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Utilization of a Low-Speed Neodymium Wind Turbine Generator as an Alternative Power Source for Homes in the North Cirebon Coastal Area, Indonesia

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ABSTRACT

Wind energy, which is a renewable energy source, is inexhaustible, clean and free. Renewable energy sources, especially wind energy, offer many environmental and economic benefits in contrast to fossil energy sources. The potential and characteristics of wind energy in the northern coastal area of Cirebon Regency are very good. This can be seen from the measurement results of an average wind speed of 3.3 m/s during the day between 10:00-15:00 WIB, which is suitable for a 100 W mini power plant. The distribution of wind speed is quite even with a range of 2.7-3.9 m/s. The neodymium type wind turbine generator design is capable of utilizing wind energy at low speeds of 2.7-3.6 m/s. The generator is specifically designed for low speeds so that it can operate and produce voltages above 11 Volts even in low wind conditions. This study uses experimental methods, system design and data analysis. The measurement results show that the generator is capable of working in the wind speed range of 2.7-3.6 m/s and produces a voltage above 11 V. There is a positive relationship between wind speed, generator rotation, and output voltage. This study is motivated by maximizing renewable energy sources and offering new solutions to reduce dependence on State Electricity Company in the region. It can be concluded that the neodymium generator is effective as an alternative electricity source because it is able to work at various wind speeds and produce adequate electrical power.

1. INTRODUCTION

Limited fossil fuel reserves, rising prices and a deteriorating environmental situation all call for more intensive use of renewable energy sources.[1] Studies on the long-term prospects of the world's energy development show that wind energy is an economically efficient and accessible energy source for large-scale utilization in the coming decades and in the more distant future.[2]

Wind energy, which is a renewable energy source, is inexhaustible, clean and free.[3] Renewable energy sources, especially wind energy, offer many environmental and economic benefits in contrast to fossil energy sources.[4] People have used wind energy since ancient times to grind grain and pump water. They have been using wind energy to generate electricity effectively for more than the last two or three decades by using modern wind turbines.[5]

Since the first electric turbine was introducedin 1888, the use of power generation, and its existencehas grown over the past century.[6] Electric turbines have proven to be a clean alternative to fuel, but they are limited to areas that are typically windy, or specifically where the wind speed and volume are suitable for energy conversion.[7]

Rising electricity prices are driving increased interest in renewable and clean energy sources.[8] Onesuch source is wind, which is available to almost all energy consumers. The rotation speed of a wind turbine depends on the dimensions, turbine diameter and wind speed.[9] Wind power generation using wind turbines is a technology that is starting to be widely applied. However, low wind speed in some areas is still a challenge in its utilization.[10] Conventional generators are less able to capture wind energy at low speeds.[11] Neodymium generators specifically designed for low speeds are present as an alternative to renewable resources.[12]

The north coastal area of Cirebon Regency (-6.670587,108.551807) Jatimerta, Kec. Gunung Jati, Cirebon Regency, West Java has sufficient wind resource potential but has not been widely utilized to meet household electricity needs in the area. Thisresearch utilizes a low-speed neodymium type wind turbine generator as an alternative source of household electricity in the north coastal area of Cirebon Regency. This research is expected to contribute in maximizing the utilization of renewable energyresources and can provide new solutions to reduce dependence on PLN electricity and develop the use of renewable energy in the region.

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1.1 Basic Theory

Before the 20th century, only 10% of wind energy could be converted into mechanical energy by wind turbines of the type used at that time. Today, with modern wind energy conversion systems (WECS), this figure reaches up to 50%. In 1920 and 1926,[13] Albert Betz calculated the optimal geometry of rotor blades, and the maximum wind turbine performance, which is now called the Betz limit.[14] According to the Betz limit, 59% of wind power can be converted into useful energy sources.

The introduction of wind turbines is favored by the high wind speeds typical of the northern regions of Russia.[15]" The highest average annual wind speeds are characteristic of the sea coast in the Arctic and Pacific oceans (above 6-8 m/s), in continental regions the average wind speed decreases to 2-5 m/s.

In the case of wind energy, the motion of the wind is used to rotate a generator that converts kinetic energy into electrical energy." Wind energy, although clean and inexhaustible, still faces many challenges at the industrial level. One of the biggest challenges is the cost of a complete wind turbine system. One of them is the design of the wind turbine generator. The desired generator should be small and lightweight, but such a design always leads to a trade-off in the aspect of output power.

Permanent Magnet Synchronous Generators (PMSGs) and Doubly Fed Induction Generators (DFIGs) are the most commonly used in wind turbines.[16] PMSGs have several advantages over DFIGs. PMSGs can be driven directly without a gearbox thereby reducing weight, mechanical losses, and maintenance requirements. These properties make PMSGs widely used in wind turbines despite losses in the converter.[17]

Horizontal axis wind turbines, or HAWTs, are the most popular type in real-world applications. Smaller versions can be found in wind farms in rural areas or near cities. Because the winds over the ocean are so strong that they carry more energy, these wind turbines are nowadays also installed in ocean areas.

2. METHODOLOGY

This research uses experimental methods, system design and data analysis. The data generated by the Use of Low Speed Neodymium Magnet Wind Turbine Generator as an Alternative Electricity Source in the North Coast Area of Cirebon Regency This research involves the steps as shown in Figure 1.

2.1 Tool Design

In this research, a buck boost converter was used to increase the voltage produced by the neodymium generator. below is a wind power generator design using a neodymium generator.

2.2 Working System Of Wind Power Plant

Wind energy is channelled through wind turbines that turn the blades of a generator rotor. The stronger the wind speed, the faster the rotation of the blades and the generator rotor. The rotation of the generator rotor will produce an alternating voltage on the generator stator.

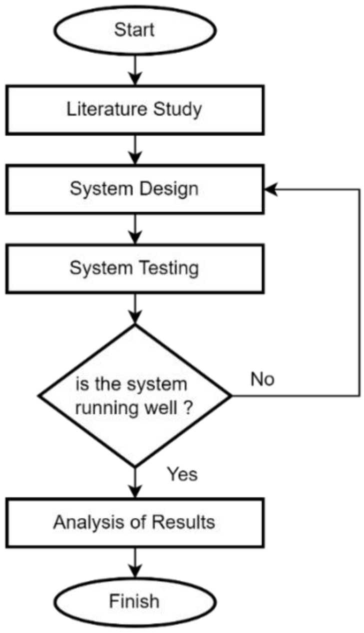

Fig. 1. Flowchart of the Methodology

This voltage will be extracted through the stator cables. The resulting alternating voltage is then rectified into a direct voltage using a diode bridge. The diode bridge will direct the unidirectional flow of electricity only so as to produce a DC voltage. The buck boost converter voltage regulator will then adjust the DC voltage to be suitable for charging the battery. cutoff functions as an automatic voltage breaker when the battery is full. The battery will be charged with a pre-regulated DC voltage. This battery will supply electrical power to the load. The electrical power from the battery will power the lamp as an example load. So in summary, wind energy is emitted, converted into electricity, directed, converted, and stored to power an electrical load. This circuit system works well, it can optimize the utilization of energy generated from turbines and generators in producing stable and efficient electricity.

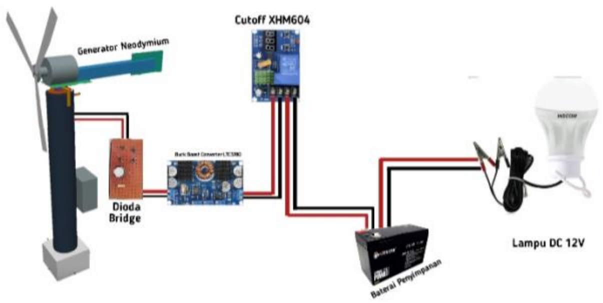

Fig. 2. Schematic design of the proposed system

Flowchart of the working system of a wind power plant in the following figure.

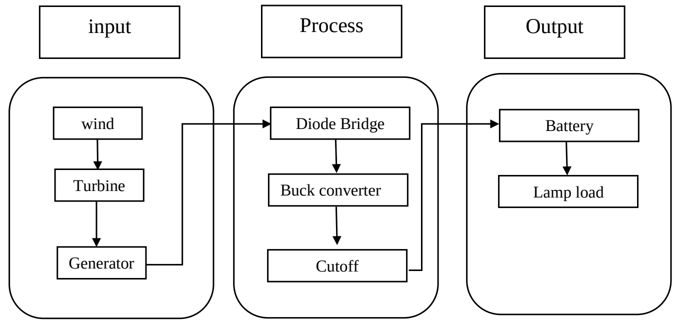

Fig. 3. Tool Design schematic

2.3 Data Collection

After the wind power plant testing process, several parameters need to be recorded, namely.

Table 1. Parameters To be Measured in the test

No.	Parameter	Symbol	Unit	Instrument
1.	Wind Speed	V	m/s	Anemometer
2.	Current	I	Ampere	Avometer
3.	Voltage	V	Volt	Clamp Meter
4.	Turbine Diameter	D	m	Meter

2.4 Time and Place

This test was conducted on June 30, 2024 and July01, 2024 starting at 09.00 WIB until 16.00 WIB in the Kertayasa pond area (-6.670587,108.551807) Jatimerta, Gunung Jati Sub-district, Cirebon Regency,West Java.

2.5 Experiment Setup

The experiment was conducted on June 30, 2024 and July 01, 2024 starting at 09.00 WIB until 16.00 WIB in the kertayasa pond area (-6.670587,108.551807) Jatimerta, Kec.Gunung Jati, Cirebon Regency, This test was carried out on the first day and the second day. the height of the pole is 4 meters with a depth of 50 centimetres below ground level. with 3 propellers that have a length of 50 centimetres each which has a total diameter of 1 meter, shown in Figure 5 and figure 6.

Figure 5 shows the design of the neodymium wind turbine generator system. Figure 7 shows the results of field wind measurements using an anemometer with an average wind speed of 3.3 m/s during the day measured using an anemometer, between 10:00-15:00, which is a good wind speed for wind power generation of about 100W. The wind speed distribution is fairly even with a range of 3.8 m/s, shown in Figure 7 and Figure 8.

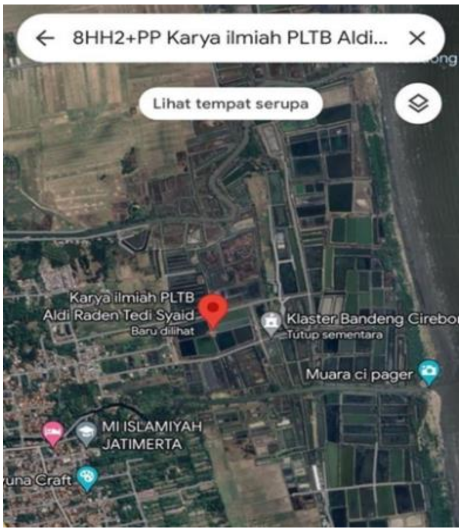

Fig. 4. Research Location Point

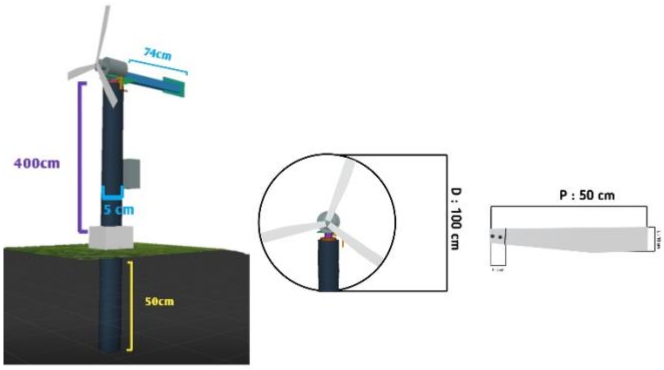

Fig. 5. Wind power plant design

Fig. 6. Wind power plant design results

Figure 6 shows the results of the neodymium wind turbine generator system design.

Fig. 7. wind speed on the ground

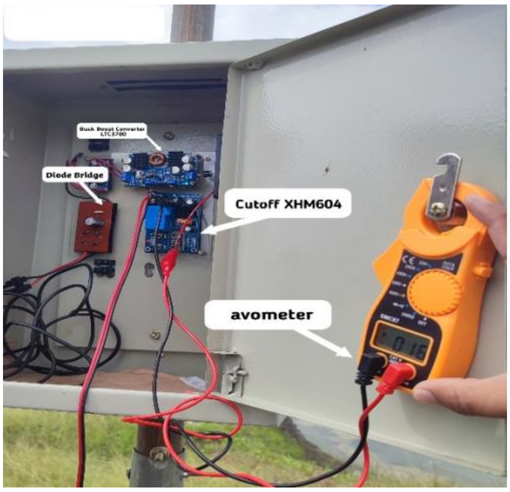

Fig. 8. Field measurement of output voltage

Figure 8 shows the output voltage results of the buck boost converter.

3. RESULTS AND DISCUSSIONS

3.1 Wind Energy Potential and Characteristics

Cirebon Regency has geographical conditions that make it potential for the utilization of renewable energy, especially wind energy. The northern coastal area of the regency, which is directly adjacent to the Java Sea, has a flat and open topography, allowing consistent wind flow. To determine the potential of wind energy in the area, direct measurement of wind speed and generator rotation data was conducted.

Table. 2. Measurement of wind speed data

Hours	RPM	Wind speed (m/s)
09.00	167	2,7
10.00	182	3,3
11.00	170	3
12.00	180	3,1
13.00	181	3,3
14.00	187	3,5
15.00	168	3,3
16.00	153	2,8

The results show a fairly even distribution pattern of wind speed. The highest average speed occurs during the day between 10:00-15:00, which is 3.3 m/s. This wind speed is considered good for application in mini/micro wind turbines in the range of 10-100W. The generator RPM also follows the wind speed pattern, showing a positive relationship between the two. This condition indicates that the considerable potential of wind kinetic energy can be exploited into two. This condition indicates that the considerable potential of wind kinetic energy can be exploited into electrical energy.[15] For papers with less than six authors: To change the default, adjust the template as follows.

3.2 Neodymium generator performance

Based on the test results, the neodymium type wind turbine generator is able to operate at various wind speeds. In the speed range between 2.7 to 3.6 m/s, the generator can already utilize wind energy even in low conditions.[18] This can be seen from the generator being able to work and produce an output voltage above 11 Volts. In general, the higher the wind speed will be followed by an increase in revolutions per minute, input voltage, and generator output voltage. This proves that there is a positive relationship between wind speed and the resulting performance.

Some of the time there were fluctuations in the output voltage even though it was low.[19] This was thought to be influenced by the unstable wind direction at that time. However, the voltage remained above 11 Volts so that it could be utilized to charge the battery. Overall, the generator has proven capable of operating in various wind speed conditions and generating adequate electrical power.

3.3 Test Results

This test was carried out at 12:00 WIB until 13:00 WIB in the area Jl. empang kertayasa (- 6.670587,108.551807) Jatimerta, Kec. Gunung Jati, Cirebon Regency, West Java. This test aims to determine the generator speed, wind speed, generator Vout and Vout buck boost converter that can be generated by the Bayu Power Plant that has been made.

From the measurement data, it can be seen that the average wind speed is 3.14m/s and the generator output voltage value is an average of 5 volts and the output voltage from the buck boost converter is an average of 12.4 volts. This can be used as a battery charging system and can be connected to an inverter so that it can be used for electrical loads.

Table 3. Wind Power Plant Test Result

No.	Hours	RPM	Wind Speed (m/s)	Generator Vout (V)	Buck Boost Converter Vout (V)
1.	12:00	180	3,1	5	14
2.	12:10	187	3,5	5	14
3.	12:20	155	2,3	4	9
4.	12:30	146	2,8	4	8
5.	12:40	182	3,4	5	14
6.	12:50	181	3,2	6	14
7.	13:00	193	3,7	6	14

3.4 Wind Power Plant Data Analysis

Based on the calculations that have been carried out, the results obtained from the wind turbine test data analysis graph are as follows:

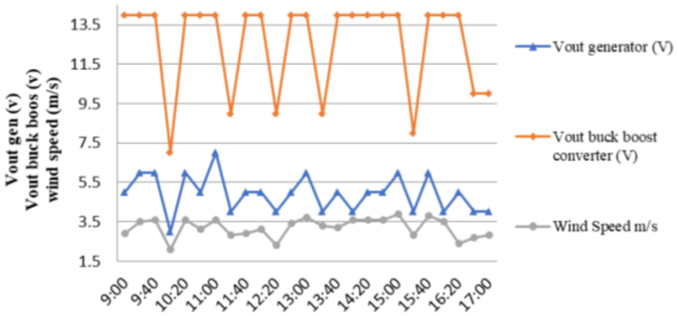

Fig. 9. Wind Power Plant Test Results

The wind speed recorded during the test ranged from 2.1 to 3.9 meters per second. This indicates that the wind speed conditions at the study site were adequate. This wind speed is in accordance with the characteristics of the northern coastal area of Cirebon Regency. In addition, there is an increase in the generator output voltage value along with the increase in wind speed. This indicates that the generator works well in utilizing the energy contained in the wind flow.

The test data shows that the buck boost converter is able to stabilize the voltage value to a range of 8-14 Volts despite fluctuations in wind speed and generator voltage. This implies a stable buck boost converter performance. There were two data points where the voltage conditions did not match even though the wind speed was relatively the same, presumably due to temporary fluctuations in wind speed. Most of the data indicated a dominance of 3-3.6 m/s wind speed and a converter voltage of 14 Volts, which is suitable for optimal electrical energy generation. The system is proven to work in the range of wind speeds at the test site, making it potentially applicable as an alternative power source.

3.5 Relationship of Wind Speed to Time

Graph of the relationship between wind speed and time taken from 10:00 am to 4:00 pm.

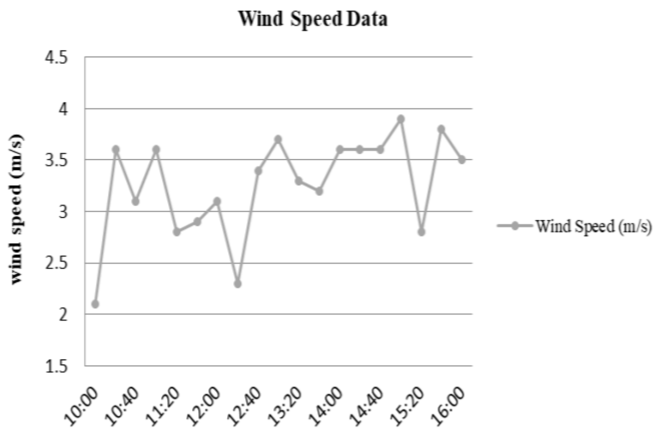

Fig. 10. Wind Speed Data

It can be concluded that the wind speed when data collection begins fluctuates. The highest wind speed was recorded at 15:00 WIB with a wind speed value of 3.9 m/s. If analyzed, the speed of 3.9 m/s is the highest value of all wind speed data recorded at these specific hours. This indicates that at 15:00 WIB, the strength and speed of the wind is the strongest compared to other times. In other words, at that time the air currents generated by the movement of the wind are blowing the fastest. While the lowest wind speed was recorded at 10:00 am, this value of 2.1 m/s is the lowest when compared to all data. This indicates that at 10:00 am, the strength and rate of airflow generated by the movement of the wind is the slowest. In other words, in that time frame, the wind blows the slowest or weakest of all other times.

4. CONCLUSION

The potential and characteristics of wind energy in the north coastal area of Cirebon Regency are very good. This is indicated by the average wind speed of 3.3 m/second during the day between 10:00-15:00 WIB which is good for mini/micro wind power plants of around 100W. The distribution of wind speed is quite even with a range of 2.7-3.9 m/sec. This area has a flat and open topography so that the wind flow is consistent. The neodymium type wind turbine generator design is capable of utilizing wind energy at low speeds between 2.7-3.6 m/sec. The generator is specifically designed for low speeds so that it can operate and produce voltages above 11 Volts even in low wind conditions. The performance of the designed neodymium type wind turbine generator is proven to be able to operate at various wind speeds. The greater the wind speed will be followed by an increase in rotation per minute, input voltage, and generator output voltage. This indicates a positive relationship between wind speed and the resulting performance. The generator is able to produce adequate electrical power despite fluctuations in wind speed.

This research has been implemented directly in coastal areas to utilize wind energy directly as a turbine drive, in contrast to previous research that has not been carried out in coastal locations and only tests using engine simulations. This research is more actual because it has conducted direct trials at the location of its wind energy resources.

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