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Publisher	IOP Publishing Ltd.
Publication type	Conferences and Proceedings
ISSN	17426588, 17426596
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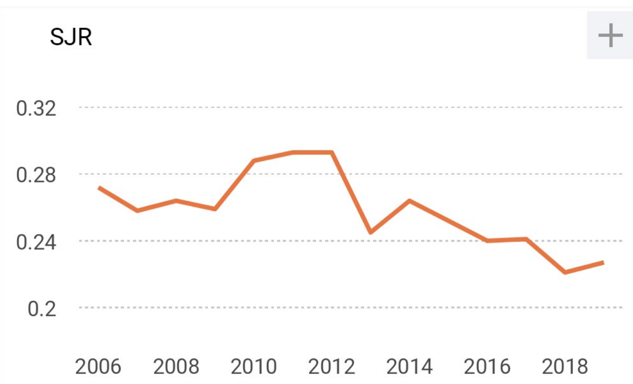

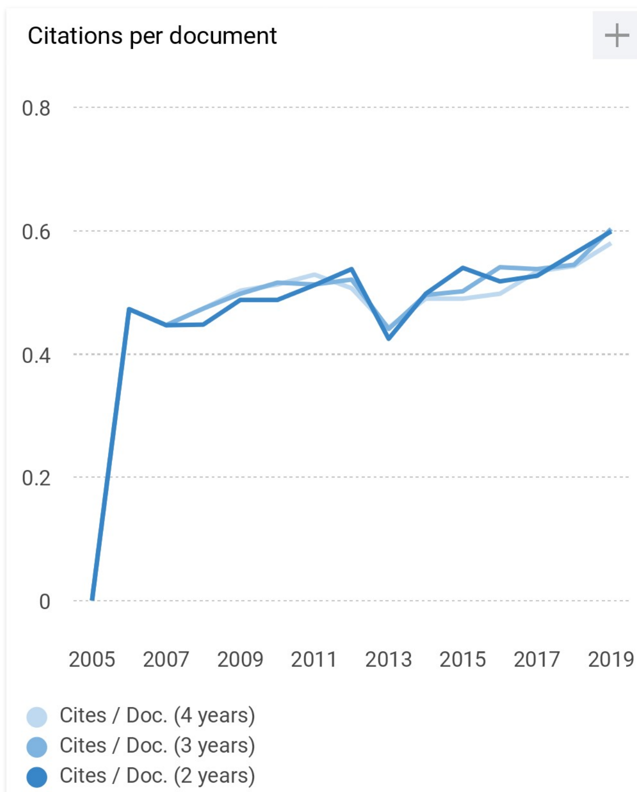

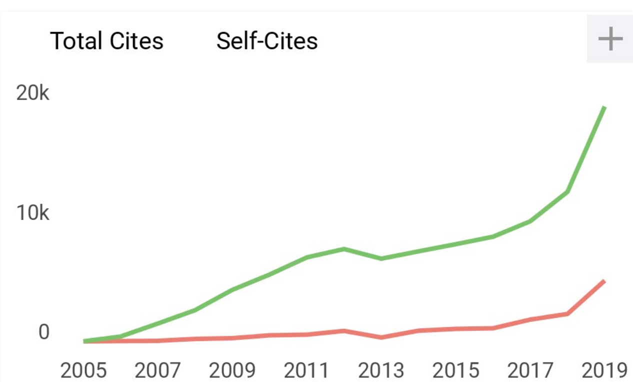

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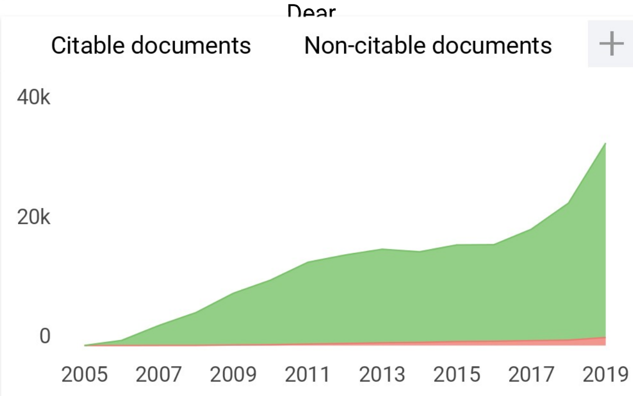

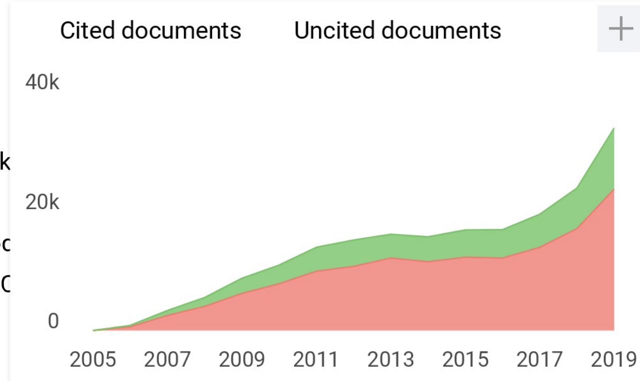

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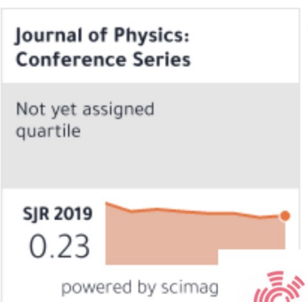

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Preface

The 1st Borobudur International Symposium on Applied Science and Engineering (BIS-ASE) 2019 is hosted by Universitas Muhammadiyah Magelang, Indonesia. The conference is also co-hosted by other twenty-one institutions as follows Badan Penelitian dan Pengembangan Kota Magelang, Universitas Muhammadiyah Surabaya, Universitas Muhammadiyah Buton, Universitas Muhammadiyah Ponorogo, Universitas Muhammadiyah Purworejo, Universitas Muhammadiyah Jember, Universitas Muhammadiyah Metro, Universitas Muhammadiyah Maluku Utara, Universitas Muhammadiyah Pekajangan Pekalongan, Universitas Muhammadiyah Riau, Universitas Aisyiyah Yogyakarta, Universitas Sains Al Qur'an Wonosobo, Universitas Tidar Magelang, FKIP Universitas Muhammadiyah Jakarta, FISIP Universitas Muhammadiyah Malang, Faculty of Law Universitas Islam Indonesia, STIKES Muhammadiyah Klaten, IAIM Sinjai, IAIN Purwokerto, Politeknik Energi dan Mineral Akamigas, and STMIK Bina Patria Magelang.

The main theme of this symposium is “Local resources empowerment towards advance, smart and sustainable system” as a part of the United Nations agenda for sustainable development goals in 2030. Therefore, we present you, four world-class keynote speakers whom able to capture the interdependence between these scientific topics. First, Professor Tony Lucey from Curtin University, Australia. Second, Professor Noorefendi Tamaldin from UTeM, Malaysia. Third, Mr Rajesh Ranolia from NIIT, India. Fourth, Yun Fatimah, PhD, Dean of the Faculty of Engineering, Universitas Muhammadiyah Magelang.

Let me inform you that the 1st BIS-ASE 2019 has received 344 submissions from 6 countries: India, The Netherlands, Malaysia, Japan, Thailand, and Indonesia. Each paper has been reviewed by the program committee. Only 232 papers were accepted for the round table session (acceptance rate: 69.46 %). All the published papers have been through a series of rigorous review process to meet the requirements and standards of international publication.

We hope that our later discussion may result transfer of experiences and research findings from participants to others, from one institution to another, from social researcher to engineering researcher and vice versa. Also, I hope this event can build a new and strong research network.

We would like to thank each co-host for the efforts to give significant contribution particularly on paper selection. We would also like to acknowledge the Rector of Universitas Muhammadiyah Magelang for the endless support to the conference. Last but not least, we would like to express our most sincere gratitude to the international advisory board, scientific committee, steering committee, organizing committee, and everybody taking parts in the success of the conference. We hope to see you in the 2nd BIS-ASE 2020.

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Vertical axis wind turbine analysis using MATLAB

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Abstract. Wind Turbines have become one of the feasible power plants to replaced fossil fuels. Because this plant is affordable cost and did not produce pollutants as an output. Vertical Axis Wind Turbine can be placed at points with high wind intensity such as; toll roads, ships, railroads, airports. The energy produced can be distributed for the civilian house light, the street lights, the fishing boats light, others. The hope is that wind turbines can generate 100 watts of power, so that charging time can be at least 6 hours. But, the average velocity data in the field is worth under 2.85 m/s (minimum wind speed to get 100 watt). Resulting in a turbine charging time more than 6 hours. In this case, The Turbine needed more than one accu as a place to store the energy even the accu take more than 6 hours to be charged.

1. Introduction

Energy is a basic human need that must be fulfilled, it continues to increase as time passes, it is directly proportional to human life. Fuel oil holds a very dominant position in meeting national energy needs. The current composition of energy consumption is fuel oil: 52.50%; Gas: 19.04%; Coal: 21.52%; Water: 3.73%; Geothermal: 3.01%; and Renewable Energy: 0.2%. [1]

Indonesia is a tropical country located on the equator, as an archipelago with varied geological contours, has more than 100 mountains, and also beaches. One of the energies that can be utilized is wind. The movement of wind from the mountains which has high air pressure towards the coast with low air pressure can be utilized in the implementation of wind turbines, which convert mechanical energy into electrical energy. At an affordable cost, didn't produced pollutants as an output, Wind Turbines have become one of the feasible power plants to replace fossil fuels.

Generally, there are two types of Wind Power Plants; Horizontal Axis Wind Turbines, and Vertical Axis Wind Turbines. The Horizontal Axis Wind Turbine is a type of porous turbine parallel to the wind direction like a typical aircraft propeller, so it requires its own mechanism to adjust the blade to be able to follow the direction of the wind turbine rotating, with the generator placed behind the turbine. Meanwhile, the Vertical Axis Wind Turbine is a type of turbine with a axis perpendicular to the wind direction, easy for each blade to catch wind even though the direction changes, and the position of the generator is at the base of the turbine so that this will facilitate maintenance of the turbine. [3]

Later, this Vertical Axis Wind Turbine can be placed at points with high wind intensity such as; toll roads, ships, railroads, airports, and so on. The energy produced can be distributed to lighting the civil house, lighting the street lights, lights on the fishing boats, and others.

There are various types of Vertical Axis Wind Turbines, and what is currently being analyzed is the Savonius type, although it generally moves more slowly than the Horizontal Axis Wind Turbine, but the torque produced is larger.

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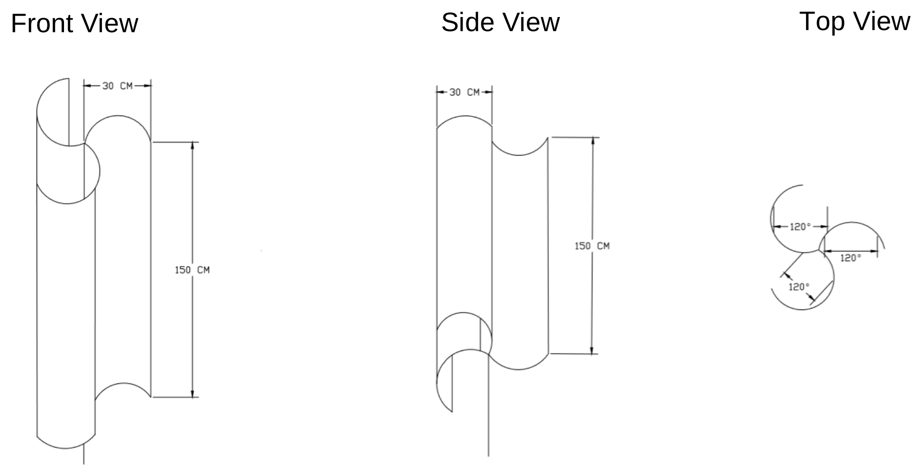

Figure 1. Vertical Axis Wind Turbine Design in 3 Perspective

Figure 1 shows the design of the Savonius Type Vertical Axis Wind Turbine and its size. The length of the blade is 150 cm, the radius is 30 cm, and the blade is 120 degrees. This 4 kg wind turbine is made of lightweight stainless-steel material which is expected to be easy to rotate, and the design of the 3 blade that forms the letter S can catch the wind even though it blows from various directions. With this size, it is also expected to produce a power output of 100 watts if the intensity of the wind in the field fulfill the expected calculations.

2. Literature Review

2.1. Beltz Limit

Beltz Limit, in theory is the maximum efficiency value for a wind turbine, put forward by German Physicist Albert Beltz in 1919. The value of Beltz Limit is 16/27 or 59.3%, that is only 59.3% of the kinetic energy of the wind can drive the turbine. In fact, the turbine cannot reach Beltz Limit. And generally, the efficiency value of a turbine is between 35% and 45%. [5]

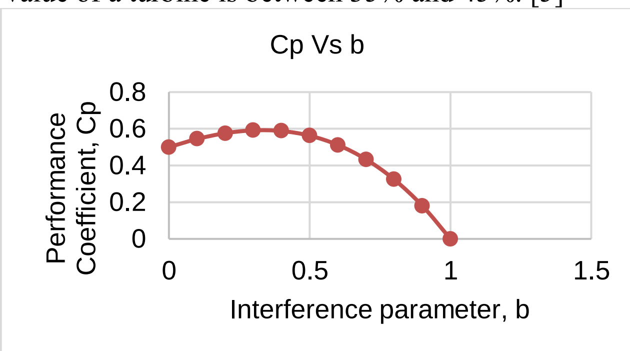

Figure 2. The Coefficient power, Cp functions as a factor b

Table 1. Performance coefficient, Cp as a factor b

b	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
Cp	0,5	0,5445	0,576	0,5915	0,588	0,5625	0,512	0,4335	0,324	0,1805	0

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2.2. Turbine Power

Wind turbines work by converting the kinetic energy in the wind first into rotational kinetic energy in the turbine and then electrical energy that can be supplied. [6]

$$E_k = \frac{1}{2} mV^2 \tag{1}$$

Where, $\frac{dm}{dt} = \rho AV$ → mass of flow air through disc of area-A

The power in the wind is given by the rate of change of energy:

$$P = \frac{dE}{dt} = \frac{1}{2}\frac{dm}{dt}V^2 \tag{2}$$

$$P = \frac{1}{2}\rho AV^3 \tag{3}$$

Where:

P = turbine power, watt
ρ = Air density = 1.225 kg.m^{-3}
A = swept surface area = πr^2 = 3,14 x $(1.5)^2$ = 7 m^2
V = wind speed (m/s)

If, Pout = 100 watt

Then,

$$V^3 = \frac{2P}{\rho A} = \frac{2 \times 100}{1{,}225 \times 7} = \frac{200}{8.575} = 23{,}32 \tag{4}$$

$$V = \sqrt[3]{23{,}32} = 2{,}85 \text{ m/s}$$

To get P_{out} = 100 watt, the turbine needs 2,85 m/s of wind speed at least

2.3. Wind Speed Sample

In reality, the average wind speed based on the sample data taken below is:

Table 2. Average of wind sample data in South Jakarta

Time		Wind Sample Average (m/s) on 1 - 3 July 2019			Wind Sample Average (m/s)
		1	2	3	
Morning	[9 Am - 10:30 Am]	1,21	1,41	1,45	1,36
Evening	[1 Pm - 2:30 Pm]	1,89	2,78	1,64	2,10
Night	[8 PM - 9:30 Pm]	2,74	4	2,71	3,15

In table 2, it can be seen that in the morning and evening, the average wind speed does not reach 2,85 m/s. So at that time the battery takes longer to fill. Whereas at night from the range of 8 PM - 9:30 PM, the average wind speed is above 2,85 m/s, it is possible to fill the battery faster and produce output power of more than 100 watts. For the calculation of battery usage and charging can be seen in the next sub-chapter.

2.4. Wind Torque

The wind torque and load torque can be expressed as follows equation 5 and 4 [6].

$$M_{wind} = \frac{\rho \, x \, R \, x \, L \, x \, \eta \, x \, V^3}{2 \, x \, \omega} \tag{5}$$

Where:

M_{wind} = wind turbine torque, Nm
V = wind speed (m/s) = 2.8 m/s
L = lenght of the blades, m = 1,5 m
R = wind turbine rotor radius = 0,3 m
ρ = air density = 1,225 kg.m^{-3}
η = wind turbine efficiency, 0,275
ω = angular speed = 6

Then, substitute the value to the equation 5,

$$M_{wind} = \frac{1{,}225 \, x \, 0{,}3 \, x \, 1.5 \, x \, 0{,}275 \, x \, 2.8^3}{2 \, x \, 6} = 0{,}27 \text{ Nm}$$

And,

$$M_{load} = \frac{\pi \, x \, \rho \, x \, R^5 x \, \eta}{2 \, x \, \lambda^3} x\omega^2 \tag{6}$$

Where:

π = 3,14
$\lambda = \frac{\omega R}{V} = \frac{6 \, x \, 0.3}{2.8}$ = 0,64 = tip speed ratio

Substitute the value to the equation 6,

$$M_{load} = \frac{\pi \, x \, \rho \, x \, R^5 x \, \eta}{2 \, x \, \lambda^3} x\omega^2$$
$$= \frac{3{,}14 \, x \, 1{,}225 \, x \, 0{,}3^5 x \, 0{,}275}{2 \, x \, 0{,}64^3} \text{ x } 6^2$$
$$= 0{,}17 \text{ Nm}$$

2.5. Battery Charging Time

$$P = V \text{ x } I \tag{7}$$

Where:

P = Power (Watt) = 100 watt (expected power output)
V = Accu voltage (Volt) = 12 Volt
I = Current (Ampere)

Substitute the value to the equation 5 to find the current,

P_{out} = V x I
100 Watt = 12 Volt x I
I = 100/12 = 8,3 Ampere

Accu specification: 12V/50Ah

$$\text{Charging Time} = T = \frac{Q}{i} = \frac{50\ Ah}{8.3\ A} = 6\ Hour$$

Where :

Q = Charging Q, (Ampere Hour)

With the Equation 3, we can find the real charging time using the wind speed average.

Substitute the value of Wind Speed Average to the equation 3 to find the Real Output Power and charging time.

1. Power with Wind Speed Average on Morning

$$P = \frac{1}{2}\rho A V^3$$
$$P = \frac{1}{2} * 1{,}225 * 7 * 1{,}36^3$$
$$P = 10.78\ \text{Watt}$$

Then, the current output will be,

$$P_{out} = V \times I$$
$$10{,}78\ \text{Watt} = 12\ \text{Volt} \times I$$
$$I = 10{,}78/12 = 0{,}89\ \text{Ampere}$$

The Charging time,

$$\text{Charging time} = \frac{50\ Ah}{0{,}89\ A} = 56\ Hour$$

2. Power with Wind Speed Average on Evening

$$P = \frac{1}{2}\rho A V^3$$
$$P = \frac{1}{2} * 1{,}225 * 7 * 2{,}10^3$$
$$P = 39{,}7\ \text{Watt}$$

Then, the current output will be,

$$P_{out} = V \times I$$
$$39{,}7\ \text{Watt} = 12\ \text{Volt} \times I$$
$$I = 39{,}7/12 = 3.3\ \text{Ampere}$$

The Charging time,

$$\text{Charging Time} = \frac{50\ Ah}{3.3\ A} = 15\ Hour$$

3. Power with Wind Speed Average on Night

$$P = \frac{1}{2}\rho A V^3$$
$$P = \frac{1}{2} * 1{,}225 * 7 * 3{,}15^3$$
$$P = 134\ \text{Watt}$$

Then, the current output will be,

$$P_{out} = V \times I$$

134 Watt = 12 Volt x I
I = 134/12 = 11 Ampere

The Charging time,

$$\text{Charging Time} = \frac{50\,Ah}{11\,A} = 4.5\ Hour$$

3. Methodology

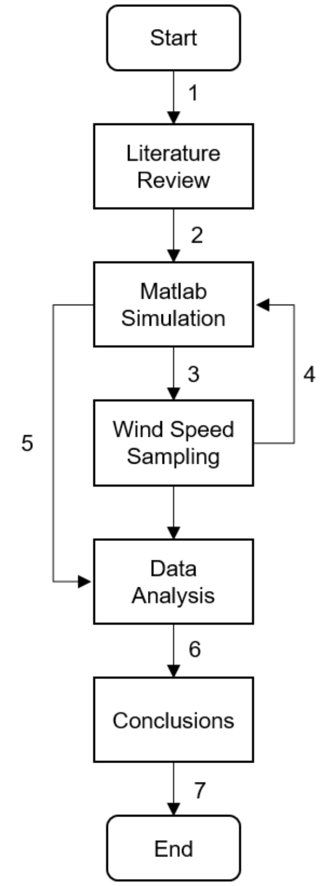

Figure 3. Research Method VAWT Analysis Flowchart

In Figure 3 we briefly explain the methodology for analysing Vertical Axis Wind Turbines.

Table 3. Work Timeline for VAWT Analysis

Step	Explanation
Start	Start
Literature Review	Literature Review is the preparation stage, journal searches and papers related to Vertical Axis Wind Turbines as a reference when making comparisons of valid sources, such as Beltz Law, Output Power, Battery charging (batteries) in Turbines, Analysis of wind speed relationships with output power .
Matlab Simulation	Try Matlab Simulation in each of the papers that have been searched for in step 1. Looking for a comparison of the relationship between Wind Speed and Power

Wind Speed Sampling	Sampling of wind speed, as a reference in the process of calculation, Turbine Torque, Output Turbine Power, Time of Use (usage), Time of Charging on turbine batteries. The collection location is on the 7th Floor of Al-Azhar University in Indonesia.
Matlab Simulation	Simulated back in Matlab using data that has been obtained directly from the Field, or real data
Data Analysis	Analyze formulas to calculate power output, usage time, battery charging time, and turbine torque at each time; morning afternoon Evening
Conclusion	Conclusions can be obtained from the graph in matlab and calculation
End	End

4. Result and Discussion

4.1. MATLAB Code and The Result

4.1.1. MATLAB Code for Wind Torque Function

```
v = [3:0.25:6];                  %wind speed m/s
L = 1.5;                         %length of the blades, m
R = 0.3;                         %wind turbine rotor radius, m
rho = 1.225;                     %air density
windt = 0.275;                   %wind turbine efficiency
omega = 6;                       %angular speed
m1 = 15;                         %mass turbine blades, kg
m2 = 1;                          %mass wind turbine rotor, kg
l = 0.01;                        %radius mass centre, m
J=(2*(m1*(m2/2))/(m1+(m2/2))*l^2);
lambda = (omega.*R)./v;          %tip speed ratio
Mw = (rho*R*L*windt*v.^3)./(2*omega);
Mlo = ((pi.*rho.*R.^5.*windt)./(2.*lambda.^3)).*omega.^2;
T=(J*omega)./(Mw-Mlo);           %time constant
plot (v,Mw,v,Mlo);
```

The plot result show below,

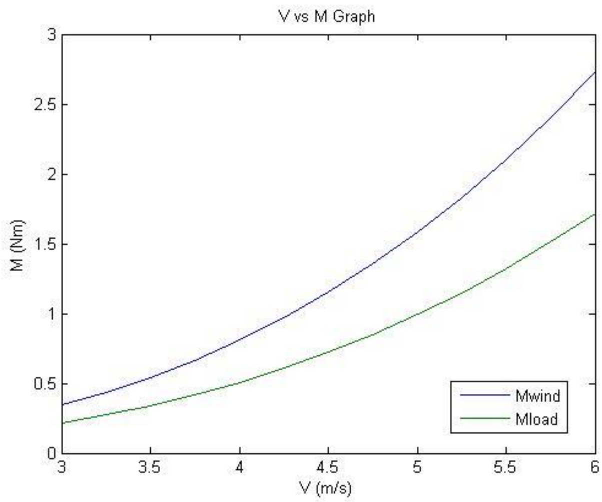

Figure 4. Wind Speed Vs Wind Turbine Torque

In Figure 4, it can be seen that the turbine torque when there is a load decreases, this occurs because there is a Beltz Limit, where only 59.3% of the kinetic energy of the wind can drive the turbine, which causes a decrease in turbine torque. From 0.27 Nm to half which is 0.17 Nm. This of course will affect many things, such as the value of the output power decreases, charging the battery will require more time, as explained in sub-section 2. Except, if the wind speed that drives the turbine can reach 2.85 m/s or more, the output power will be as desired, which is 100 watts, so charging the battery only takes 6 hours.

4.1.2. MATLAB Code with Power Function

```
v = [0:0.25:5];              %wind speed, m/s
rho = 1;                      %air density, assumption 1 kg/m^3
R = 1.5;                      %Lenght of blades,m
A = pi.*R.^2;                 %Swept surface area, m^2
P = (1/2)*rho.*A.*(v.^3);     %Power, watt
plot (v,P);                   %graph, wind speed vs power
```

The plot result show below,

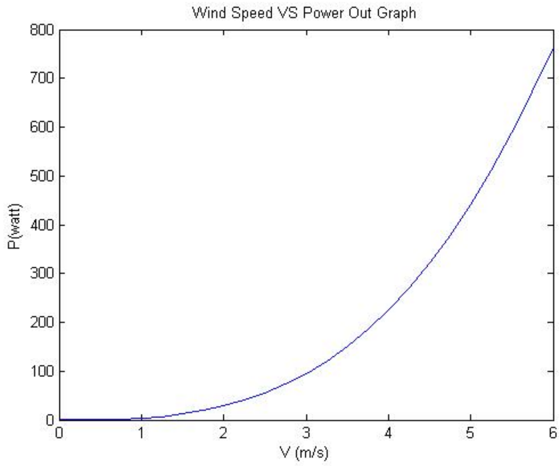

Figure 5. Wind Speed Vs Power

According to the Power equation referred to equation 3, There are two things that can affect the value of output power. First is wind speed. The second is the cross-sectional area of the blade.

The relationship of Power to wind speed is, directly proportional to power 3, only at the speed of 2 m/s, the value of power will be 8. If the wind speed is 3 m/s, then the power value will be 27. The Power difference is very significant, even though the wind speed only increases by one number. And also, the greater the cross section, the more wind is captured, causing large torque, and the output power also increases.

5. Conclusions

As mentioned in the Chapter Introduction, that Vertical Axis Wind Turbine moves more slowly, but produces a large Torque. Which Turbine Torque Wind with a length of 1,5 m, and radius of 0,3 m, mass of will produce a torque of 0.27 Nm. Because the wind turbine has an efficiency value, commonly referred to as Beltz Limit, the torque value will decrease because the Turbine absorbed wind energy is only 59.3%, then the torque value when there is a load drops to 0.17 Nm. And even though the hope is that wind turbines can generate 100 watts of power, so that charging time at least 6 hours. The average velocity data in the field is worth under 2.85 m/s (minimum wind speed to get 100-watt output power), except the night time. Resulting in a turbine charging time is more than 6 hours. The solution of the Wind Turbine that is analysed is, the addition of batteries is needed, so that the capacity of the number of usages can be increased even the charging time take more than 6 hours.

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