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IMPLEMENTATAION OF PITCH ANGLE WIND TURBINE POSISION FOR MAXIMUM POWER PRODUCTION

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ABSTRACT

This study implementation to trace the position of pitch angle wind turbine on the wind energy conversion system (WECS). The accurate position could maximize mechanical power. This evidence can be achieved by developing a prototype of wind turbine considering of dimensions and components of wind turbines, blade type, blade radius, specified work area of angular velocity and power production. Furthermore, the external aspects consist of the situation and condition of the wind farm with a low wind speed (3-6) m / s is also considerate. Tracking test of the blade angle position is achieved by providing a wind from the blower with a varied pace, the position of the turbine blade pitch angle can be set up online via PC with a change of 5.6^0 *every single step angle for range* $(0\text{-}90)^0$*.. When the wind energy is input to a turbine at 5193 watts in 100 seconds, the wind energy that can be extracted into the mechanical energy of = 1630 watts or = 16 watts / s. This number is the maximum power value. In contrast, the minimum mechanical power production at the position of blade angle* $(72.8^0$*, produces mechanical power = 89 watts, or an average of 1,3 watt /s. This ratio of the position of the minimum and maximum blade angle indicates the minimum and the maximum power ratio = 1:16. Thus the position of the turbine blade angle significantly influence on the production of mechanical and electrical power.*

Keywords: Pitch angle, wind turbine, kinetic energy, mechanical energy, Electrical power.

INTRODUCTION

Global crisis in 2008, viz namely the financial crisis, energy crisis and climate-environmental crisis, has motivated and encouraged the world community to seek alternative energy resources, such as new and renewable energy to replace conventional energy. For now on, wind energy has a claim on new and renewable energy; therefore wind energy can be proven to solve the three crises above. The world wind turbine installation development in 2010 reached 30% with a total capacity of 160 GW. They comprises of USA = 39 GW, Germany and China = 26 GW, followed by Spain, India, Italy, etc. Indonesia as a tropical country with low wind speeds (3-6 m / s) is also not left behind. In 2008, Indonesia has 1.2 MW wind turbine installations, and in 2011 a new plant is built in South Sulawesi and Aceh Bulukumba consist of 0.5 MW and 10 MW respectively. However, the majority of the installed wind turbines in Indonesia are from other countries, as a result there is a great dependency of the components from other countries. Therefore, it is needed to develop local wind turbine either by LAPAN, BPPT, colleges, or the general public [1-2-3].

Wind energy conversion systems (WECS) consists of wind turbines, generators, power electronics, network systems and control systems. Small scale of WECS is wind turbines with <10 kW capacities, this turbine is suitable for low-speed wind farms such as Indonesia. The important part of SKEA is the wind turbine. In this part, the wind kinetic energy will be transformed into mechanical energy and then converted into electrical energy. Fluctuation in the wind kinetic energy value was often influenced by the wind speed changes and the type of air. Wind turbine mechanical energy production value is parallel with the wind kinetic energy input [4-5]. Maximum mechanical power production of wind turbines can be attained by increasing the angle of wind turbine rotational speed. Wind turbine mechanical power production depends on several variables of wind turbines, such as power coefficient (Cp), which depends on the value of (λ, θ). λ is the tip speed ratio (TSR) that cost = $\omega R / V$), the value of R constant wind turbines, meanwwhile the fluctuation of V value depend on the condition of the wind field, ω is the angular velocity of the wind turbine correlated to a blade angle position. Hence, the most influence variable of mechanical power production of wind turbines is the blade angle position other quantities which influence over mechanical power production is the type of blade and blade number, but its value is constant after the system was designed [6].

The wind turbine performance can be monitored, if a prototype wind turbine is outfitted with a computer-based electronic monitoring system. Here, major scales such as V, ω and θ are likely to be monitored. To obtain these quantities, wind turbine is outfitted with a sensing rotary encoder for sensing turbine rotational speed. Furthermore, this rotation data is processed by processor, and then it is displayed and recorded in real time by the PC. The variations of blade angle position changes can be set via PC, so the blade angle position changes can be done in every single step 5.6 ^{o} quickly and precisely [7]. From these experiments, all data related to head position blade angle changes, wind speed and the speed will be processed to obtain the relation between the wind power and mechanical power output. The maximum power production values are obtained when the blade angle is in a particular position and then this value is used as a reference for developing the wind turbine. In this study aerodynamic performance characteristics of HAWT were invertigated teoritically by combination analysis involving , energy and blade element theory and experimentally by the use prototype. Every pitch angle step of blade examined under condition differen of wind speed. Ffocuses study are to find and trace the position angle blade wind turbine that can produce maximum mechanical power.

REASEARCH METHOD

Figure 1 describes the working principle of a wind turbine blade which is the main determinant for the performance of wind turbines. Aairfoil will generate respective lift force vector (FL), drag force (FD) and resultant force (FT) as it is subjected to wind from the front. Changes in lift and drag force are directly influenced by the geometric shape of the blade. When wind speed and wind direction attack from position at an angle relative to the main line chord, as skecthed in Figure 1, then the wind speed and wind direction will change of lift and drag forces so that the angular velocity and the torque shaft chord changes as well. Chinges in blade angle, due to wind direction, will eventually affect the speed of rotating shaft. Thus the influence of blade angle positions is crucial to be further investigated.

In paper we report study to investigate the role of pitch angle in correlation with power generation. A blade angle position tracking experiments were done on a prototype wind turbine, with constrain to its the smallest angle step changes that can be set. Through the investigation, we will know under what angle the maximum power can be achieved. The discussion starts from the conversion of wind energy content towards wind power production, which is described as follow.

A wind power productionon a wind turbine can be expressed through a kinetics wind energy equation using equation (1) and (2) [8-9].

$$U = \frac{1}{2} m v_w^2 = \frac{1}{2}\left(\rho_{air} A_r x\right) v_w^2 \tag{1}$$

$$P = \frac{dU}{dt} = \frac{1}{2}\rho_{air} A_r v_w^2 \frac{dx}{dt} = \frac{1}{2}\rho_{air} A_r v_w^3 \tag{2}$$

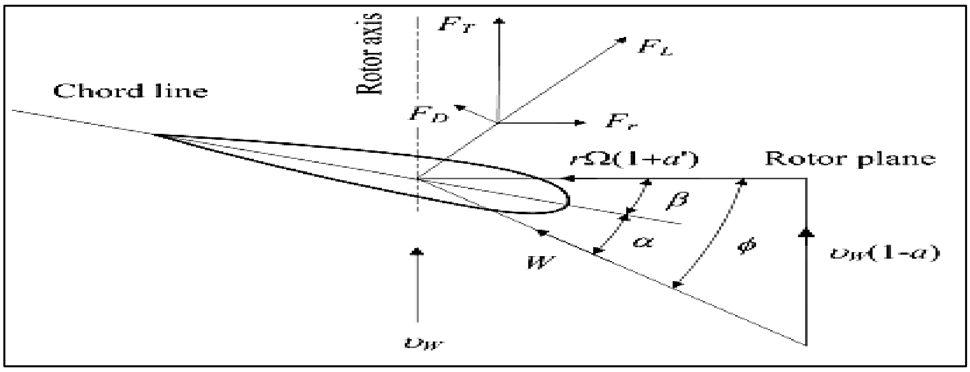

Figure 1: Force-vector in blade wind turbine

Where *U* is a kinetic energy (Joule), ρ_{air} is air density (kg/m^2), A_r is a sweeping blade area (m^2), v_w is a wind speed (m/s), and *P* is wind turbine power (watt). The kinetics energy is converted into rotational energy or wind turbine power. When the wind passed through the blade, a wind velocity profile can be illustrated using a contour tube as in given Fig. 2, with four points to be considered.

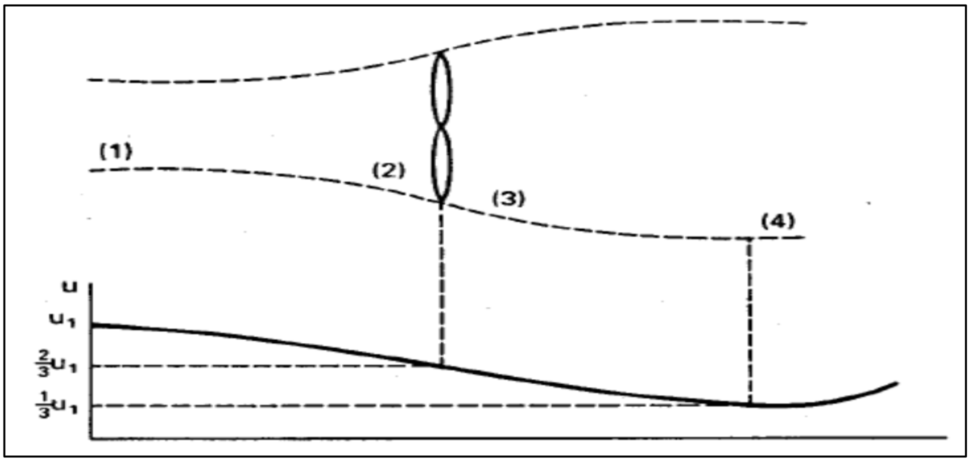

Figure 2: Velocity profile in the wind turbine area

The velocity profile and its relation to the sweeping blade area are given below:

$$v_2 = v_3 = \frac{2}{3} v_1 \tag{3.a}$$

$$v_4 = \frac{1}{3} v_1 \tag{3.b}$$

$$A_2 = A_3 = \frac{3}{2} A_1 \tag{3.c}$$

$$A_4 = 3A_1 \tag{3.d}$$

Equation (4) can be used to calculate the extraction of wind power. The power can be calculated by comparing the wind power before and after the blade:

$$P = P_1 - P_4 = \frac{1}{2}\rho_{air}\left(A_1 v_1^3 - A_4 v_4^3\right) = \frac{1}{2}\rho_{air}\left(\frac{8}{9} A_1 v_1^3\right) \tag{4}$$

$$P = \frac{1}{2}\rho_{air}\left[\frac{8}{9}\left(\frac{2}{3} A_2 v_1^3\right)\right] = \frac{1}{2}\rho_{air}\left(\frac{16}{27} A_2 v_1^3\right) \tag{5}$$

A substitution of eq. (5) into eq. (4), and substitution the value of A, a constant value of 16/27 = 0.59 it can be obtained, which is known as a Betz coefficient [9-10]. This coefficient shows a maximum efficiency of wind turbine or it is called a power coefficient (Cp). It is known that wind power production is also effected by the Cp. The bigger the Cp can produce the bigger wind power production. The expression of extracted wind power also can be written as in eq. (6).

$$P = \frac{1}{2}\rho_{air} C_p A_r v_w^3 \tag{6}$$

Cp also can be determined in a simple way based on P_1 and P_4 as in eq. (7)

$$Cp = \frac{P_4 - P_1}{P_1} \; . \tag{7}$$

A designed wind turbine is shown in Figure 3. It consists of three blades, a gear blade, motor servo, a generator and others supporting components. The blade is designed based on an air foil contour standard of NACA 0012.

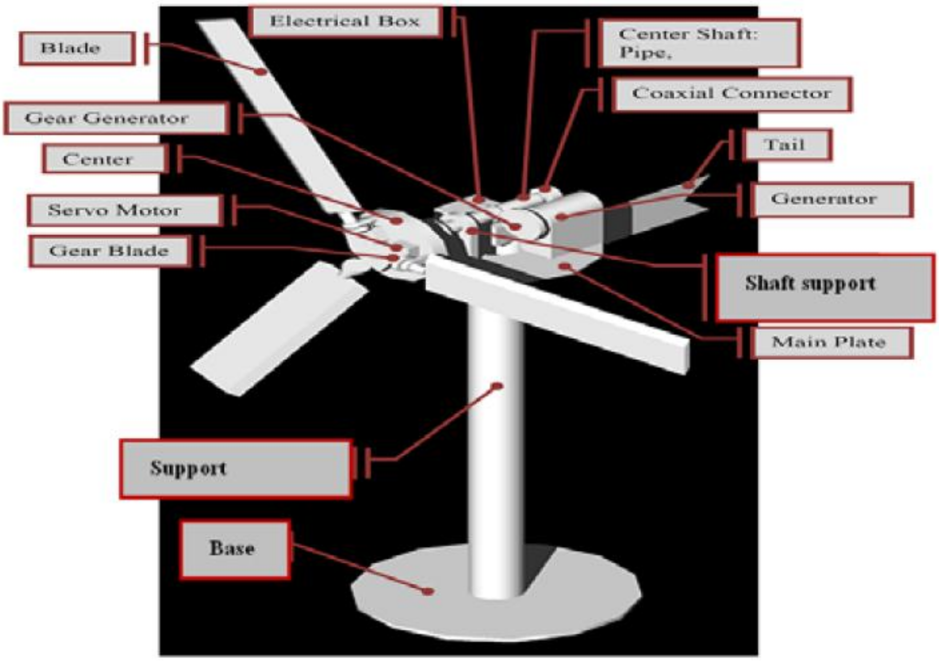

Figure 3: Prototype of wind turbine

This blade type is chosen with a consideration of its symmetrical and easiness of fabrication process. The blade has a length of 50 cm, a width of 10 cm, and a thickness of 1.2 cm. It is made of fiber material. A gear box is fabricated based on a specification of the motor servo. The gear box can achieve a movement resolution of 5.6^o. The fabricated wind turbine parameters are shown in the following Table 1.

Table 1: Specification of the wind turbine prototype

Item	Value
Rated power (kW), v=5m/s	50 W
Rotor diameter (m)	1
Hub height (m)	10
Swept area of rotor (m2)	0,785
Rotor speed (rpm)	20-500
Tower type	Tubular
Generator type	ALD50.PMA.
Rating power (KW)	0,05
Rating volt (V)	14/28
Rating amp (A)	3,57/1,79
RPM	500
(N*M)	< 0,15
Power	>65 %
Weight (kg)	6

The fabricated wind turbine is equipped with monitoring software based on Visual Basic 6 with a serial port interface for data communication. This software is used to control and to show the position of the pitch angle of the wind turbine blade. The measurement data can be presented in real time to indicate all of the important information. Monitoring system is also equipped with recording data system based on Microsoft Office-Excel integrated with the Visual Basic. Therefore, all of measurement process for the wind turbine can be accessed in real time and online. In this paper, wind speed data for experiment ttaken for a period of 100 seconds, in a steady state for the variation of wind speed 3-6 m/s. It indicates that the most of wind speed is in the range of 3-6 m/s. Therefore, it is necessary to design a wind turbine with an operational wind speed within this range.

RESULTS AND DISCUSSION

Wind turbine prototype testing is done by test of each component block and device; which includes hardware testing; rotating connector, rotary encoder sensors, signal conditioners, transmitters and displays. Testing is also done on the system software. When test results have met the criteria state, and then performed the integration of hardware and software systems. WECS Testing is done by performing experiments in the laboratory of ITS, which suport by wind power generating system (blower) that wind speed can be set varied in the range of 3-6 m/s. At the initial stage of experiments carried out setting changes blade pitch angle position (θ) through the software starts the smallest angle followed by the blowing of the wind speed varied start low then increase to the highest speed. Monitoring and recording system to read wind turbine angular velocity indicated by the PC screen. The experimental results are used to calculate the amount of power coefficient (Cp).

An example of the calculation technique Cp performed when the average wind speed before the blade is worth 5.6 m / s and average speed after crossing the blade 3,42 m/s. Then the value of Cp can be calculated through equation 3, by transforming the velocity at the point A1 and A2 A4 into shape. At this point the wind speed measurement within 2 meters before and after the blade. A case of precise measurements of wind speed at blade point value of 5 m/s and pitch angle of the blade is at the setting position is worth 28^0, reader on the display screen 13 pps produce a display value, so the value of 13 pps with a position angle 28^o. Cp scale relationships can be calculated as follows: Cp = (P1-P2) / P1 = {(51.33 to 40.01) (ρπ R2)} / {51.33 (ρπ R2)}; subsequently obtained the final value of Cp = 0.22.

Relationship varied position blade angle and wind speed varied to produce wind turbine rotational speed is varied as well, as a whole shown in Table 2. Testing of wind turbine systems are also made to find relationships wind speed, angular position, rotational speed, and coefficien of power and Tip speed ratio (TSR). The result of calculation and the correlation shown in Figure [4-8]. Fig.4 shows wind speed data varied 4-6 (m/s) during the period of 100 seconds imposed on a wind turbine to see the performance of wind turbines. From the test data obtained subsequently calculated the value of tip speed ratio. λ values obtained from the relationship pitch angle position and rotational speed are then used to calculate the tip speed ratio (TSR). λ and Cp values, obtained at a position angle between the (12-20)^0. Rrelationships of Cp, θ and λ from the calculation for the whole range shown in Fig. 7.

In the view of this experiment, there is correlation of all process variable including wind speed, blade angle position, rotational speed, tip speed ratio, power production, and wind turbines coefficient. The correlation of those variables can be seen in Fig. [4-8]. After V, θ, λ, ω, Cp, is found, and then the input and output mechanical power can be calculated. The two amounts of those powers are shown in Fig.6. In the line with that, wind turbine power coefficient is also shown in Fig.8.

Table 2: Corelations of rotasional speed (ω) with wind speed (v) and pitch angle (θ)

Pitch Angle (deg.)		Wind	Sspeed	
	3m/s	4m/s	5m/s	6m/s
0	0	0	0	0
6	0	92	142	202
11	0	124	182	252
17	20	135	202	282
22	0	117	162	218
28	0	106	146	195
34	0	96	117	145
39	0	81	99	123
45	0	45	78	117
50	0	38	63	93
56	0	18	47	81
62	0	2	27	57
67	0	0	18	39
73	0	0	2	6
78	0	0	0	1
84	0	0	0	0
90	0	0	0	0

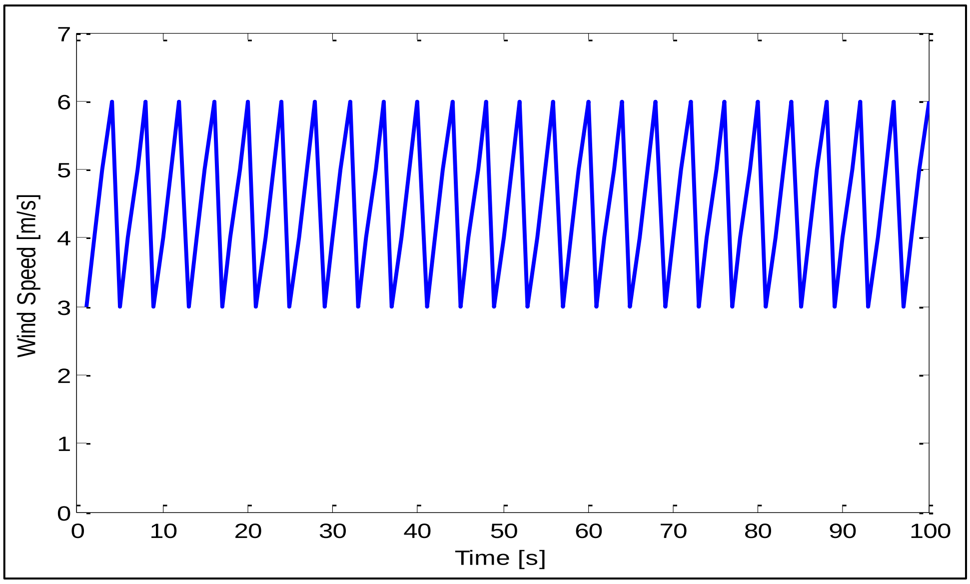

Figure 4: Wind speed versus time

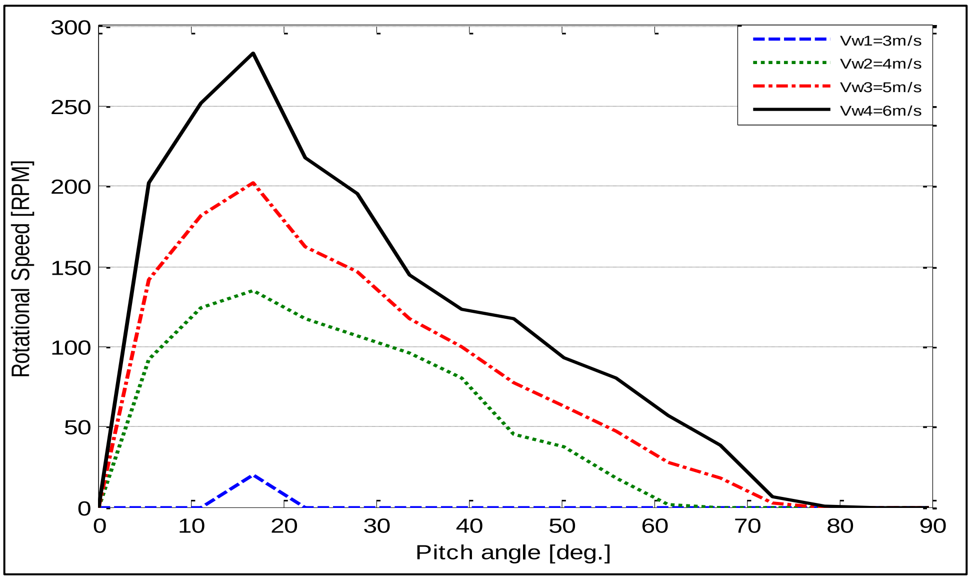

Figure 5: Rotational speed versud pitch angle wind turbine for differen wind speed

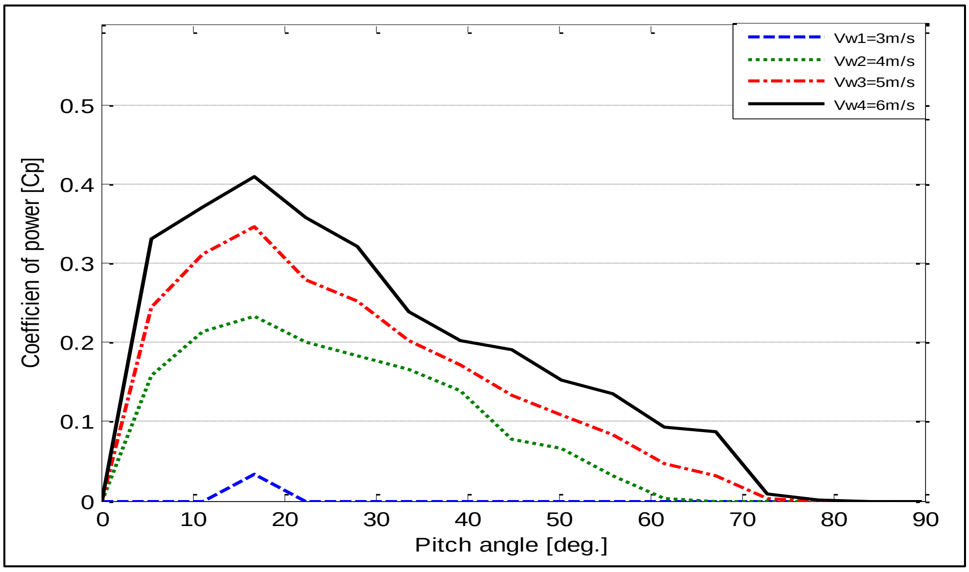

Figure 6: The optimal regime characteristics

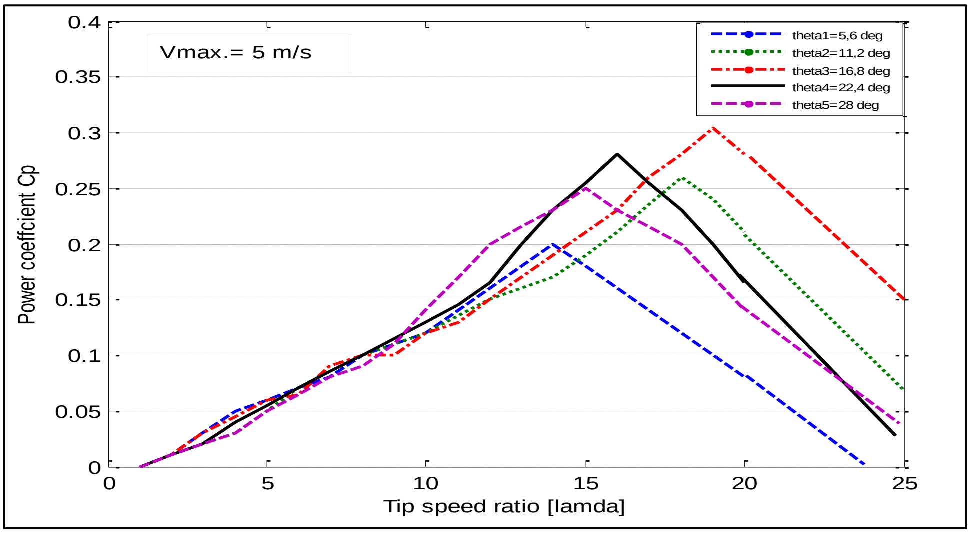

Figure 7: Power coefficient versus Tip Speed Ratio

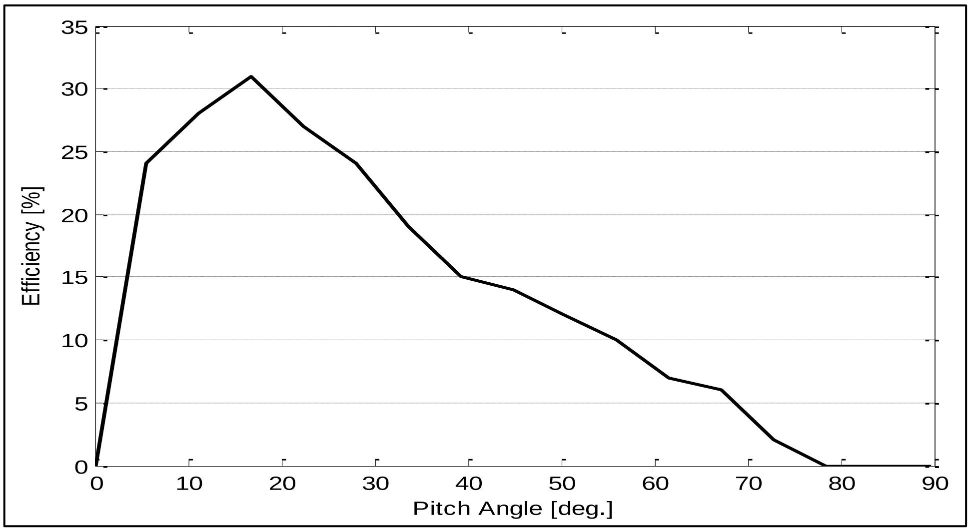

Figure 8: Effisiency versus Pich angle wind turbine

Table 3: Corelation theta, Vw and Pm for 100 s

Pitch angle position (deg.)	Wind power input (watt)	Mechanical power input (watt)	Electrical power output (watt)	Uncertainty (µ)
0	5193	0	0	0
5,6	5193	1233	850,77	1,3
11,2	5193	1461	1008,09	1,5
16,8	5193	1630	1124,70	1,6
22,4	5193	1394	961,86	1,4
28,0	5193	1250	862,50	1,3
33,6	5193	994	685,86	1,1
39,2	5193	777	536,13	1,0
44,8	5193	726	500,94	0,7
50,4	5193	602	415,38	0,7
56,0	5193	512	353,28	0,6
61,6	5193	338	233,22	0,6
67,2	5193	311	214,59	0,5
72,8	5193	89	61,41	0,5
78,4	5193	0	0	0
84,0	5193	0	0	0
89,6	5193	0	0	0

CONCLUSION

A prototype of the wind turbine blade head angle has been successfully designed and Wind turbines can produce a maximum angle rotation when the wind speed is 6 m/s, and the blade angle position is 16.8^{o}. This condition can produce the angular velocity = 283 rotation per minute (RPM), with maximum power coefficient of; 0.40. Wind turbines can extract wind kinetic energy as input for = 5193 watts over a period of 100 seconds. It generates mechanical energy output = 89 watts, and electrical power = 61,41 watts, (average of 0.61 watt/s.) uncertainty of measurement, $\mu = 0.5$ in blade angle position 72.8^{0} which is the smallest value of wind energy extraction and zero value for the greater blade angle position than 78^{0} (no energy is extracted). Maximum mechanical power production is achieved at 16.8 ^{o} blade angle position with mechanical power production = 1630 watts, or Electrical power = 1124, 7 watts (average power = 11, 25 watt/s). With uncertainty measurement $\mu = 1.6$.

Based on this calculation, it can be concluded the ratio of the blade angle position to mechanical power changes is 1: 16. So that ratio significantly affects the mechanical power production. It would be highly recommended for the blade pitch angle at theta angle position 16.80, or at least in the range (5.6^{0} - 28^{0}). The blade angle at that position can generate power > 12 watts with μ=2. This situation would facilitate the integration of the system with an electric generator.

Nomenclature

A	rotor swept area [m^{2}]
Cp	power coefficient [pu]
R	maximum rotor radius (m)
P_{aero}	aerodynamic power [W]
T_{rot}	torsional rotation at the turbine's rotor [N.m]
T_a	aerodynamic torque [N.m]
T_g	torque generator [N.m]
T_{aux}	torque auxiliary [N.m]
J_g	generator inertia [kg/m^{2}]
J_t	rotor inertia [kg/m^{2}]
γ	arodynamic damping coefficient [N.m.s/rad]
c_T	torsion coefficien (-)
v_t	wind speed (m/s)
ω_t	rational speed (rad/s)
T_o	optimum torsion (N.m)
v_o	optimum wind speed (m/s)
C_{op}	optimum power coefficient (-)
B_t	friction coefficien of turbine
Greek symbols	
ω_{rot}	angular speed of rotor
η	efficiency (-)
λ	tip speed ratio [pu.]
λ_o	optimal tip speed ratio [pu.]
ρ	air density (kg/m^{3})
θ	pitch angle blade (^{o})
u	Hellman coefficient (-)

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