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Study of Optimization Darrieus Wind Turbine Using Numerical Investigation

Edy Susanto[1,2*], Paryanto[2], Hadiyanto[2], Ariyo Nurachman Satiya Permata [3], M. Yasep Setiawan[4]

[1] *Departemen of Mechanical Engineering, Institut Teknologi PLN, 11750, Jakarta, Indonesia.*
[2] *Program Studi Program Profesi Insinyur Fakultas Teknik, Universitas Diponegoro, Semarang, Indonesia*
[3] *Departemen of Mechanical Engineering Republic of Indonesia Defense University, Sentul, Indonesia.*
[4] *Universitas Negeri Padang, Padang, Indonesia*

*Corresponding author: *edy.susanto@itpln.ac.id*

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ABSTRACT

The difficulty of accessing the PLN electricity network, especially in the 3T area, has led to the need to develop and implement adequate use of New Renewable Energy (EBT). Wind resources are sources that fulfill part of the electrical energy needs with the help of wind turbines. The Darrieus Wind Turbine in Vertical Axis Wind Turbine (VAWT) performance is exploited for its extraordinary potential in the application of additional advantages and omni-direction. Three different blade number variations were considered in the tests with the NACA 4415 airfoil type. The wind speed was determined based on a wind speed of 15 m/s. From numerical testing, optimal results were obtained for 4 blade variations due to less turbulence.

Keywords: *VAWT, wind power, airfoil, Darrieus*

1. INTRODUCTION

Wind turbines are used to generate energy from wind energy and convert mechanical energy into electrical energy. Wind turbines are classified into two types: horizontal -axis wind turbines and vertical axis wind turbines. A horizontal axis wind turbine rotates the turbine parallel to the ground, and a vertical axis wind turbine rotates the turbine perpendicular to the ground. Horizontal axis wind turbines require a lot of space and produce high power but require high wind speeds. Ideal depending on local wind speed. A vertical axis wind turbine rotates the turbine at a low wind speed and produces the same power as that speed.

They also require less land and are too efficient for local wind speeds. Wind vitality could be a renewable vitality source since it has focal points, negligible effect on the environment, and inexhaustible accessibility [1,2]. Wind power is characterized as a critical development within the 20th century. Already, control plants utilizing steam and fossil powers played a major part in vitality era. In any case, steam control plants have a negative effect on the environment, while fossil powers are in restricted supply. Subsequently, wind control may be a arrangement to overcome this issue. Wind vitality makes up 2.3% of the world's add up to power supply [3] and is anticipated to extend to 22% by 2030 [4]. Wind vitality potential in Indonesia comes to 60,647 MW with wind speeds over 4m/s, making it the third biggest potential in Indonesia. Be that as it may, indeed although this potential is so huge, the introduced capacity for wind vitality utilization has as it were come to 3.1 MW. Within the genuine utilize of wind vitality, as it were 0.01% of the existing potential is accomplished.

Vertical hub wind turbines (VAWTs) have gotten to be imperative in wind control era due to their compactness and capacity to be introduced in household situations. In any case, it is known that VAWTs have lower productivity compared to level hub wind turbines (HAWTs) [1]. Subsequently, it is essential to optimize the turbine to make strides its execution. As was done by [5] which presented edge dividing settings to progress the execution of the Savonius wind rotor. Rotors with distinctive edge dispersing were tried from the wind burrow, and their execution was compared with routine rotors. The result is that the most extreme control coefficient of the Savonius wind rotor increments by almost 38.5% with ideal edge dividing. This thinks about [6] numerically analyzes the insecure stream around a Darrieus sort turbine utilizing Familiar and applies it to the edge plan. The unsteady RANS condition and the turbulence demonstrate, either the k-e or k-ω demonstrate, as suitable for each edge area, were utilized. By shifting the two airfoils NACA 634-021 and NACA 653-018 utilizing 2-dimensional and 3-dimensional numerical examination concluded that the 3-dimensional numerical investigation comes about are near to exploratory values.

This paper has covered up the impact of barrel breadth on the vertical hub of the savonius water turbine [7]. Numerical investigation was carried out to decide the impact of varieties in barrel distance across on the execution and stream characteristics of the turbine by setting the barrel before it. Numerical 2D recreations have been carried out employing a sliding work to unravel hardware revolution beneath temporal conditions and the turbulence demonstrate utilized is realizable k-ε (RKE). A ponder on the impact of robustness and airfoil profile on the execution of Vertical Shaft Wind Turbines (VAWTs) has been displayed by [8]. Next, 3 deflector variations were analyzed numerically to determine the increase in wind speed in the Darrieus rotor type wind turbine and NACA 0015 type blades [9]. Four diverse airfoils – NACA 0012, NACA 0015, NACA 0030 and Discuss 001 – were considered within the investigation. Numerical analysis was performed utilizing Ansys Familiar. The result may be a two-blade VAWT creating more control than a three-blade turbine. This appears that turbines with moo strength work superior at tall λ. A test was conducted to watch the behavior of the vertical hub of the Savonius Wind Turbine (SWT) on a four-way interstate [10]. The beginning behavior of SWT is considered by measuring and calculating the beginning torque coefficient. The explore was carried out on a four-way thruway by setting the turbine in two distinctive positions (center and side). From the information investigation it can be caught on that the wind heading plays an imperative part in expanding the vitality created by the turbine.

The Darrieus wind turbine investigation was assessed by changing the Tip Speed Proportion (TSR) from to 3 m/s due to wind speed with a term of 0.2 m/s as well as approving the freedom of the work and the freedom of time. From the numerical examination, the Tip Speed Proportion (TSR) of 1.8 demonstrates superior execution in little misfortune spaces for moo wind territorial wind speeds. This ponder proposes a unused permeable redirector before the Savonius wind turbine to extend its execution [15]. Numerical examination utilizing the Navier-Stokes condition Reynolds normal which is unsteady in connection to the SST k-ω turbulence model unraveled numerically. Employing a permeable diverter causes wind stream to pass through the permeable zone coming about in harm to the wake zone behind the diverter. The comes about show that there's a fitting porosity esteem to urge the most noteworthy torque and control coefficient. The greatest esteem of the control coefficient is expanded by almost 10% employing a permeable redirector setup which is invaluable at top speed. A few ways, such as vortex demonstrate, or multithreaded pipeline show have been created to predict VAWT execution and optimize its effectiveness. In past inquire about, there are two ways to maximize wind turbine control. The primary is by altering the turbine plan, and the moment is by joining control upgrade gadgets into the wind turbine without changing the most plan. In this ponder, optimization of vertical hub wind turbines by altering the turbine plan was carried out. This turbine adjustment employments a NACA 4415 propeller since it produces a moo ductile drive compared to a propeller with a bigger profile thickness. Numerous numerical recreations think about have been carried out utilizing 2D recreation, where the comes about are well acknowledged as a design parameter in turbine plan [16-19]. Meanwhile [20] predicts recovery wake that occurs behind the dual hybrid VAWT turbine, the results obtained show that the wake recovery in the wind tunnel experiment, in the field x/d = 3 with 99%. Based on the explanation above, the aim of this research is to analyze the NACA 4415 type on variations in the number of blades and wind speed to get the best results that can be used in the 3 T area.

2. METHODOLOGY

2.1. PROBLEM DESCRIPTION

This simulation was carried out by numerical examination of three H-type Darrieus VAWT variations, 4, 5 and 6 blades. The edge contains a NACA 4415 profile, and the underpins have been excluded for ease of investigation.

(a) 4 blades (b) 5 blades (c) 6 blades

Figure 1. H-type Darrieus VAWT configurations

The main reason for varying the number of blades in this research is to obtain optimal results at a speed of 15 m/s. The flow phenomena that occur at the front and rear of the blade are interesting to study.

Table 1. *Blade variations and wind speed*

Variation	Blade	Wind Speed (m/s)
1	4	15
2	5	15
3	6	15

The influence of the number of blades has been studied using three variations of the number of blades between 4.5 and 6. NACA 4415 is an optimal airfoil designed to provide optimal VAWT performance at low speeds. The performance of this optimized airfoil has been compared with conventional symmetric NACA profiles. Turbine details are summarized in figure 1. SolidWorks software has been used to study these parameters for a speed of 15 m/s.

2.2. NUMERICAL MODEL

In isothermal, incompressible flow, the equations of conservation of mass and conservation of momentum in this case are very dominant which are then given by equations (1) and (2). Since the flow velocity in the domain is much less than the speed of sound, it can be assumed that the density remains constant throughout the flow field.

$$\nabla \cdot \bar{v} = 0 \qquad (1)$$

$$\nabla . (\bar{v}) = \nabla\ p + \nabla \cdot (\bar{\bar{r}}) + \rho \bar{g} \qquad (2)$$

Where:

$$\bar{\bar{r}} = (\mu + \mu)\ [\nabla \bar{v} + (\nabla \bar{v})^{T\text{-}2} - \nabla \bar{v} I] t \qquad (3)$$

Where $\bar{v}$ is the velocity, ρ is the density, *p is the pressure,* $\bar{g}$ is acceleration due to gravity, $\bar{\bar{r}}$ is the stress tensor, μ_t is the turbulent viscosity closed by a suitable turbulence model, μ is the dynamic viscosity and I is an identity matrix.

The numerical solution of simulation parameters such as mesh size and processing time duration must be independent. Studies for time step independence were carried out using tΔ which corresponds to 1° and 2° rise per time step and the independenceof the turbulence model was studied using Transition SST and SST-kω models. For the wind speed, turbine speed, and band length considered, re based on the band length is between 4.23x10 and 9.42x105, which indicates the flow is in the transitionregion. The inlet and outlet sections are made at the front and rear while the others are considered as walls at the boundary conditions.

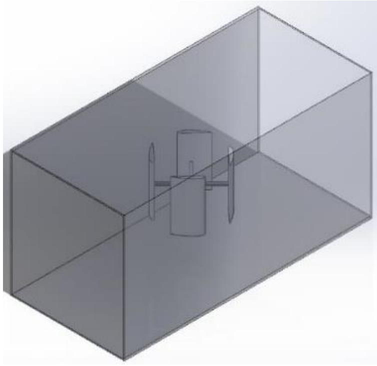

Figure 2. Boundary Condition

Figure 2 shows the Boundary Conditions applied in the research simulation. In this simulation it is assumed that the simulation is carried out in a closed wind tunnel and uses a static simulation model. And to reduce the impact of the intersection ratio or blockage of the wind tunnel with the turbine intersection, first calculate the ratio of the area of the front of the object (2D area seen from the front view) to the cross-sectional area of the test section, it is best to keep it below 3–5%. Therefore, the right, left, top and bottom of the wind turbine model are provided with walls to prevent excessive wind flow and unwanted turbulence.

The application of walls in a wind tunnel simulation has several purposes. First, the wall helps isolate wind flow hitting the wind turbine to focus on the interaction between wind, turbine, and deflector under study. By limiting wind flow from irrelevant sides, it is possible to focus attention on the influence of the deflector on wind turbine performance.

The use of walls in the simulation also facilitates calculations and analysis. By reducing turbulence interference from unconnected sides, the calculation of wind flow and interaction with the turbine and deflector becomes simpler and more controllable. This enables the acquisition of more accurate simulation results and facilitates the interpretation of the data obtained.

However, it is important to note that the use of a wind tunnel and the application of walls in a simulation has limitations and assumptions that need to be considered. For example, the effect of boundary effects on turbine and deflector performance in a real environment may differ from that in a wind tunnel simulation. Therefore, the simulation results need to be analyzed carefully and compared with the actual field test data to validate the findings and conclusions reached.

Overall, the application of a wall in a wind tunnel simulation in this study has the benefit of isolating the wind-turbine-deflector interaction being studied and facilitating calculations and analysis. However, keep in mind that the simulation results need to be verified with actual field data to ensure the accuracy and validity of the research findings.

3. RESULTS AND DISCUSSION

The results of CFD (Computer Fluid Dynamic) simulations using SolidWorks for flow phenomena in turbines that occur at a speed of 15 m/s are as follows:

Mathematical modelling of all blades variations generated results are as follows:

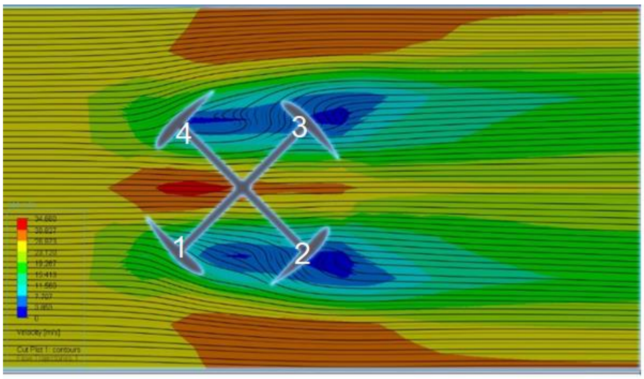

Figure 3. Contour Velocity with 4 blades

Figure 3 shows the contour of air speed towards a turbine with 4 blades at a speed of 15 m/s. For variations in the number of 4 blades, it can be seen that there is a very large air velocity occurring between blades number 1 and 4, this can be seen by the presence of red degradation and this occurs because the position of each blade is formed like a door so that there is no air resistance at that position. the. However, there was a decrease in speed on the back side of each blade, especially blades number 2 and 3.

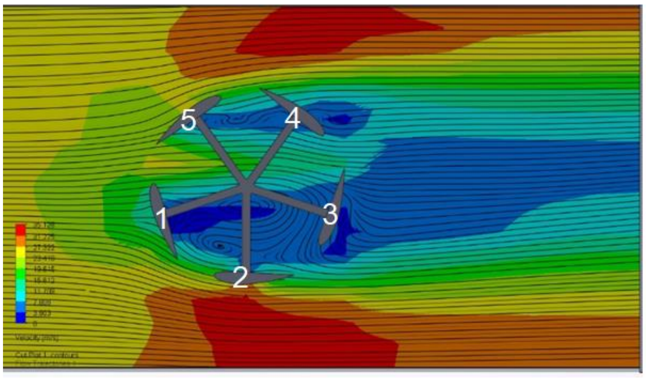

Figure 4. Contour Velocity with 5 blades

The image above shows the contour of air speed towards a turbine with 5 blades at a speed of 15 m/s. Variations in the number of 5 blades show a loss of air speed that occurs between the front side blades, this is due to the presence of air resistance at that position. In fact, the air speed increases on the lower side of the blade (number 3) and turbulent flow phenomena also begin to form on the side of the blade between numbers 1,2 and 3.

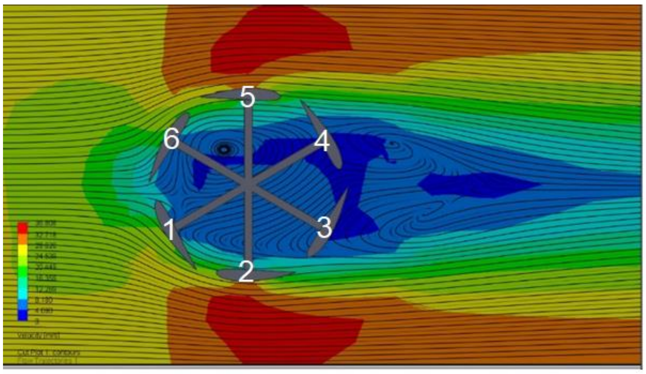

Figure 5. Contour Velocity with 6 blades

The image above shows the contour of air speed towards a turbine with 6 blades at a speed of 15 m/s. For variations in the number of 6 blades, it shows that there is a very large increase in air speed on the sides of blades number 2 and 5, this is because the position of blade numbers 1 and 6 seems to be a profile that blocks the air flow across the turbine blades. And a turbulent flow pattern is formed almost throughout the turbine blade which will certainly become an obstacle to the rotational movement of the turbine.

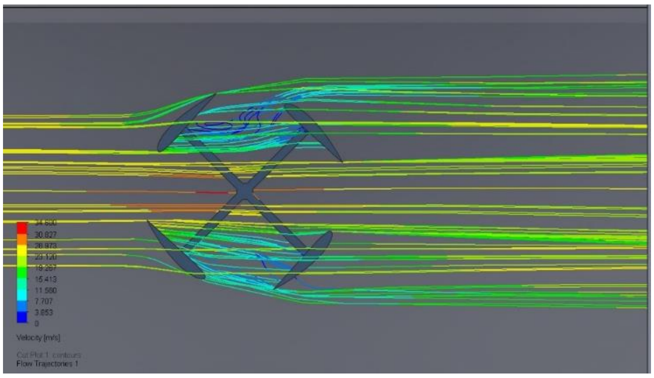

Figure 6. Velocity vector with 4 blades

Figure 6 displays the air velocity vector against a turbine with 4 blades at a speed of 15 m/s. Using this speed vector model will help us observe the flow patterns that occur in the Darrius wind turbine.

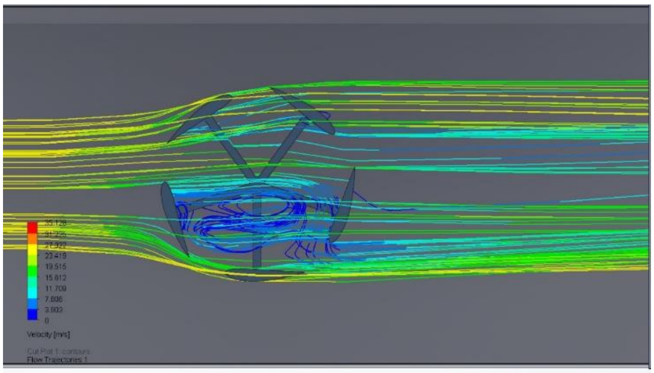

Figure 7. Velocity vector with 5 blades

Figure 7 displays the air velocity vector towards a turbine with 5 blades at a speed of 15 m/s. For variations in the number of 5 blades, it shows that turbulent flow is starting to form between blades number 1, 2 and 3 which will definitely cause the turbine rotation to be unbalanced on the side of the blade where turbulent flow does not occur.

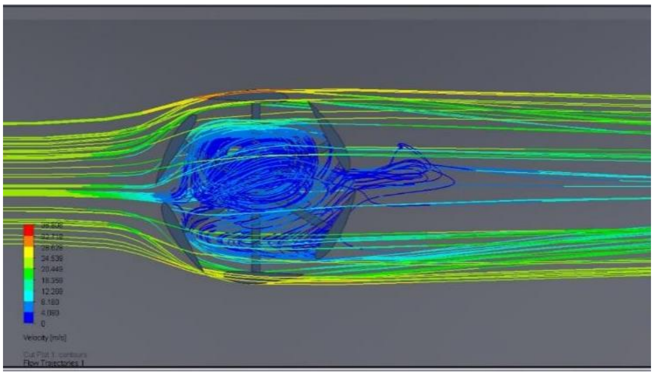

Figure 8. Velocity vector with 6 blades

Figure 8 displays the air velocity vector against a turbine with 6 blades at a speed of 15 m/s. For variations in the number of 6 blades, turbulent flow phenomena tend to dominate on the inner side of the blade. This will of course cause a blockade of air flow.

4. CONCLUSION

Based on the experiments carried out, the effect of blade variations causes an increase in turbine rotation speed ranging from 34.68 m/s, 35.12 m/s, and 36.8 m/s. However, increasing the number of blades causes more air to be trapped in positions in the turbine which then produces a turbulent flow phenomenon. Of course, this turbulent phenomenon increases the frictional force between the air and the blade, causing the torque to decrease. The largest increase in torque force occurred on the Darrius turbine blade in 4 blade variations of 12 Nm. Therefore, the optimal variation obtained is 4 blades.

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