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Modeling And Analysis Of The Savonius Type L Wind Turbine With Variations In Geometry And Number Of Blades On Airflow Using CFD (Computational Fluid Dynamics) Method

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Abstract: The use of fossil energy has a negative impact on the preservation nature, wind turbines are one form of renewable energy utilization solutions that are environmentally friendly. This study was conducted to determine the performance of the L-type Savonius vertical axis wind turbine modified with variations in geometry and number of blades against airflow. Based on the simulation results using Ansys 2023 student version, it is known that the smaller the angle of attack of the blade, the greater the potential power , while the increase in the number of blades makes the potential power decrease. Turbines with the number of blades 3 with an angular geometry of 30° have the most optimum performance, namely with a maximum airflow velocity at the tip of the turbine blade of 11.2 m/s, the resulting torque of 2345 Nm with an optimum angular velocity of 46.914 rad/s resulting in a potential power of 110.014 Watt.

Keyword: Vertical axis wind turbine, Savonius, Simulation, Potential Power, Torque

INTRODUCTION

Energy is an essential need in human life, especially in the present era where technological advancements are rapidly progressing. The equipment used to support human activities largely relies on fossil energy, which is a non-renewable energy source that will eventually be depleted.

Wind energy is one of the natural energy forms available, obtained through the conversion of kinetic energy using turbines. Wind energy is transformed into kinetic energy, mechanical energy, and electrical energy. Wind energy plays an important role in reducing carbon emissions because there is no CO2 emission produced during electricity generation by wind turbines.

There are two main types of wind turbines based on their rotational axes: vertical-axis wind turbines (VAWT) and horizontal-axis wind turbines (HAWT). The wind potential in Indonesia generally has low wind speeds ranging between 3-8 m/s (I.B. Alit, Nurchayati, 2016), making vertical-axis wind turbines particularly suitable for use in such conditions. The wind speed is low. Generally, the most commonly used wind turbine design is the horizontal-axis wind turbine. However, vertical-axis wind turbines are becoming an alternative for generating electricity due to several advantages (Yulianto, 2020).

Previous research by Ridwan and Abdul Latief concluded that the number of blades on the vertical-axis wind turbine of the Savonius type affects the distribution of wind velocity and the distribution of pressure exerted on the turbine blades (Ridwan, 2019). Therefore, the author conducts a study on wind turbines to determine the performance of the L-type Savonius vertical-axis wind turbine on airflow by varying the geometry and the number of blades.

The research problem to be addressed in this study is the effect of geometry variations on the performance of the L-type Savonius vertical-axis wind turbine on airflow using the CFD (Computational Fluid Dynamics) method.

METHOD

The research method contains the type of research, sample and population or research subject, time and place of research, instruments, procedures and research techniques, and other matters related to the research method. This section can be divided into several sub-chapters, but it is not necessary to include the numbering.

Figure 1. Research Flowchart

Tools and Materials

The tools used in this study include a computer for the simulation process. The software used on the computer includes Solidworks and Ansys 2023 RI Student Version.

Research Procedure

The research procedure is conducted as shown in Figure 2. Based on the figure, there are several stages in this study. The first stage is identifying and formulating the problem, followed by determining the research objectives, and then conducting a literature review. The next stage is the simulation process. Afterward, the analysis and discussion of the results are carried out to draw conclusions.

Simulation Process

The simulation of the vertical-axis wind turbine in this study is conducted in several steps, as shown in Figure 2. The simulation process begins with modeling the turbine. The next step is importing the model into Ansys. The following step is preparing the turbine mesh. The geometry preparation has been carried out using CAD software, specifically Solidworks. In Ansys 2023 software, the maximum mesh element limit is set to 512,000 elements. Then, the simulation area boundaries are defined, followed by setting up turbine and simulation parameters. These parameters include air velocity, initial angular velocity of the turbine, fluid turbulence model, environmental pressure, fluid material, and turbine material (the turbine material used is the default material specified by the software). The process is then followed by iteration or computation in the Ansys software. It is important to ensure that the simulation is valid, and the computational results show converging data. If the data results are convergent, the process can proceed to the next step. If errors occur, it will return to step two, the mesh preparation. The final step involves calculating the simulation results using the power equation.

RESULT AND DISCUSSION

Wind Turbine Specifications

The turbine used in this study is a vertical-axis wind turbine (VAWT). The variations to be discussed are the comparison of the blade angle geometry and the number of blades. The blade angles used are 30°, 40°, and 50°, with the number of blades being 3 and 4. Figure 2 shows an example of the specifications of the wind turbine used.

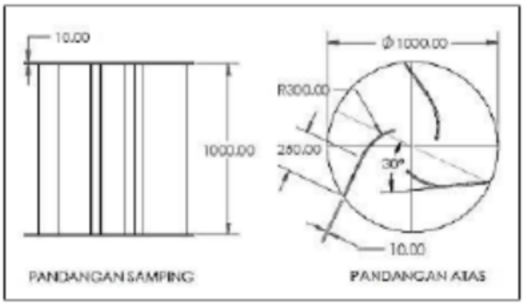

Figure 2. Turbine Specifications

Modeling of the Wind Turbine using SolidWorks

The turbine modeling is done using the CAD software, SolidWorks.

Research Parameters

The results obtained from the simulation process are the torque of the wind turbine and the wind speed on the blades. The torque and angular velocity of the turbine obtained are then input into the power equation. The parameters input into the simulation are shown in Table 1.

Table 1. Simulation Parameters

Tipe Sudu	Tipe L
Kecepatan Angin	5 m/s
Massa Jenis Udara	1,225 kg/m^3
Temperatur	288 K
Viskositas Udara	1,7894x10^{-5} kg/m.s
Kecepatan Sudut	10 rad/s
Model Turbulensi	k-ε Realizable
Gauge Pressure	0 Pa
Kecepatan Sudut	10 rad/s
Material Turbin	Aluminium

Simulation Results

Residual Graph

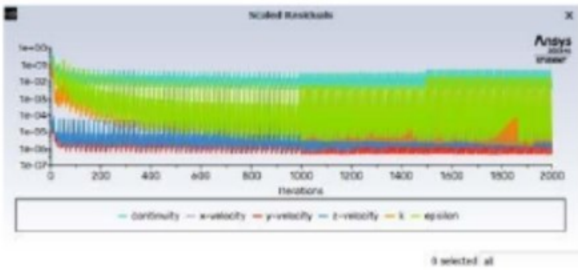

Figure 3. Residual Graph

The residual graph can be observed during the computation process until completion, where the final condition indicates convergence, as shown in Figure 4 below, marked by the absence of errors. The residual graph appears to fluctuate due to the repeated computation process from the beginning after completing the calculation for 10 iterations up to 200 number of time steps.

Torque Graph

Based on the torque data from the simulation, the torque graph shown in Figure 5, the torque obtained is 2.345 Nm.

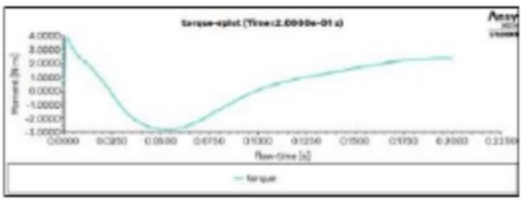

Figure 4. Torque Graph of the Wind Turbine Simulation Results with 3 Blades and a 30° Blade Angle

Fluid Flow Contour

In this simulation, the fluid characteristic taken is the flow velocity. The flow velocity data on the turbine blades is required for calculating the optimum angular velocity of the turbine.

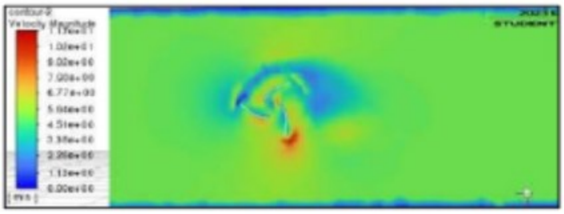

Figure 5. Fluid Flow Contour

Using the known values, here is the calculation and the data results for the optimum angular velocity calculation.

$$\omega_{opt} = \frac{2\,.\pi\,.v_{maks}}{n\,.\,r}$$

$$= \frac{2\,.\pi\,.11{,}2\ m/s}{3\,.\ 0{,}5\ m}$$

$$= \frac{70{,}371\ rad.m/s}{1{,}5}$$

$$= 46{,}914\ rad/s$$

Discussion

The data obtained from the simulation results in torque and air flow velocity values, which are then calculated using the relevant equations to find the optimum angular velocity and power potential, which will subsequently be plotted into a graph. From this graph, the characteristics of each wind turbine model that has been simulated can be concluded.

Table 2. Simulation Results Data

Geometri	Jumlah sudu	v_{maks} (m/s)	Torsi (Nm)	ω_{opt} (rad/s)	Potensi Daya turbin (Watt)
Sudut 50°	3	9,4	2,668	39,374	105,051
Sudut 40°	3	10,2	2,539	42,725	108,480
Sudut 30°	3	11,2	2,345	46,914	110,014
Sudut 50°	4	10,1	0,885	31,730	28,081
Sudut 40°	4	10,3	1,284	32,358	41,548
Sudut 30°	4	11,7	1,514	36,756	55,649

Relationship Between Blade Geometry and Wind Turbine Power Potential with 3 Blades

Figure 6 shows that the relationship between blade geometry and the power potential of a 3-blade wind turbine is directly proportional. As the blade angle facing the wind direction decreases, the power potential produced increases. This is because a smaller blade angle allows more efficient use of wind energy, resulting in higher optimal speed at the blade tip. From the graph above, it can be seen that the highest power potential is produced by the wind turbine with a blade angle of 30°, which is 110.014 Watts.

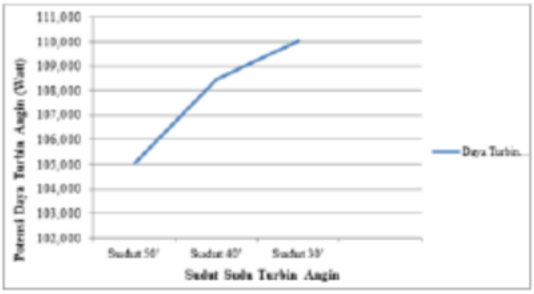

Figure 6. Graph of the Effect of Blade Angle on Power Potential of a 3-Blade Turbine

Relationship Between Blade Geometry and Wind Turbine Power Potential with 4 Blades

Figure 7 shows that the relationship between blade geometry and the power potential of a 4-blade wind turbine is directly proportional. As the blade angle facing the wind direction decreases, the power potential produced increases. This is because a smaller blade angle allows more efficient use of wind energy, resulting in higher optimal speed at the blade tip. From the graph above, it can be seen that the highest power potential is produced by the wind turbine with a blade angle of 30°, which is 55.649 Watts.

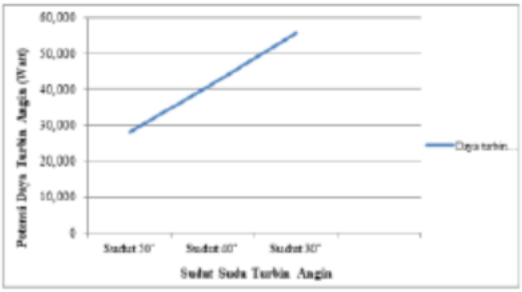

Figure 7. Graph of the Effect of Blade Angle on Power Potential of a 4-Blade Turbine

Relationship Between the Number of Blades and Wind Turbine Power Potential

Figure 8 shows that the relationship between the number of blades and the power potential of the wind turbine is directly proportional, meaning that as the number of blades increases, the power potential produced decreases. This is due to the increase in vortex flow, which results in a decrease in wind turbine performance. From the simulation results, there are 6 wind turbine models, and the turbine that produces the highest power potential is the wind turbine with 3 blades and a 30° blade angle, which generates 110.014 Watts.

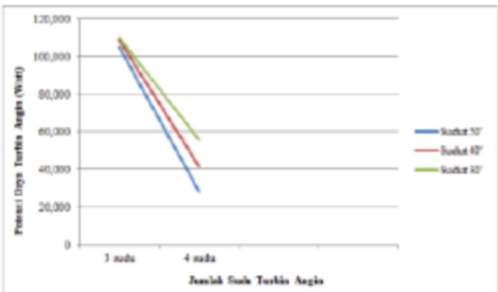

Figure 8. Graph of the Effect of the Number of Blades on the Power Potential of the Turbine

CONCLUSION

Based on the research results conducted on the L-type Savonius wind turbine design, it was found that there is an influence of blade angle geometry and the number of blades on the power potential generated. The smaller the blade angle facing the wind direction, the greater the power potential produced. On the other hand, increasing the number of blades results in a decrease in the power potential produced by the L-type Savonius wind turbine.

The optimum performance of the wind turbine is achieved with 3 blades and a blade angle of 30°, with the maximum airflow velocity at the turbine blade tip being 11.2 m/s, a torque of 2.345 Nm, and an optimum angular velocity of 46.914 rad/s, resulting in a power potential of 110.014 Watts.

Suggestions

The suggestions that can be made from this study are as follows:

1. The research can be continued by varying the airflow velocity, blade angle, and using more blades.
2. The study can be extended to include simulations of material strength to determine the wind turbine geometry with the best resistance to airflow and the rotational movement of the wind turbine.

Acknowledgments

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