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Analysis of the Effect of Variation in the Number of Taperless Type Blades on the Performance of a Horizontal Axis Wind Turbine with Naca 4412 Airfoil

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Abstract

The need for electrical energy which continues to be widely needed by society and industry today is a major factor in their daily needs and activities. Wind energy is one of the renewable energy that is environmentally friendly. At present the utilization of wind energy continues to be developed, one of which is a wind energy conversion system that converts wind kinetic energy into mechanical energy and then converts it into electrical energy through a generator. The amount of electricity generated by the generator depends on the rotating speed of the blades and the speed of the wind that hits the blades on the wind turbine. In this research is how the performance of horizontal shaft wind turbines with variations in the number of blades with the aim of obtaining optimal results of torque, power and efficiency. The tests carried out in this study were simulated on the Q Blade v 0.96 software with variations in the number of blades 2 to 6 and the average wind speed data in the West Java region. That the results of the tests carried out produce a graph that compares the number of blades to the power, torque, and efficiency produced by a wind turbine.

Keywords: Number of Blades, Taperless, Torque, Power, Solidity

INTRODUCTION

Renewable energy is one of the main alternative needs in human life, as the population continues to increase and the rapid development of the industrial world results in an increase in energy needs, wind energy is an alternative source of clean and potential renewable energy today as a source of generators for exploited and developed. Currently in Indonesia the need for electrical energy is increasing along with the increasing population. Almost all human activities every day require electrical energy from a power plant that can meet their daily needs. The sources of wind energy are unlimited and do not cause air pollution. Applying this source of electricity generation is called the Wind Energy Conversion System (SKEA). A wind turbine is an energy conversion tool by utilizing wind energy as an energy source to drive a wind turbine shaft. According to Atmadi, et al., 2011 that a wind turbine is a device capable of converting kinetic energy by utilizing the wind speed hitting the blades so that it becomes mechanical energy which is passed on to the generator shaft as a producer of electrical energy (Fitroh: 2011). The principle of this tool is that the kinetic energy of the wind is converted into mechanical energy and then the shaft is connected to a generator to be driven which produces electrical energy (Wuratama: 2019).

The most widely used type of wind turbine today is the horizontal axis wind turbine. Some of these wind turbines generally have two or 3 blades, but there are also wind turbines with more than 3 blades. The workings of a wind turbine rotor rotates due to the lift force on the blades caused by the air fluid flow. Many horizontal axis wind turbine developments have been carried out in order to optimize performance [3]. Wind turbine efficiency can be increased to get the maximum power coefficient. There are several important factors in choosing the type of blade that must be considered, namely the power coefficient (CP) and tip speed ratio (TSR). The greater the CP value, the higher the ability of a turbine to obtain energy. The greater the TSR value, the greater the rotation. This indicates that the tip speed ratio, wind speed and lift and drag coefficients are important parameters in analyzing taperless blades, because they can affect the performance of horizontal shaft wind turbines (Alfaridzi: 2020).

Initially, many farmers used wind turbines to pump water for irrigation canals and wells to irrigate their agricultural land. In the past, many wind turbines were built in the Netherlands, Denmark and other European countries, known as windmills. Now wind turbines are more widely applied to electricity needs by using the principle of energy conversion that uses natural resources by utilizing wind (Mulkam: 2019).

RESEARCH METHODS

Wind Turbine

A wind turbine is a tool that is used to convert energy or to change the kinetic energy of the wind by utilizing the wind speed that hits the blades so that it becomes mechanical energy which is passed on to the generator shaft as a producer of electrical energy (Fitroh: 2011). Initially, wind turbines were widely used by farmers to pump water from irrigation canals and wells to irrigate their agricultural land. Many earlier wind turbines were built in Denmark, the Netherlands and other European countries and are better known as windmills. Now wind turbines are more widely used to accommodate people's electricity needs, using the principle of energy conversion and using renewable natural resources, namely wind (Taufan: 2015).

Horizontal Wind Turbine

In general, horizontal shaft type wind turbines have blades that resemble propellers. Small wind turbines with a tail-shaped wind direction system at the end of the generator must adjust to the wind direction, while large wind turbines generally use servo motors and wind direction sensors. The characteristics of a horizontal axis wind turbine have stiff blades so they don't bend at high wind speeds. The blades that are owned by a horizontal type wind turbine with a cross-sectional shape with airflow on each side can move faster when the wind passes through the blades. This incident can cause an area with low pressure behind the blade and an area of high pressure on the front side of the blade so as to form a force that causes the blade to rotate (Alfaridzi: 2020).

Rotors and generators in horizontal axis wind turbines are at the ends of the tower which are mounted horizontally. Large wind turbines generally have a gearbox which aims to obtain a higher rotation than the rotation of the turbine blades. This type of wind turbine has an airfoil-shaped blade geometry resembling the shape of an airplane wing. The horizontal axis wind turbine has the advantages of high efficiency and low cut-in wind speed. However, there are drawbacks to this wind turbine, namely the design is complicated because the rotor can only catch wind from one direction, so a wind direction is needed. (Alfaridzi: 2020).

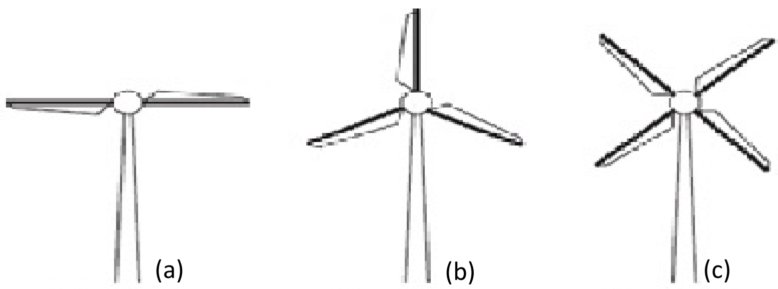

Figure 1. Types of Horizontal Axis Wind Turbines (a. 2 blades; b. 3 blades; c. 4 blades) (Hau: 2012)

Lift Force and Drag Force

The flow of fluid that passes through an object will affect the lift of an object caused by the difference in pressure above and below the surface of the object. In addition, the drag force is a force parallel to the direction of the fluid's arrival (Taufan: 2015).

Blade Element Momentum Theory (BEMT)

Blade element momentum theory (BEMT–Blade Element Momentum Theory), this theory is a combination of blade element theory and momentum theory which was first put forward in 1878 by Rankine-Froude (Hau: 2012). This momentum theory was first modified in 1921 by Betz, then in 1926 Glauert perfected it. This theory contains a mathematical model for calculating ideal power in wind turbines, wind thrust for turbines and the effect of turbine operation on wind conditions in the surrounding environment which applies the principle of calculating linear momentum to the disk actuator model. However, elemental blade element theory explains the principle of calculating the aerodynamic forces of the blade (Saefudin: 2018).

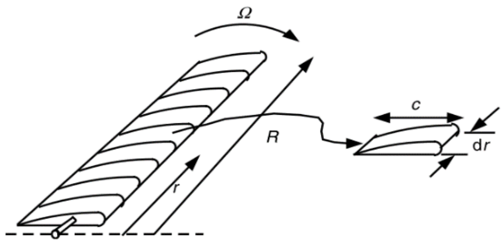

Figure 2. Schematic of the Elements on the Blade (Gral: 2020)

Power Output

The power coefficient is the ratio between the power produced by a wind turbine and wind power:

$$d(\mathbf{x}, \mathbf{y}) = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + \cdots + (x_n - y_n)^2}$$

RESEARCH RESULTS AND DISCUSSION

Process Simulation

In this section, we will discuss a simulation of a wind turbine with a horizontal axis taperless blade type with a varying number of blades using the Qblade v 0.96 application to obtain wind turbine performance results in the form of numbers and graphics from the simulation results.

Count Reynolds

The first stage before carrying out the simulation process using the Qblade v 0.96 application is to determine the variables used by calculating the Reynolds value. The following are the parameters and measures that will be used in the research process.

1. To determine the value of the Reynolds number, use the following equation: Re = (ρ .V .c)/μ
2. After getting the Re value based on the parameters and values that have been determined. The Reynolds value is calculated based on the relative wind speed and the diameter of the turbine for more details in Table 1. With the parameters of relative wind speed (W) and absolute wind speed hitting the turbine (V).

Table 1. Calculation of Reynolds (Re)

Wind velocity [m/s]	R [m]	Ur [m/s]	Wr [m/s]	Re
3	0,1 - 1,2	1,75 - 21	3,4 - 21,2	27940 - 170654
4	0,1 - 1,2	2,3 - 28	4,6 - 28,2	38105 - 232739
5	0,1 - 1,2	2,9 - 35	5,7 - 35,3	46566 - 284422
6	0,1 - 1,2	3,5 - 42	6,9 - 42,42	55880 - 341307
7	0,1 - 1,2	4 - 49	8,1 - 49,49	65193 - 398192
8	0,1 - 1,2	4,6 - 56	9,2 - 56,56	74506 - 455076
9	0,1 - 1,2	5,25 - 63	10,41 - 63,63	83820 - 511961
10	0,1 - 1,2	5,8 - 70	11,5 - 70,7	93133 - 568845
11	0,1 - 1,2	6,4 - 77	12,7 - 77,7	102447 - 625730
12	0,1 - 1,2	7 - 84	13,8 - 84,85	111760 - 682615

From the results of these calculations, it is obtained that the different Reynolds number ranges are caused by different wind speeds. In the simulation that will be carried out on the Qblade v 0.96 software. using the Reynolds number from the smallest, namely 27940 to the largest, namely 682615.

Making Blade Shapes with NACA 4412 Airfoil

When going to do a simulation there are a number of things that need to be input when doing a simulation of making a blade shape. These points include determining the number of blades to be simulated, the hub radius and the twist angle on the blades. From these points, input the mass of each experiment, namely the variation in the number of blades with blade variations 2 to 6. Here the author will present the shape of the blade variations with NACA 4412 airfoil with a pitch angle of 15° in Figure 3 below:

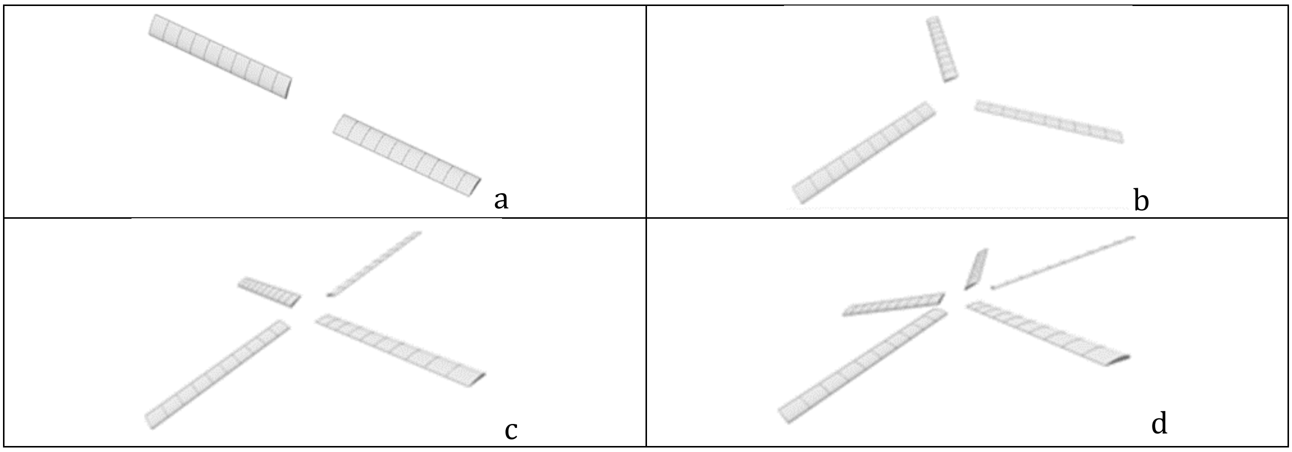

Figure 3. Variation in Number of Blades (a. 2 Blades; b. 3 Blades; c. 4 Blades; d. Blades)

Calculation Simulation on Blades

The power value generated by the variation in the number of blades has a significant difference from the number of 2 blades to 5 blades which is affected by the wind speed that hits the blades. At low wind speeds, a wind turbine with a number of 2–4 blades is very effective because it does not need to start the wind turbine rotation with a large wind speed, compared to a wind turbine with a total of 5 blades which must start the wind turbine rotation with a relatively high wind speed. large, because the more the number of blades, the value of solidity in wind turbines is greater and the value of efficiency in wind turbines decreases. With a comparison, the variation in the number of horizontal wind turbine blades will affect the most efficient value for the performance of the wind turbine. Where the blades that have the most number will produce greater torque and power, but on the other hand, the more blades are not necessarily a good efficiency value, while the smaller number of blades produces less torque and power but has a good efficiency value.

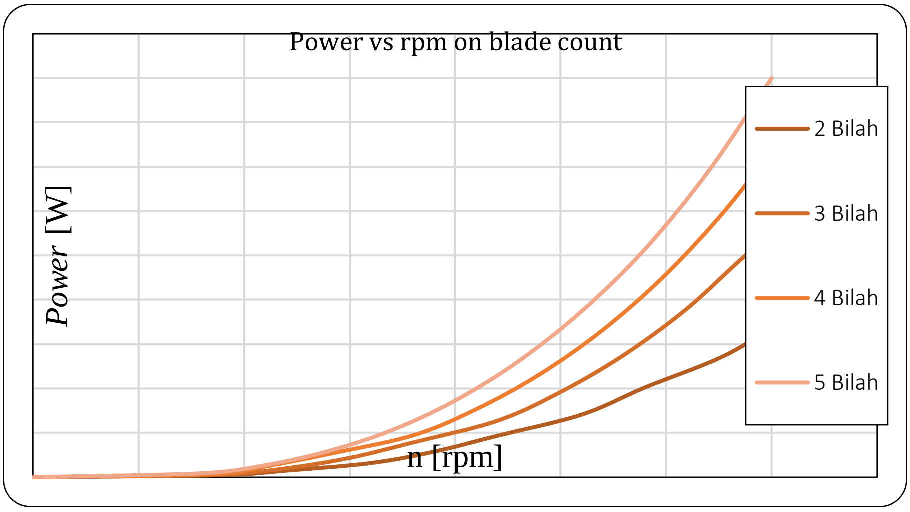

Figure 4. Graph of Power vs rpm on Number of Blades

CONCLUSION

Based on the results of the simulations performed, it indicates that the performance of wind turbines with variations in the number of blades has a significant difference in torque and power as well as the resulting efficiency. This is because it is influenced by the increasing number of blades and increasing wind speed. In research conducted by varying the effect of the number of blades to get optimal results, namely on blades 3 – 5, where the value of the power generated in the wind turbine increases and the value of good efficiency can be seen up and down in the graphical form shown in Figure 4.

Notation List

Re	= Reynolds number	A	= Area [m2]
P	= Density of fluid [kg/m3]	CD	= Coefficient of drag
W	= Relative speed of flow [m/s]	D	= drag force [N]
C	= chord length / blade width [m]	T	= Thrust / wind thrust [N]
Utip	= Tangential velocity at the tip of the blade [m/s]	Q	= Wind turbine torque [N]
V	= Inlet flow/wind absolute speed [m/s]	A	= Linear induced flow factor
CP	= Power coefficient	a'	= Rotational induced flow factor
Pturbine	= Turbine power [W]	r	= Local radius/element position [m]
Flow	= Flow power [W]	R	= Turbine radius [m]
CL	= Coefficient of lift	Ω	= angular speed of the wind turbine [rad/s]
L	= Lift force [N]	B	= Number of wind turbine blades [pieces] φ

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