



Cairo University

# **HORIZONTAL AXIS WIND TURBINE PERFORMANCE: THE EFFECT OF PITCH ANGLE**

By

**Eng. Moamen Badr Saad Farghaly**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the Degree of  
**MASTER OF SCIENCE**

In

**MECHANICAL POWER ENGINEERING**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
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**Title of Thesis:**

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PITCH ANGLE**

**Key Words:**

Renewable energy; Wind turbine; CFD; Pitch angle; Validation

**Summary:**

The principal objective of the proposed CFD analysis is to investigate the flow field around a horizontal axis wind turbine rotor and calculate the turbine's power. A full three dimensional computational fluid dynamics method based on K- $\omega$  SST approach was used in this study. The simulation results include the velocity distribution, pressure distribution along the flow direction, turbulent wake behind the wind turbine, and the turbine's power. The discussion will also include the effect of pitch angle on turbine's power.

## ***Disclaimer***

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledge all sources used and have cited them in the references section.

Name:

Date:

Signature:

## *Acknowledgment*

All gratitude is due to God almighty who guided and aided me bring fourth to light this work.

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# Nomenclature

## ❖ SYMBOL QUANTITY

- $a$  = Axial interference factor
- $a'$  = Rotational interference factor
- $A$  = Rotor swept area
- $B$  = Number of blades
- $c$  = Chord
- $F$  = Prandtl loss factor
- $r$  = Local blade radius
- $u$  = Wind speed through rotor plane
- $w$  = Local tangential wind velocity at rotor plane
- $x$  = Local speed ratio
- $X$  = Tip speed ratio
- $C_d$  = Section drag coefficient ;  $C_D$  = Drag coefficient
- $C_l$  = Section lift coefficient ;  $C_L$  = Lift coefficient
- $C_p$  = Power coefficient
- $V_0$  = Free-stream wind velocity

## ❖ GREEK LETTERS

- $\alpha$  = Blade segment angle of attack
- $\beta$  = pitch angle
- $\varepsilon$  = Drag/lift ratio
- $\alpha$  = Blade segment angle of attack
- $\theta$  = Angle of blade chord with rotor plane
- $\phi$  = Angle of relative wind from rotor plane
- $\Omega$  ( $\omega$ ) = Rotor angular velocity

## Abstract

Wind energy is created when; the atmosphere is heated unevenly by the sun. Some patches of air become warmer than others. The warm patches of air rise. Other air rush in to fill the void. Horizontal axis machines have some distinct advantages such as low cut-in wind speed and easy furling. In general, they show relatively high power coefficient. However, the generator and gearbox of these turbines are to be placed over the tower which makes its design more complex and expensive. Another disadvantage is the need for the tail or yaw drive to orient the turbine towards wind. Horizontal axis machines have some distinct advantages such as low cut-in wind speed and easy furling. In general, they show relatively high power coefficient. However, the generator and gearbox of these turbines are to be placed over the tower which makes its design more complex and expensive. Another disadvantage is the need for the tail or yaw drive to orient the turbine towards wind.

For present study, CFD reproduction intended for horizontal axis wind turbine, mathematical method were used to form airflow characteristics. The governing equations of fluid flow represent mathematical statements of the conservation laws of physics. For present study, CFD reproduction intended for horizontal axis wind turbine, mathematical method were used to form airflow characteristics.

The calculation has been made of horizontal rotation axis wind turbine using a 3D model of horizontal rotation axis turbine for wind flow speed 4 with the stable rotational speed of the rotor of 90 rotations per minute. This analysis has been made to illustrate and follow the turbine behavior and to present the calculation opportunities of horizontal rotation axis turbines.

The rotor is 4 m diameter and it consists of an aluminum hub and three blades. The blades are attached to the hub by aluminum male pins. The blades are made from fiberglass material. The blade length (span) is 1.75. It has a NACA-4418 airfoil profile. Objective of the best airfoil at this application is to maximize the lift coefficient and minimize the drag coefficient at the same conditions.

We doing validation for more than five mesh grid, and then we fitted all mesh on the power curve, which get from experimental test (Reference Data), we founded that the best approximation mesh is the 3.5 million cells, which is the best power coefficient and the smallest error nearly 5 %.

## Chapter 1 Introduction

This chapter presents an introduction for horizontal axis wind turbine evolution. We mentioned the types, constructions, components, and parameters that effect on the performance of the turbine. This chapter presents the advantages, disadvantages and how to increase the performance of WT. The types and parameters of horizontal axis wind turbine are illustrated.

### 1.1 Wind Power generation

Wind energy is created when: The atmosphere is heated unevenly by the sun. Some patches of air become warmer than others. The warm patches of air rise. Other air rush in to fill the void Thus, wind blows [1]. The wind speeds change with different heights which shown in Figure 1.2.

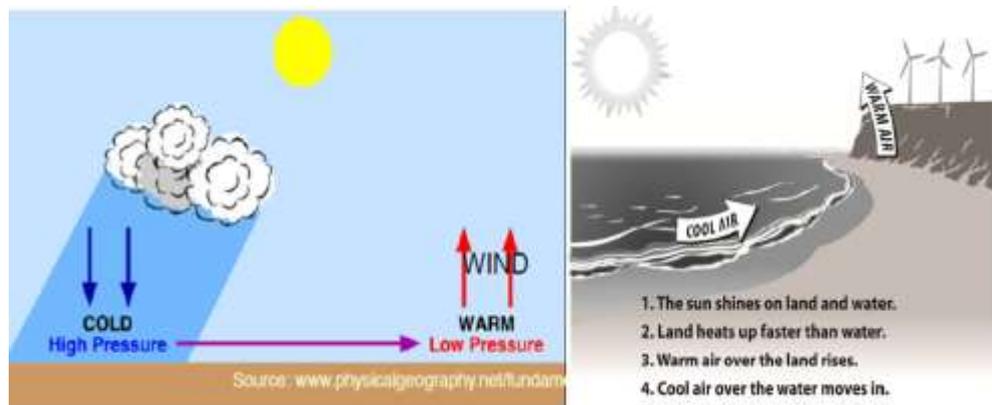


Figure 1.1: Wind resources [1].

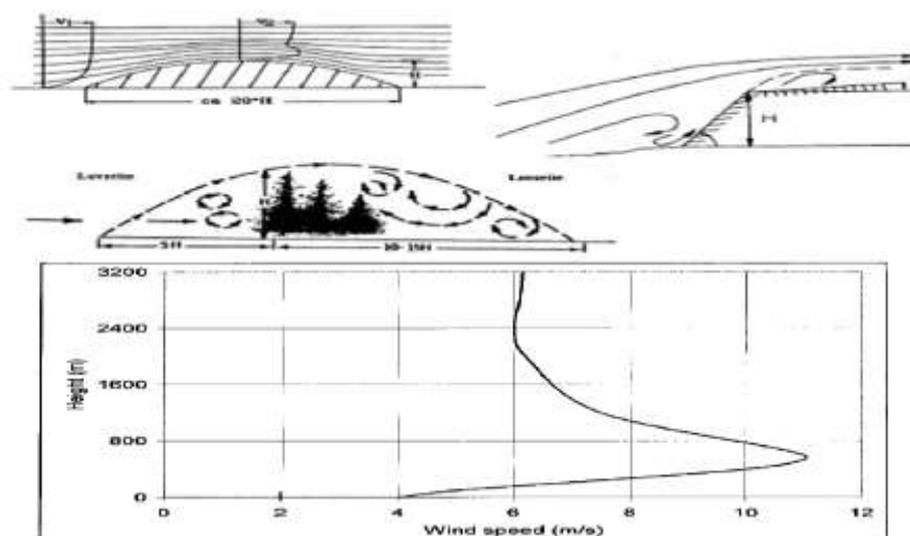


Figure 1.2: Wind speed variation with height [1].