Design of Mini Horizontal Wind Turbine for Low Wind Speed Area

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Abstract. Demand for energy continues to increase lately due to the increase in the number of people in the world. The technology of wind turbine is currently under development, especially for a low wind speed characteristic. This study was research which was conducted to determine the output of voltage and current produced by the designed wind turbine. The direct current motor was used and worked as a generator of the wind turbine. Data collection of the outputs produced were obtained by the direct analysis using a fan. It was found out that the designed wind turbine could rotate with a low wind speed started from the wind speed of 1.5 – 2.4 m/s. Based on results, it concluded that the designed wind turbine had a potential to be converted into electrical power at a low wind speed area with the cut-in speed of 1.5 m/s.

1. Introduction

Over the past few years, the issue of increased demand for energy has become one of the major problems due to the increased number of people in the world. The world population is around 6.8 billion in 2009 and expected to increase. Based on the high demand for energy, the total energy consumption in the world increased from 549 x 10¹⁵ in 2012 to 629 x 10¹⁵ in 2020 and 815 x 10¹⁵ in 2040 [1]. Renewable energy is one of the solutions to overcome and to reduce the emission produced by using the fossil energy [2,9].

There are several types of renewable energy that have been developed such as solar energy, biomass, hydro energy, geothermal and wind energy [3]. The wind energy is one of the promising alternative and renewable energy [4,11]. Compared to other available energy sources, the wind energy offers environmentally friendly, and it costs smaller operational and maintenance cost [13]. Some of the areas have a low wind speed characteristic [10]. It motivates researchers in the world to develop technology by using wind as a source to produce electricity from the rotation of its blade, known as a wind turbine. Based on the axis of its rotation, the wind turbine is categorized into two types, the horizontal axis, and the vertical axis wind turbine. Many researchers claimed that the horizontal axis wind turbine (HAWT) had better performance and widely used compared to the vertical axis wind turbine (VAWT) [5,6].

A horizontal axis wind turbine is a turbine with an axis of rotation parallel to the wind direction or the ground. The horizontal axis wind turbine has been developed into many variations based on the blade quantities. The quantities of the blade are one of an important term. The efficiency of the turbine is influenced by the number of blades implemented in the wind turbine [7]. The most commonly used for a wind turbine is three blades [14]. Some of the areas have a low wind speed characteristic, especially in Indonesia. Based on the data taken from the monthly report of Meteorology, Climatology and
Geophysics Council, the highest wind speed was 6 knots or around 3 m/s [19]. Thus, the purpose of this research is to determine the output of the designed horizontal turbine in the low wind speed characteristic area such as rotational speed, voltage, and current. In recent years, most of the researchers were interested in developing a mini size wind turbine for areas that had a low wind speed characteristic as shown in Table 1. This research was conducted by making and testing the designed wind turbine. The blades of the wind turbine were rotated using the fan. The fan used had five variations of wind speed. Later, the rotor rotated and produced electricity based on the wind speed applied.

### Table 1. Summary of the current mini size wind turbine

| Author                | Number of Blades | Rotor Diameter (cm) | Wind Speed (m/s) | Power (mW) |
|-----------------------|------------------|---------------------|------------------|------------|
| Federspiel et al. (2003) [16] | 4                | 10                  | 2.5              | 8          |
| Priya et al. (2007) [17]  | 12               | 10.2                | 4.4              | 5          |
| Xu et al. (2009) [18]   | 4                | 7.6                 | 4.5              | 18         |

2. Methodology

The research was started with a literature study of the theory development and the study of horizontal axis wind turbine researches. The results of the literature study will contribute to the progress of the research and determine which theory used.

2.1 Working Principle of Wind Turbine

Wind is a natural movement of air flowing from an area with high pressure to an area with low pressure [12,15]. Air itself consists of mass, and then kinetic energy is produced by the movement of the air. Basically, every wind generator work on the same basic principles. Wind turbine blades are rotated by the wind. Then, the blade attached to a generator will start to rotate. The rotation of the generator produces electricity to distribute either directly to the grid or charge the battery [8].

2.2 Design Parameter

Based on the working principle of the wind turbine, there are several parameters to be considered to generate power such as wind speed, size of the blades, number of the blades, height and generator used to produce electricity. The overall design is shown in Figure 1. The designed wind turbine consists of blades attached to a plastic hub, a DC motor, and a tower. The swept area of the wind turbine was about 0.038 m².
2.2.1 Wind Speed. Based on the purpose of this research, the wind speed was classified into five stages started from 1.1 m/s, 1.5 m/s, 1.7 m/s, 2 m/s and 2.4 m/s. The distance between the designed wind turbine and the fan was 40 cm. Wind speed was measured by anemometer based on the flow of wind came from the fan to the wind turbine.

2.2.2 Height. The wind turbine was located at 75 cm above the ground. The turbulence was minimalized due to the closed area during the test.

2.2.3 Number of Blade and Size of Blade. The material used for the blade was aluminum with a thickness of 1.3 mm. Aluminum was selected because of the weight and the durability. The weight of each blade was around 1 gram. The number of blades applied to the wind turbine was three blades with a length of 10.5 cm and the width of 5 cm. Due to the greater stability and durability of the wind turbine, the three blades was chosen. [7] The designed blade of the wind turbine is shown in Figure 2.
2.2.4 Generator. The generator is classified into two types which are direct current (DC) and alternating current (AC). The generator used for this research was a DC motor manufactured by Mabuchi Motor. The specification of the generator is described in Table 2.

| Type     | Value                        |
|----------|------------------------------|
| Model    | Ultra-Dash DC Motor          |
| Voltage  | 2.4 – 3V                     |
| Current  | 4 – 5 A                      |
| Torque   | 24,000 – 27,500 rpm          |

3. Result and Discussion
The results were obtained by observing and analyzing the effect of the wind speed on the rotational speed and the electrical energy produced without the load connected to the output of the designed wind turbine. The output of the wind turbine was measured by multimeter and anemometer as shown in Figure 3, Figure 4, and Figure 5.

![Figure 3. Rotational speed output of the wind turbine](image)

Based on the chart above, the designed wind turbine could produce a rotational speed of 561 rpm at a wind speed of 2.4 m/s. The designed rotor of wind turbine started to rotate at a wind speed of 1.5 m/s and could produce a rotational speed of 443 rpm.

![Figure 4. Voltage output of the wind turbine](image)
Based on the chart above, the designed wind turbine did not want to rotate at a wind speed of 1.1 m/s. The cut-in speed of the turbine was 1.5 m/s and the turbine produced a voltage of 18 mV. The rotation of the wind turbine increased when the rotation of the fan was increased so that the output voltage produced also increased. The highest voltage produced by the designed wind turbine was 37 mV at a wind speed of 2.4 m/s.

![Figure 5. Current output of the wind turbine](image)

During the cut-in speed of the designed turbine, it produced a current of 1.16 mA. The current output also increased when the rotation of the fan was increased. The highest current produced at a wind speed of 2.4 m/s was 2.59 mA. The detailed results of the wind turbine are shown in Table 2.

| Wind Speed (m/s) | Rotational Speed (rpm) | Voltage (mV) | Current (mA) |
|------------------|------------------------|--------------|--------------|
| 1.1              | 0                      | 0            | 0            |
| 1.5              | 443                    | 18           | 1.16         |
| 1.7              | 456                    | 20           | 1.28         |
| 2                | 509                    | 26           | 1.67         |
| 2.4              | 561                    | 37           | 2.59         |

4. Conclusion
The designed horizontal axis wind turbine could rotate at a minimum wind speed of 1.5 m/s, but the voltage and current produced were smaller compared to the previous researches. The designed wind turbine could produce a voltage of 18 mV and current of 1.16 mA at a wind speed of 1.5 m/s. The highest voltage output produced from the wind turbine was 37 mV and the highest current output produced was 2.59 mA at a wind speed of 2.4 m/s. The wind turbine could produce better voltage output and current output by using a wind tunnel. The wind tunnel was used to reduce the turbulence around the wind turbine during the observation and analysis phase.

5. References
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