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Optimization of Savonius Turbine Performance with Variations in Blade and Shaft Spacing on the Coast of Sarmi Regency, Papua Province

Optimasi Kinerja Turbin Savonius dengan Variasi Jarak Sudu dan Poros di Pesisir Kabupaten Sarmi Provinsi Papua

Johni Jonatan Numberi*, Joni, Pither Palamba, Obed Rante Allo, Nourish C. Griapon, Yane A. Ansanay, Lazarus Ramandei, Wilfriedf Wanane, Rombe Allo, Janviter Manalu, Apolo Safanpo, Endang Hartiningsi, Marthen Liga, Enos Karapa, Yosef Lefaan, Prihananto Setiadji, Herbert Innah
Universitas Cenderawasih, JL. Kamps Wolker, Jayapura 99351, Indonesia

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Abstract

The use of wind energy as one of the producers of electrical energy is done by converting mechanical energy into electrical energy from wind turbines, one of which is the savonius wind turbine. Savonius wind turbines in use are able to work at low wind speeds. This study aims to evaluate the potential of wind energy that can be generated by optimization in savonius wind turbines by measuring the power generated by varying the gap distance between Balde and turbine shafts and analyzing the most optimal power as a source of power generation on the coast of Sarmi Regency, Papua Province. The analysis method in this study is field surveys, wind speed measurements, power optimization, BHP and tool efficiency carried out with variations in the distance between the blade and turbine shaft, namely 5 cm, 10 cm and 15 cm. The results of this study stated that the most optimal and stable results on the power generated by the turbine as well as the BHP value and the best tool efficiency were a distance variation of 15 cm with an average power value produced (P0) of 15.55 Watts, an average BHP value of 0.56 Watts and an average efficiency value of 7.59%.

Keywords: wind energy, optimization, distance of blades and turbines, coastal sarmi regency.

***SDGs*:**

7 AFFORDABLE AND CLEAN ENERGY

Abstrak

Pemanfaatan energi angin sebagai salah satu penghasil energi lisrik dilakukan dengan mengonversikan energi mekanik menjadi energi listrik dari turbin angin salah satunya turbin angin savonius. Turbin angin savonius pada penggunaannya mampu bekerja pada kecepatan angin rendah. Penelitian ini bertujuan untuk mengevaluasi potensi energi angin yang dapat dibangkitkan dengan optimalisasi pada turbin angin savonius dengan melakukan pengukuran daya yang dihasilkan dengan memvariasikan jarak celah antara Balde dan poros turbin dan menganalisis daya paling optimal sebagai sumber pembangkit listrik di pesisir Kabupaten Sarmi, Provinsi Papua. Metode analisis dalam penelitian ini adalah survei lapangan, pengukuran kecepatan angin, optimasi daya, BHP dan efisiensi alat dilakukan dengan variasi jarak antara blade dan poros turbin, yaitu 5 cm, 10 cm dan 15 cm. Hasil penelitian ini menyatakan bahwa hasil yang paling optimal dan stabil pada daya yang dihasilkan turbin serta nilai BHP dan efisiensi alat terbaik adalah variasi jarak 15 cm dengan nilai daya rata-rata yang dihasilkan (P0) 15,55 watt, nilai BHP rata-rata 0,56 watt dan nilai efisiensi rata-rata 7,59%.

Kata Kunci: energi angin, optimasi, jarak sudu dan turbin, pesisir kabupaten Sarmi.

*Correspondence Author
email : j_numberi@yahoo.com

1. INTRODUCTION

Energy needs throughout Indonesia are projected to increase along with the increasing population, Business Plan for Providing Electricity (RUPTL) 2021 – 2030 projects that in 2021 – 2030 electricity sales growth will reach 4.9%, this value is reduced by 1.5% from the previous figure of 6.4% projected in RUPTL 2019-2028, one of the factors reducing this figure is the increase in the use of mixed energy (low carbon) in the 2030 projection, namely, the use of renewable energy 24.8%, gas 15.4%, coal 59.4% and fuel 0.4 (PLN, 2021).

The data above illustrates that the development of the use of new and renewable energy is being carried out until 2030, so the construction of mixed energy generation facilities is planned to be built throughout Indonesia. One of the promising renewable energy is wind energy whose utilization is still very minimal in Indonesia. Handbook of Energy and Economic Statistics of Indonesia 2021 notes that the total installed wind power plant capacity is 157.41 MW with details of 153.83 MW installed on-grid or in other words installed on the State Electricity Company's systems (PLN) and 3.58 MW installed off-grid or outside the PLN (Pristiandaru, 2023; Sidik *et al.*, 2023).

Based on BPS-Statistics Indonesia data report on 2022, Sarmi Regency has an area of 14,068.37 km2/sq.km, with a population of 42.68 thousand people with a growth rate of 1.05% from 2020 – 2023. This population growth rate is also directly proportional to the energy needs of various sectors. The number of PLN electricity customers in Sarmi Regency reached 10,859 thousand customers spread across 8 districts in Sarmi Regency, while around 11 other districts have not been reached by PLN electricity. By looking at this condition, it is necessary to have an alternative power plant that is able to help fill the needs of electrical energy independently and Wind Power Plant (PLTB) is promising. This type of power plant has been widely developed, especially in areas adjacent to the coast that are difficult to reach. The average wind speed in Sarmi Regency is expected to reach an average of 3.80 m/s with the maximum speed being 17 m/s throughout 2023 (BPS, 2024).

Wind power plants use several types of turbines in their power generation mechanisms, one of which is the savonius type or known as the vertical shaft type with the advantage of this type of wind turbine is that it can rotate with wind impulse from all directions, with high and low wind speeds even so that this turbine is superior to use in areas that have variations in wind speed compared to wind turbines horizontal type (Putra, Kananda and Muhtar, 2021).

Research on wind potential has been carried out in the Rectorate of Cenderawasih University by producing wind potential data of 2.8 – 3.27 m/s and the actual power produced is 33.13 W (Numberi *et al.*, 2023). Previous research provided information that one of the factors that affect the amount of power generated from this savonius type wind turbine is the turbine blade and the distance of the blade gap to the shaft with wind speeds below average is 3 m/s which was tested in the Rectorate area of Cenderawasih University (Pasulu, 2021). The design of the turbine blade is very influential on the mechanical force converted from wind energy, this is influenced by the tilt of the propeller and the area of the propeller used to capture the wind and converted into mechanical energy, the load that can be received by the turbine also affects the conversion (Sulistiyanto, Wibowo and Kabib, 2022). The tilt of the blade will also affect the work of the rotor on savonius type wind turbines (Patel and Patel, 2023). In several studies leading to savonius turbine blades, it was explained that the diameter of the turbine blades and the distance to the shaft affected the area of wind catchment using torque calculations as a comparison (Shuhufam and Yuwono, 2021). Research with the Savoni wind turbine design, a simple construction design with a vertically rotating main rotor capable of producing output power of 7.20 watts, with an average rotation of 631 rpm, an average generator speed calculated at 1,243 rpm and an average generator efficiency of 36% of the wind speed of 4.64 m/s (Sudirman, Kurniati and Arifin, 2020).

From the description, the purpose of this study was to evaluate the potential of wind energy as a source of electricity generation on the coast of Sarmi Regency, Papua Province. Through analysis involving field surveys and wind speed measurements.

2. METHODOLOGY

2.1. Location

This research was conducted in the coastal area of Tarontha Beach with geographical coordinates 2°15'50"S 139°34'01"E. This area is located in Bonggo District, Sarmi Regency, Papua Province. Research location that shown in Figure 1.

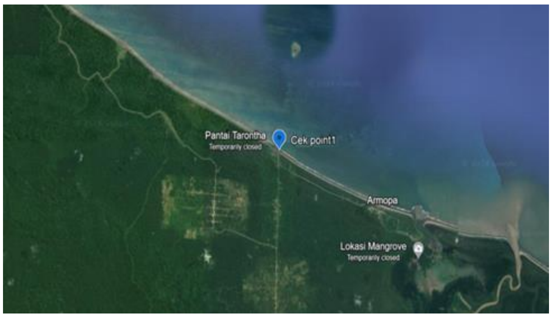

Figure 1. Wind speed measurement location point (check point 1).

2.2. Methods

Techniques data retrieval techniques are carried out by measuring wind speed at a predetermined point (check point 1).

2.3. Tools

This research was conducted using several supporting equipment, namely anemometer to calculate wind speed, tachometer to calculate rpm on blades and shafts and multimeter to calculate voltage and electric current generated from turbine mechanical force.

2.4. Calculation Analysis

The movement of the wind has a certain speed so that we can calculate wind energy using the kinetic energy equation:

$$E_K = \frac{1}{2} mv^2 \quad (1)$$

The air trapped in the turbine blades with a certain cross-sectional area is calculated as the volume of air/unit of time moving at a certain

$$V = v.A \quad (2)$$

speed, so the equation can be written with:

The moving air mass can be calculated using the frequency of air (ρ), so it can be written as follows:

$$m_{air} = \rho . V = \rho . v . \quad (3)$$

The calculation of wind energy (kinetic) that can be generated from the above equation is described as follows:

$$P_0 = \frac{1}{2} \rho . A . v^3 \quad (4)$$

where:

P_0 = Wind force (Watt)
ρ = Air density (kg/m^3)
v = Wind velocity (m/s)
A = Cross-sectional area (m^2)

The calculation of power optimization is seen from how much the engine can withstand the load at a certain rotation capacity (BHP), in BHP calculations it is necessary to calculate generator power which is calculated from the voltage and current strength measured by the equation (Pasulu, 2021):

$$P_{generator} = V . I \quad (5)$$

$$BHP = \frac{P_{generator}}{\eta_{generator}} \quad (6)$$

where:

BHP = Brake Horse Power (Watt)
$P_{generator}$ = Generator Power (Watt)
$\eta_{generator}$ = Generator Efficiency (0,85)

3. RESULTS AND DISCUSSION

3.1. Data Variables Retrieved

This research was conducted by varying the distance between the blade and turbine shaft to get maximum results so that in this study several variable data were also taken that support the calculation of power optimization produced. The variable data taken in this study is described in Table 1.

3.2. Result Data

The results of this study obtained the measured wind speed is the average wind speed, minimum wind speed and maximum wind speed with a variation in the distance of the blade and turbine 5 cm; 10 cm; 15 cm. Measurements were carried out 1 day at 08.00 – 09.00 WIT, 12.00 – 13.00 WIT and 16.00 – 17.00 WIT with a vulnerable distance measurement per 5 minutes of wind speed measurement. Data from measuring wind speed with the gap distance between the blade and shaft shown in Table 2.

Table 1. Data variables retrieved.

Symbol	Meaning
v	Wind speed to calculate the potential power that can be generated (m/s)
V	The voltage generated from the mechanical power of the turbine (Watt)
I	Strong electric current generated from mechanical turbines (Ampere)
n	Rotation of the turbine shaft with variations in the distance between the blades and shafts (rpm)

Table 2. Measured wind speed (m/s).

Time (WIT)	The distance of blades and shaft (cm)	Average wind speed (m/s)	Minimum wind speed (m/s)	Maximum wind speed (m/s)
08.00 - 09.00	5	4.0	3.2	4.6
	10	5.5	4.1	8.1
	15	3.7	2.4	5.9
12.00 - 13.00	5	2,9	1.9	3.6
	10	3.9	3.0	6.7
	15	3.6	3.0	6.0
16.00 - 17.00	5	5.1	5.0	5.1
	10	2.0	0.7	3.4
	15	3.5	2.5	5.1

Graphs of wind speeds measured in the periods 08.00-09.00 WIT, 12.00-13.00 WIT and 16.00-17.00 WIT with variations in the distance between the blade and the shaft are shown in Figure 2, Figure 3, and Figure 4.

Figure 2 shows the distribution of average wind speed as measured by the difference in gap distance between the blades and the turbine shaft. The average wind speed measured was 4.0 m/s at a gap distance of 5 cm, 5.5 m/s at a gap distance of 10 cm and 3.7 m/s at a gap distance of 15 cm.

Figure 3 shows the distribution of the minimum measured wind speed of 3.2 m/s at a gap distance of 5 cm, 4.1 m/s at a gap distance of 10 cm and 2.4 m/s at a gap distance of 15 cm.

Figure 4 shows the distribution of maximum wind speeds that occurred at the time of measurement, namely 4.6 m/s at a gap distance of 5 cm, 8.1 m/s at a gap distance of 10 cm and 5.9 m/s at a gap distance of 15 cm.

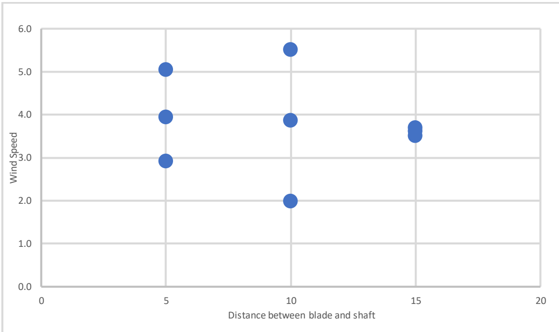

Figure 2. Average wind speed graph.

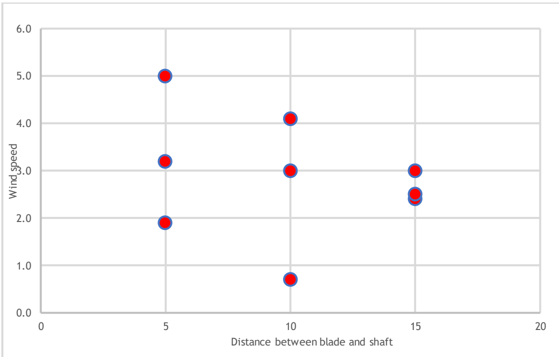

Figure 3. Minimum wind speed graph.

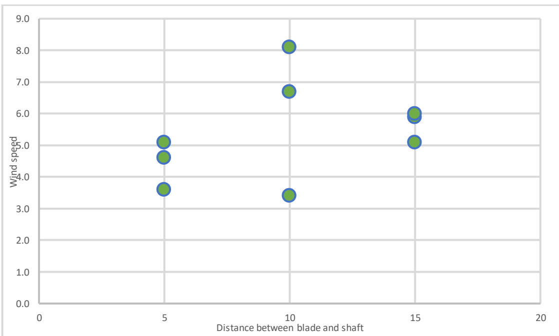

Figure 4. Maximum wind speed graph.

Based on the explanation above, the level of stability of wind speed for 3 hours measurements increase and decrease in each 5-minute measurement time span and are said to be balanced because those who have variables are not so far away so that they are more consistent (Sandika, Christover and Rozikin, 2019). The measured data tends to look stable at speeds of 2 m/s - 6 m/s, with occasional increases in wind speed at 8.1 m/s and decreases in wind speed at 0.7 m/s.

3.3. Power, BHP and Efficiency Calculations

The calculation of power optimization is carried out by comparing the power (P0) produced, BHP or engine power in holding loads in units of revolutions per minute and the efficiency of the tool.

3.3.1. Power Calculation (P0)

The calculation of power (P0) is carried out to find out how much power can be generated by the turbine with a certain wind speed by calculating the surface area of the turbine blade (Pasulu, 2021). This study carried out 3 variations in the distance between the blade and the shaft so that the results obtained were as follows:

$$P_0(5\ cm) = \frac{1}{2} x 1{,}2\ x\ 0{,}41\ x\ (3{,}2^3) = 8{,}1\ Watt$$

$$P_0(10\ cm) = \frac{1}{2} x 1{,}2\ x\ 0{,}41\ x (5{,}4^3) = 38{,}7\ Watt$$

$$P_0(15\ cm) = \frac{1}{2} x 1{,}2\ x\ 0{,}41\ x\ (5{,}9^3) = 50{,}5\ Watt$$

3.3.2. Brake Horse Power (BHP) calculation

BHP calculations are carried out to determine how much the ability of a tool to withstand loads with a certain rotation (Pasulu, 2021), For this study, 3 variations in the distance between the blade and the shaft were carried out so that the following calculations were obtained:

$$BHP_{(5cm)} = \frac{0{,}29}{0{,}85} = 0{,}34\ Watt$$

$$BHP_{(10\ cm)} = \frac{0{,}16}{0{,}85} = 0{,}18\ Watt$$

$$BHP_{(15\ cm)} = \frac{0{,}4}{0{,}85} = 0{,}47\ Watt$$

3.3.3. Efficiency calculation

Efficiency calculations on this tool are also carried out to see the effectiveness of this wind turbine in generating energy by utilizing wind speed (Pasulu, 2021). The calculation of efficiency in this study was carried out with variations in the distance between the blades and turbine shafts obtained below:

$$\eta_{(5\ cm)} = \frac{0{,}3\ Watt}{8{,}1\ Watt} x\ 100 = 4{,}23\%$$

$$\eta_{(10\ cm)} = \frac{0{,}2\ Watt}{38{,}7\ Watt}\ x\ 100 = 0{,}5\%$$

$$\eta_{(15\ cm)} = \frac{0{,}5\ Watt}{50{,}5\ Watt}\ x\ 100 = 0{,}9\%$$

The calculation data and comparison between Power (P0), BHP and efficiency in this study can be seen in the graph shown in Figure 5, Figure 6, and Figure 7.

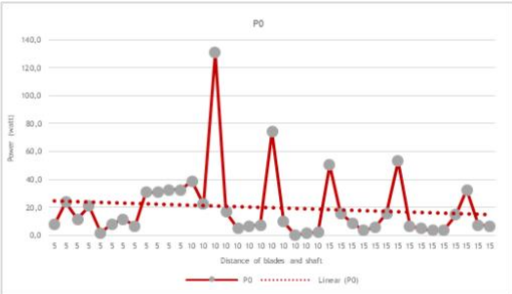

Figure 5. Power (P0) generated (Watt).

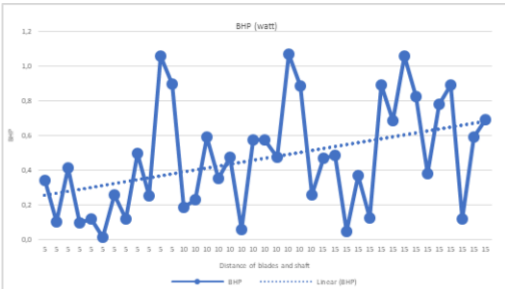

Figure 6. BHP from savonius turbine (Watt).

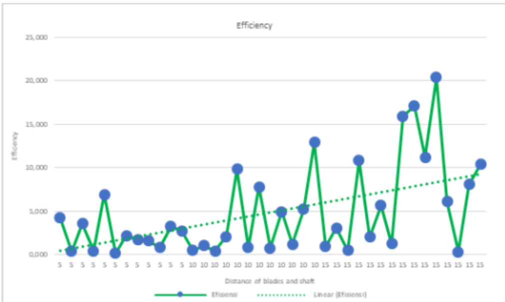

Figure 7. Savonius turbine efficiency (%).

Figure 5 shows that the power produced varies, on measurements made 3 variations in the gap distance between the turbine blade and the shaft. Power generated at 5 cm tends to experience a steady increase and decrease with the average power generated at this distance is 18.26 watts, the average power generated at a gap distance of 10 cm is 26.25 watts and the average power generated at a gap distance of 15 cm is 15.55 watts.

Figure 6 shows the value of Brake Horse Power (BHP) or the ability of an engine to withstand a load in one rotation, or at a certain rotation. The BHP value on this turbine is calculated using variations in the gap distance between the blades and turbine shafts. The average BHP value of 5 cm gap is 0.35 watts, for 10 cm gap is 0.48 watts and for a gap distance of 15 cm is 0.56 watts.

Figure 7 shows the efficiency of a turbine working with variations of turbine blades and shafts. The average efficiency of 5 cm distance is 2.35%, the distance of 10 cm is 3.96% and the distance of 15 cm average efficiency value is 7.59%.

4. CONCLUSION

The wind potential in Tharonta Beach, Bonggo District, Sarmi Regency has sufficient wind potential to generate energy using savonius wind turbines, with wind speeds recorded between 2 m / s - 6 m / s. The best performance of savonius wind turbines from the variation in gap distance between the blade and the shaft is 15 cm with the average power produced is 15.55 watts, an average BHP value of 0.56 watts and an efficiency of 7.59%. Based on the results of research and experiments. it was found that sea water can be used as a substitute for fresh water in concrete mixes. Corrosion effects caused by the content of chloride ions in seawater can be minimized by mixing inhibitors into the concrete mix.

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