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Study of Solar and Wind Energy Potential for Power Generation in Pulo Aceh

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Abstract. Pulo Aceh is a region located in the westernmost part of Indonesia. The remote location of Pulo Aceh, far from urban areas, makes transportation costs for economic activities more expensive and affects the income of the community. On the other hand, the lack of adequate infrastructure and the long transmission distance make it difficult to establish electricity from the national power company (PLN), resulting in limited electricity supply in Pulo Aceh. This study aims to assess the potential of wind and solar energy in Pulo Aceh as alternative sustainable energy sources. The study was conducted by collecting wind speed and solar radiation data for four months, from January to April. The data was analyzed to determine the energy potential that can be generated from these sources. The research results show that Pulo Aceh has significant potential for harnessing wind energy. The average wind speed during the research period reaches 4-8 m/s, which is sufficient to drive wind turbines and generate electricity ranging from 319-666 W. Furthermore, the potential of solar energy generated is also promising, with an average solar radiation intensity of 814-827 W/m² throughout the research period. Therefore, the potential of both wind and solar energy can be utilized, either in rotation or in combination (hybrid) form.

Introduction

The need for energy is very large because technological developments in various sectors are very advanced, with very large needs, thus fuel oil is unable to meet all of these needs. [1] The right step to reduce fuel oil, especially as a power plant, is to utilize renewable energy sources as a power plant. The use of renewable energy has great potential as electrification for rural areas. Generally, solar energy can be utilized in the dry season which lasts about 8 months a year which shines between 10:00 WIB and 15:00 WIB. Meanwhile, wind energy can be utilized if the average wind speed is above 4 m/s with a gust duration of 4-5 hours per day. [2] Seeing the large potential for utilizing both of these energies, this study will review the potential and utilization of renewable energy (solar and wind) in Pulo Aceh, Aceh Besar Regency, Aceh Province.

Solar Energy and Wind Energy

Solar energy converted into electrical energy is also called *photovoltaic energy*. Solar modules can take sunlight containing electromagnetic waves (photon energy). Photon energy in the sun creates kinetic energy that can release electrons moving towards the conduction band, causing an electric current. [3]

The energy available in the wind is essentially the kinetic energy of a large mass of air moving over the earth's surface. The blades of a wind turbine that receive kinetic energy will be converted into mechanical or electrical energy, depending on the end use. The efficiency of converting wind energy into other forms of energy use depends on the efficiency of the rotor interacting with the air flow. [4] According to [5] , wind speed measurements should be carried out at a height of 10 meters above ground level. However, potential wind speeds can be much higher at higher heights.

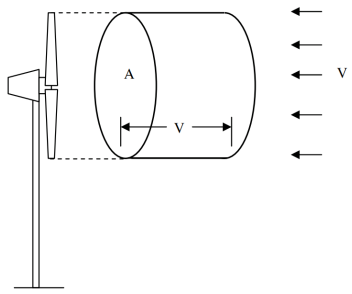

Fig. 1. Field of air moving towards a wind turbine.

Source: Sathyajith Mathew [4]

To determine the amount of power generated from the air field on the rotor, you can use the formula:

$$P = \frac{1}{2}\dot{\rho}\, A\, v^3 \quad (1)$$

The factors that affect the power available in the air flow are air density, wind rotor area and wind speed. [4]

Hybrid energy systems consist of two or more renewable energy sources used simultaneously to increase system efficiency and promote greater balance in energy supply. [6]

Research Methods

This research was conducted for 3 months in Melingge Village, Pulo Aceh District, Aceh Besar Regency, and Ulee Lheue Village, Banda Aceh City. Data processing was conducted at the Thermal Engineering Laboratory, Mechanical Engineering Study Program, Department of Mechanical and Industrial Engineering, Faculty of Engineering, Syiah Kuala University.

The process of collecting solar radiation intensity data is carried out using a Luxmeter measuring instrument. The measuring instrument is placed in an open field with solar radiation that is not blocked by buildings, trees or clouds. The process of collecting wind data is carried out using an Anemometer measuring instrument at a predetermined location point with a height of 10 meters and wind speed is recorded every hour.

Primary wind speed data taken from measurement data conducted every hour from 7:00-22:00 WIB, by comparing the values between the two location points, if the values obtained are the same then the measurement is only carried out at one point. While for solar radiation measured at 10:00-16:00WIB, measurements were carried out from January-April. While for secondary data taken from BMKG Aceh Besar which has been going on for the last 3 years every month and every day.

Results and Discussion

The data obtained from the measurements are data measured daily, weekly, and monthly. While the annual data as a comparison of data is taken from BMKG Aceh Besar.

1. Analysis of Daily Measurement Results

The results of measurements carried out from 07.00-22.00 WIB taken over three days, the average wind speed can be seen in Figure 2.

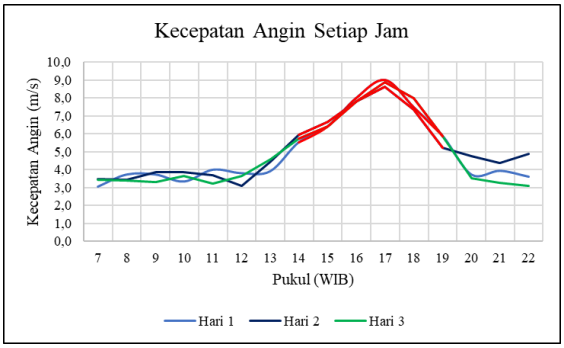

Fig. 2. Hourly wind speed distribution.

Figure 2 shows data taken over three days, it can be seen that the wind speed on the red line is the wind speed that has the potential to generate electrical energy, with wind speeds ranging from 5-9 m/s starting at 14.00 to 19.00 WIB. According to [2] the minimum wind speed that can be used to generate electricity is 4 m/s. While the wind speed below 15.00 WIB is only around 3 m/s and above 18.00 WIB the wind speed decreases again, so that wind speeds below 4 m/s cannot be used to generate electricity.

The results of solar radiation intensity measurements measured at 07.00-19.00 WIB can be seen in Figure 3.

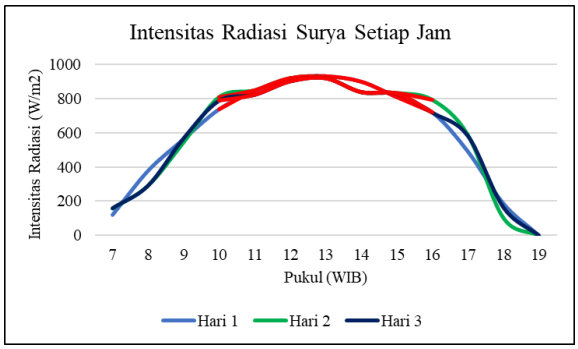

Fig. 3. Hourly solar radiation intensity.

The intensity of solar radiation that occurs at 7:00-19:00 WIB shows that the highest solar radiation intensity value is at 12:00-13:00 WIB, which is 900-932 W/m2. The solar radiation intensity value looks quite high starting at 10:00 WIB, which is 739 W/m2 to 16:00 WIB, which is 721 W/m2. While at 17:00-19:00 WIB. According to [7] the intensity of solar radiation can be utilized at a minimum value of 600 W/m2 , from the results obtained, generally the solar intensity value that occurs is very optimal when conditions are sunny, but at certain times the solar intensity value is obtained which is not optimal due to the movement of clouds that cover the sun so that the optimal time for sunlight occurs is faster.

2. Analysis of Weekly Measurement Results

The results of measurements every day of every week obtained the average wind speed value which can be seen in Figure 3.

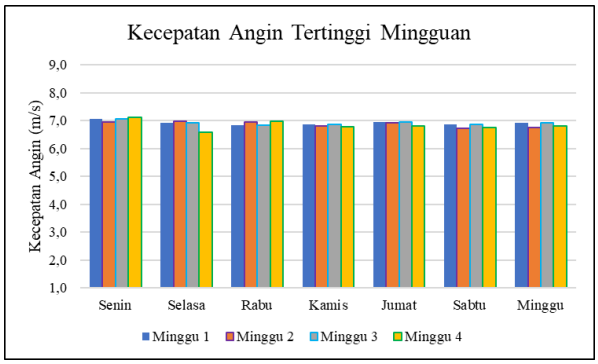

Fig. 4. Weekly highest average wind speed.

The analysis in Figure 3 shows the highest weekly average wind speed during a 6-hour period, from 14:00-19:00 WIB. Based on the figure, it can be observed that the wind speed that occurs every day is relatively the same and stable, with a value above 6 m/s.

The constant and stable wind speed above 6 m/s in that time span indicates good potential for wind energy utilization in that location. High wind speeds like this allow the use of wind turbines with high efficiency in generating electrical energy.

The results of daily measurements in each week on the average solar radiation intensity value from 10.00-16.00 WIB can be seen in Figure 4.

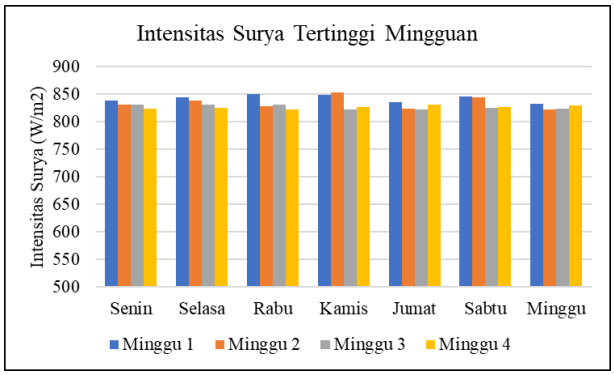

Fig. 5. Weekly highest average solar radiation intensity.

Data analysis shows that the intensity of solar radiation measured daily between 10:00 and 16:00 WIB shows stability and relatively consistent values. The intensity of solar radiation observed daily reaches a figure above 800 W/m2 , indicating high radiation levels and significant solar energy potential at the location.

However, it is important to note that this analysis is based on data collected over a specific time period and may not capture all variations that may occur at a given location. More extensive data collection and more in-depth analysis are needed to ensure the accuracy and appropriateness of the information regarding solar energy potential at a specific location.

3. Monthly Measurement Results Analysis

The results of wind speed measurements for each month starting from January to April can be seen in Figure 5.

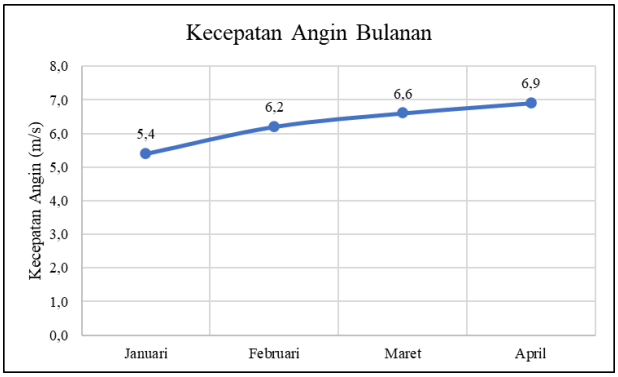

Fig. 6. Monthly highest average wind speed.

Wind speed measured from January to April with the highest average wind speed measurement process starting at 14.00-19.00 which lasted for approximately 6 hours and the results stated that for 4 months the wind speed was very feasible to be utilized. Although the wind speed shows a potential that is feasible to be utilized, it is important to remember that wind speed can vary and is not always optimal all the time. Wind speed can experience daily, seasonal, or even annual fluctuations, depending on factors such as weather conditions, topography, and local wind patterns.

The results of solar intensity measurements during the period from January to April can be found in Figure 6. The figure presents data on the intensity of solar radiation recorded each month.

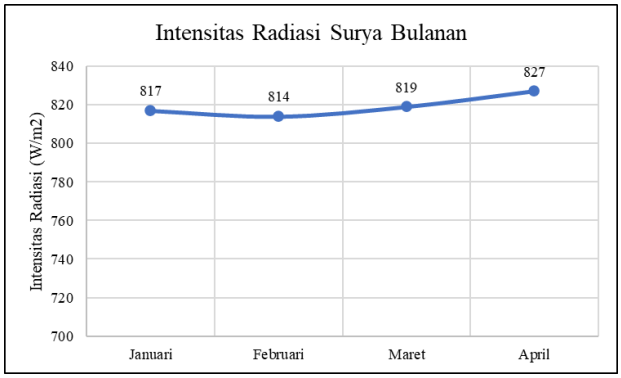

Fig. 7. Average highest monthly solar radiation intensity.

Through the analysis of the data in Figure 7, it can be seen that the intensity of solar radiation that occurs each month remains within a range that is feasible to be utilized. This shows that even though there are fluctuations in the intensity of solar radiation throughout the months, the potential for solar energy still exists and can be used effectively. However, it should be noted that the data presented in Figure 7 only reflects the results of measuring the intensity of solar radiation and does not consider other factors that can affect the utilization of solar energy.

4. BMKG Wind Speed Data Analysis

The wind speed data obtained is data from 2020 to 2022, the wind speed values can be seen in Figure 8.

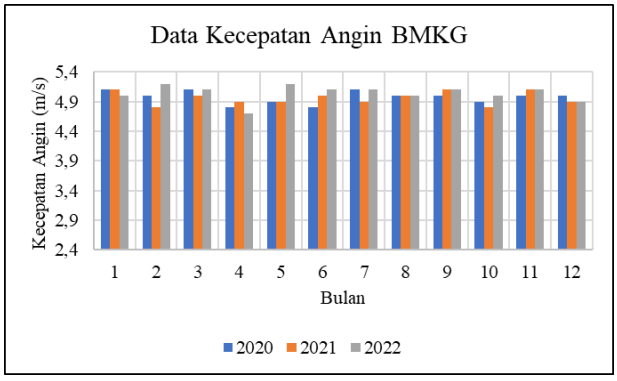

Fig. 8. BMKG wind speed data.

Wind speed data obtained from BMKG Aceh Besar shows that the wind speed that occurs is relatively the same, ranging from 4-5 m/s, the wind speed recorded by BMKG can be categorized as a decent result and has the potential to produce electrical energy that can be utilized every month.

5. BMKG Solar Radiation Intensity Data Analysis

The solar radiation intensity data obtained is data from 2020 to 2022, the solar radiation intensity value can be seen in Figure 9.

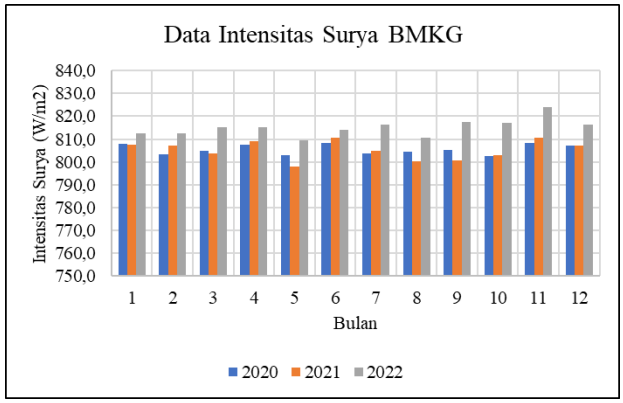

Fig. 9. BMKG solar radiation intensity data.

Solar radiation intensity data shows that the average value for the last 3 years has relatively no significant difference, the visible solar radiation intensity value is always above 780 W/m2. The solar radiation intensity value for each month is not much different, thus the overall solar energy potential can still be utilized for each month.

6. Comparative Data Analysis

Comparison of wind speed and solar radiation intensity at the research location and BMKG data from 2020 to 2023 can be seen in Figure 10.

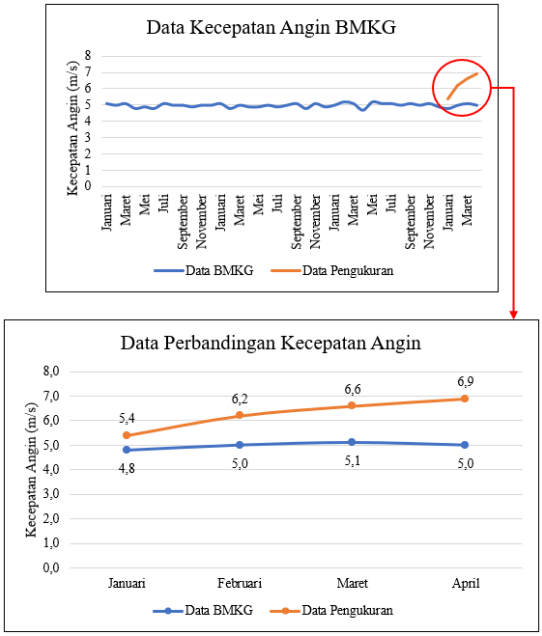

Fig. 10. Comparison of wind speed data.

In Figure 10, it can be seen that the measured wind speed has a not too significant difference, where the wind speed obtained from BMKG ranges from 4.8 - 5 m / s while the wind speed obtained from direct measurements ranges from 5.4-6.9 m / s. This difference in value occurs because of the difference in the location of the data collection point carried out by BMKG and there are differences in the data collection methods carried out by BMKG.

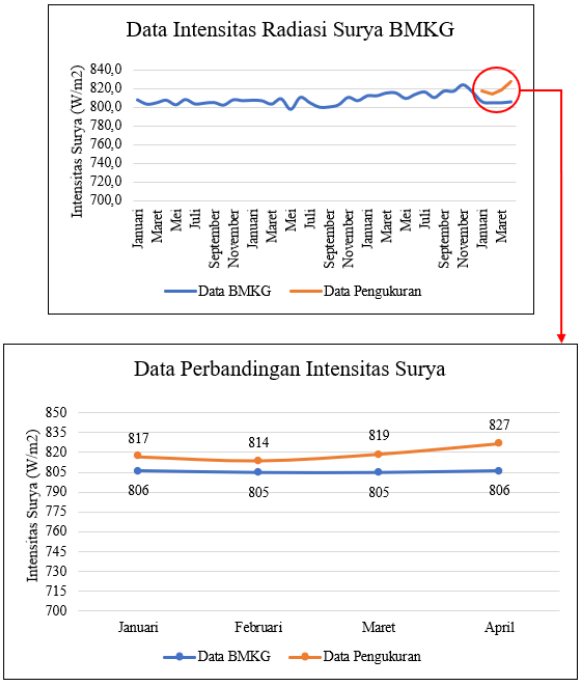

Fig. 11. Comparison of solar radiation intensity data.

Figure 11 shows that the measured solar radiation intensity values have a difference in value that is not much different between the data obtained from BMKG and data based on measurements, where the data obtained from BMKG ranges from 805-806 W/m2, while the data based on measurements ranges from 817-827 W/m2. This difference can be caused by differences in data collection methods carried out by BMKG.

7. Wind Energy Potential

Based on the data obtained, it is known that the average wind speed in Pulo Aceh is above 4 m/s with a total time of approximately 6 hours a day. Based on research conducted by [8], it is stated that by using a horizontal propeller-type wind turbine with five blades and a blade length of 100 cm paired with a 1000 W generator using a 2:10 transmission, it can generate electricity starting at a wind speed of 4 m/s. The turbine is capable of rotating at a speed of 400 rpm and can generate 50 W of electrical power. The power that can be generated by wind speed can be calculated using equation (1) which can be seen in Figure 12.

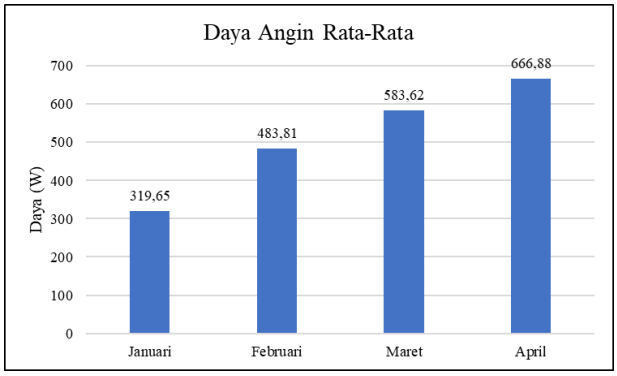

Fig. 12. Average wind power.

Figure 12 shows that the average wind power obtained with data measured over 4 months, the largest power gain was 666.88 W in April, while the smallest power was in January at 319.65 W. The power obtained is sufficient to meet electricity needs (small scale). [9]

8. Solar Energy Potential

Based on the data obtained, Pulo Aceh has a fairly high intensity of solar radiation which lasts for approximately 7 hours starting from 10:00 WIB to 16:00 WIB which has a solar radiation intensity above 600 W/m2. The power generated each month can be seen in the following image.

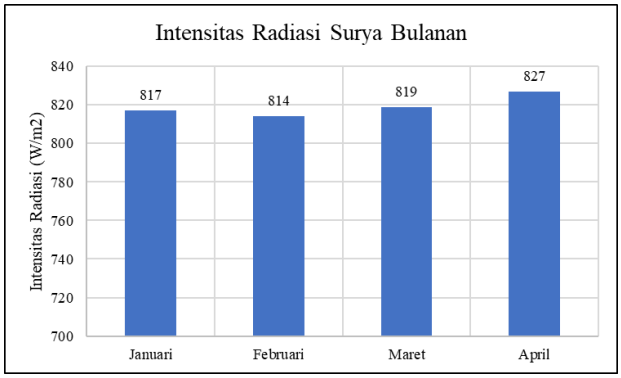

Fig. 13. Average solar radiation intensity.

Figure 13 shows that the potential for solar energy in the Pulo Aceh area is very adequate so that it has important potential to provide electrical energy that can be used simultaneously with wind energy, and can be used alternately if on certain days there is no wind potential at all, so that solar energy can be used as a source of electrical energy. [10]

This shows that Pulo Aceh has the appropriate parameters for building solar, wind or hybrid power plants (a combination of solar and wind energy).

Conclusion

Based on the results of the research that has been conducted, several conclusions can be drawn as follows:

1. Wind speed in Pulo Aceh reaches significant potential with an average wind speed of 4-8 m/s, with a duration of approximately 6 hours from 14.00 to 19.00 WIB with a power of 319-666 W in January to April.
2. The solar intensity starting from January to April has an average solar radiation intensity of 814-827 W/m2 · This provides a great opportunity to utilize solar energy as a powerful source of electricity.
3. The use of solar power as an energy source can be used during the day, and at night, electricity can be used from wind turbines that have been stored.

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