The potential of wind velocity in the Banda Aceh coast to the ability to generate electrical energy by horizontal axis wind turbines

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Abstract. The wind is air that moves from a high-pressure area to a low-pressure area. Indonesia has the potential of winds that have speeds ranging from 2 m/s to 6 m/s which blow for a period of 6 hours/day. Many researchers have examined what kinds of problems are in the context of wind turbine energy generation. This study discusses the effect of wind speed and variations in the number of turbine blades on the power generated by horizontal wind turbines to rotate generators, case studies on the coast of Banda Aceh. The windmill used is a horizontal turbine propeller type with 5, 6 and 7 blade variations and made from Meranti wood. Electricity data retrieval is done by pairing the generator, so that the data taken in this measurement is in the form of wind speed data (m/s), speed of rotation of the wheel shaft and generator shaft, and generator voltage (V) and electric current generated. Data collection is carried out for 6 days at 3-9 m/s wind speed. The results showed that for wind speeds below 5 m/s it is more ideal to use a small number of turbines and for wind speeds greater than 7 m/s it is better to use a turbine blade with a large number of blades.

Keywords: Wind Speed, Energy, Voltage, Wind Turbines and Horizontal Shaft

1. Introduction
The wind is air that moves from high pressure areas to low pressure areas. As for the wind factor, there are four factors: Barometric gradient, location, height and time that effect the pressure. In Indonesia winds ranging in speed from 2 m/s to 6 m/s blow within 6 hours/day This is considered very suitable for building small (10 kW) to medium wind power generation (10 - 100 kW) [1]. Whereas in the Banda Aceh region, especially the coastal areas have wind speeds with an average of 4 m/s, but wind can blow at a speed of 4-6 m/s within 4-5 hours per day [2].

There are huge potential of hybrid power systems to power agricultural water pumps, a combination of solar and wind energy, to drive agricultural pumps is an extraordinary potential that can be developed [3-6].

Experimental studies were carried out in the building fields of Horizontal Axis Flow Turbines in various Loading Conditions. The aim of the study was to investigate the characteristics of horizontal tidal axis turbine wake in various conditions of tip speed ratio. Wake fields were measured by a towed
underwater stereoscopic particle image Velocimetry system. The scale ratio of the turbine model was 1/20 and the Reynolds numbers based on 0.4R chord length ranged from 53,000 to 63,000. The turbine was rotating in constant revolution rate of 240 rpm, while advance speeds of the turbine model were varied to achieve various tip speed ratio (TSR) conditions [7-9].

Surface pressure data from the National Renewable Energy Laboratory’s “Unsteady Aerodynamics Experiment” were analysed to characterize the impact of three dimensionalities, unsteadiness, and flow separation effects observed to occur on downwind horizontal axis wind turbines (HAWT). Surface pressure and strain gauge data were collected from two rectangular platform blades with S809 airfoil cross-sections, one flat and one twisted [10].

Wind turbines convert the kinetic energy of wind into mechanical energy and then this energy is converted into electrical energy. Khin Kyawt Lin's research has described the design calculation and stress analysis of horizontal wind turbines (1kW) with the average wind speed, \( V_{avg} \) is 4 m/s and the Reynolds number, 46406 is calculated based on viscosity, density, and wind speed [11, 12].

Ikhsan [13] tested the effect of the number of 3-7 blade windmills with a horizontal axle on shaft rotation which produced a maximum rotation of 1751 Rpm in the number of blades 5 when the wind speed was 6 m/s without generator load. Rijal [14] conducted a comparison of the number of blades 3 and 4 made of wood (meranti wood type) horizontal propeller windmill type Naca 4418 airfoil model with wind speeds of 1-8 m/s and different rotation speed between 3 and 4 windmills blades.

Other researchers also studied the characteristics of wind turbines both experimentally and numerically. Saravanan et al. conducted an experimental investigation on small horizontal axis wind turbine rotor using winglets [15]. Jadallah et al. investigated the optimal performance of horizontal axis wind turbines for low wind speed regime [16]. Furthermore, Shanmuga studied about power, performance and energy generation analysis of horizontal axis wind turbines [17].

Malik, et. al. modelled and simulate three-dimensional adjustable horizontal axis wind turbine blade, using a commercial Computational Fluid Dynamics (CFD) code [18]. Eshwaran et al. examined an aerodynamic design and analysis of horizontal axis wind turbine (HAWT) blades Using CFD [19].

Based on the above phenomenon, in this study, we will experimentally measure the ability of wind turbines to generate electricity based on the potential wind speed on the coast of Banda Aceh. Tests are carried out on wind turbines that have a number of blades of 5, 6, and 7 pieces, which will be placed at wind speeds ranging from 3-9 m/s. The blade material is made from local wood of meranti wood. Meranti wood is a versatile wood that is easily found in Aceh, has a hard texture and has a long durability. This makes meranti wood as one type of wood, which is widely used for various purposes such as household furniture and building construction materials. The shape of the turbine blade is taken from the provisions of the Naca 4418 type airfoil with a horizontal shaft.

This study is to determine the electrical power generated by generators with variations in the number of blades 5, 6 and 7 at 3-9 m/s wind speed. So that in this test data retrieval is only done at 3-9 m/s wind speed. Then the windmill that will be tested on the shape of the pinwheel is taken from the provisions of the Naca 4418 type airfoil, the Material of Blade is made of wood (meranti wood type). The turbine testing is performed on variations in number of blades 5, 6 and 7.

2. Experimental method
In this test the parameters measured are wind speed, turbine shaft rotation, electric generator shaft, and voltage generated by the generator. The test is carried out for 6 days in December 2018 on the coast of Ulee Lheue, Banda Aceh City, Indonesia. To measure wind speed (m/s) a digital anemometer is used, the altitude measurement of wind speed is 10 m above sea level, equivalent to a wind turbine shaft. To measure shaft rotation speed (rpm), Tacometer Laser is used. Measurement of electrical voltage (V) uses a voltmeter and measurement of electric current (A) using a clam meter by attaching a clam meter to the cable and connecting it directly to the generator.
The tested wind turbines have blades made from meranti wood with a length of 100 cm per blade, a maximum width of 20 cm, and a maximum thickness of 30 cm. This wooden blade is made using a planer and grinding machine by hand as shown in figure 1 and figure 2. The variation in the number of blades is shown in figure 3.

**Figure 1.** Work results of blade airfoil naca Type 4418.

**Figure 2.** Horizontal shaft wind turbine with 5 blades.

**Figure 3.** Horizontal shaft wind turbines with number of blades 5, 6 and 7.
Specifications of horizontal wind turbines
1. Type: Propeller.
2. Turbine diameter: 200 cm.
3. Number of turbine blades: 5, 6 and 7.
   • Material: Wood (merante).
   • Blade weight: 1.2 Kg.
   • Blade length: 100 cm.
   • Blade width: 20 cm.
   • Thickness: 2 cm.
   • Airfoil type: Naca 4418.
   • Pitch angle: 10°
4. Generator: Induction
   • Capacity: 1000 watts
   • Speed: 1500 - 6000 rpm
5. Transmission Pulley: Carbon steel, 2:10

3. Experimental results
This study examines and analyzes the wind speed potential on the coast of Banda Aceh against the ability to generate electrical energy using horizontal shaft wind turbines. Because of that, the measured parameters are wind speed, turbine rotation and voltage generated by the generator and the electric current produced.

3.1. Effect of wind speed on rotation.
The relationship between wind speed and rotation produced by windmills and generators using 5, 6, and 7 blades is shown in figure 4 below.

From figure 4 we can see that the wind speed greatly affects the magnitude of the rotational speed of the turbine shaft and the electric generator shaft, which is obtained. Wind turbines with a number of 7 pieces of blades give the highest shaft rotation value of 1488 Rpm at wind speeds of 9 m/s. Furthermore, the wind turbine with a number of blades of 6 pieces produces a maximum shaft rotation of 1428 Rpm. While the wind turbine with a number of 5 pieces produces the highest rotation of 1306 Rpm.

However, in wind turbines that have a number of 7 blades, the initial rotation of the shaft produced at wind speed conditions is 3–4 m/s, very low compared to other wind turbines. This is due to the greater blade weight compared to wind turbines, which have fewer blades.

It can be explained based on figure 4, that in terms of the relationship of wind speed to the initial rotation of the shaft, wind turbines with a number of blades 5, have better characteristics for electricity...
generation. Although the maximum speed is a little lower compared to the other number of blades, the most important wind turbine with 5 blades is able to do the initial low wind speed rotation.

In general, electric current can be generated if the generator rotation is around 2000 rpm, so to increase the rotation of the shaft of the electric generator; a pulley is used with a magnification of 2:10 times. So that the generator shaft rotation can be increased as shown in figure 4.

3.2. Effect of wind speed on electrical voltage
The relationship of wind speed to the electricity voltage generated by the generator with variations in the number of wind turbine blades as 5, 6 and 7 pieces can be seen in figure 5. From figure 5, it can be seen that each number of blades will produce the highest voltage of 220 V, but it is produced at different wind speeds. In the 7 blades wind turbines, the highest voltage is generated at wind speeds of 8 m/s whereas in the 6 blades wind turbines the highest voltage is generated at 8.5 m/s wind speed. In the 5 blades wind turbines, the highest voltage is produced at a speed of 9 m/s.

From the picture, it can be seen that each blade can produce the highest voltage similar. But we can also see that in 7 blades, voltage can only be generated when the wind speed starts to reach 5 m/s and the speed does not exceed 8 m/s, because the voltage fails because the rotation exceeds the generator capacity. Similarly, in the case of 6 blades wind turbines, the initial voltage can be generated at wind speeds of 4.5 m/s and fail at 9 m/s.

So, it can be concluded that blade 5 works best because it can work when high wind speeds are 9 m/s and when the wind is still at a low speed of 3.5 m/s.

3.3. Effect of wind speed on power generated
From figure 6 we can see that the wind speed and number of blades greatly affect the turbine power produced. At the initial speed of 3 m/s to 4.5 m/s turbines that have 5 blades produce high generator power compared to the others. But when the wind speed reaches 5 m/s, the turbines with 6 and 7 blades are capable of producing a slightly greater power. When wind speeds reach 6 m/s to 9 m/s, turbines that have 7 blades produce higher power output than others. At a maximum wind speed of 9 m/s, a 5-blade turbine produces only 600 watts of power, a 6-blade turbine produces 800 watts of power and a 7-blade turbine can produce power above 1000 watts.

From the relationship between wind speed and turbine power we can conclude that the 5-blades turbine has optimal performance at wind speeds of 3 m/s to 6 m/s compared to other turbines. Whereas at wind speeds above 6 m/s, turbines that have 6 and 7 blades have better performance in generating power.
3.4. Effect of wind speed on generator power
This objective of this study is to determine the ability of wind turbines to generate electrical energy available by wind speeds on the coast of Banda Aceh. In figure 7, it can be seen that based on the measurement results, the electric power produced will increase with increasing speed, until a condition of the optimum speed of the wind to the turbine. The 5 blades turbine shows that the speed continues to increase power and produces a maximum power of 800 Watts at 8-9 m/s wind speed. The power produced by this turbine is far greater than the others at 5-6 m/s wind speed, which reaches 200 Watts, but then decreases to lower than other turbines at 7 m/s wind speed of 500 Watts.

While the turbine which has 6 blades produces a maximum power of 825 Watts at wind speeds of 8 to 8.5 m/s, and produces optimal electrical power and is greater than other turbines at wind speeds of 6 to 7 m/s which is equal to 350 Watts and power of 600 Watts at 7.5 m/s wind speed.
4. Discussion

Based on the measurement results, it is clear that the number of turbine blades and the wind speed that blows greatly affects the performance of the wind turbine. In a turbine that has 5 blades, the turbine shaft starts rotating at a wind speed of 3 m/s with a rotation of 200 rpm. Turbines with 6 blades begin to rotate at a wind speed of 4 m/s with a turbine shaft rotation of 250 rpm, where in these wind speed conditions, turbines that have 5 blades have reached a rotation of 400 rpm. Whereas the turbine with 7 blades starts rotating at wind speeds of 4.5 m/s with a rotating speed of 200 rpm, where at this wind speed the turbine with 5 blades has reached shaft speed 450 rpm and turbine with 6 blades, shaft rotation reaches 300 rpm.

At wind speeds of 6 m/s, the turbine rotation with 5 blades has reached 550 rpm, while in turbines with 6 blades and 7 blades, the rotation has reached 700 rpm. Furthermore, at a wind speed of 8 m/s, the rotation of the 5 blades turbine reaches 1100 Rpm, the 6 blades turbine rotates 1200 rpm and the 7 blades turbine reaches 1250 rpm. While at 9 m/s wind speed, the 5 blades turbine produces a rotation of 1300 rpm, a 6 blades turbine produces a rotation of 1400 rpm and a 7 blades turbine produces a rotation that reaches 500 rpm.

The turbines with a small number of blades can rotate at low wind speeds because the weight of the propeller turbine is small so that it requires a smaller thrust force to rotate the inertia of the turbine shaft, compared to the turbines that have 6 and 7 blades. This is caused by the weight of the propeller, which is, of course, linear with the number of blades. In this case the weight of the 5 blades turbine propellers is 6 Kg, and the 6 blades turbine is 7.2 Kg and the 7 blades turbine is 8.4 Kg.

The voltage distribution trend generated by the generator is almost the same as the rotation generated by the electric generator in each number of turbine blades. In the 7 blades turbine the voltage recorded on the measurement is only up to 8 m/s wind speed with a voltage of 218 Volts, this is due to the limited ability of the generator used, with capacity of 1000 Watt. While in the 6 blades turbine are still recorded up to a wind speed of 8.5 m/s with a voltage of 214 Volts, and in a turbine of 5 blades, the voltage is still recorded when the wind speed reaches 9 m/s which is equivalent to 206 Volts.

The power that can be generated by a 7 blades turbine increases rapidly after wind speeds above 5 m/s to wind speeds of 9 m/s with turbine power of more than 1 KW. At speeds below 4 m/s turbine power generated by turbines that have 5 blades is bigger than the others. While the electric power generated by the generator due to the rotation of the 5 blades turbine at wind speeds below 6 m/s is greater than the 6 and 7 blades turbines. At wind speeds above 7 m/s to 8 m/s the 7 blades turbine has a higher electric power compared to the 6 blades turbine and 5 blades turbine.

From the discussion above it can be seen that for wind speeds below 5 m/s it is better to use small number of turbines and for wind speeds greater than 7 m/s it is precise to use turbines with a large number of blades. The choice of the number of turbine blades is very dependent on the wind speed available in the area where the turbine is placed. The selection of the right wind turbine will greatly affect the performance and sustainability of the use of wind turbines as a power plant.

5. Conclusion

From the results of experiments on three horizontal type wind turbines with different number of blades on Banda Aceh coastal, it can be concluded as follows:

- Turbines with a small number of blades can rotate at small wind speeds because the weight of the propeller turbine is smaller so that it requires a push force to drive the turbine inertia smaller than the turbine with a larger number of blades.
- At low wind speeds, higher rotations will produce by turbines that have a slight blade. But at higher wind speeds, turbines that have many blades will result in higher rotational speeds.
- At wind speeds below 6 m/s, the electrical power released by a 5 blades turbine is greater than that of 6 and 7 blades turbines. However, at higher wind speeds electric power of 7 blades turbines is larger compared to 6 blades turbine and 5 blades turbine.
Wind turbines with a small number of blades are more appropriate to use at wind speeds below 5 m/s while wind turbines with a large number of blades are more suitable to use at wind speeds greater than 7 m/s.

The selection of the number of turbine blades is very dependent on the availability of wind speed in the area where the turbine is placed.

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