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Simple Hawt Prototype Efficiency at Small Scale Wind Speed

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Abstract

Nowadays, the wind energy research for alternatif anergy has been progress. Wind energy can be found if the wind turbine is available.This paper explains small scale of Horizontal Axis Wind Turbine (HAWT) prototype by using 200 ohm resistor and LED at small scale wind speed. The blade material is acrilic. This material property is light, no easy broken, no corrosive and easy to find it. The blade model is flat plate section. Rotor diameter is 1 meter. The research was did at the beach. Permanent magnet synchronous generator is used to change wind energy to electric energy. The result shows that the generator increase linearly with wind speed. Measured wind speed was 1.9 m/s to 3.9 m/s. Average efficiency of HAWT prototype was 6.2% at delta connected load and 3.7% at wye connected load.

Keywords: HAWT prototype, flat plate blade model, efficiency

1. Introduction

One of the most promosing alternative energies as renewable energy is wind energy which has abundant and free resource. Many researchers have been studying the wind speed characteristics and its potential as a wind turbine generation (WTG) in many countries worldwide [1]. Indonesia which is an archipelagous country has potential wind for developing wind turbine generation (WTG). Unfortunately, Padang, which is a beach city in Indonesia, has wind speed at low rate scale (≤ 7 m/s) [2]. To capture this small scale wind speed, it is needed some technologies in wind turbines for getting higher efficient energy convertion from mechanical energy to electrical energy. From the literatures, it is known that the maximum efficiency is generated by wind energy is about 53% [3],[4]. Although the resulting efficiency is small, but the research related to the utilization of wind energy as an alternative energy source continues to grow.

As the general form of wind turbines, Horizontal Axis Wind turbines (HAWT) are still built even though the dimension of rotor blade become disadvantages. The first disadvantage, the effect on turbine blade crossed by wind cause the vibration and deformation give additional stress and influence the strength of the blade [5]. Another disadvantage, due to the large rotor blade fault, several accidents and also other incidents happened not only in UK [6] but also in other countries [7].

In this paper, to anticipate the disadvantages of the large scale wind turbine, the small scale wind turbine is proposed with some policies. First, the prototype should be able to harvest energy at low speed of wind [1],[8],[9]. Second, the built wind turbine should be applicable for rural or residence utility. Finally, considering the first and second policy, the turbine should be built by using cheap materials and also it needs just small space for installation [10].

2. Research Method

Wind energy conversion systems is a system which aims to transform the kinetic energy of the wind into mechanical energy to the turbine shaft and then modified again by the generator into electrical energy. Wind kinetic energy with mass "m" is moving with velocity v has the equation [3]:

$$Kinetic\ Energy = \frac{1}{2}mv^2 \qquad\qquad Joule \qquad\qquad (1)$$

Wind power is the energy per unit of time, then:

$$P_T = \frac{1}{2}.(mass\ flow\ rate\ per\ second).v^2 \qquad\qquad (2)$$

$$P_T = \frac{1}{2}.(C_p\rho Av).v^2 = \frac{1}{2}\rho Av^3 \qquad Watt \qquad\qquad (3)$$

where:
P_T = mechanical power in the moving air (Watt)
C_p = power coefisient, $C_p < 0,6$
ρ = air density (kg/m^3)
A = area swept by the rotor blades (m^2) = $\frac{1}{2}\pi R^2$
v = wind speed (m/s)

The performance of the HAWT prototype was also determined from the tip speed ratio.Tip speed ratio is the outermost side speed comparison of the rotor against the wind speed. Equation tip speed ratio is:

tsr = ω.π.D/60/v   (4)

where: ω = shaft speed (rpm)
         π = 3.14
         D = rotor diameter oh the blade (m)
         v = wind speed (m/s)
the tsr was selected among the 5 s/d 8.

2.1 Blade Design

The material used for the manufacture of the blade is acrilic. Reasons for choosing this material because it was easy, lightweight and not prone to corrosion. The radius of the blade used is 0.5 m and blade design is flat plate section. As a reference to determine the chord width equation is [11]:

$$C = \frac{6\pi R(R/r)}{9\lambda^2 B} \qquad\qquad (5)$$

where :   C = chord width (m)
             R = the radius of the rotor = 0.5 m
             r = the distance from the midline chord (m)
             λ = tip speed ratio = 7
             B = blade numbers = 3

(a) One blade (b)Three Blades

Figure 1. HAWT Blade Design

Figure 1 shows the shape of the blade is produced. Three blade is mounted on the hub are each a 120°.

2.2 The Estimated Power at HAWT Prototype

Estimated of the output power at HAWT prototype with low wind speed was based on equation (2), can be seen in Figure 2.
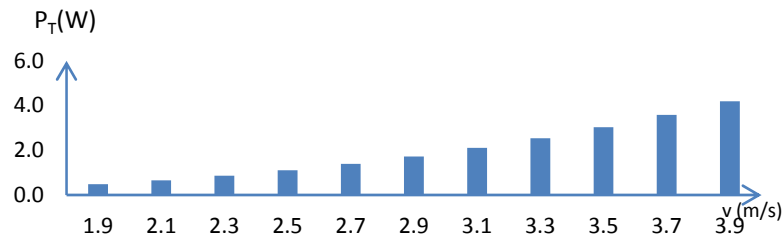

Figure 2. Estimated Power from small scale wind speed

2.3 The Liaison between the Blade and Shaft

Liaison between the blades and shafts using an iron bar which is made in the shape of the letter "T". Liaison in this twist of the blade was obtained by a bit slope about 5^{0}. The purpose of this is to make the acquired-twisting lift and drag force that is good so that wind turbines can work well [3],[4],[11].
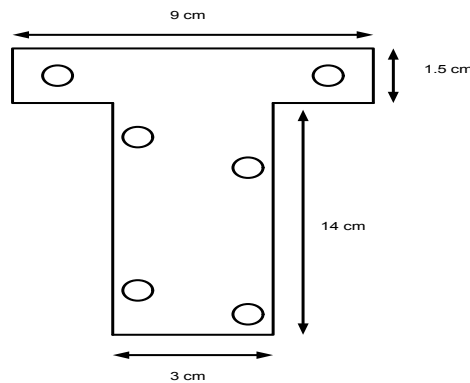

Figure 3. The Liaison between shaft and blade

2.4 Generator

Generators synchronous generators used are three phase with magnetic excitation of harvesters. This is a used generator at wind turbines with a capacity of water-X-power 400 Watts. This Generator is considered according to the design of wind turbines to be made because it is a type of generator that is made for the purposes of small-scale wind turbine which has 6 poles excitation. Based on the technical specifications on the User Manual Wind turbine Air-X wind turbine is known that began spinning at wind speeds of 3.0 m/s. However, on horizontal Axis wind turbine designs are expected to be starting the turbine wind speeds can be lower than 3.0 m/s.

In general the voltage generated by the generator has the equation [12]:

$$e = B.l.v \qquad (6)$$

where,

e = Induction Voltage (V)
B = magnetic field (Wb/m^2)
l = the long entanglement (m)
v = rotation speed (rpm)

Usually the power equation for alternating voltage source is:

$$S = P_L + jQ \qquad (7)$$

where,

S = apparent power = V.I (VA) $\qquad (8)$

P_L = active power or load power = V.I.cosϕ = I^{2}R (Watt) $\qquad (9)$

Q = reactive power = V.I.sinϕ = I^{2}X (VAR) $\qquad (10)$

R = resistor (Ω)
X = reactance = X_L - X_C (Ω)
X_L = inductive reactance = 2.π.f.L (Ω)
X_C = capacitive reactance = 1/(2.π.f.C) (Ω)
f = frequency (Hz)
L = inductance (Henry)
C = capacitance (Farad)

From equation 2 and 9, then the efficiency of the HAWT prototype is:

$$\eta = \frac{P_L}{P_T} x 100\% \qquad (11)$$

where.

η = efficiency HAWT Prototype
P_L = load power (W)
P_T = turbine mechanical power (W)

3. Eksperiment Results and Analysis

Prior to the field, the permanent magnet synchronous generator used to be tested in the laboratory. By providing the energy of motion coming from the motor, the generator will generate electrical energy. Figure 4a shows the circuit for testing permanent magnet generator. Figure 4b shows the resulting voltage permanent magnet generator for several rounds of the shaft. By providing the 300 rpm to 2500 rpm, generator produces a voltage from 2.1 Volts up to 21.1 volts.

The procedure for testing are as follow. First, Prototype was tested without load to know wether there was current or not. Then, circuit was loaded by LED. The LED used is a kind of

super bright white LED which consists of two groups of LED. Each group consists of ten LEDs. In the first group, LED construction are parallel which is a maximum of 5 kΩ resistance connected. While in the second group, every two LED is arranged parallelly and connected to a 1 kΩ, so the circuit will consist of the simillar five groups of LED. Before being connected to LED, alternating voltage must be rectified by diode rectifier.Finally, the experiment conducted with load in ∆ and Y connection. The circuit for testing can be depicted in Figure 5.
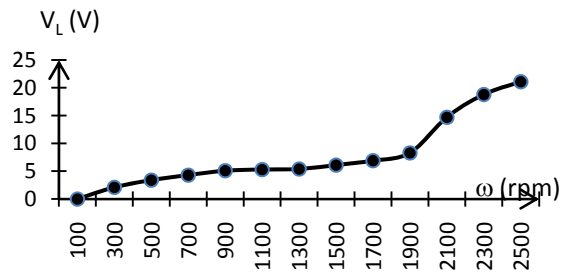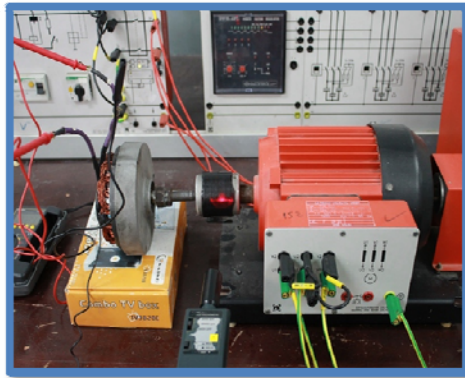
a. Circuit   b. Result Voltage

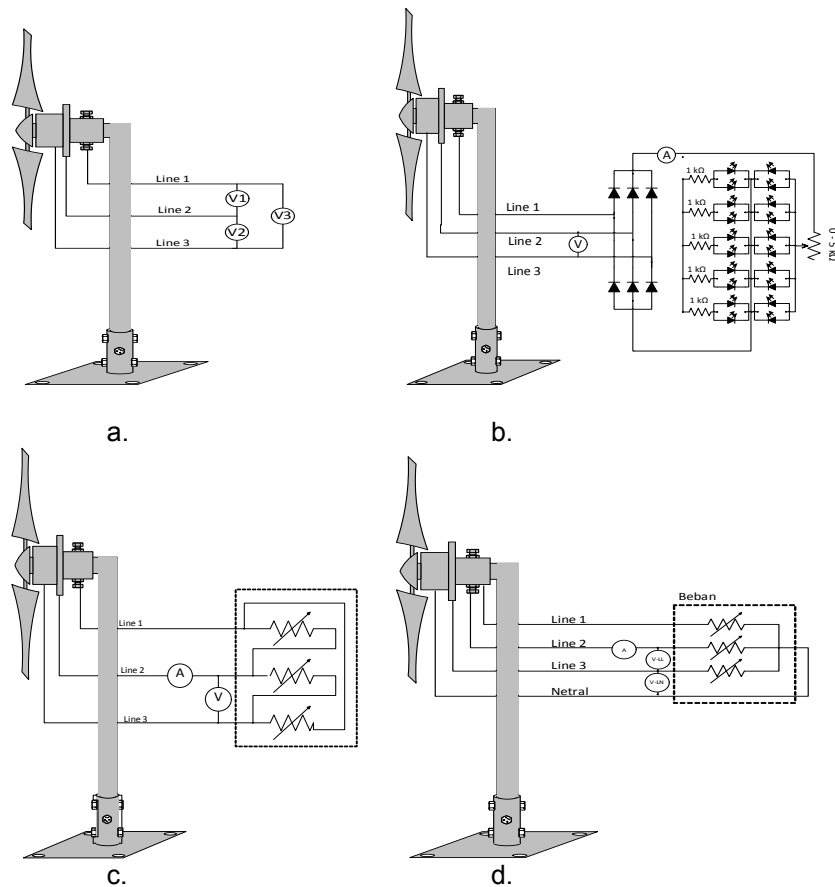Figure 4. Permanent Magnet Synchronous Generator Testing

a.   b.

c.   d.

Figure 5. HAWT prototype experiment: a. No load circuit b. Circuit with LED load c. Circuit with ∆ connection d. Circuit with Y connection

3.1 No Load Eksperiment

Figure 6 shows the circuit and the voltage was produced on the HAWT prototype without load.
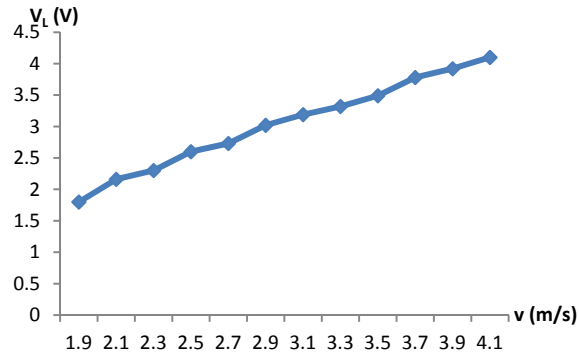
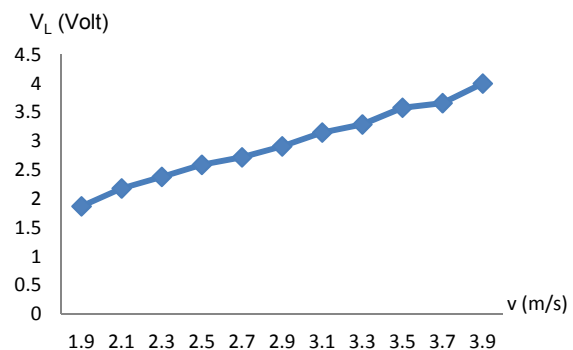Figure 6. The curve of line voltage vs wind speed at no load condition

The graph shows that it looks that the greater the wind speed the greater resulting voltage generator will be. This is because the generator voltage is directly proportional to wind speed. Wind turbine begins rotating in the wind speed 1.9 m/s.

3.2 Eksperiment with LED

Figure 7 shows HAWT prototype that its blade are spinning. It is seen that LED is on.

a.   The Prototype and circuit   b. The result of LED Voltage

Figure 7. LED experiment in the Beach

Figure 7b shows that the resulting voltage rises linearly with an increase in wind speed. The resulting voltage of the generator is then rectified by the rectifier. The direct current from rectifier is used to light on the LEDs. LED started light on speed of wind at 2.3 m/s.

3.3 Eksperiment with Delta Connected Load

Figure 8a shows the voltage produced on the prototype delta relationship was HAWT with the load resistor 200 Ω. The resulting voltage generator will be even greater when the wind

speed that appears increasingly elevated, because the resulting voltage is proportional to the given rotational speed.
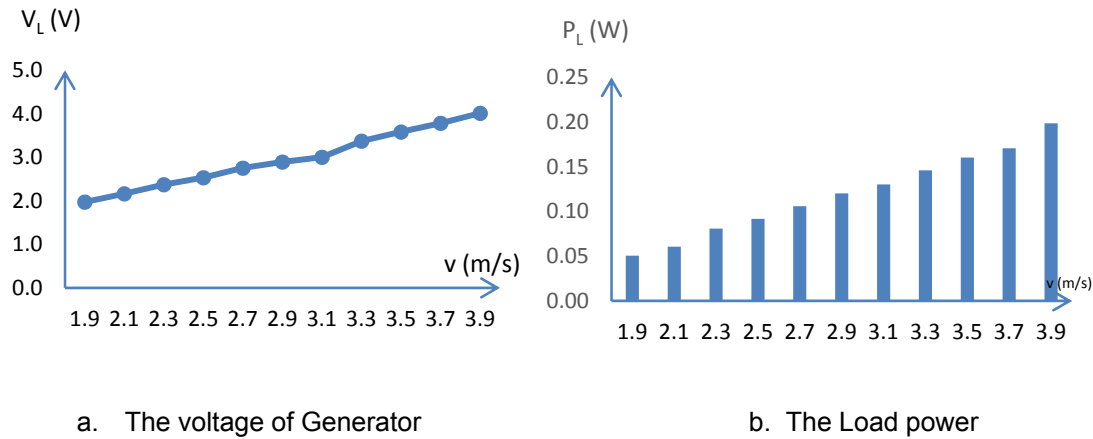

a.   The voltage of Generator   b. The Load power

Figure 8. HAWT Prototype with Δ Connected Load Results

Figure 8b shows that load power is not equal to turbine power. Load power P_L is calculated from eq. (8), turbine power P_T from eq. (2), efficiency η from eq. (11). The decrease of efficiency because there are losses at turbine such as drag force and at generator such as magnetic and copper losses. The average efficiency is obtained is 6.2%.

3.4 Eksperiment with Wye Connected Load
Figure 9a shows the curve of line voltage versus wind speed to 200 Ω.resistor load with wye connection. The curve shows that line voltage increase linearly to wind speed.

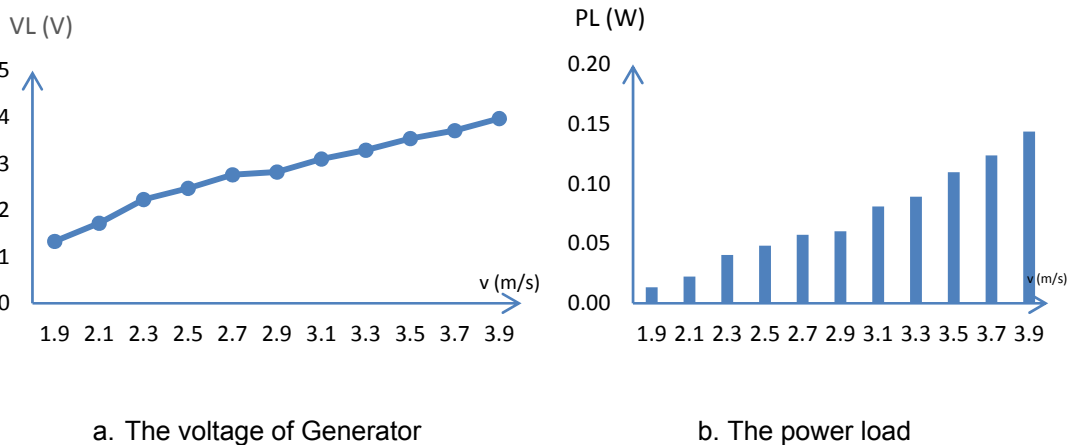a. The voltage of Generator   b. The power load

Figure 9. HAWT Prototype with Y Connected Load Results

Figure 9b shows the load power. Based on the load power, efficiency is calculated.The efficiency, then is obtained on the HAWT prototype Y connection was smaller than delta connection. The low efficiency of Y connection is caused by inductive reactance at the line. The average efficiency which resulted on this prototype is 3.7%.

Generally, small scale wind speed gives low efficiency of the prototype of wind turbine. This result is the same result as the study by [1] that little wind resource gives only 10% of the

total output voltage of WTG. Therefore, it is needed to increase the efficiency by developing a special wind turbines which is simple, effective and low-cost wind turbine [13]. In addition, the using of speed-increase gearbox can increase generator rpm even though the gearbox can contribute to vibration [14]. The hybrid between horizontal and vertical axis can increase the efficiency due to vertical axis wind turbine can rotate at smaller scale speed rather than the horizontal axis [15]. Finally, for the generator point of view, Refs. [16] and [17] can increse the performance of the prototype.

4. Conclusion

The simple HAWT prototype has already been made. This prototype has three blades. Design of blade is flat plate section. By using resistor 200 Ω, average efficiency to delta connection is 6.2% and wye connection is 3.7%. Actually, the efficiency of both are still small. There are many losses in this prototype. Those are losses at turbine, generator and at line.

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