# WIND TURBINE VERTICAL AXIS H ROTOR TYPE WITH 1 kW CAPACITY AT SUWUK BEACH, KEBUMEN

**Achmad Gustiantono[1], Dominicus DDPT[2], Syamsul Hadi[2]**
[1]Pelajar – Jurusan Teknik Mesin – Universitas Sebelas Maret
[2]Staf Pengajar – Jurusan Teknik Mesin – Universitas Sebelas Maret

**Kata Kunci :**
***Potensi angin, Desain, Turbin angin, H-rotor***

**Abstrak :**
*Tulisan ini membahas tentang analisa potensi energi angin di pantai Suwuk Kebumen dan perancangan turbin angin tipe H-Rotor yang sesuai dengan karakteristik angin di pantai tersebut. Analisa potensi energi angin menggunakan metode distribusi Weibull berdasarkan data kecepatan angin di lokasi pengukuran selama 2 tahun. Analisa distribusi Weibull menunjukkan karakteristik kecepatan angin di lokasi pengukuran yang akan dijadikan dasar dalam perancangan turbin angin H-Rotor. Perancangan turbin angin H-Rotor terdiri dari komponen-komponen seperti sudu, strut, dudukan strut, poros, tiang, dan generator. Diperoleh rancangan turbin angin H-Rotor dengan diameter x tinggi sebesar 2,7 x 2,7 meter menggunakan airfoil tipe NACA 0018 dengan kapasitas daya keluaran sebesar 1 kW..*

## PENDAHULUAN

In recent years, the energy crisis that hit the world and particularly in Indonesia became a problem which is quite crucial. The fuel needs of human life is increasing, while supplies of oil or gas is very limited and can not be renewed cause oil reserves from year to year decrease dramatically.

It can be seen from the data above that oil production declining in Indonesia from year to year and 163.633 thousand barrel of crude oil production was down 50% from the previous year by 2012. In addition, due to the pollution, the global warming has been arising from the burning of fossil energy sources. It made us to enterprise for alternative energy sources that are clean and not limited to generating electricity.

Indonesia is a country with energy resources are very abundant, one of them are water and wind energy sources. Indonesia is an archipelago and one of the countries which located at the equator to be one factor why Indonesia has an overflow wind energy feasible. Its potential is quite adequate, due to 3.5 to 7 m/ s of the average wind speed ranges in Indonesia. The mapping of National Institute of Aeronautics and Space (LAPAN) at 120 locations shows some regions have wind speeds above 5 m/ sec, East Nusa Tenggara, West Nusa Tenggara, South Sulawesi, the southern coast of Java, respectively. The wind power applications as a source of renewable energy in Indonesia is very likely to be further developed [1].

The southern coast of Java has wind energy potential is tremendous with 3.5 to 7 m/ s of the average wind speed ranges. The suwuk beach become one of southern coast of Java is located in the southern city of Kebumen and used as tourist attractions. As a tourist attraction, the suwuk beach requires a supply of electrical energy among others for food stall lighting, drain the water, and the fulfillment of electricity at some recreation places.

The electrical energy source on this coast is originate from PLN and only available on a small scale by this time. In addition, the power outages is frequently happen which caused electricity shortages at Suwuk beach. Therefore, we need another energy source to overcome an electricity. A large number of wind energy potentials on Suwuk beach made wind turbine is the right choice to tackle the problem.

## RESEARCH METHODOLOGY

The H-rotor wind turbine design begins with wind speed data processing by using Weibull distribution method. The Pandansimo Bantul beach wind speed data was used due to its complete and located in the same geographic of suwuk beach which placed the south coast of Java island. Data has been obtained by measuring wind speeds at the beach Pandansimo for two years from June 2013 to 2015. It was found that wind speed often arise (VF) 4.37 m/ s of wind speed while carrying 7.99 m/ s of maximum energy (VE). Based on its characteristics, calculation and determination of each component H-rotor wind turbine models can be done.

## RESULT AND DISCUSSION

### Wind Speed Data Processing

The wind speed data processing results was obtained during the two years from June 2013 to June 2015 by using the graphs and cumulative probability density of Weibull distribution [2], as shown in Figure 1 and Figure 2.

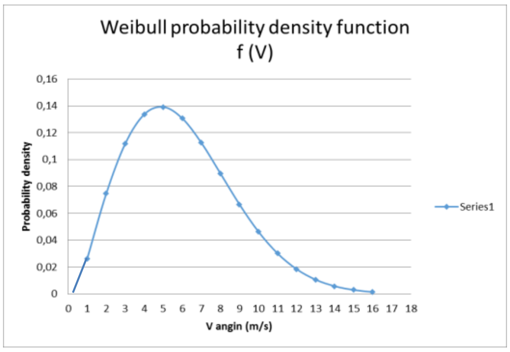

Figure 1. Density probability function

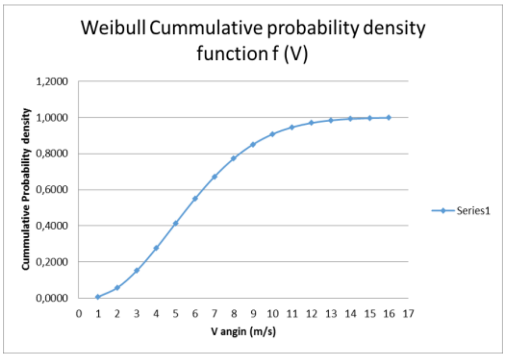


Figure 2. Cumulative Distribution Function

It can be clearly seen on Figure 1 that often frequently appears 4.37 m/ s of wind speed with 14%. Figure 2 shows the wind speed appearance chance at certain intervals. The cut-in wind speed is equal to or greater than 2 m/ s, 3 m/ s and 94.24%, 84.8% respectively.

**The H-Rotor Wind Turbine Design**

Hybrid turbine construction is shown in Figure 1. The components that will be constructed are blade, strut, strut mounting, shaft, mast, generator and transmission systems.

Figure 3. Vertically Axis Hybrid Wind Turbine Construction

1. Turbine Blade

Blade which was designed as a straight blade of NACA 0018 airfoil shape due to its strong and good aerodynamic construction characteristics [3]. The number of blades which used was 3 pieces that make loading variations spoon evenly by using carbon fiber material that performs corrosion resistant and strong. According to Oyedepo by 2012, wind speed design that was brought maximum energy (VE). The unknown 8 m/ s VE value, the H-rotor wind turbine size can be determined by reference [3] is

Solidity = 0.24
Rotor diameter ( D ) = 2.7 m
Blade lenght (b) = 2.7 m
Chord length ( c ) = 0.216 m
Swept area ( A ) = 7.29 $m^2$

2. Force Analysis on Blade

The aerodynamics H-rotor analysis is quite complex though the rotor shape is relatively simple. As the wind strikes the blade, not only wind speed are affecting lift (L) and propulsive force (D) on the blade but also influence the relative wind speed [3].

Lift (L) is a force that perpendicular to the relative wind speed while the thrust (D) is a force that parallel to the relative wind speed. Normal force (N) is a force that is perpendicular to the chord of the blade while the axial force (A) is a force that is parallel to the chord of the blade as shown in Figure 4. The forces are calculated using the equation, [4].

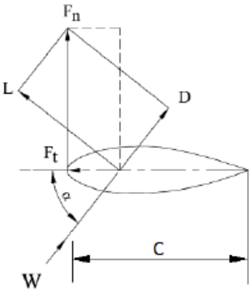


Figure 4. Turbine Blace Force Diagram

$$L = \frac{1}{2}\rho W^2 \times Cl \times C \times H$$
$$D = \frac{1}{2}\rho W^2 \times Cd \times C \times H$$
$$N = L\cos\alpha + D\sin\alpha$$
$$A = L\sin\alpha - D\cos\alpha$$

The calculation results forces that occur on the blade indicated by Table 2. From the table it can be seen that the value of lift (L) and normal force (N) consecutive maximum of 610.36 N and 603.44 N at position angle of pitch 140$^{o}$.

Table 2. Lift force, thrust, normal, and axial pitch angle variations

| No | pitch angle (θ) (deg) | sudut serang (α) (deg) | *Lift force* (N) | *Drag force* (N) | *Normal force* (N) | *Axial force* (N) |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 30 | 5,75 | 471,23 | 13,53 | 470,21 | 33,72 |
| 3 | 60 | 10,66 | 607,67 | 19,83 | 600,86 | 92,89 |
| 4 | 90 | 13,71 | 482,47 | 40,48 | 478,33 | 74,97 |
| 5 | 120 | 13,54 | 507,45 | 37,06 | 502,04 | 82,7 |
| 6 | **140** | **10,93** | **610,36** | **21,83** | **603,44** | **94,25** |
| 7 | 150 | 8,81 | 574,71 | 17,29 | 570,58 | 70,9 |
| 8 | 180 | 0 | 0 | 0 | 0 | 0 |
| 9 | 210 | -8,77 | -359,04 | 10,83 | -356,5 | 44 |
| 10 | 240 | -13,52 | -235,24 | 17,42 | -163,34 | 13,38 |
| 11 | 270 | -13,72 | -219,87 | 18,74 | -218,04 | 33,92 |
| 12 | 300 | -10,69 | -340,44 | 11,13 | -336,6 | 52,18 |
| 13 | 330 | -5,78 | -348,65 | 10,01 | -347,89 | 25,15 |
| 14 | 360 | 0 | 0 | 0 | 0 | 0 |

3. Shaft

Material for the shaft was selected AISI 4130 steel with 359 Mpa of material maximum tensile stress. A safety factor value equal to 8 was used for steel materials [5].

Shaft diameter calculation of hybrid vertical axis wind turbine considers the style of the axis of the twisting moment (Te) and bending moment (Me), the shaft diameter (d) was obtained 90 mm.

4. Cradle Strut and Strut

a. Cradle Strut

A holder AISI 6061 of aluminum strut material was practiced with 55.15 MPa of yield strength [5]. Diameter mounting strut (D) is set at 250 mm. Stand strut under pressure due to heavy pressure turbine blade bending and compressive stress due to centrifugal force [6].

Width (b) strut is 60 mm, since there will be screw mounted to a strut, then the size of the thickness (h) strut to:

Bending compressive stress due to the weight of the turbine blade

a. $$= \sqrt{\frac{2\, b\, \sigma_d}{18\, M}}$$

= 54,55 mm

b. Press tension due to sentrifugal force

$$h = \frac{mb \times \omega^2 \times R}{b \times \sigma} \times \frac{1}{N}$$

= 39,05 mm

then it was selected thick strut holder (h) of 39.05 mm.

b. Strut

The strut material was the same as the material for the holder strut. Strut was tensioned a bending pressure due to turbine heavy blade and compressive stress due to centrifugal force [6]. Number strut for each blade was 2 [7].

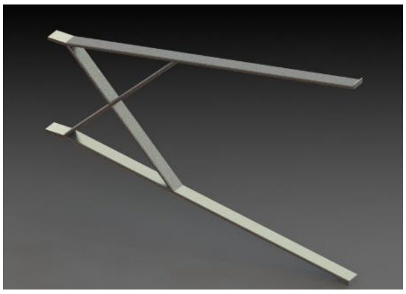

Figure 5. Strut

Width (b) strut 60 mm was taken, since there will be screw mounted to a strut, then the thickness size (h) strut against bending compressive stress due to the weight of the turbine blade

$$h = \sqrt{\frac{2\, b\, \sigma_d}{6\, M}}$$

= 12 mm

Checking the strut dimensions has been secured against centrifugal loads then it can be calculated by the equation,

$$\sigma = \frac{Fs}{A} = \frac{wb \times w^2 \times R}{b \times h \times N}$$

$$\sigma = 3{,}32\ MPa$$

From the calculations above, the resulting voltage was on below of the maximum allowable stress design that was 27.57 MPa. It can be concluded that the size of the strut with a width x height of 60 x 12 mm it was safe to use.

5. Generator

Generators were used in the wind turbine design was a permanent magnet generator which is capable of producing 1000 watts at 450 rpm of rotation. These generators were imported from Ginlong Manufacturer, an electric generator factory, PMG types.

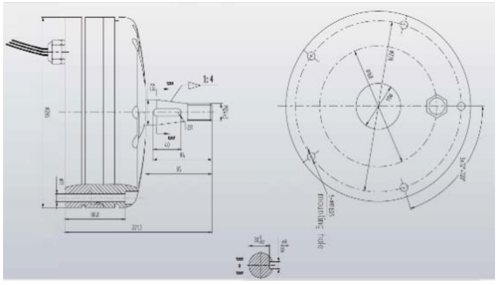

Figure 6. Generator GL-PMG-1000

Table 3 shows the specifications of generator GL-PMG-1000. It can be seen that the rated rotation speed of 450 rpm to produce a power output of 1000 watts.

Tabel 3. Spesifikasi GL-PMG-1000

| Electrical Specification | |
|---|---|
| Rated Output Power(W): | 1000 |
| Rated Rotation Speed (RPM): | 450 |
| Recified DC Current at Rated Output (A): | 6 |
| Requied Torque at Rated Power: | 31.5 |
| Phase Resistance (Ohms): | 12 |
| Output Wire Square Section (mm²): | 4 |
| Output Wire Length (mm): | 600 |
| Insultation: | H Class |
| Generator configuration: | 3 Phase star connected AC output |
| Design Lifetime: | >20 years |

6. Transmision

From Table 3, the generator rated rotation in order to produce an output power of 1 kW is 450 rpm while the axis wind turbines rotation only at 233 rpm. Therefore, it is necessary to raise the transmission shaft rotation. Transmission used was a bevel gear as shown in Figure 4:20.

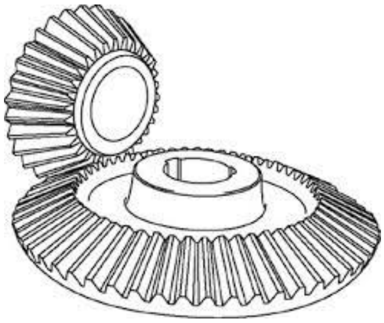

Figure 7. *Bevel gear*

Determining the size of the diameter of the gear (DG) and the diameter of the pinion (DP) using the equation, [8],

$$\frac{DG}{DP} = \frac{nP}{nG}$$

obtained DP = 100 mm dan DG = 200 mm.

7. Shaft

The main shaft will be reinforced using a hollow shaft which also will become a pillar of the wind turbine. In addition, this pillar also serves to put the taper bearing on the end of a pole. Calculation of shaft diameter of hybrid vertical axis wind turbine the axis type of the twisting moment (Te) and bending moment (Me).

a. From twisting moment (Te) maka,

$$Te = \frac{\pi}{16} \times \tau \left[\frac{(do)^4 - (di)^4}{do}\right]$$

b. From maximum normal tension (Me) so,

$$Me = \frac{\pi}{32} \times \sigma \left[\frac{(do)^4 - (di)^4}{do}\right]$$

Diameter was obtained in (on) and outer diameter (do) a maximum of hollow shafts are respectively 110 mm and 220 mm.

## CONCLUSION

Based on the analysis and discussion of the H-rotor turbine 1kW design for coastal areas, Suwuk Kebumen, some conclusions can be drawn as follows:

1. The data processing speed of the wind result on the suwuk beach using Weibull distribution shows that wind speeds are frequent or frequent (VF) 4.37 m/ s meanwhile the wind speed that can produce the maximum energy (VE) amounted to 7.99 m / s.
2. The result design of H-rotor wind turbines for the coastal areas is as follows suwuk:

**H-Rotor**

| | |
|---|---|
| Airfoil Setion | NACA 0018 |
| Jumlah Sudu | 3 |
| Solidity Ratio ($\sigma$) | 0,24 |
| Diameter Rotor ($D_d$) | 2,7 m |
| Tinggi Rotor ($H_d$) | 2,7 m |
| Panjang Chord (c) | 0,216 m |
| Luas Sapuan (A) | 7,29 $m^2$ |

**Komponen Turbin**

| | |
|---|---|
| Diameter poros | 90 mm |
| Panjang poros | 9000 mm |
| Lebar dan tebal pasak | $28 \times 16$ mm |
| Panjang pasak | 15 mm |
| Diameter dudukan strut | 250 mm |
| Tebal dudukan strut | 55 mm |
| Lebar strut | 60 mm |
| Tebal strut | 12 mm |
| Diameter luar bearing | 140 mm |
| Diameter dalam bearing | 90 mm |
| Tebal bantalan poros | 21 mm |
| Tinggi tiang | 8000 mm |
| Generator | Ginlong GL PMG-1kW |
| Transmisi | *Bevel gear* |

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