Development of Micro Hydro Power Screw Archimedes Turbines Types in Small Irrigation Channel

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Abstract: Bongkasa Pertiwi, Sangeh, Mengwi, Pelaga and Pangsan are five villages in Badung Regency, Bali Province. These five villages are planned by Badung Regency Tourism Office as tourism villages that supported by green energy. For this purpose, a study on the potential of solar energy that can be used for solar cells was conducted using data from the Prediction Of Worldwide Energy Resources (POWER) at the average latitude and longitude position of the five village offices location, i.e., -8.44209 lat and 115.21381 lon. We collect the data of all sky insolation incident on a horizontal surface (kW-hr/square metre/day) for this position from 2010 to 2019. The prediction of solar energy in these areas can be calculated using sixth order polynomial equation and its coefficients. This equation can be used to forecast the maximum, mean and minimum values of insolation in these areas by using coefficients as stated in Table II – IV. The statistic shows that all of the adjusted r-square of insolation fitness equations have values of more than 90 percent.

1 INTRODUCTION

Research on solar energy in Bali Province has been carried out by several researchers in several locations, such as Nusa Penida, Kayubihi, Denpasar and Badung Regency focused on sunlight intensity, required battery capacity, comparison of simulation results with real production of electrical energy and also solar energy modeling.

Research on solar energy in Nusa Penida, a small island located at 8°44’4’’ south latitude and 115°32’2’’ east longitude in Klungkung Regency, shows that the area gets light intensity average of 5.34 kWh/m2/day with wind speed average of 4.4 m/s . In Kutampi Village, Nusa Penida, there is a solar power plant to supply a base transceiver station (BTS) load of 174.66 kWh that requires 45 panels with total battery capacity of 3,800 Ah and total battery of 16 units. Solar-powered street lighting in Nusa Penida had also been analyzed and summarized about the causes of battery damage were due to disproportionate to the load capacity requirements and because the battery has been old.

The study found at Pemecutan Kaja Village, Denpasar City, Bali Province that daily average energy produced by the solar panel is 23.59 kWh yielding cost of energy at IDR 7,766/kWh. Experiment to clean filters of the plant reduced daily energy consumption from 8.84 kWh to 3.05 kWh or 65%.

In Kayubihi, Bangli Regency, a 1 MWp solar power plant has been built and connected to the electricity network. The comparative study of simulation results with real production of electrical energy has been carried out which shows a difference of 32.3%.

In Denpasar City, the capital of Bali Province, research on solar energy has been carried out at elementary school no. 5, which is located in Pedungan area, with roof angle of 30.96o produces energy potential of 3214.6 kWh, lower than the optimal angle of 15o that produce larger potential value of 3407 kWh. Statistically, the electrical characteristics of 150-Watt peak solar panel in Denpasar can be modeled using Boltzmann's sigmoid function with good fit. The lighting systems with 150-Watt peak solar panel in Denpasar shows that the maximum received wattage is 0.76 kW/day in October based on NASA data (Waters S,2 013).

In Badung Regency, the hybrid solar power plant for parking area of Cipta Karya Building, Office of Highways and Irrigation of Badung Regency has been planned which works automatically controlled by the inverter system that produces 148.274 kW, which is

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equal to 30% of the electrical energy consumption in the building of 2.310 MWh (Kumar U, 2016).

In this paper we discuss the projections of solar energy in Bongkasa Pertiwi, Sangeh, Mengwi, Pelaga and Pangsan area that has never been studied by other researchers. The research aims to support this area to become tourism villages that supported by green energy.

2 METHODOLOGY

The development of micro hydro power screw Archimedes turbines were divided into two sections. The first was creates a design of the screw Archimedes turbines that suites for irrigation water channel, and the second was build the micro hydro power. The flowchart of the research are shown in Figure 1.

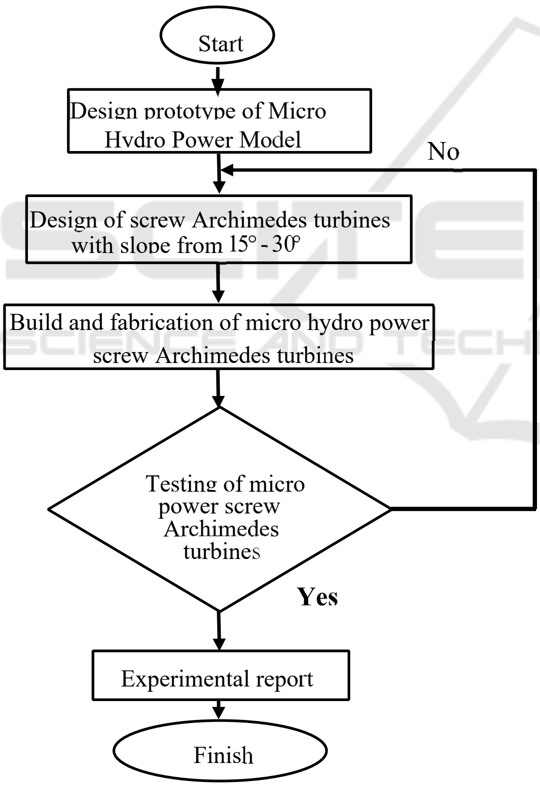
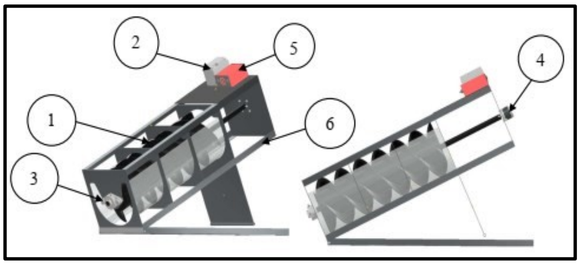


Figure 1: Flowchart of the research.

By using CAD the design of the micro hydro power screw Archimedes turbines were shown in Figure 2.



1.Screw Archimedes Turbine
2.Battery
3.Bearing
4.Generator
5.*Inverter*
6.Box

Figure 2: Design of micro hydro screw Archimedes turbines.

3 RESULT AND DISCUSSION

From the geometry design using CAD in Fig.2, then the prototype of micro hydro power screw Archimedes turbines were built and developed. The rotor construction has 3 screw blades, a thread range of 492 mm, a radius of outer blade (Ro) 112.5 mm and an inner screw radius (Ri) of 55 mm. The turbine was 70 cm long with the number of turbines turns of 2 turns with 3 blade, and the length of turbine turn are 24 cm. The turbines shaft designed with adjustable slope which was 15°, 20°, 25°, and 30°. The turbine shaft conducted with a generator from DC stepper motor with power output 24V. The generator connected to an inverter to convert the current output generator from DC into AC. The power produce from the system will be storage in a battery. The prototype of micro hydro power screw Archimedes are shown in Fig. 3 below:

Figure 3: Prototype micro hydro screw Archimedes turbines portable.

Figure 4: I Power generation components (generator, inverter, and battery).

Table 1: Micro Power Hydro Specification.

Name	Specification
Dimension (p x l x t)	100 cm x 30 cm x 30 cm
Number of blade	3
Turbine	stainless plat
Number of turn	2
Length of turn	24 cm
Screw length	70 cm
Do	20.5 cm
Di	11 cm
Generator	DC stepper, Output 24 V
Inverter	AC 230V, 500
Battery	12V 3Ah

The micro hydro power tested in small irrigation channel with the widh about 70 cm and the depth of the water about 12 – 15 cm. The test done 2 times in different irrigation channel, where both has the same average size of channel. The water velocities (v) were test by the average speed of water flow in 1 meter length of the irrigation channel.

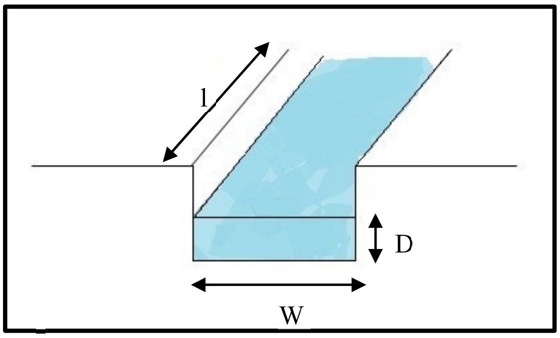


Figure 5: Schematic of water irrigation channel.

$$A = l\,D$$

$$A = 70\ x\ 12$$

$$A = 875\ cm^2$$

$$A = 0.0875\ m^2$$

By measure the average time of water flow in 1 m length, it can be known the water flow rate of the irrigation channel upstream the micro hydro power generator. Test 1 the average time of water flow in 1 m length was 1.95 s, and the Test 2 the average time was 1.62 s.

The water flow rate:

$$V = \frac{l}{t}$$

Test 1.

$$V = \frac{1}{1.95}$$

$$V = 0.513\ {}^{m}/_{s}$$

$$V = \frac{l}{t}$$

Test 2.

$$V = \frac{1}{1.62}$$

$$V = 0.513\ {}^{m}/_{s}$$

The power output from the generator measure using a digital AVO meter, and the rotation of generator measured using a digital tachometer. The water flow to the micro hydro generator were assumed to be homogen, which was it's a steady condition of water flow, no rainfalls, no turbulence of water flow upstream the micro hydro generator.

The power output from generator analyze using the formula:

$$P = V.I \quad (1)$$

Where:
P = Power (watt)
V = voltage (volt)
I = current (ampere)

The result of the micro hydro power test were shown in table 2 and table 3 below:

Table 2: Micro Hydro Power Performance (v = 0.513 m/s).

No	Slope/ inclination (°)	Rotation (rpm)	Output		
		Generator	V (Volt)	I (Ampere)	P (watt)
1	15	901,6	8,9	2,2	19,58
2	20	1318,17	11	2,92	32,12
3	25	906,008	9,65	2,36	22,77
4	30	1061,43	10,7	2,7	28,94

Table 3: Micro Hydro Power Performance (V = 0.617 M/S).

No	Slope/ inclination (°)	Rotation (rpm)	Output		
		Generator	V (Volt)	I (Ampere)	P (watt)
1	15	953,3	9	2,4	21,6
2	20	1345,7	12,3	3,12	38,4
3	25	934,02	11,1	2,56	28,5
4	30	1100,04	11,8	2,96	34,9

The performances analysis of micro hydro power screw Archimedes are shown in Fig. 6 and Fig. 7 below:

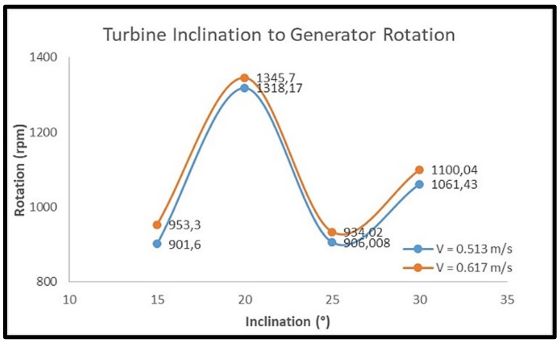


Figure 6: Turbines inclination to generator performance.

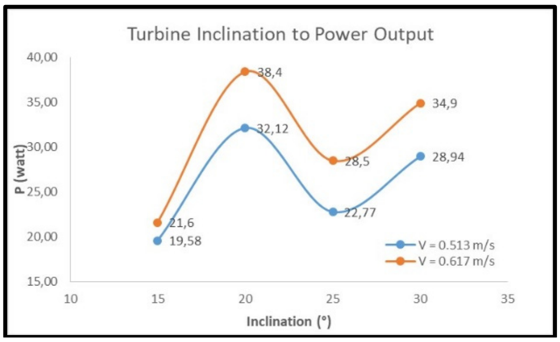


Figure 7: Turbines inclination to power output.

Fig. 6 and Fig. 7 above shows that the micro hydro power screw Archimedes can work properly for uses in small irrigation channel. The flow velocities of the water was 0.513 m/s and 0.617 m/s with depth of water about 12 cm. The screw Archimedes turbine can rotate with all various shaft inclination.

The test result showed that the inclination takes a good effect to the output of generator, which was the highest turbine and generator rotation (about 1300 rpm) and also the highest power output generate about 38 W at the inclination of turbine 20°. This shown that the inclination of turbine to the water flow take an important things. When the water flow constantly and flew smooth to the micro hydro screw Archimedes the maximum inclination was about 20°. Whenever we set the inclination higher than 20° the water flew in the screw turbine will floods and take effect to the performance of rotation of generator. The generator will be flooded and drown with the water so the rotation will decrease. It will cause the power generate from generator also decreasing.

4 CONCLUSIONS

From the foregoing analysis, it can be concluded that the micro hydro power screw Archimedes turbines that has been design and build with adjustable turbine inclination can work properly. The construction of the design is made with turbine specifications: the rotor construction has 3 screw blades, a thread range of 492 mm, a radius of outer blade (Ro) 112.5 mm and an inner screw (Ri) of 55 mm. The box frame has a dimensions of 1m long, 30cm wide and 30cm high. The screw Archimedes turbine and the generator in the prototype of micro hydro power that have been developed were not equipped with any coupling system but it's connected directly so that the turbine rotation was always the same as the generator rotation.

The result showed that the screw Archimedes turbines can produce enough rotation with low head from irrigation water channels and produce an electricity. The voltage generated by the generator is not able to charge the battery yet. If the power on the battery is allowed to quickly run out of use by the inverter, therefore a step up module is installed to increase the output voltage of the generator so that the power from the generator to the battery becomes more stable. The highest rotation of generator were found in turbines inclination of 20° which was about 1300 rpm, and the power output produce from the generator about 38 watt.

From the results of experimental it can be suggested several things to improve the micro hydro power screw Archimedes turbines performances. The first is an improvement on the system design. The design of blade and number of turn of the turbine can more varying for a better rotation performance, it can also connected with a gearbox as a transmission in order to step up the rotation of generator. The second improvement are the material, include the material of turbines blade, the generator, and the box frame

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