Application of Partial Blade Pitch for Power Regulation of HAWT

By

Hazem Wahed Abd El Fattah

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
AEROSPACE ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

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Title of Thesis: **Application of Partial Blade Pitch for Power Regulation of HAWT**
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Summary:

Partial blade pitch is investigated as a means for wind turbine power regulation after the rated wind speed. Traditionally blades are pitched fully along the span, which is becoming increasingly difficult as the blades are getting longer. Since the power is generated from the outboard section, a partial blade twist of the outboard section is investigated. Two models are used in this study: (1) the BEM model and (2) the CFD technique. The BEM offers speed and versatility and is only used to explore the concept of partial twisting, whereas the CFD can examine effects of flow separation at the blade discontinuities caused by the partial twist. Further, two wind turbines are investigated: (1) the NREL Phase VI and a small lab wind turbine. The NREL VI turbine is examined to compare the model results to published data, whereas the lab model was pursued to test in the lab in future studies. The results found that it is possible to use partial blade twisting for power regulations.

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Abstract

Partial blade pitch is investigated as a means for wind turbine power regulation after the rated wind speed. Traditionally blades are pitched fully along the span, which is becoming increasingly difficult as the blades are getting longer. Since the power is generated from the outboard section, a partial blade twist of the outboard section is investigated. Two models are used in this study: (1) the BEM model and (2) the CFD technique. The BEM offers speed and versatility and is only used to explore the concept of partial twisting, whereas the CFD can examine effects of flow separation at the blade discontinuities caused by the partial twist. Further, two wind turbines are investigated: (1) the NREL Phase VI and a small lab wind turbine. The NREL VI turbine is examined to compare the model results to published data, whereas the lab model was pursued to test in the lab in future studies. The results found that it is possible to use partial blade twisting for power regulations.

CHAPTER 1

INTRODUCTION

The wind energy is considered one of the cleanest sources of energy. The continuous desire to harness more wind energy was the main reason to design different sizes of wind turbine rotors. The progress of wind turbine size can be seen in the following Figure 1-1.

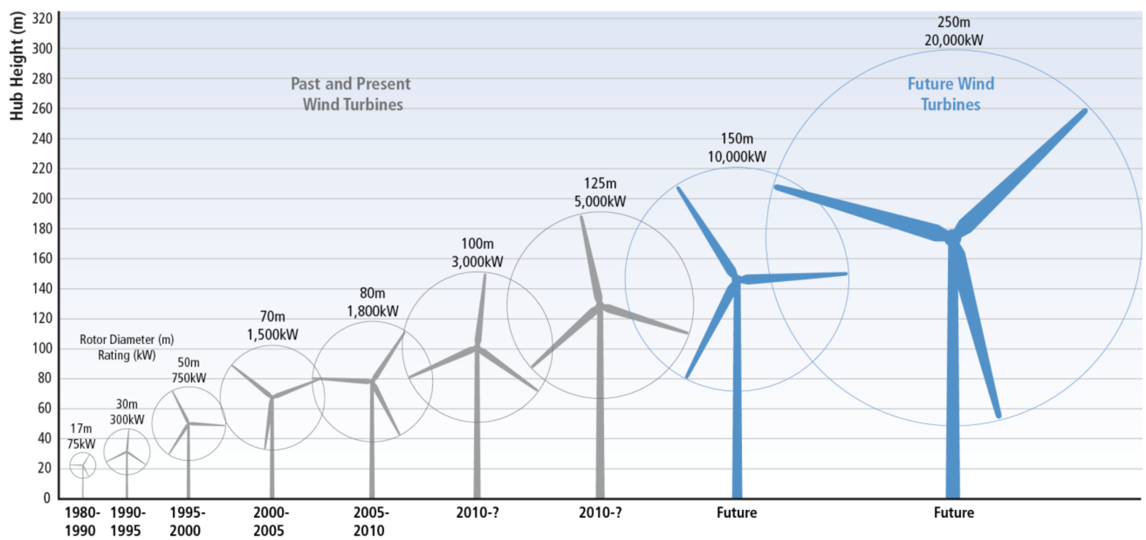

Figure 1-1: The Progress of Wind Turbine Size [1]

Controlling and regulating the power from the wind turbine is a very important process. There are two types of power regulation and control:

- Pitch control, the blades are rotated about their axis modifying the lift and drag characteristics, and hence the generated power.
- Stall control, the blades are designed to be stalled at certain operating wind speed, which prevent the power from increasing above certain limits. There are two methods of controlling the output power under stall control :
  - Passive stall, a fixed blade pitch is chosen such that the turbine reaches its maximum or rated power at a desired wind speed.
  - Active stall, the power limitation achieved by changing the blade pitch angle to a larger angle.

The objective of the work in this thesis is to consider power regulation using pitching, however, the novel approach is to consider partial pitching of the blade. This is beneficial for larger blades since the pitch actuator systems can be simple and lighter.

1.1 Wind Turbine Torque

It is known that the torque is directly proportional to the radius along the blade span. The torque decrease at the blade tip as a result to the tip vortices as shown in Figure 1-2 [2].

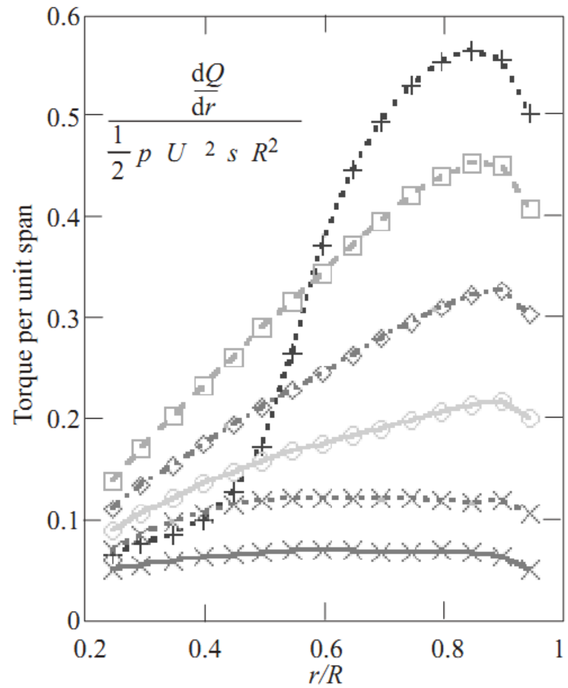

Figure 1-2: Torque Variation Wind Turbine Blade

The cumulative torque at different radial stations compared to the total torque is shown in Table 1-1 for the NREL Phase VI turbine. This is calculated using the BEM method which will be highlighted in chapter 2. The result shown here is to highlight the importance of the outboard sections in power generation. The cumulative torque is calculated in two regions (0-0.7) and (0.7-1) normalized with respect to the blade tip.

Wind Speed (m/s)	Percentage of Partial Torque to Total Torque	
	Outboard Section 1 - 0.7	Inboard Section 0.7 - 0
4	47.79%	52.2%
7	56.44%	43.55%
10	64.13%	35.86%
12	60.07%	39.92%

Table 1-1: Percentage of Partial Torque to Total Torque for NREL Phase VI