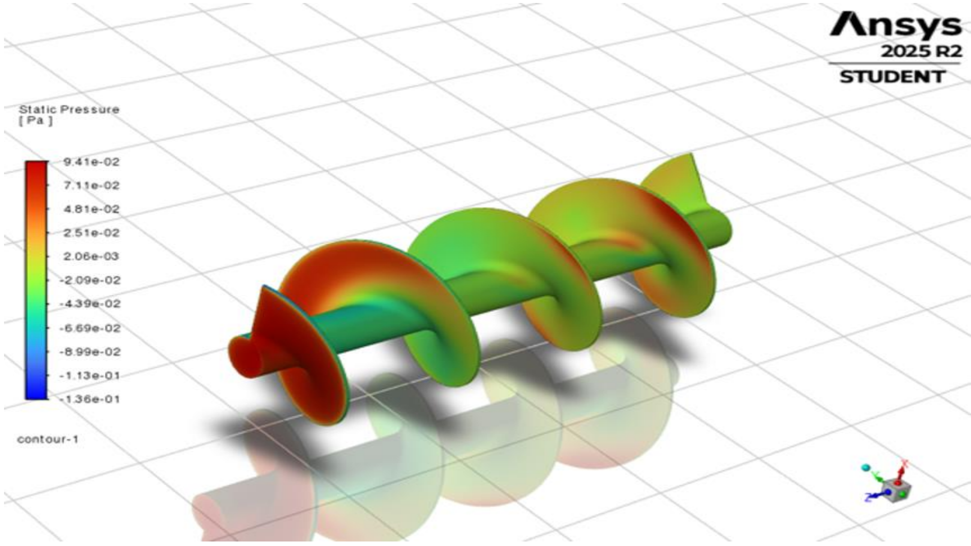


Figure 8: ANSYS Contour of Static Pressure Simulation of Archimedes Screw Turbine Prototype.

3.4.3 Particle Pathlines Water Flow Inside Archimedes Screw Turbine Prototype

The particle path simulation results shown in Figure 9 show the particle pathlines of the water flow inside the archimedes screw turbine that rotates following the turbine thread geometry. The color of the trajectory indicates the intensity of the particle's movement, where the active particles follow the groove of the spoon stably without showing excessive reverse vortices. This flow pattern indicates that the turbine design is able to direct the flow of water efficiently, so that the process of transferring energy to the spoon takes place well and produces stable torque. Overall, the flow characteristics in the turbine are controlled and suitable for PLTPH applications under low head conditions.

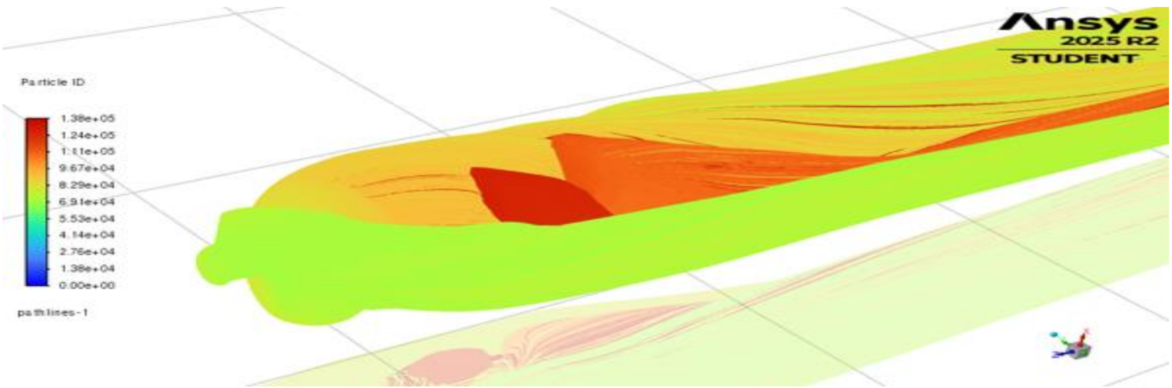


Figure 9: Particle Pathlines of Water Flow in Prototype Archimedes Screw Turbine.

3.4.4 ANSYS Simulation of 3D Design of Floating PLTPH Prototype

ANSYS simulations on the 3D design of the floating PLTPH prototype shown in Figure 10 were performed to evaluate the flow behavior and overall stability of the system. The results of the CFD simulation showed that the flow of water with an inlet speed of 0.3 m/s remained directed with a decrease in velocity around the frame and pontoon due to fluid interaction with the structure, without causing excessive turbulence. The maximum velocity value of about 0.358 m/s and the low pressure drop, which is about 1.97 Pa, indicate that the prototype design does not significantly inhibit the flow. Thus, the floating system is considered stable and feasible to be applied to low-head waterways with minimal risk of energy loss.

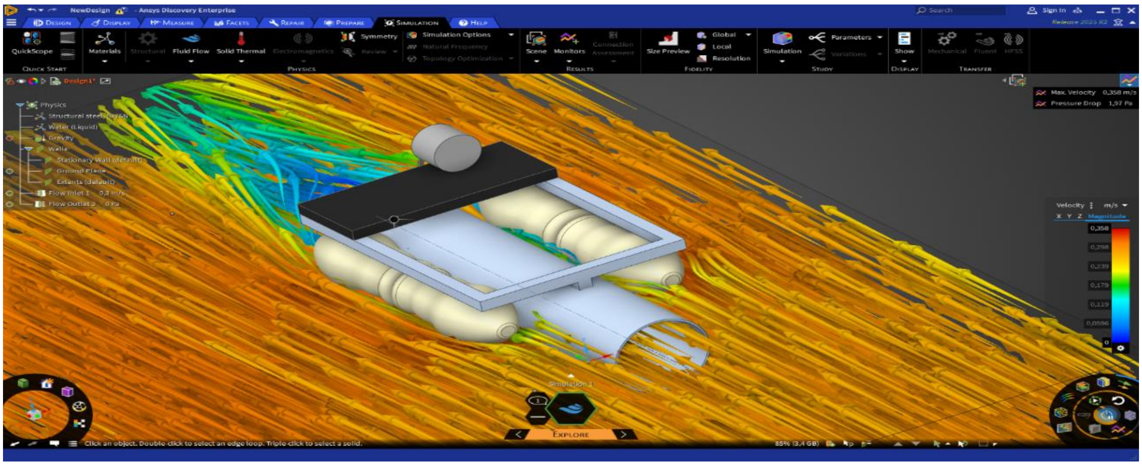


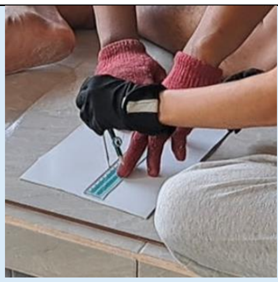
Figure 10: ANSYS Simulation of 3D Design of PLTPH.

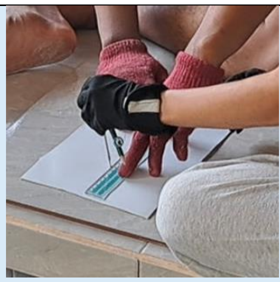
3.5 Implementation

The implementation of the prototype is carried out by assembling all components of the floating PLTPH based on the design results that have been carried out previously. The prototype consists of an archimedes screw turbine, a frame, a transmission system, a DC generator, and a buoy integrated into a single generating system. Furthermore, the prototype was installed on the Tukad Ayung Mambal waterway with ultra-low head characteristics. At this stage, the turbine position is adjusted to the direction of the water flow and the function of each component is checked to ensure that the system can operate properly before testing.

The implementation stages are summarized in Table 5.

Table 5: Stages of Picohydro Implementation

			
1. D pipe cutting for turbine blades.	2. Pipe D splitting.	3. Measurement according to design.	4. Blade polishing on the turbine shaft.

			
			
5. Turbine painting.	6. Manufacture of PLTPH frames.	7. Assembly of PLTPH.	8. Implementation of PLTPH in the field.

3.6 Testing Plan

Contains a design for testing the generator rotation and the power generated by the PLTPH.

3.6.1 DC Generator Testing Plans

The DC generator test design aims to analyze the characteristics of the output voltage to the variation in rotational speed as well as evaluate the ability of a permanent magnetic DC generator to generate voltage at low rotation according to the working characteristics of the Archimedes screw turbine-based Picohydro Power Plant (PLTPH) system shown in Figure 11.

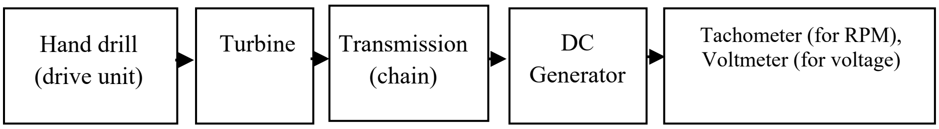


Figure 11: DC Generator Testing Plan

3.6.2 Battery Charging Condition PLTPH Testing Design

Testing of Picohydro Power Plants (PLTPH) in battery charging conditions was carried out to determine the system's ability to produce electrical energy and channel it to the battery. This test aims to evaluate the performance of the generation system during the battery charging process, specifically on the relationship between the generator rotation speed, generator output voltage, and battery charging current. With this test, it can be found out whether the electrical energy produced by the generator can be used for the battery charging process optimally according to the needs of the system shown in Figure 12.

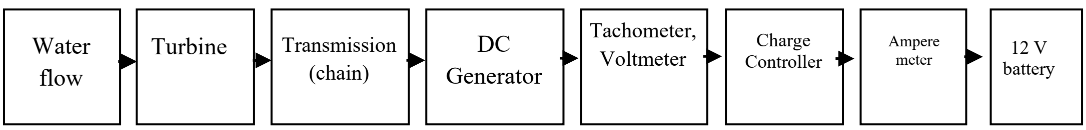


Figure 12: PLTPH Battery Charging Condition Testing Design

3.7 Results

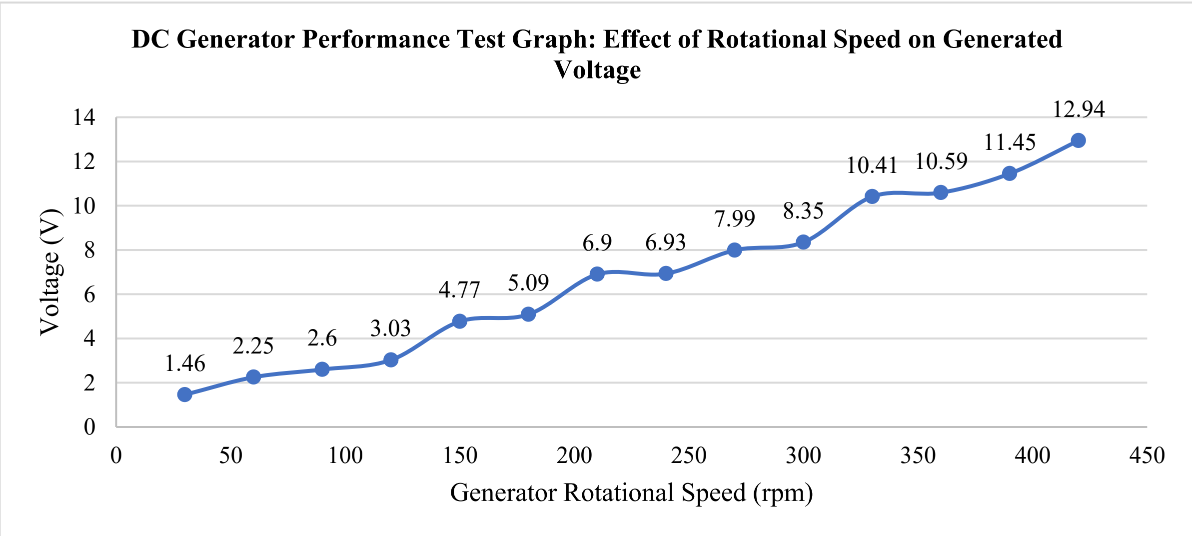
3.7.1 DC Generator Test Results

The generator test results are summarized in Table 6.

Based on the test results, the higher the generator revolution, the voltage and current produced also increase. At 30 rpm, the generator produces a voltage of 1.46 V. Whereas at a maximum speed of 420 rpm, the generator produces a voltage of 12.94 V. Test results show that the performance of the DC generator has a linear positive correlation between the rotational speed (rpm) and the output voltage (V).

Table 6: Generator Test Results

Testing to-	Generator Rotation Speed (rpm)	Voltage (V)
1	30	1,46
2	60	2,25
3	90	2,60
4	120	3,03
5	150	4,77
6	180	5,09
7	210	6,90
8	240	6,93
9	270	7,99
10	300	8,35
11	330	10,41
12	360	10,59
13	390	11,45
14	420	12,94
Test Date: April 10, 2026		



The relationship between generator rotational speed and generated voltage is shown in Figure 13.

Figure 13: DC Generator Performance Test Graph: Effect of Rotational Speed on Generated Voltage

3.7.2 PLTPH Test Results for Battery Charging Condition

The battery-charging test results are summarized in Table 7.

Based on the test results of the PLTPH system, it is able to charge a 12 V battery with a charging voltage in the range of 12.88 – 13.00 V. The average charging power produced is 0.91 W with a daily electrical energy of 21.84 Wh. The system has been able to convert the kinetic energy of water flow into electrical energy even though the power produced is relatively small. The relationship between generator rotation and charging power is shown in Figure 14.

Table 7: PLTPH Test Results of Battery Charging Conditions Without Load

Day/date	Generator Rotation (rpm)	Generator Charging Conditions			Input Voltage to Battery (V)
		Voltage (V)	Current (A)	Power (P = V x I)	
Monday/11-05-2026	210	12.88	0.04	0.52	12,2
Tuesday/12-05-2026	240	12.93	0.07	0.91	12,3
Wednesday/13-05-2026	270	12.96	0.08	1.04	12,3
Thursday/14-05-2026	300	13	0.1	1.30	12,4
Friday/15-05-2026	270	12.96	0.07	0.91	12,4
Saturday/16-05-2026	270	12.96	0.07	0.91	12,5
Sunday/17-05-2026	250	12.94	0.06	0.78	12,5
Average	258.57	12.95	0.07	0.91	12,37

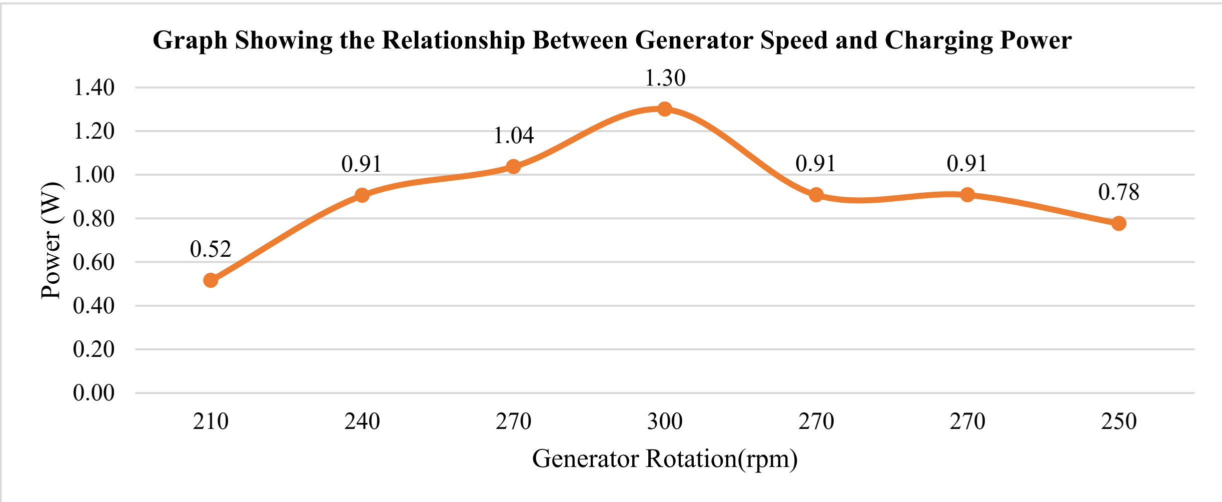


Figure 14: Graph of the relationship of generator rotation to charging power

3.7.3 Theoretical Power Efficiency with Actual Power

Based on the calculations, the estimated power produced by the turbine is 21.94 W, while the actual electrical power produced is 0.91 W. Based on this value, the efficiency of the power generation system is 4.14%.

$$\eta = \left(\frac{P_{out}}{P}\right) \times 100\%$$

$$\eta = \left(\frac{0{,}91\ W}{21{,}94\ W}\right) \times 100\%$$

$$\eta = 4{,}14\ \%$$

4. Conclusion

The conclusions obtained from this study are:

1) The Archimedes Screw turbine was successfully designed based on the results of the calculation of the hydraulic characteristics of the Tukad Ayung Mambal waterway with ultra-low head conditions. The installation location was chosen on the LP1 cross-section which has a water discharge of 0.53 m^3/s with an average flow speed of 0.30 m/s, so that a theoretical power potential of 23.85 W was obtained. and a thread angle of 8°. With these dimensions, the estimated turbine output power is 21.94 W.

2) The results of the CFD simulation using ANSYS show that the turbine design and floating PLTPH system are able to work well under ultra-low head conditions. The water flow follows the turbine thread shape effectively with a maximum speed of 0.456 m/s and produces a relatively small pressure drop, which is about 16.2 Pa in the turbine and 1.97 Pa in the floating PLTPH system. These results show that the developed design has low flow resistance, stable pressure distribution, and is suitable for application to irrigation channels with very low head conditions.

3) The results of the implementation and field tests showed that the floating PLTPH prototype was able to convert the kinetic energy of the water stream into electrical energy for the 12 V battery charging process. The system has an overall efficiency of 4.14%. Although the efficiency obtained is still relatively low due to mechanical and electrical losses, the results of the study prove that the floating Archimedes Screw turbine has the potential to be used as a renewable energy source in irrigation canals with ultra-low head conditions.

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Declarations

Ethics approval

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Competing interests

The authors declare no competing interests.

Author contributions

All authors contributed to the study and approved the final manuscript.

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