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Research Original Article

Study of Wind Power Plant for Alternative Energy in Vannamei Litopeneaus Shrimp Cultivation

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Abstract
The focus of this research is to utilize wind energy for power generation as an electric power service for shrimp farming in the Kulon Progo district of Yogyakarta. This is done in order to minimize the use of diesel fuel in daily operations to drive the aerator pump that produces air bubbles and needs lighting. The method used is to calculate the need for electrical power in 24 hours, plan the windmill according to the local average wind speed. Parameters for measuring the final result are net present cost (NPC), cost of energy (CoE), and payback period. The scenario is used by installing a wind power generator compared to a generator from a diesel engine. The results of the study with a wind power generation system capable of producing 41755,07kW/year of power with the NPC value having a more efficient economic value of Rp. 158,254,000.00, a more efficient CoE value of Rp. 477.41, and for a diesel power plant of Rp. 1,569,015,240.00 and CoE worth Rp5,867,45. The payback period for the scenario with wind power is 3 years and 9 months and and 15 years 7 months for the scenario with diesel power plants.
Keywords: Renewable Energy; wind turbine; NPC; COE; payback period

Introduction
Concerns The use of diesel fuel should have begun to be reduced and converted to new renewable energy. The location of the shrimp pond is on the beach, the distribution of electricity from PT. PLN is not yet affordable, so for shrimp ponds, power is used from diesel engine. The wind blows all day, then can be use as an option to be used instead. In its utilization alternative energy can be used as a primary or secondary energy source (Burton et al., 2011).

The kinetic energy of the wind blowing, turning the blades coupled to an electric generator, produces electric power. The resultant electricity is transmitted to the control device, and the output of electric power is used operationally and the excess is stored in the battery (Ahshan et al., 2018).

The utilization of electricity from wind power plants is generally in accordance with a voltage of 220 volts and a frequency of 50 Hz. The results of electric power are directly utilized in accordance with the power capacity and reserves they have (Nehrir et al., 2011).

Shrimp production in Indonesia in 2014 reached 645,000 tons with the largest export value to the United States of US $ 938 million with a total volume of 77,000 tons (Katadata KKP., 2016). In an effort to maintain and increase shrimp production, through the Decree of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia No. 41/2001, on July 12, 2001 the Indonesian government officially submitted vannamei litopeneaus shrimp (Litopeneaus Vannamei) as a superior variety to be cultivated by shrimp farmers in Indonesia.

Until now, the supply of electricity from PT. PLN for shrimp ponds is still not evenly distributed, especially for shrimp ponds which are relatively small and for areas far from electric power grid facilities. This study seeks an alternative solution by generating electricity at the location of shrimp ponds in Bantul Regency in the form of a wind power generation system design. The design is adjusted to the available wind speed and electrical power requirements for shrimp farming operations. The final result compares the economic value between the wind power generation system and the diesel power generation system by calculating the net present cost (NPC), cost of energy (CoE) and payback period.

Literature Review

Wind power plants have four main components, namely blades, generators, controllers, and data loggers. The blade functions to convert wind energy into mechanical energy. Furthermore, the mechanical energy in the coupling directly with the generator. The output of the generator is a 3-phase alternating current (AC). In order for the output voltage to be stable, the generator output is input to the controller, the result is direct current, through the inverter is obtained in the form of an alternating voltage of 220 volts with a frequency of 50 Hz, and the remaining usage is flowed to the battery for storage.

Based on the wind speed data, the dimensions of the blades of the windmill can be designed, the capacity of the generator to be installed, the type of generator, and the tower where the generator and windmill are located. The wind speed data in this study were obtained from the Power Data Access Nasa website. The speed of wind gusts at the research location of Kuwaru Hamlet, Poncosari Village, Srandakan District, Bantul Regency is shown in Table 1. The data used is the average wind speed per month in a year in 2019 (Putri et al., 2022). The average wind speed obtained varies from 4 to with 7m/s per month in a year, thus obtained an average wind speed of 5.82m/s.

Table 1 Wind speed data per month

No.	Mounth	Wind Speed (m/s)
1	January	5,30
2	February	4,23
3	March	4,36
4	April	5,51
5	May	6,67
6	June	6,18
7	July	6,70
8	August	6,69
9	September	7,10
10	October	5,95
11	November	5,40
12	December	5,76
	Average	5,82

1. Determining the turbine type.

In determining the type of wind turbine to be used in research, one must know the power produced by the wind turbine (Piggot, 1997). The resulting power is calculated using equation (1).

$$\text{Power (P)} = \frac{1}{2 * \rho * V^3 * A} \quad (1)$$

description: P is power (Watt); is the density of wind/Air (1.225 kg/m3); V is wind speed (m/s); A is the cross-sectional area (m2); D is the cross-sectional diameter of the wind turbine (m).

2. Charge Controller

The charge controller is used to regulate the electric current from the generator to the battery according to the capacity of the current generated and the charging capacity of the battery. How to determine the parameters of the charge controller must first know the maximum load installed. Then the capacity of the current flowing in the charge controller is equation (2).

$$I = \frac{Pmax}{Vs} \quad (2)$$

description: I is the charge controller current (A); Pmax is the maximum power (W); Vs is the system voltage (V).

3. Battery

Batteries as a backup in the event of a repair condition or when the yield from the generator is less than required. The calculation of the power and current capacity of the battery is based on the ampere hour and voltage capability (Susanti, 2019). The battery requirements for the shrimp pond electrical system are referred to as Felicity's 12V 200AH battery data with four units, with a total of 96000WH.

4. Inverter

Inverter is a power electronic circuit that is used to convert or convert direct voltage (DC) into alternating voltage (AC). Determine the inverter capacity to be used on the load by adding up all the power in the load (Fara, 2012).

5. Diesel power station.

A diesel power plant is a power plant that uses a diesel engine as the prime mover. This prime mover is a piece of equipment that produces the mechanical energy needed to rotate the generator rotor. It is generally called a generator (Badaruddin & Hardiansyah, 2015). The fuel requirement can be calculated by equation (3):

S = 0.21 x P x t…………………………………………3)

description: S is diesel fuel consumption (liter); the constant 0.21 is a fixed factor of diesel consumption per kilowatt per hour; P is Genset Power (kVA); and t is time (hours).

6. Vannamei Shrimp Cultivation Equipment.

The tools used that use electrical resources are aerator machines, water pump machines, and lighting equipment. This will be described as follows:

a) Aerator An aerator is an electric machine that produces air bubbles whose purpose is to move the water in the shrimp pond so that the water is rich in dissolved oxygen in the sea. There are several types of aerators that can be used according to the needs of managed ponds, namely waterwheels, water jet aerators, and turbo jet aerators.
b) Water pump A water pump is a device that is used to move other water into the pipe as a channel as needed. The decrease in water in the pond is caused by evaporation and absorption of the soil.
c) Shrimp pond lighting. Lights are used for inspection around the pond at night and feeding shrimp at night. Shrimp ponds are often predators of snakes and other aquatic animals.

7. Net Present Cost

Net Present Cost (NPC) is to calculate the total cost of all expenditures for purchasing materials, tools, installation costs and operating permits, as well as the duration of the project. (Juwito et al., 2012). In determining the Net Present Cost (NPC) is calculated using Equation (4).

NPC= Capital Costs + Replacement Costs +O&M Costs+Fuel Costs
Salvage……………………………………………….(4)

description of equation (4): Capital Costs are component capital costs (Rupiah); Replacement Costs are component replacement costs (Rupiah); O&M Costs are costs; operations and maintenance (Rupiah); Fuel Costs are fuel costs (Rupiah); Salvage is the remaining cost of the component (Rupiah).

8. Cost of energy

Cost of energy (CoE) is the cost incurred to produce electrical energy per 1 kWh. COE can be determined by dividing the annual cost by the annual energy production by the generator. The COE value can be determined by equation (5).

$$CoE = \frac{\mathrm{TAC}}{\mathrm{E_{tot.served}}} \quad (5)$$

description: TAC (total annualize cost) is the annual total cost of the hybrid plant; Etot.served is the total annual energy for the load (kWh).

9. Payback Period

Payback period method is used to determine the time required to recover the costs incurred in building a project. The payback period can be determined by dividing the investment cost of the project development by the income from the power plant being built (Yasuha et al., 2017)[10]. Knowing the value of the payback period can be calculated using equation (6).

$$\text{Payback period} = \frac{\text{investment cost}}{\text{income per year}} \quad (6)$$

description of equation (6) payback period is the payback period (years); Investment costs are the capital issued in rupiah.

The project is said to be feasible if the payback period is less than the project design time. If the payback is more than the project design time, then the project is not feasible to build (Hasibuan et al., 2022). Before knowing the value of the Payback period, first know the value of income from the sale of electrical energy in a year. Sales revenue of electrical energy can be calculated using equation (7).

Income per year = total energy production x selling price (7)

description of equation (7) annual income is income earned per year (Rp); total energy production is electrical energy produced by generators per year (Rp); The selling price is the cost per kWh (Rp).

Research Method

Some of the stages that must be carried out are shown in Figure 1.

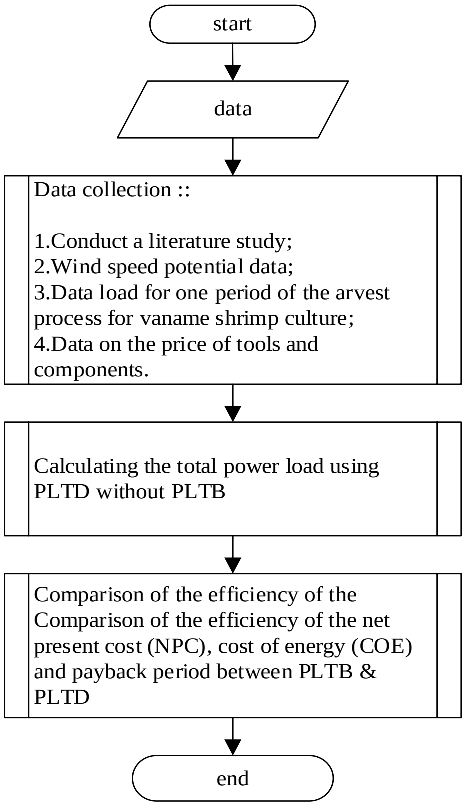

Figure 1 Flowchart

The block diagram of the wind power generation system is shown in Figure 2 and the diesel power generation system is shown in Figure 3.

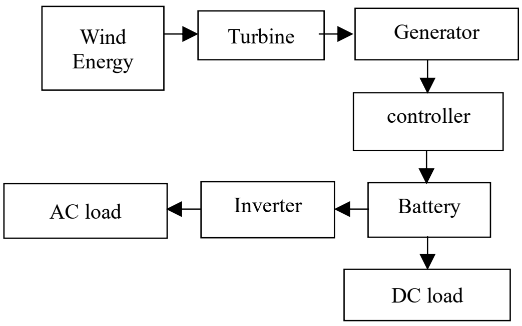

Figure 2 Block diagram of a wind power plant

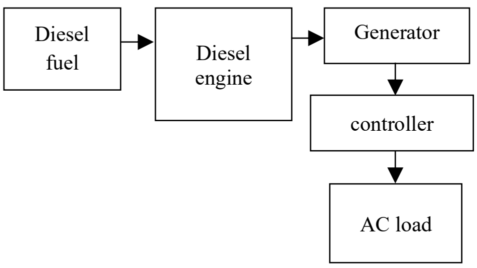

Figure 3 Block diagram of a diesel power plant

Result And Analysis

In this study, the calculation of the electrical energy load used in shrimp ponds was carried out, then compared the wind power generation system with the diesel power generation system. It aims to obtain environmentally friendly electrical energy and benefit from the energy use side.

1. Electric power load

Figure 4 shows the graph of maximum power consumption in one day (kWh). The maximum load is at 08.00 to 12.00 because at that time it is using an aerator and a water pump.

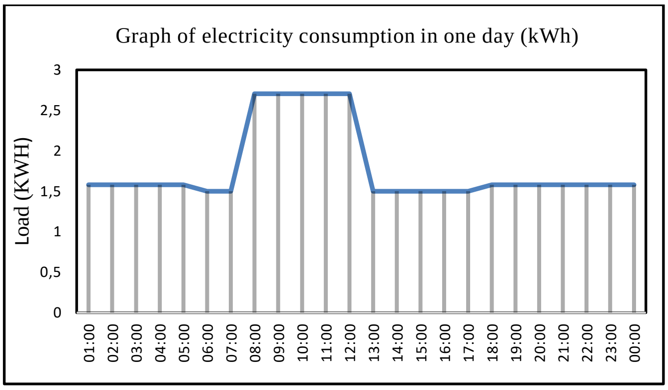

Figure 4 Graph of power consumption in one day (kWh)

The total maximum load of electric power used in shrimp ponds for one day is around 24.5kW, while the total load of electric power used in shrimp ponds for one year is 8,942.5kW.

2. Wind turbine

The wind turbine used in this study uses a 2kW Wind Turbine. Wind Mill has a blade diameter of 3.2 m as many as 5 units with a capacity of 10 kW and can be used for 10 years. The initial capital used for the procurement of this wind turbine is Rp. 45,500,000.00.

3. Charger Controller

The charger controller used in this study uses the Off Grid PWM Wind Solar Hybrid Charge Controller type with the model number RX-3KWC-SG. Determining the charger controller can be taken from formula 2 with a maximum load of 2705W divided by 220V system voltage and the result is 12.29A, so the current flowing in the charger controller is 12.29A.

4. Battery

The battery used in this study uses 4 units of Felicity 12V 200Ah battery and can be used for 5 years. The initial capital used to buy this battery is Rp. 13,818,000.00. The battery to meet an average daily load of 1.774531kWh from 80% of the total battery capacity to 7680W can supply an electrical load for 4.32 hours in conditions where the PLTB does not produce electrical energy or does not operate.

5. Inverters

The inverter used is a 3 Phae Grid Tie Solar Inverter which has a total capacity of 11kW. The costs incurred are Rp.15,495,50,00 and can be used for 5 years.

6. Production of wind power generation

The results of the production of wind power are shown in Figure 5. The amplitude values for each month are taken on average based on the wind speed.

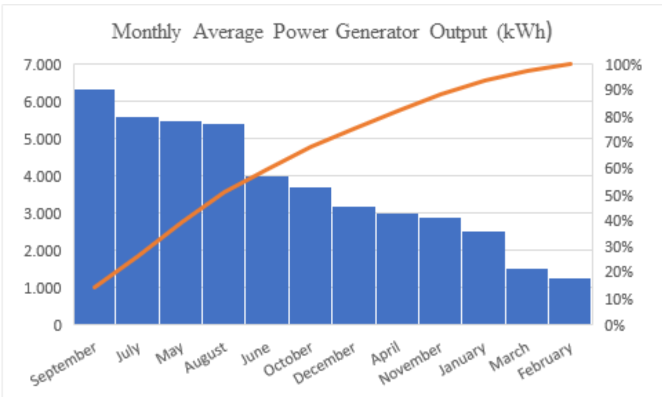

Figure 5 Graph of electrical energy produced by wind turbines per month

Based on Figure 10, it can be explained that the electrical energy produced per month from the lowest to the highest is between 1252,091kW (in February) – 6343.855kW (September). The total production of energy generated during the year from the wind power system as a provider of electrical energy reserves in shrimp ponds is 45453.189kW/year.

4. Analysis of the economic value of the generating system

Analysis of the economic value of the power generation system is carried out by calculating the NPC (Net present cost) and COE (Cost of energy) values of the wind power generation system as scenario 1 and the diesel power generation system as scenario 2.

a) Scenario 1

The economic value obtained from scenario 1 which is a wind power generation system can be seen in Table 2. According to the Ministry of Energy and Mineral Resources regarding the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia in 2017, the selling price of renewable electricity for the Java region as a whole is Rp. 911.00/kWh. So that the annual income generated by the generator is Rp. 41,407,855.179 per year.

Table 2 Economic value of wind power generation in scenario 1

Parameter	Value
Energy consumption (kW/year)	13,307.27kW/year
Total energy production (kW/year)	45,453.189kW/year
Initial capital (Rp)	Rp99,364,000.00
Net present cost (Rp)	Rp158,254,000.00
Cost of energy (Rp/kWh)	Rp477.41
Payback period (year)	3 years 9 months

Then calculate the Payback period value, to find out the time needed to return the capital development costs can be calculated using the Payback period equation, it takes 3 years 9 months

b) Scenario 2

The economic value obtained in scenario 2 which is a diesel power generation system can be seen in Table 3. The total diesel fuel needed in a year or 8,760 hours from 6.5kW or 8,125kVA generator with a diesel cost of Rp. 5,150 per liter is Rp. 76,975,762 per year, with an income of Rp. 51,872,340 per year. Then calculate the Payback period value, to find out the time needed to return the capital development costs can be calculated using the Payback period equation 15 years 7 months

c) Comparison of the Economic Value of Scenario 1 with Scenario 2

From the results obtained in scenario 1 can be compared with the results obtained in scenario 2, with this comparison it can be seen the effectiveness of a type of power plant. The comparison of the two power generation scenarios can be seen in Table 4. From the table it can be seen that the energy production of scenario 2 is greater than the energy production of scenario 1.

Table 3 Economic value of diesel power plant in scenario 2

Parameter	Value
Energy consumption (kW/year)	13,307.27kW/year
Total energy production (kW/year)	56,940kW/year
Initial capital (Rp)	Rp18,671,000.00
Net present cost (Rp)	Rp811,768,000.00
Cost of energy (Rp/kWh)	Rp5,910.75
Payback period (year)	15 years 7 months

From the economic point of view, the value of NPC scenario 1 is Rp. 158,254,000.00 less than the value of NPC scenario 2 which is Rp. 811,768,000.00. This is because scenario 2 uses diesel fuel compared to scenario 1 which does not use fuel. The use of renewable energy in the scenario 1 system has a lower COE value of Rp. 477.41 than CoE value of scenario 2 of Rp. 5,910.75, so that in the long term it is more economical to use scenario 1 because CoE value is lower and more environmentally friendly because it does not require fuel cost. The payback period in scenario 1 has a faster return on investment with a time of 3 years and 9 months than scenario 2 with 15 years and 7 months.

Table 4 Comparison of scenario 1 with scenario 2

Parameter	Value	
	Scenario 1	Scenario 2
Energy consumption (kW/year)	13,307.27kW/year	13,307.27kW/year
Total production (kW/year)	41,755.07kW/year	56,940kW/year
Total production (kW/year)	41,755.07kW/year	56,940kW/year
Cost of energy (Rp/kWh)	Rp477.41	Rp5,867.45
Payback period (year)	3 years 9 months	15 years 7 months

Conclusion

Based on the results of the calculation of the wind power generation system and diesel power generation system for vannamei litopeneaus shrimp ponds with a power load of 13,307.27kW/year with 10kW wind turbine generating capacity, the estimated power obtained is 45,453.189kW/year. The initial capital required from scenario 1 using a wind power generation system is Rp. 99,364,000.00 and the initial capital for scenario 2 using a diesel power generation system is Rp. 18,671,000.00. The NPC value of scenario 1 is Rp. 158,254,000.00 which is smaller than the NPC value of scenario 2 is Rp. 811,768,000.00. The fuel cost in scenario 2 requires 14,946.75 liters of fuel/year. The COE value for scenario 1 is Rp. 477.41, which is lower than the COE value for scenario 2 is Rp. 5,910.75. The payback period in scenario 1 has a faster return on investment with a time of 3 years and 9 months and in scenario 2 with 15 years and 7 months.

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