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Application of Hybrid Solar and Wind Energy Generation for Paddle Wheel Aerator

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Abstract. At the coastal areas of South Sulawesi, Indonesia, there are many of villagers work as fisherman, shrimps and fish farmers. Most of them use aerator paddle wheel that are operated by high wattage motors that are ranged from 750 Watt to 1000 Watt. Some others use gasoline engine for one aerator every day. Consequently, the use of high wattage motors will cost the farmers and the use of gasoline will contribute to the air pollution. Therefore, it is necessarily important to invent a renewable base energy source for aerator which in turn economically effective that in the same time could apply the energy diversification. Fortunately, solar and wind potency are quite promising in the area. In this paper, an investigation, examination and application of hybrid solar-wind turbine generator are conducted and applied to aerator paddle wheel for shrimp's pond. The required energy is 420 Wh/day. The measured average wind speed at Pancana Village is ranged from 3.25 m/s to 5.28 m/s. The averaged solar radiation potency in the village is 975 W/m^2. The hybrid system is a combination of two 150 Wp solar panels and 500 W wind turbine. The experimental result show that the solar panels could generate energy by about 370.54 Wh in average, while wind energy could generate 165.60 Wh energy every day. Therefore, it can be concluded that the required energy of the aerator at average paddle wheel of 80 rpm can be fulfilled although solar energy is dominant as energy supplier.

1. Introduction

The use of conventional energy could evoke the catastrophic impact to environment due to exhausted pollutant contents. Moreover, the deposits of conventional energy such as oil, gas and coal have been decreased from time to time [1]. This condition has force many countries including Indonesia to optimize the energy saving and the efforts to develop the new energy sources. Solar and wind energy are two popular renewable energy that have been implemented widely in the world [2]-[4]. Most of them are used for large scale to generate electric power that connected to the grid [5]-[7]. As a country that located in equator, Indonesia has a huge potency of solar and wind energy. This energy sources could be applied to many of farmers' equipment's Indonesia is a country of fishes and shrimp's producer. One of fishery equipment is aerator that is used to provide sufficient oxygen to the habitants of ponds. The aerator paddle wheel required high power that is range from 750 W to 1000 W. One of area in Sout Sulawesi, Indonesia that has potency of shrimp's production is Pancana. Pancana is a coastal village that is located at Barru District which land area of ponds and fishery is about 17.5 hectare. Majority of its community are work as shrimp farmers. The key factor that influences the aeration system at shrimp pond in order to improve the productivity of shrimp production is the control of flow direction and speed of air at the diffuser system. The rotation mechanism and energy source of rotation of paddle wheel are also factors that affecting the aerator performance system. Up today, shrimp farmers in Pancana are still using energy from the electrical grid and gasoline engine which in turn contribute to high cost and air pollution. Meanwhile, in Pancana village, the measured average wind speed is ranged from 3.25 m/s to 5.28 m/s and average solar radiation is about 975 W/m^2. Therefore, in this paper, an investigation, examination and application of hybrid solar-wind turbine generator are conducted and applied to aerator paddle wheel for shrimp's pond.

2. Experimental
2.1. Selection of Motor for Paddle Wheel

The selection of motor based on the paddle wheel requirements. Brushless DC Motor (BLDC) has specification with nominal voltage of $48V_{dc}$, rated current of 30A and maximum power of 350 W/1200W. Torque capability is up to 70 Nm with BLDC motor speed can be adjustable using twist throttle of maximum 30 Mph. In this paper, BLDC could operate the paddle wheel for 9 hours with constant speed of 80 rpm with consumed averaged power is 110 W. The paddle wheel speed is regulated at 80 rpm has been adjusted with the requirement of shrimp pond aeration need.

2.2. Battery Selection

The battery selection is based on the requirement of BLDC motor, if the paddle wheel operates in the night time, the energy will be supplied from the battery only because no solar radiance and limited wind speed. Based on energy calculation, the batteries capacity can be determined as 70W x 6h/12V = 35Ah to allow long duration life of batteries, 60% of maximum used is determined. Therefore, it can be obtained that the required battery capacity is 35Ah/60% = 58.33Ah. To match with the energy requirement of BLDC motor, 4 @12V, 50Ah battery that is connected in series are required to obtain 48V. The used average power for aerator is 70W that operate for 6 hours or equal to 420 Wh.

2.3. Solar Panel Selection

Solar energy is an alternative energy source that clean, abundantly available naturally and renewable. This solar energy is claimed to be a fast solution, measured, sustainable that could mitigate the climate change. According to the research that was conducted by Green Tech Media, solar panel installation has been increased about 34% in 2015 compared to prior year [8]. The solar panel configuration is a fixed slope where the fluctuation of solar radiance is considered against these parameters: Number of module and angle of solar panels slope. Number of module is considered the voltage of Maximum Power Point Tracking (MPPT) of inverter and the voltage of module open circuit [9],[10]. In this paper, to fulfill the energy requirement on batteries charging, 2 x 150Wp (300 Wp). This selection is based on the nominal energy requirement of BLDC Motor 110W, easiness of it installation on the aerator, solar panel mechanical stability against the buoys. Two solar panels will give simplicity in configuring the panels whether in series or parallel. The specification of the used solar panel can be seen in Table 1.

Table 1. Solar Panel Specification

Output power	2 x 150 Wp
Cell type	Monocrystaline
Voltage at P_{max}	18.3V
Current at P_{max}	8.21A

2.4. Wind Turbine Selection

Generator selection is an important part for every design and construction of a wind turbine system. It is important to review the generator capability in generating voltage at low rpm. Magnet Permanent Alternator (PMA) is much efficient compared to DC generator. In this paper, wind turbine generator is selected based on daily average of wind speed at Pancana Village. Small Scale Wind Turbine type is suitable for low wind speed. Wind turbine i500 Ista Breeze is selected based on its suitability of the speed range at the location and generate power based on *IEC 61400-2* standard [11]. The detail specification of the wind turbine is shown in Table 2.

Table 2. Wind Turbine Specification

Output power	500 W
Wind speed start up	3 m/s
Rotor type	Permanent Magnet
Type	Brushless, Direct Drive, HAWT
Storage energy	Battery 4 x 12 VDC/ 2 x 24 VDC

2.5. Charge Controller

Charge controller is used to adjust the voltage and current from solar panel and wind turbine based on battery capacity. The operational algorithm of the controller allows the disconnection of current from

power supply to stop charging process. The disconnection is occurred when the battery voltage reaches 16V±1%V. On the other hand, when voltage battery drop up to 10.8V±1%, load current will be disconnected, therefore battery supply will be stopped simultaneously. In this state condition, hybrid charge controller is also work to control the charging and discharging of the batteries to avoid over charging process. The specification of the charge controller can be seen in Table 3. Additionally, this charge controller could detect the battery capacity. When battery is fully charged, automatically current charge process of both solar and wind turbine generators will be stopped [12].

Table 3. Charge Controller Specification

Type	Maximum Power Point Tracking (MPPT) eSmart 12V/24V/36V/48V-series
Efficiency	≥99.5%

2.6. Application of Hybrid Solar-Wind Turbine Based Paddle Wheel Aerator

Hybrid solar-wind turbine based paddle wheel aerator consisted of electrical and mechanical systems. Mechanical system is designed to consider the structural frame of solar panel stand based on size and weight of the panels. Stand for BLDC motor is designed to be robust, light, and capable to hold the vibration. Anti corrosion slide bearing is used to guarantee the rotation performance of the paddle wheel. To allow the mechanical power transmission from motor to drive shaft, an appropriate chain transmission is employed. To support the reliability of mechanical system, the mechanical structure is constructed using elbow-iron, long hollow shaft 200 mm, ϕ 1" *stainless steels*, slide bearing of ϕ 1" and paddle wheel with diameter of 620 mm. Number of blades is 8 and pontoon boat with size of 1760 mm, x 330 mm x 113 mm. The chain transmission is equipped with *Chain Guard Double Gear*. The construction frame is placed on the pontoon boat with aforementioned size of 1760 x 330 x 113 mm x 2 pieces with 1000 mm long of PVC pipe of 5". The heavy capacity of pontoon boat is 118.86 kg. It is important for the mechanical design to take into account some of parameters in order to achieve the stability consideration such as position of mass center, buoyancy point and metacentre point [13]. Based on calculation, the buoyancy point is 1792 N and gravity force of pontoon boat is 618.03 kg. The buoyancy point is larger than the gravity force of pontoon boat, therefore the pontoon boat could withstand with equipments weight of 61 kg where the stability is evenly stable. The design construction of the hybrid solar-wind turbine paddle wheel aerator can be seen in Fig. 1.
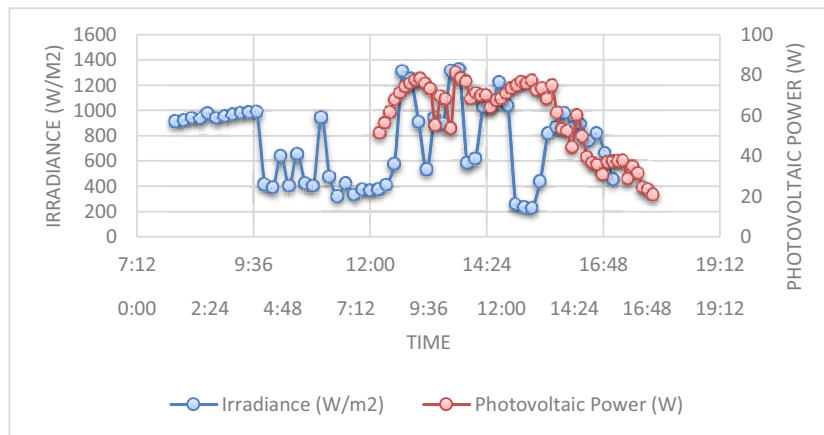

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Figure 1. Hybrid Solar-Wind Turbine Paddle Wheel Aerator

3. Results and Discussion

3.1. Solar panel testing result

The testing of solar panel in area of shrimp ponds at Pancana Village is aimed to obtain the relationship between the output power and solar radiation per time unit of the solar panels. The result of the testing is shown in Fig. 2.

Figure 2. Solar (PV) Power Measurement

Fig. 2 shows the the relationship between the output power and solar radiation per time unit of the solar panels for series-batteries charging. The measurement is conducted from 08:00 am to 17:00 pm. Solar power characteristic is increased simultaneously with the increase of solar radiation that is ranged from 320 W/m^2 to 1123 W/m^2 with the range of solar power increase from 24.4 W to 77.3 W.

3.2. Wind Turbine testing result

The wind turbine is placed at the land that closes to the shrimp pond. The height of the wind turbine is 10 m. The test is conducted to investigate the relationship between wind speed variation on rotor speed and its generated power. The result is demonstrated in Fig. 3.
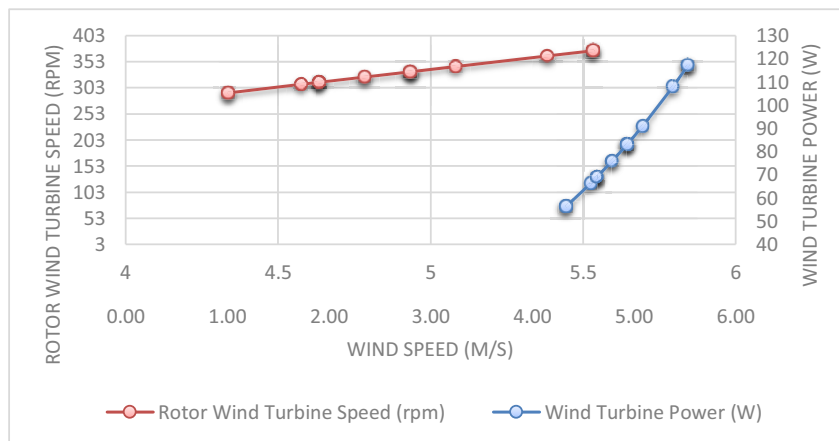

**Figure 3.** Wind Turbine Power Measurement

From Fig. 3, it can be seen that the wind speed is directly proportional to the generated power. The maximum rpm of the turbine is 374.11 rpm in maximum wind speed of 5.53 m/s. The maximum power generated is 117.11 W. Meanwhile, the minimum rpm (293.22 rpm) is reached at wind speed of 4.34 m/s. The generated power at this condition is only 56.46 W.

3.3. Hybrid Solar-Wind Turbine testing result

In this hybrid system, the average power generated of solar panels and wind turbine is 58.86 W and   82.80 W respectively. The generated power of the solar panels is continued based on the solar radiation from 08:00 am to 17:00 pm. However, wind turbine can only supply power momentary due to the intermittent characteristic of wind speed at the location. The total output power can be described from Fig. 4.
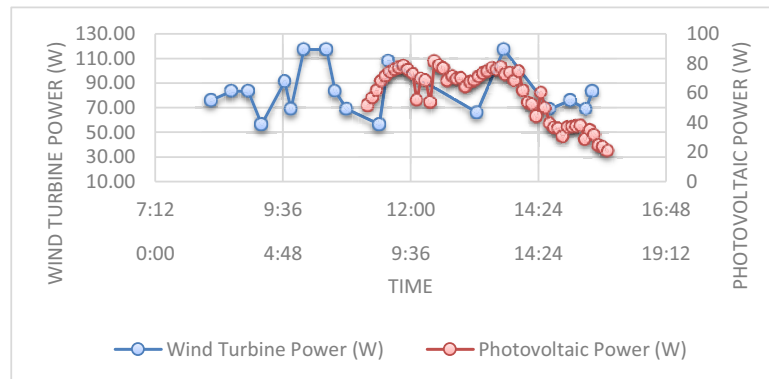
Figure 4. Output Power from the Hybrid System for Paddle Wheel Aerator
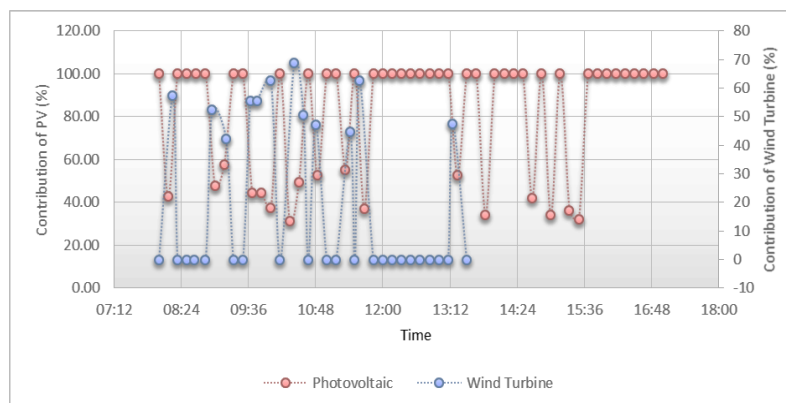
Figure 5. Energy Contribution by Wind Turbine - solar system for the Total Energy Production by the Hybrid System.

Fig. 5. exhibits the summary of energy contribution (energy share) of both solar and wind turbine. The total averaged generated power of the hybrid system is 526.90 Wh. From Fig. 5, it can be seen that solar panels contribute about 82.40% while the rest is by wind turbine. The diurnal contribution of solar panles to the hybrid system is 32.14% and it could supply maximum 100% in certain time. The maximum supply of solar panels occur during the wind turbine does not operate due to the very low wind speed. However, the contribution of wind turbine is varying from minimum 42.4% and maximum 68.67% depends on the wind speed condition at area.

4. Conclusion
The hybrid system has been installed and investigated for paddle wheel aerator application at shrimp's pond at Pancana Village. The use of average energy for the paddle wheel aerator application is   526.90 Wh. The amount of energy required to operate the BLDC motor for paddle wheel aerator is   420 Wh. Therefore, the required energy for the paddle wheel aerator using hybrid solar-wind turbine generator as the main energy sources can be fulfilled.

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