# ANALYSIS OF EFFECT OF THE PITCH ANGLE TO OBTAIN THE OPTIMAL POWER OF THE LPN WECS 10 KW WIND TURBINE AT SEVERAL WIND SPEED CONDITION IN LOSPALOS DISTRICT USING POWERSIM

Agostinho Pinto[1], Susatyo Handoko[2], Iwan Setiawan[3]

[1]*Estudents , Magister of Electrical Engineering, Diponegoro University, Semarang, Indonesia,*
[2]*Lecturer , Magister of ElectricalEengineering, Diponegoro University, Semarang, Indonesia,*
[3]*Lecturer , Magister of Electrical Engineering, Diponegoro University, Semarang, Indonesia,*

**ABSTRACTS**

*The potential of wind power is a new and renewable energy source that is warmly developed in this millennial era to meet the current and future needs of electrical energy. Optimization of electrical energy production is like according to the right wind direction in order to get maximum wind power input to obtain optimal results.*

*Conducted research by taking wind speed data in lospalos district, modeling the energy conversion system (SKEA) on a 10 kW wind turbine in kabupaen lospalos. The simulation circuit model consists of a wind turbine, PMSM generator and retifire that will measure the output power in the wind energy conversion system.*

*The simulation results of the effect of pitch angle on the optimization of the average output power are converted by wind turbines between 1.69kW to 1.70 kW at wind speeds of 3.22 m / s to 6.22 m / s. The rotation of the rotor is set at 30 to 150 rpm at a pitch angle of 20o to 30o. The results of this study the output power value from manual calculations and simulations with a power simulator is very small so that the power efficiency of a 10 kW wind turbine is very small. The optimal value is obtained at a speed at a pitch angle of 30o at a wind speed of 6.22 m/s at a rotation of 150 rpm*

**Keywords** *: Wind Turbine, Speed, Pitch Angle, Output Power ,PSIM*

## 1. INTRODUCTION

Wind turbines are designed to generate output power at a given wind speed. Designed to have the lowest possible start-up and cut-in speeds so that it can generate electricity at low wind speeds. The main component of a wind turbine is a rotor that functions to convert wind kinetic energy into rotary kinetic energy which is then converted into electrical energy by a generator. Taking into account the loss losses in the generator, the rotor is designed to be capable of generating design power at a given wind speed [1].

With a certain configuration and geometry, the rotor is expected to be able to produce power as designed. By aligning the rotor's starting torque loss at the initial torque of the generator, the start – up wind speed is obtained. If the start-up wind speed is still considered too high or incompatible with the wind conditions where the wind turbine is installed, it is necessary to modify it. One of the modifications to lower the start-up wind speed is to increase the pitch of the blade. The disadvantage is that the rotor's rotational speed becomes smaller so that the power generated is also reduced [1].

Wind energy conversion system (WECS) turbine of 10 kW has been design and a power curve has been obtained. The lower start up wind speed to match the average wind condition in lospalos by increasing pitch angle this research need to fine out the effect pitch angle to the power curve of the 10 kW wind turbine. [1]..

From the results of previous studies, researchers want to use powersim software to compare optimization results with the power generated when increasing the pitch angle with a certain wind speed.

**1.2 Objectives**

1. To determine the effect of adding pitch angles on wind turbine output power on some wind speed conditions in lospalos district.
2. To determine the potential for existing wind speeds in order to determine the appropriate wind turbine capacity in lospalos district

**1.3 Scope**

Referring to the problem referred to in the problem formulation, the scope of the research will focus on scope of the discussion on the power curve with the wind speed parameter and the change in pitch angle and simulation with the power simulator .

## 2. THEORY

### 2.1. Wind

Wind is air that moves due to a difference in pressure. Air will flow from the high-pressure area to the lower pressure area. . According to classical physics the ethical energy of a body with Mass m and velocity v is E= 0.5.m.v2, assuming that velocity v is not close to the speed of light. So formulated Formula as an equation to calculate the kinetic energy of the wind:[4]

$$E = \tfrac{1}{2} mv^{2.} \qquad (1)$$

: $$m = \rho V \Rightarrow m = \rho vA \qquad (2)$$

So that the kinetic energy of the wind blowing in units of time (wind power) is: wind kinetics: [4]

$$P_w = \frac{1}{2}mV^2 ) \qquad (3)$$

where $m = (\rho Av)$

where $Pw$ = wind power (watt)

$\rho$ = air Density ($\rho$= 1,225 kg/m$^3$ )

A = Turbine cross-sectional area (m$^2$ )

v = wind speed (m/s) .

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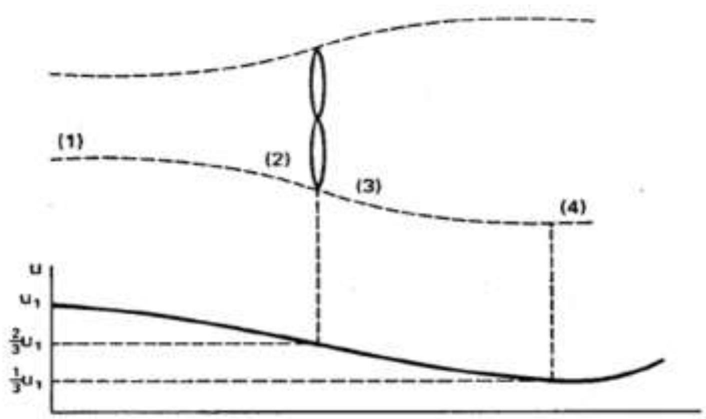


**Figure1:** profile wind speed

Profile Wind speed and in relationship to the propeller sweep area as in the following equation]

$$V_2 = V_3 = \frac{2}{3}V_1 \quad (5)$$

$$V_4 = \frac{1}{3}V_1 \quad (6)$$

$$A_2 = A_3 = \frac{3}{2}A_1 \quad (7)$$

$$A_4 = 3A_1 \quad (8)$$

Where : A = sweep area of wind turbin blade ( $m^2$)

**2.2. Wind Turbine Power**

The wind turbine power curve describes the wind speed and power generated by the wind turbine, If the power coefficient, Cp is constant valuable to other parameters, then power is a function of the wind speed of the third power, as in the following equation:

$$P = \frac{1 C p \rho \pi D^2 V^3}{8} \quad (9)$$

Where:

P = power (W)
Cp = power coefficient
ρ. = wind density (1,225 kg/$m^3$)
π = angle of circle
D = diameter of blade ( meter)
V = wind speed

Wind turbine force

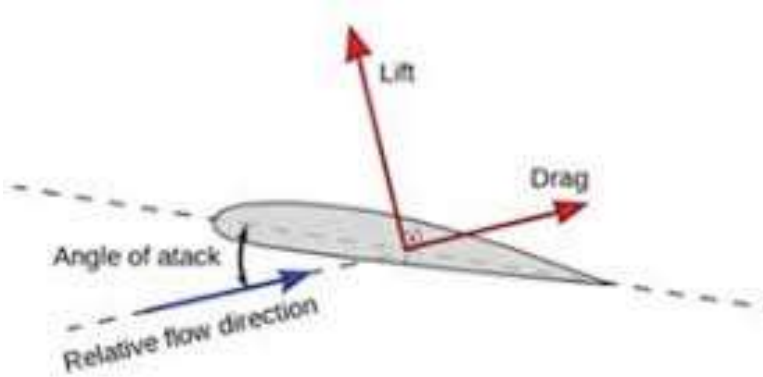


**Figure 2** : wind turbine blade force

The change in pitch angle indirectly affects the output power of the rotor. With a certain wind speed and rotation, each blade segment has a flow angle expressed in the equation

$$tan\phi = \frac{V}{\Omega r} \quad (10)$$

Where

φ = angle flow
V = wind speed
Ω = rotation
r = radius (m)

The angle flow(φ) is the summation between the angle of attack(α)

and the pitch angle (β) expressed by the following equation :

$$\phi = \alpha + \beta \quad (11)$$

From the equation above the wind speed and a certain rotation, the greater the pitch angle, the smaller the angle of attack. The decrease in the angle of attack directly affects the price of cl and cd . The conversion of the two parameters into lift force and inhibitory force is expressed in the equation) Sulistio Atmadi, Ahmad jamaludin Fitroh 2009.).

$$l = \frac{1\ \rho w^2 c c_l}{2} \quad (12)$$

Where

l. = Lifting force

$$d = \frac{1\ \rho w^2 c c_l}{2} \quad (13)$$

Wind turbine power is the power generated by wind turbines. It is formulated as follows:

$$P_{out} = T.\omega \quad (14)$$

Where:

Wind turbine power is the power generated by turbine

Pout = Power generated by wind turbines (watts)

T = Torque generated by shaft rotation ( Nm)

ω = Angular velocity of radians /secon)

To calculate the angular velocity using the following equation:
. It is formulated as follows:

$$\omega = \frac{\pi . n}{30 \text{ detik}} \text{rad/secon}, \tag{15}$$

where:
n = rotation( rpm),

**2.3. Wind Torque**

Wind torque is the rotating moment produced by the thrust from the rotation of the blades of the blades rotated by the wind, to calculate the value of the torque generated by the wind turbine using the following equation:

$$T = F.\ell \text{ ( Nm)} \tag{16}$$

Where :
F = Force on the shaft due to rotation (N)
l = The distance between the torque arm and its axis ( m)

$$F = \frac{\pi}{9} \rho D^2 V_i^2 \tag{17}$$

**2.4. Tip Speed Ratio (TSR)**

Tip speed ratio is a comparison between the speed at which the windmill is rotated and the wind speed.
The speed at the end of the blade (Vt) can be searched by the equation :

$$V_t = \omega . r \text{ (m/s)}$$

Where:

Vt = blade tip velocity (m/s)

$\omega$ = angular speed ( radian /second)

= radius of wind turbine (m)

Then the TSR can be found by the equation:

$$\textbf{TSR} = \frac{\pi . r . n}{30 . v} \quad \textbf{rad/secon}$$

Where:

$r$ = wind turbine radius(m)

$n$= shaft rotation speed(rpm).

$v$ = wind speed m/s)

**2.5. Power Coefficient**

The Power Coefficient ($Cp$) is the ratio between the power generated by the windmill ($Pout$) and the power generated from the wind ($Pin$). With the following equation:

$$Cp = \frac{Pout}{Pin} x \text{ } 100 \text{ \%}$$

CP = *Coefficient power /Power wind.*

Where:
$C_p$ = Power Coefficient (%)

$P_{out}$ = Power generated by wind turbines(watt).
$P_{in}$ = Power generated from the wind(watt).

**2.6. Wind Energy Conversion System**

Wind energy is energy that can be converted into other forms of energy through a system that is interdependent and mutually supportive in the process of transferring or converting energy. In this case wind energy is converted to other energy which is referred to as wind energy conversion system ( WECS). Overall, the conversion system consists of important sub-systems that are interdependent on each other as shown in the following scheme:

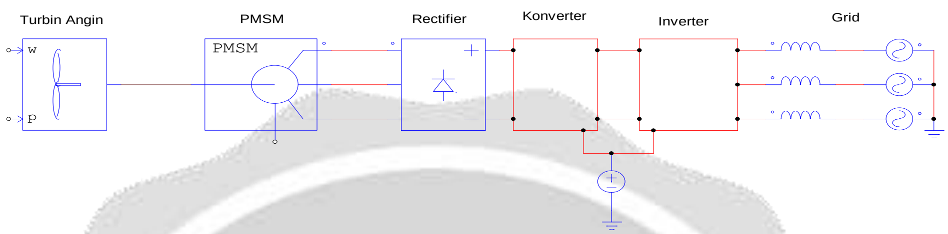


**Figure 3**. : WECS design

**2.6. Power Simulator**

Power simulator (Psim) is a simulation software specifically designed for power electronics, motor drives and power system conversion. With fast simulation speed and friendly user interface, PSIM provides powerful simulation to meet simulation and development needs.PSIM simulation consists of PSIM schematic program, simulation engine, and SIMVIEW waveform processing program(6).
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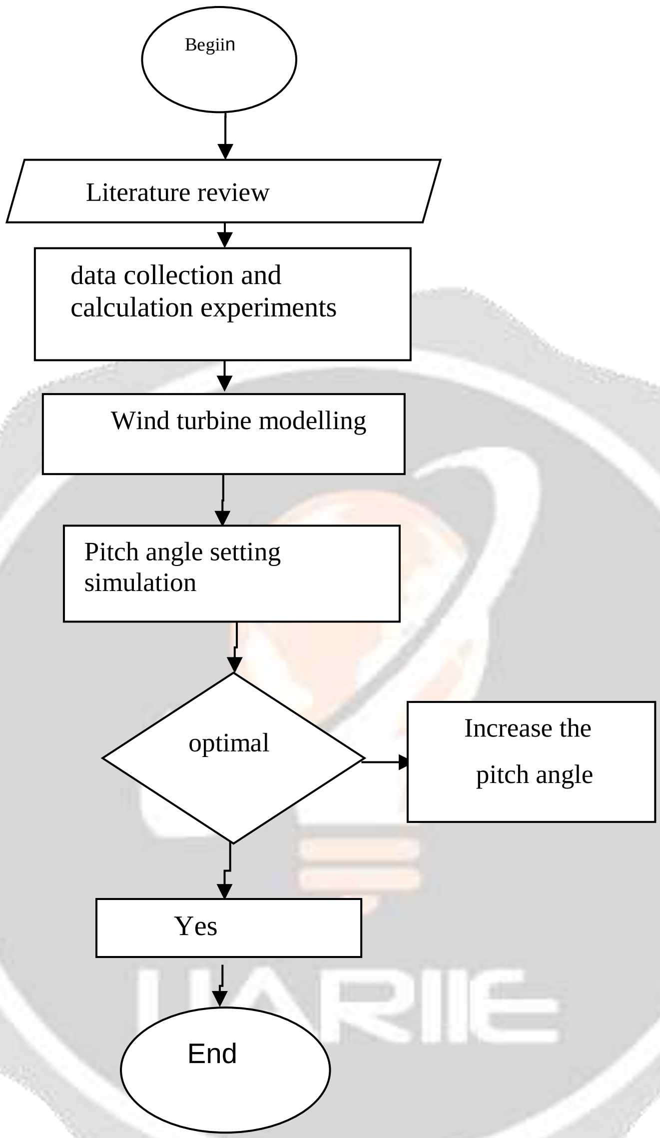
## 3. METODOLOGY

### 3.1. Flow chart




### 3.2 Simulation with Psim

**S**earch for output power with a power simulator to obtain a power curve with parameters of wind speed, rotor rotation and pitch angle. From the interim results, the data obtained from the simulation results carried out based on reference data on wind speed variations as simulation inputs on wind turbines are as follows:

#### 3.2.1. Wind turbine circuit, PMSM and Rectifier to simulate

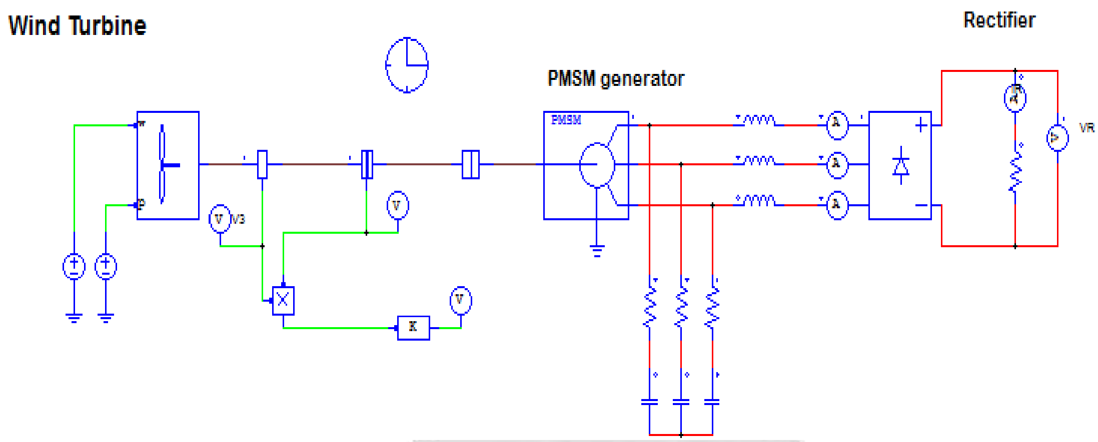



**Figure4**. Configuration of wind turbine PMSM and rectifier and Rectifier

## 4. RESULTS AND DISCUSSION

### 4.1. Maximum and Minimum power analysis.

In this study, it uses a horizontal shaft wind turbine with data specifications that are used as a reference in calculations and simulations using a power simulator, as stated in the following table:

4.2 Calculation of wind turbine output power and power coefficient (Cp)

$$C_p = \frac{P_{in}}{P_{in}}$$

$$= \frac{0.21}{1.03} \; , \quad = 20.39$$

**.Table 1 :** Calculation results of input power, out put and power coefficient of wind turbines

| V | F | T | λ | Pin | Pout | Cp |
|---|---|---|---|---|---|---|
| 3.22 | 383.58 | 13.68 | 62.8 | 1.03 | 0.21 | 20.39 |
| 3.47 | 329.32 | 27.35 | 31.4 | 1.29 | 0.43 | 33.33 |
| 3.69 | 372.4 | 41.03 | 20.93 | 1.55 | 0.64 | 41.29 |
| 4.11 | 462 | 54.71 | 15.7 | 2.14 | 0.86 | 40.19 |
| 4.28 | 501.01 | 68.38 | 12.56 | 2.41 | 1.07 | 44.40 |
| 4.28 | 501.01 | 82.06 | 10.47 | 2.41 | 1.29 | 53.53 |
| 4.44 | 539.17 | 95.74 | 8.97 | 2.69 | 1.5 | 55.76 |
| 4.86 | 646 | 109.41 | 7.85 | 3.53 | 1.72 | 48.73 |
| 5.1 | 711.37 | 123.09 | 6.98 | 4.08 | 1.93 | 47.30 |
| 5.52 | 833.37 | 136.76 | 6.28 | 5.15 | 2.15 | 41.75 |
| 6.12 | 1024.38 | 150.44 | 5.71 | 7.08 | 2.36 | 33.33 |
| 6.12 | 1024.38 | 164.12 | 5.23 | 7.08 | 2.58 | 36.44 |

### 4.3 Power curve simulation with power simulator

#### 4.3.1. Simulation results of power curves at wind speeds of 3.22 m/s with an angle of 20°

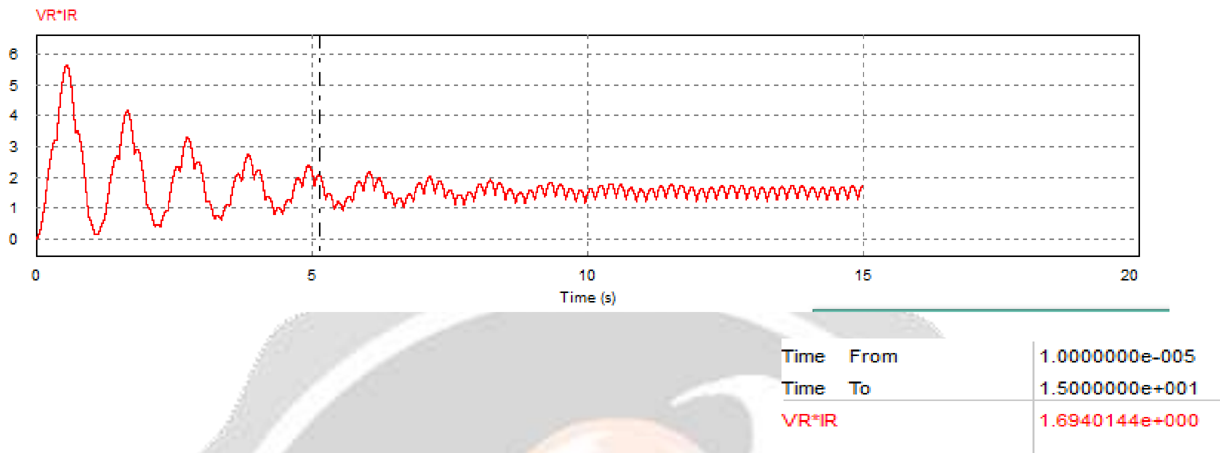



Figure 5: Simulated result of power curve with wind speed of 3.22 m/s with an angle of 20°

Figure 5 shows the power curve at a wind speed of 3.22 m/s resulting in an average power of 1.69 kW with a pitch angle of 20 degrees at a rotor rotation of 30 rpm and a transient period of 0 to 10 seconds towards steady state.

4.3.2. Simulation results of power curve with wind speed of 6 .12 m/s with an angle of 20 °

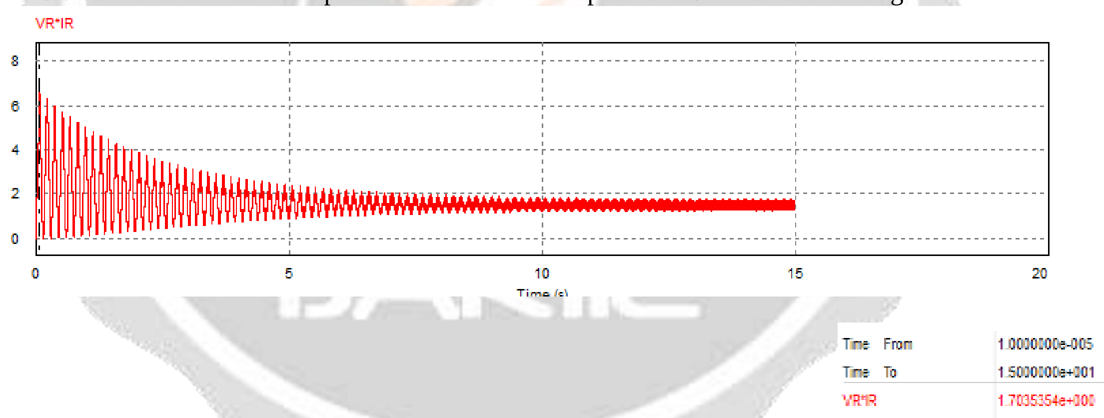
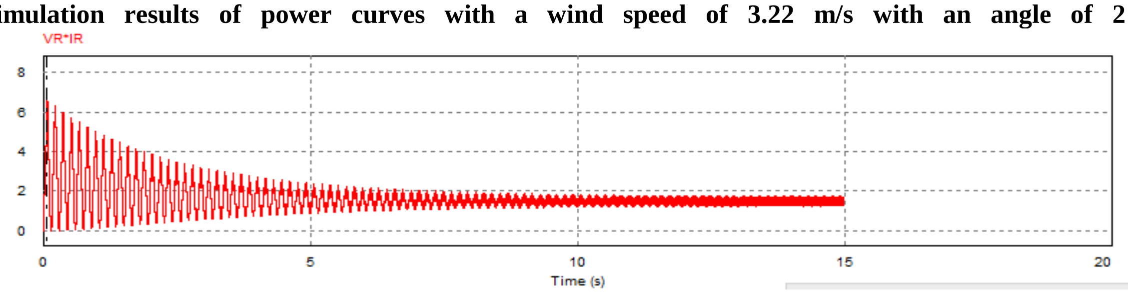



Figure 6: Simulated result of a power curve with a wind speed of 6.12 m/s with an angle of 20°

The simulation results as shown in figure 19, the wind turbine produces an output power of 1.70 kW at a wind speed of 6.22 m/s with a pitch angle of 20 degrees and reaches steady state after a transient period from 0 to 10 seconds.

#### 4.3.3. Simulation results of power curves with a wind speed of 3.22 m/s with an angle of 25°

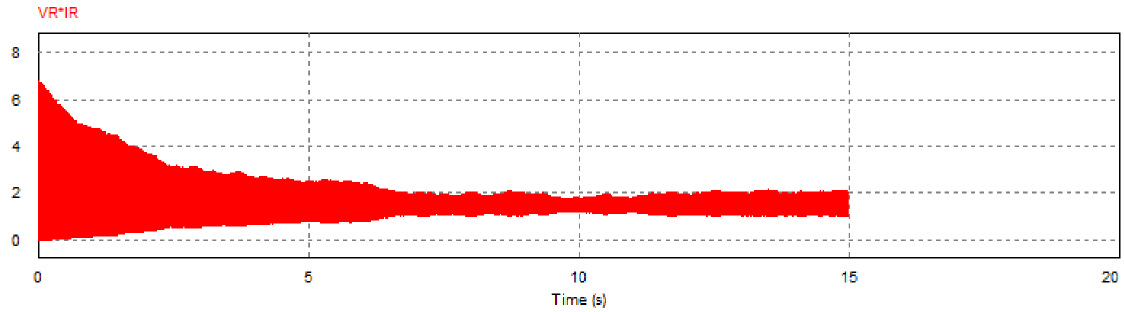


| | |
|---|---|
| Time From | 1.0000000e-005 |
| Time To | 1.5000000e+001 |
| VR*IR | 1.7035354e+000 |

. Figure 7 : Simulated result of power curve with wind speed 3.22m/s with an angle of 25$^o$

Wind turbine simulations such as in figure 20 show a power curve at a wind speed of 3.22 m/s resulting in an average power of 1.70kW with a pitch angle of 25 degrees at a rotor rotation of 30 rpm and a transient period of 0 to 8 seconds towards steady state.

#### 4.3.4. Power curve at a wind speed of 6.12 m/s with an angle of 25$^o$

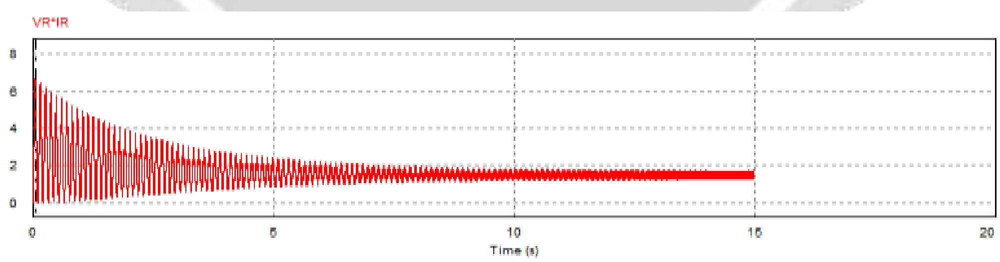



| | |
|---|---|
| Time From | 1.0000000e-005 |
| Time To | 1.5000000e+001 |
| VR*IR | 1.6988216e+000 |

Figure 8 : Simulated result of power curve with wind speed of 6.12 m/s with an angle of 25$^o$

Figure 8 shows the power curve at a wind speed of 6.12 m/s producing an average power of 1.69 kW with a pitch angle of 25 degrees at a rotor rotation of 150 rpm and a transient period of 0 to 10 seconds towards steady state.

#### 4.3.4. Simulation of a power curve with a wind speed of 3.22 m/s with an angle of 30$^o$




| | |
|---|---|
| Time From | 1.0000000e-005 |
| Time To | 1.5000000e+001 |
| VR*IR | 1.6988216e+000 |

Figure 9: simulated results of a power curve with a wind speed of 3.22 m/s with an angle of 30$^o$

Figure 9 shows a power curve at a wind speed of 3.22 m/s resulting in an average power of 1.69 kW with a pitch angle of 25 degrees at a rotor rotation of 30 rpm and a transient period of 0 to 10 seconds towards steady state.

### 4.3.5. Power curve with a wind speed of 6.12 m/s with an angle of 30°

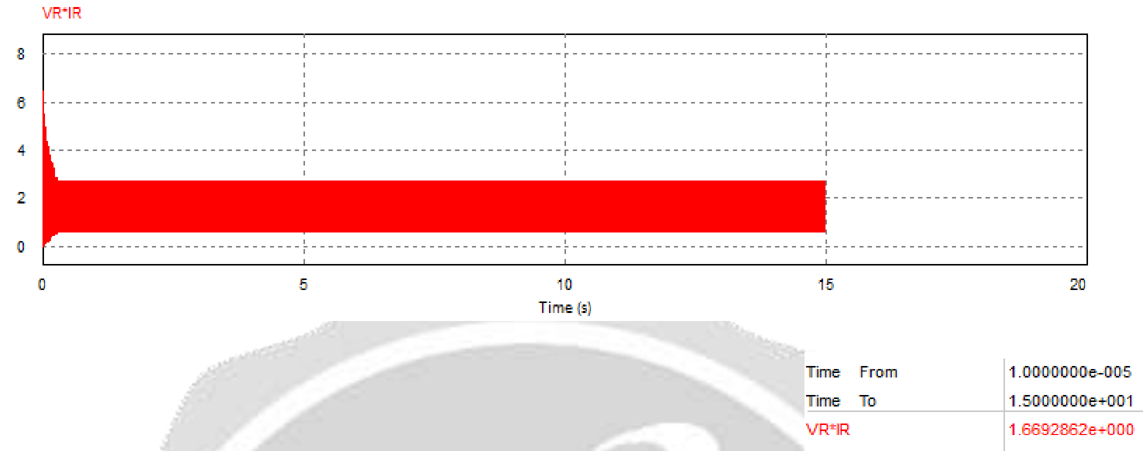



Figure 10 : Simulation of power curve with wind speed 6.12 m/s with an angle of 30°

Figure 10 shows a power curve at a wind speed of 6.12 m/s resulting in an average power of 1.67 kW with a pitch angle of 25 degrees at a rotor rotation of 150 rpm and a transient period of 0 to 10 seconds towards steady state.

### 4.4. Discussion .

In the wind energy conversion system using a pitch angle of 0o to 30o with an average wind speed from 3.12 m / s to 6.22 m / s. In the simulation, the pitch angle of 0 to 19 degrees does not affect the output power so that the output power is 0 or illegible at a significant number. With pitch angles starting from 20 degrees with variations in wind speed, the output power varies differently from the existing calculation of output power. Power curve with the addition of pitch angles to wind speed variations. A wind turbine with a capacity of 10 kW can achieve optimal power with a pitch angle of 30° at a wind speed of 4.44 m/s with a turning angle of 90 rpm as in table 11

**Table 11**. Result simulation power curve using PSIM

| Pitch angle | V | n | Power Manual calculation ( kW) | Using Psim (kW) |
|---|---|---|---|---|
| 20 | 3.22 | 30 | 0.21 | 1.69 |
| | 3.69 | 40 | 0.43 | 1.66 |
| | 4 | 50 | 0.64 | 1.67 |
| | 4.11 | 60 | 0.86 | 1.66 |
| | 4.28 | 70 | 1.07 | 1.67 |
| | 4.28 | 80 | 1.29 | 1.66 |
| | 4.28 | 90 | 1.5 | 1.67 |
| | 4.44 | 100 | 1.72 | 1.66 |
| | 4.86 | 110 | 1.93 | 1.67 |
| | 5.1 | 120 | 2.15 | 1.66 |
| | 5.52 | 130 | 2.15 | 1.67 |

| Pitch angle | V | n | kW | Psim |
|---|---|---|---|---|
| | 6.12 | 140 | 2.36 | 1.66 |
| | 6.12 | 150 | 2.58 | 1.7 |
| 25 | 3.22 | 30 | 0.21 | 1.7 |
| | 3.69 | 40 | 0.43 | 1.7 |
| | 4 | 50 | 0.64 | 1.69 |
| | 4.11 | 60 | 0.86 | 1.7 |
| | 4.28 | 70 | 1.07 | 1.69 |
| | 4.28 | 80 | 1.29 | 1.7 |
| | 4.28 | 90 | 1.5 | 1.69 |
| | 4.44 | 100 | 1.72 | 1.7 |
| | 4.86 | 110 | 1.93 | 1.7 |
| | 5.1 | 120 | 2.15 | 1.69 |
| | 5.52 | 130 | 2.15 | 1.7 |
| | 6.12 | 140 | 2.36 | 1.69 |
| | 6.12 | 150 | 2.58 | 1.69 |
| 30 | 3.22 | 30 | 0.21 | 1.7 |
| | 3.69 | 40 | 0.43 | 1.7 |
| | 4 | 50 | 0.64 | 1.69 |
| | 4.11 | 60 | 0.86 | 1.69 |
| | 4.28 | 70 | 1.07 | 1.7 |
| | 4.28 | 80 | 1.29 | 1.7 |
| | 4.28 | 90 | 1.5 | 1.7 |
| | 4.44 | 100 | 1.72 | 1.69 |
| | 4.86 | 110 | 1.93 | 1.69 |
| | 5.1 | 120 | 2.15 | 1.7 |
| | 5.52 | 130 | 2.15 | 1.69 |
| | 6.12 | 140 | 2.36 | 1.7 |
| | 6.12 | 150 | 2.58 | 1.69 |

Power curves resulting from manual calculations and simulations with average wind speed powersim in table 1.1 that each wind speed with a certain rotor rotation, the output power generated by the wind turbine is 0.21 kW to 2.58 kW or an average of 1.45 kW at the rotation of the steady state wind turbine rotor

Power curves resulting from manual calculations and simulations with average wind speed powersim in table 1.1 that each wind speed with a certain rotor rotation, the output power generated by the wind turbine is 0.21 kW to 2.58 kW or an average of 1.45 kW at the rotation of the steady state wind turbine rotor

## 5. CONCLUSIONS.

Based on the analysis of simulation results with power simulators, it can be concluded that:

1. The average wind speed in lospalos district is 6 m/s which can generate small and optimal electrical power in wind turbines with an output power of 1.45 kW in manual calculations
.2. The pitch angle affects the optimal output power of the wind turbine at variations in wind speed with a certain rotation (rpm), but it is not very significant, any change in the pitch angle from 0 to 19 degrees does not affect the output power based on the wind speed data obtained.
.3. Optimal output power at pitch angle in simulation with power simulator at $30^o$ angle with 150 rpm rotor rotation at wind speed 6.12 m/s
4. A wind speed of 20 m/s is considered a storm and will damage the wind turbine due to a speed that exceeds the ability of the wind turbine to operate normally.

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