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Savonius Turbine Angle Control System for Optimization of Wind Power

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Abstract:

The advancement of civilization has always been accompanied by a rise in the usage of fossil fuels. This rise is directly proportional to the improvement in the living standards of the people and the advancement of industrialization. As a result, the demand for gasoline is increasing at an alarming rate, necessitating the development of a fuel source that can overcome all obstacles. To alleviate the issue of fossil fuel reliance, it is preferable to pursue the development of renewable energy sources. Wind energy is one of the renewable energy sources available. Wind energy is a clean source of energy that does not contaminate the environment throughout the manufacturing process. Because it has a high beginning torque, the Savonius vertical shaft wind turbine is well suited for usage in low wind speed environments. This turbine has a straightforward design and construction, with its components organized in the form of the letter S. Wind speeds that are unpredictable provide the backdrop against which the vertical wind turbine with the Savonius S rotor shape is acceptable and useful for use as an efficient electric power generator that generates the greatest amount of electricity. There are many benefits to the Savonius S rotor over the Savonius U rotor, the most significant of which is that the Savonius S wind that hits the rotor flows further into the rotor blades, so supplying greater energy to the rotor blades. A prototype of the Savonius S wind turbine was built using inexpensive materials in previous studies but it was not controlled to generate the most amount of electricity possible. Because the wind entering and being able to drive the turbine is always changing, it is necessary to manage the wind speed so that it stays consistent.

Keywords —***Savonius vertical wind turbine, wind turbine efficiency, wind energy***

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I. INTRODUCTION

Energy from the wind, which is considered to be one of the sustainable resources, is energy that can be converted into energy or mechanical while being viable and harmless to the ecology. By converting wind energy into mechanical rotation of the machine and then spinning a tool that is required to be employed, wind energy may be transformed into electrical energy and be used. The transition of wind energy occurs throughout the cycle of this shift, and the equipment used to turn it into energy is referred to as a windmill or a wind turbine at that point in the cycle.

When using wind energy, it is necessary to have knowledge or data on the original wind energy potential that may be obtained in the region of establishment, and the usage of wind energy is dependent on the local context. With a more exact research and evaluation from these two points of view in addition to the financial point of view, an area's energy transformation framework may be used optimally in that region.

The flat shaft wind turbine is the most often utilized form of wind turbine; however, the upward hub wind turbine is the preferred type of wind turbine for producing electrical energy owing to a number of advantages. The vertical wind turbine has a great self-starting capacity, which allows it to revolve the rotor even when the wind speed is low; in addition, the force generated is relatively significant (Sargolzaei, 2007).

Indonesia's wind potential is often characterized by modest wind speeds ranging from 3 m/s to 7 m/s. The Savonius turbine is the kind of turbine that is best suited for low wind speeds. This turbine offers a high beginning torque even at low wind speeds, making it an excellent choice for small wind farms (Kamal, 2008). In order to be effective in low wind speed situations, this sort of vertical wind turbine is believed to be quite reasonable.

Additionally, an upward hub wind turbine has the benefit of being able to spin effectively with the wind from all bearings, making it well-suited for use in places where the wind direction is constantly variable. A decent shaft should be obtained by using a flat hub wind turbine rather than one that is coordinated in the opposite wind direction situation. When the wind conditions are different, the flat hub type turbine cannot rotate well because it must track down the strong situation of the light breeze breezy towards first.

Because the wind speed at any given moment is often varied, the number of turbine rotations per unit of time will likewise vary. The higher the wind speed, the larger the rotation speed of the turbine, and the bigger the amount of electricity produced (HalidaRahmi, 2015).

Vertical axis wind turbines have a poor efficiency since they rely on drag forces to generate electricity (Vaishali, 2014). Positive and negative moment driving forces are produced in the rotor, and the resulting power is derived from the difference between these two driving forces. The Savonius wind turbine is a vertical axis wind turbine, which means it has a vertical axis. This turbine has a straightforward design and construction, with its components organized in the form of the letter S. (Ali, 2014).

Previous studies shown that the number of blades in a turbine has an effect on the outcomes of the turbine's spinning. Turbines with two blades create greater rotating speeds compared to turbines with three or four blades. Turbines with two blades produce less torque than turbines with three or four blades (Jamal, 2019).

Based on this context, the erratic wind speed is the context in which the turbine with the Savonius S rotor shape is a combination of the U-shaped Savonius profile and the curve, which is generally in the form of a quarter circle, which is suitable and effective for efficient power generation and produces the highest output.

The Savonius S rotor has an advantage over the Savonius U rotor in that the wind that strikes the rotor flows more into the rotor blades, supplying more energy to the rotor blades. The Savonius U rotor, on the other hand, has a disadvantage.

II. REVIEW LITERATURE

The blades of the savonius wind turbine are shaped in a semicircular fashion. In 1922, a Finnish engineer by the name of Sigurd J. Savonius created the world's first commercially viable wind turbine.

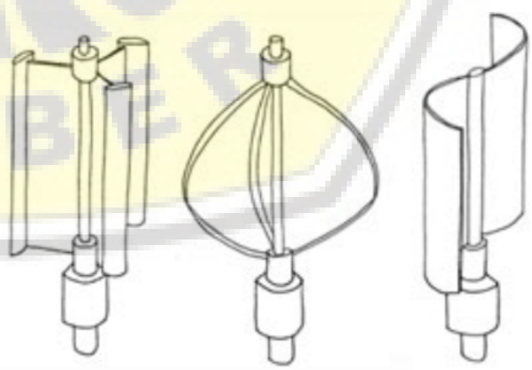

Fig.1 Vertical axis wind turbine

The premise behind this wind turbine's operation is pretty simple: it creates electricity by harnessing the drag force caused by the blades of each blade. The drag force is the force that the blade experiences when it comes into contact with the wind (White, 1986, page 412).

A. *Rotational Wind Turbine Energy*

The turbine converts kinetic or potential energy from the flow of the fluid hitting the blades into mechanical energy. The kinetic energy of the wind may be extracted by the turbine. wind is a moving air mass the quantity of energy in the wind depends on its speed and density. The kinetic energy of wind or air with mass m and speed v is:

$$Ek = \frac{1}{2} mv^2 \ldots\ldots\ldots\ldots\ldots\ldots(2.1)$$

Ek = Kinetic energy (joules)
m = mass of air (kg)
v = wind speed (m/s)

The kinetic energy of the wind is directly proportional to the mass of the air and directly proportional to the square of its velocity.

B. *Power Coefficient*

The power coefficient is defined as the relationship between the power produced by the rotor and the power generated by the wind. The value of the power coefficient will not be more than the optimal value of 0.593. The following is the equation for the power coefficient:

$$Cp = \frac{Pg/\eta g}{\rho.A.v^3/2} \ldots\ldots\ldots\ldots\ldots\ldots(2.3)$$

Pg = Generator power (W)
g = Generator efficiency (%)

C. *Turbine Torque*

A power source is created by multiplying rotational speed with torque. Power absorption increases with increasing rotational speed, and vice versa. The higher the applied torque, the larger the power absorption. As a result, the torque may be expressed mathematically as:

$$T = \frac{30\,P}{\pi\, RPM} \ldots\ldots\ldots\ldots\ldots\ldots(2.4)$$

T = Torque (Newtons)
P = Design Power = 100 Watt
RPM = Turbine speed = 79.34 rpm

D. *Blade Pitch Control Mechanism*

Pitch Blade Control is a technology used to operate and control the blade angle on wind turbines. The main turbine controller calculates the required tilt angle from a series of conditions. Such as wind speed, generator speed and electricity production. The required tilt angle is transferred to the control blade pitch system as a set point to make the actuator move the blade to the required angle.

Table 1.Average Wind Speed (m/s)

Time	Average Wind Speed (m/s) (22-24 May 2021)			Average (m/s)
	May 22	May 23	May 24	
10.00 WIB	1.67	1.67	1.94	1.76
13.00 WIB	2.5	2.5	2.7	2.57
16.00 WIB	1.94	1.94	2.2	2.03
19.00 WIB	0.56	0.56	0.56	0.56

Pitch Blade Control is a method that is operated when the wind speed is outside the average value. The electromagnetic torque is not sufficient to control the rotor speed and the generator will be overloaded. Wind turbine power conversion should be limited and this can be done by reducing the wind turbine power coefficient (Cp). The power coefficient can be manipulated by varying the angle of inclination of the blades.

E. *Wind energy*

Power is defined as energy per unit of time. In accordance with the equation below, the power of the wind is exactly proportional to the density of the air and to the cubic speed of the wind.

$P = \frac{1}{2} \rho . A . v^3$ …………. (2.5)

As an example, consider the following equation relating to wind energy: Because of the difference in air density between the lowlands and the highlands, the amount of wind energy that can be harvested in coastal locations will be larger than the amount that can be harvested in mountainous places. When a site has a wind speed that is twice as fast as another, the first place has 8 times the amount of wind energy as the second one. As a result, the absorption of wind energy is determined by the site that is chosen.

In this case, the greatest amount of wind power that can be harvested by the turbine by sweeping the rotor area

$P = \frac{16}{27} \frac{1}{2} \rho . A . v^3$ …………(2.6)

The Betz limit is defined as the percentage of the population that is 59.3 percent of the total population (Betz limit, taken from the German scientist Albert Betz). Using a vertical-axis wind turbine, this graphic illustrates the greatest efficiency that may be obtained by the blades of the bladeless turbine (Daryanto et al., 2007).

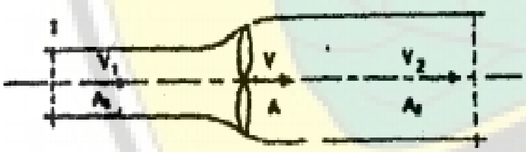

Fig. 2 Assumptions of Betz theory

In 1927, DieWindmuhlenimLichteNeurerForschung, A. Betz describes how he discovered the windmuhlen. This discovery is widely regarded as the first academic work to provide a theoretical framework for wind turbines. According to this model, the ideal turbine is composed of an unrestricted number of blades with no resistance and is hub less in design. Also expected is that the air flow in front of and behind the rotor has a uniform velocity in both directions (laminar flow). As shown in Figure 2, if V = wind speed in front of the rotor, V2 = wind speed behind the rotor, and V = wind speed as it passes through the rotor, the continuity equation is used to calculate the wind speed (Tedjo, R. N. 2005).

AiVi = AV = A2V2 = AiVi…. (2.7)

III. RESEARCH METHODS

The experimental study technique employed in this work is Simulink Matlab, and it is described in detail below. The design of the Savonius S turbine is one of the actions carried out as part of this research. The first step is data collection on the uncontrolled matlabsimlink with the input wind speed increasing from 1 m/s to 8 m/s by entering the angle value from 10 degrees to 90 degrees in increments of 10 degrees. The second step is data analysis on the uncontrolled matlabsimlink with the input wind speed increasing from 1 m/s to 8 m/s by entering the angle value from 10 degrees to 90 degrees in increments of 10 degrees.

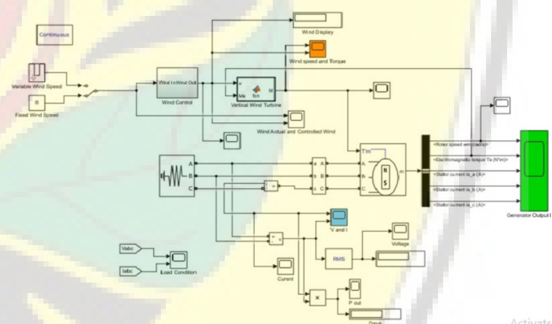

Fig.2 Total Simulation Circuit in Simulink Matlab

The ideal power value and the blade angle that must be opened in order to provide the most power from each blowing speed are determined based on the uncontrolled data retrieval. In Simulink Matlabutilizing the control and calculating using basic linear regression, the testing process is carried out after deciding on the optimal power to use.

This investigation was carried out via the use of simulation in Matlab Simulink. The following is a complete simulation of the Savonius Turbine Blade Pitch Angle Curve Control system, which is designed to optimize wind energy production.

The overall goal of the simulation above is to pull the wind that powers the wind turbine to create fluctuating speeds, resulting in an unstable and variable amount of energy produced. It is placed with a big angle on the blade so that the wind speed entering the turbine matches the angle of the blade, which results in optimum and steady power. When the wind enters the turbine, the angle of the turbine is adjusted to match the speed of the wind.

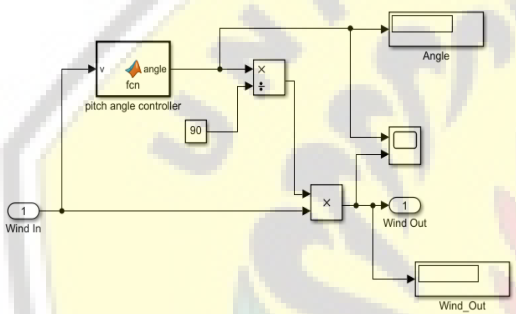

Fig.3 Block diagram for Pitch blade controller in wind turbine

IV. RESULT AND DISCUSSION

Testing in this research was separated into two parts, the first of which included testing the system without control and the second of which involved testing students with control. It is necessary to adjust the angle input for periodic testing to vary the wind speed from 1 m/s to 8 m/s by entering the angle at each wind speed from 10 degrees to 90 degrees with incremental intervals of 10 degrees in order to create the most power. Test System with speed from 1 m/s to 8 m/s without control.

The angle entered for periodic testing is to change the wind speed from 1 m/s to 8 m/s by entering the angle at each wind speed from 10 degrees to 90 degrees with intervals of 10 degrees increments.

Table 2. Data of System Test Results without control with wind input 1 m/s

Input Wind Speed (m/s)	Turbine Pitch Blade (degrees)	Output Wind Speed (rpm)	V out RMS Generator (V)	Power (Watts)
	10	10	218.1	86
	20	20	6539	96
	30	30	5544	124
	40	40	1.15	131
1	50	50	1.63	148
	60	60	1.86	152
	70	70	1,948	168
	80	80	1.98	173
	90	90	1.99	174

Tests without control with input wind speed of 1 m/s resulted in an optimal power of 174 Watts with a large blade pitch angle of 90 degrees. The power generated is not large because the incoming wind is very low.

Table 3. Data of System Test Results without control with wind input 2 m/s

Input Wind Speed (m/s)	Turbine Pitch Blade (degrees)	Output Wind Speed (rpm)	V out RMS Generator (V)	Power (Watts)
	10	20	1,693	126
	20	40	1.145	130
	30	60	1,863	213
	40	80	1.98	236
2	50	100	2004	250
	60	120	1.145	230
	70	140	1.98	247
	80	160	2006	244
	90	180	2006	258

Tests without control with input wind speed of 2 m/s resulted in optimal power of 258 Watt with a large blade pitch angle of 90 degrees. The power generated is not large because the incoming wind is very low.

Table 4. Data of System Test Results without control with 3 m/s .wind input

Input Wind Speed (m/s)	Turbine Pitch Blade (degrees)	Output Wind Speed (rpm)	V out RMS Generator (V)	Power (Watts)
3	10	90	1.99	364
	20	60	1.86	412
	30	90	1993	464
	40	120	2004	600
	50	150	2006	744
	60	180	2006	745
	70	210	2006	819
	80	240	2006	839
	90	270	2007	842

Tests without control with input wind speed of 3 m/s resulted in an optimal power of 819 Watts with a large blade pitch angle of 70 degrees.

Table 5. Data of System Test Results without control with wind input 4 m/s

Input Wind Speed (m/s)	Turbine Pitch Blade (degrees)	Output Wind Speed (rpm)	V out RMS Generator (V)	Power (Watts)
4	10	40	1.145	630
	20	80	1.98	867
	30	120	2004	600
	40	160	2006	934
	50	200	2006	848
	60	240	2006	833
	70	280	2007	829
	80	320	2007	831
	90	360	2007	838

Tests without control with input wind speed of 4 m/s resulted in an optimal power of 848 Watt with a large blade pitch angle of 50 degrees.

Table 6. Data of System Test Results without control with wind input 5 m/s

Input Wind Speed (m/s)	Turbine Pitch Blade (degrees)	Output Wind Speed (rpm)	V out RMS Generator (V)	Power (Watts)
5	10	50	16.34	680
	20	100	19.9	821
	30	150	20.06	870
	40	200	20.06	979
	50	250	20.06	893
	60	300	20.07	914
	70	350	20.07	915
	80	400	20.08	918
	90	450	20.08	918

Tests without control with input wind speed of 5 m/s resulted in an optimal power of 893 Watt with a large blade pitch angle of 50 degrees.

Table 7. Data of System Test Results without control with wind input 6 m/s

Input Wind Speed (m/s)	Turbine Pitch Blade (degrees)	Output Wind Speed (rpm)	V out RMS Generator (V)	Power (Watts)
6	10	60	1,863	413
	20	120	2004	600
	30	180	2005	750
	40	240	2.04	600
	50	300	2007	923
	60	360	2007	927
	70	420	2007	935
	80	480	2007	733
	90	560	20001	471

Tests without control with input wind speed of 6 m/s resulted in optimal power of 923 Watt with a large blade pitch angle of 50 degrees.

Table 8. Data of System Test Results without control with wind input 7 m/s

Input Wind Speed (m/s)	Turbine Pitch Blade (degrees)	Output Wind Speed (rpm)	V out RMS Generator (V)	Power (Watts)
7	10	70	19.4	688
	20	70	19.4	688
	30	210	20.06	929
	40	280	20.06	911
	50	350	20.07	915
	60	420	20.08	918
	70	490	20.09	919
	80	560	20.1	921
	90	630	20.11	922

Tests without control with input wind speed of 7 m/s resulted in optimal power of 929 Watt with a large blade pitch angle of 30 degrees.

Table 9. Data of System Test Results without control with wind input 8 m/s

Input Wind Speed (m/s)	Turbine Pitch Blade (degrees)	Output Wind Speed (rpm)	V out RMS Generator (V)	Power (Watts)
8	10	80	1.98	937
	20	160	20.06	940
	30	2240	2006	939
	40	320	2007	931
	50	400	2007	935
	60	480	2007	936
	70	560	2007	955
	80	640	2007	933
	90	720	2007	963

Using an 8 m/s input wind speed as a starting point, tests without control produced an ideal output of 940 Watt while using a big blade pitch angle of 20 degrees.

The results of each wind speed test were obtained by selecting the optimal power value for each test, as given in Table 10 below.

Table 10. Data on System Test Results with control

Input Wind Speed (m/s)	Turbine Pitch Blade (degrees)	Output Wind Speed (rpm)	V out RMS Generator (V)	Power (Watts)
1	90	90	1.99	174
2	90	180	2006	258
3	70	210	2006	819
4	50	200	2006	849
5	50	250	20.06	893
6	50	300	2007	923
7	30	210	20.06	929
8	20	160	20.06	940

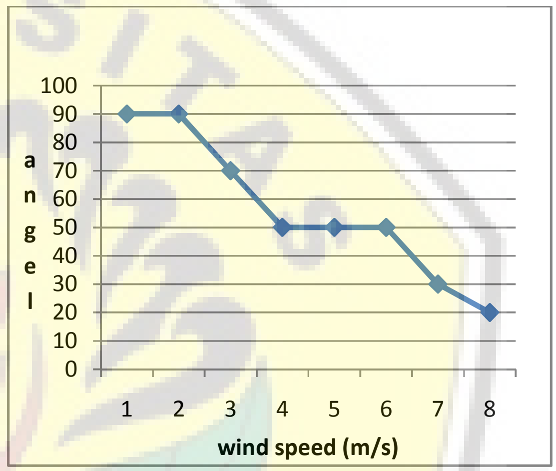

Fig. 1 Relationship between wind speed and angle

The link between wind speed and turbine blade angle is shown in Fig. 1, and it can be deduced that the larger the wind speed entering the turbine, the smaller the blade angle on the turbine.

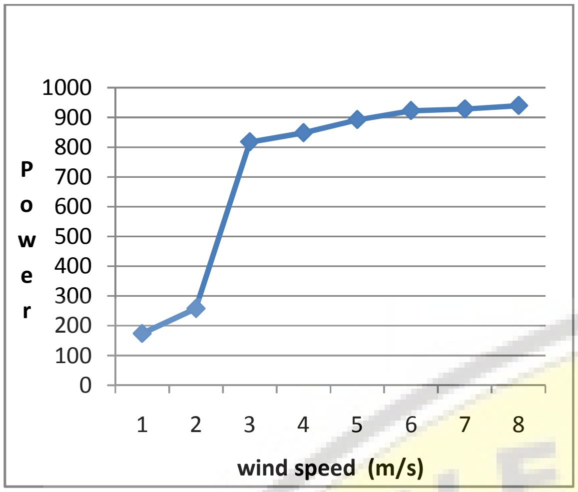

Fig. 2. Relationship between wind speed and power generated

The link between wind speed and the power produced is shown in Fig. 2, and it can be deduced that the larger the wind speed entering the turbine, the bigger the power produced. The maximum amount of power that may be created begins with a wind speed of 3 m/s. It is also true that when the entering wind speed is too low, such as between 1 and 2 m/s, the power produced is likewise too low.

V. CONCLUSION

In accordance with the results of the test using Simulink matlab and the analysis performed, the optimum power value was selected from the test without control and entered into Simulink to be controlled with a linear regression equation so that the function used was discovered, which resulted in controlling the blade angle which opened how many degrees so as to produce optimal power. According to the results of tests conducted at wind speeds ranging from 1 m/s to 8 m/s, the angle of the blades utilized to generate the most power may be changed. The maximum amount of power that may be created begins with a wind speed of 3 meters per second. If the entering wind speed is too low, for example, between 1 and 2 m/s, the power produced will be minimal as well. When the wind speed is 3 m/s, the blade is angled at a 70-degree angle to the ground. When the wind speed is between 4 and 6 m/s, the blade is angled at a 50-degree angle to the ground. With a wind speed of 7 m/s, the blade is angled at a 30 degree angle to the ground. Assuming a wind speed of 8 meters per second, the blade angle employed will be 20 degrees.

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