Reliability test prototype wind turbine savonius type helical as an alternative electricity generator

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Abstract. The consumption of energy in the world today is still dominated by fossil fuels that will gradually run out. This period we must utilize renewable energy sources. One source of renewable energy that is environmentally friendly and we can use is wind energy. Wind turbines can be used to generate electrical energy so that it can solve one of the energy problems for people in need. A suitable wind turbine at low wind speed and medium wind speed is a type of Savonius turbine. The development of research is made prototype wind turbine. This test is carried out on a prototype of a vertical axis type wind turbine and aluminum flask. The rotor has a diameter of 350 mm and a height of 440 mm. The measured parameters were wind speed, rotation speed of rotor, voltage, and current of the generator. The performance of wind turbine savonius in this test at wind speed 4 m/s up to 6 m/s, maximum rotation of turbine shaft 35.40 rpm, electric power 6.94 watts at 6 m/s, at 6 m/s wind speeds produce wind power of 18.65 watts and produce electrical power of 6.94 watts.

1. Introduction

Wind power production has been under the main focus for the past decade in power production and tremendous amount of research work is going on renewable energy, specifically on wind power extraction [1]. With the rapid development of wind power industry, wind turbine reliability has become a hotspot in wind power[2]. Wind power is one of the most abundant sources of renewable energy in our country and environmentally friendly because it depresses CO2 emissions, therefore we can obtain unlimited electricity from wind energy[3]. Wind power is useful energy from wind[4]. Wind power plants convert wind power into electrical energy by using windmills or wind turbines. The way it works is simple enough that wind turbine spins are passed to the generator rotor where the generator has a copper winding that functions as a stator[5].

One of the wind turbines capable of starting to spin at low wind speeds because it has a high self-starting wind turbine is a vertical axis type savonius [6]. This wind turbine has a simple construction that can be applied on a small to medium scale. In this research will be seen and observed the reliability of prototype wind turbine savonius type. This type has been designed and manufactured by Siregar [7] which, the size of the rotor diameter 350 mm and height 440 mm, as well as 10 Watt and a diameter of 8 mm turbine shaft.
2. Wind Turbine

Based on the orientation of the rotor rotation, the wind turbine is divided into two types namely horizontal and vertical axis. The horizontal axis of rotation is parallel to the direction of the wind, while the vertical axis is opposite to the direction of the wind. Horizontal axis-based axis lift, slim blade, and high rotational speed. The rotor-based vertical axis drag force, wide blade and low rotational speed.

2.1. Savonius Wind Turbine

Type Savonius as shown in Figure 1, was created by a Finnish engineer SJ Savonius in 1929. This Vertical Axis Wind Turbine (TASV) is the simplest and most large version of an anemometer. Savonius turbine can rotate because of the force of the thrust from the wind so that the rotation of the rotor will not exceed the wind speed. This type of turbine is suitable for low power applications and is usually used at different wind speeds.

Figure 1. Working Principles of TASV Savonius [8]

One type of vertical axis wind turbine that can be used at low-speed winds is the Savonius wind turbine. The turbine construction is very simple, composed of two half-cylinder blades. On the development of this turbine Savonius undergo many changes in the shape of the rotor, as shown in Figure 2.

Figure 2. Changes in the shape of the rotor

2.2. Wind Power

Wind power, \( P_a \) defined as multiplication between the mass flow rate, \( \rho A v \) with kinetic energy per unit mass \( \frac{1}{2} V^2 \) wind [7], can be expressed:

\[
P_a = \frac{1}{2} \rho A v^3
\]  

(1)

Wind power is the input power carried by the wind to be converted by the turbine rotor into a shaft rotational mechanical power.

2.3. Electrical Power

Electrical power, \( P_g \) is the power out of the generator in the form of voltage (V) and current (I). By measuring the amount of voltage generated, the amount of power generator can be written:
\[ P_{g} = V \cdot I \]  \hspace{1cm} (2)

2.4. Tip Speed Ratio

Tip speed ratio (TSR), \( \lambda \) is the ratio of the rotor tip to the free wind speed. For certain nominal wind speeds, the speed ratio tip will affect the rotor speed. The elevator type wind turbine will have a larger speed ratio tip compared to the drag type turbine. The magnitude of the speed ratio tip can be calculated by the equation;

\[ \lambda = \frac{w_r}{v} \]  \hspace{1cm} (3)

Figure 3 shows the variation of speed ratio and power coefficient, \( C_p \) for various wind turbines.

![Figure 3. Value of speed ratio and power coefficient on different types of wind turbines [7]](image)

2.5. Power Coefficient

To state the performance of a wind turbine is usually expressed in terms of power coefficients, \( C_p \) which is the ratio of the power generated by the turbine to the wind power obtained. Coefficient Wind turbine power can be calculated by the formula;

\[ C_p = \frac{P_m}{P_a} \]  \hspace{1cm} (4)

3. Experiment and Methods

The prototype of the wind turbine type savonius turbine has been made and placed on a wind tunnel for observation, as shown in Figure 4.

![Figure 4. Prototype wind turbine type savonius turbine [5]](image)
Wind turbine design savonius vertical axis helical type has the following dimensions and specifications:

- Rotor diameter = 350 mm = 0.35 m
- High rotor = 440 mm = 0.44 m
- Area of Turbine Cross section (rotor) \( A = 0.15 \) \( m^2 \)
- Shaft diameter = 8 mm
- Rotor power = 10 Watt
- Maximum power \( P_m = 5.82 \) Watt

3.1. Measuring instrument
In testing wind turbine savonius helical type is used measuring tools, among others:

- Anemometer serves to measure wind speed.
- Tachometer serves to measure the rotation of the turbine shaft (rpm). Measurements are made on the wind turbine shaft.
- Multimeter serves to measure the quantity of electricity often known as VOM (Volt-Ohm meter) which can measure voltmeter, ohm-meter, and current (ampere meter).

3.2. Test Procedure
Test to determine the performance of wind turbine savonius helical type which have been made with the following test procedures:

- Setup of wind tunnel test equipment.
- Arrangement of measuring equipment research equipment
- Place the wind turbine savonius wind turbine in the wind tunnel suction test
- Prepare the measuring instrument (anemometer, tachometer, multimeter) and capture data simultaneously.
- Record the data.
- Data processing.

4. Results and Discussion
From the measurement and calculation results obtained as in Table 1

| V (m/s) | N (Rpm) | \( P_a \) (Watt) | \( P_g \) (Watt) | \( \lambda \) | \( C_p \) |
|--------|---------|-----------------|-----------------|-----------|---------|
| 4      | 20.40   | 5.53            | 1.68            | 0.093     | 1.052   |
| 4.5    | 23.20   | 7.87            | 2.28            | 0.094     | 0.740   |
| 5      | 28.60   | 10.79           | 3.52            | 0.104     | 0.539   |
| 5.5    | 32.80   | 14.37           | 5.66            | 0.109     | 0.405   |
| 6      | 35.40   | 18.65           | 6.94            | 0.108     | 0.312   |

4.1. Wind Speed Against Turbine Round
The effect of wind speed on the turbine rotor rotation is shown in Figure 5. In this case, the wind speed is directly proportional to the resulting rotation, meaning the greater the wind speed that touches the blade, the greater the turbine rotation produced, the greater the energy given by wind to the turbine, the turbine's energy can be turned into a bigger turn. With wind speed 6 m/s obtained shaft rotation 35,40 rpm, while wind speed 4 m/s obtained spindle shaft equal to 20,40 rpm.
Figure 5. Effect of wind speed on the turbine spin

4.2. Axis Round Against Power
The graph is shown in Figure 6, that the increasing speed of rotation of the turbine shaft increased the electrical power and wind power.

Figure 6. Effect of shaft rotation on power

4.3. Wind velocity with Power Coefficient and Wind Power
The power coefficient and wind power obtained are inversely proportional to wind speed, where the faster the wind, the smaller the power coefficient produced and the greater the winding power produced.

Figure 7. The Wind Speed Relation with the Power and Power Coefficients
5. Conclusions
The performance of Savonius prototype wind turbines can be taken as follows: (1) The resulting wind turbine rotation is directly proportional to the wind speed, where the wind speed of 6 m/s produces a wind turbine rotation of 35.40 rpm and a wind speed of 4 m/s produces a turbine rotation of 20.40 rpm; (2) The power coefficient at wind speeds of 6 m/s is 0.312; (3) At a wind speed of 6 m/s produces wind power of 18.65 watts and produces electrical power of 6.94 watts.

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