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INVESTIGATION OF FACTORS AFFECTING POWER CURVE WIND TURBINE BLADE

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ABSTRACT

The present study aims at investigating of factors affecting in enhancing the energy capture capabilities of performance wind turbine. The considered parameters are turbine swept area, air density, wind speed, and power coefficient as a function of pitch angle. A tool aerodynamic analysis based on the Blade Element Momentum Theory (BEMT) is developed to study the parameters that affect the power curve of blade wind turbine. The study shows that the operational parameters has a direct effect on the performance of wind turbine which will lead the developers and researchers to focus on the highest priority parameter that should be considered for optimizing the new generations of wind turbines blade.

Keywords: blade element momentum theory, blade, pitch, density.

INTRODUCTION

Power generated by wind turbine is the most important factor in determining the economic effectiveness of design blade wind turbine. A reliable estimate of expected power production is therefore critical to assessing wind turbine potential on the site. Unfortunately, estimating wind production can be challenging because it depends on many factors unique to each situation.

A wind turbine can generate power is a function of many site-specific factors and aerodynamic performance of blade. Most important are the average annual wind speed,pretwist, pitch, angle of attach and rotor swept area; however, air density also affects power generation of performance wind turbine and air density can change with altitude and temperature.

Various methods can be used in order to identify the performance wind turbine and flow characteristics. These methods can be classified mainly as BEMT-based methods and computational fluid dynamics -based methods [1-5].

Computational Fluid Dynamics (CFD) methods provide more accurate result of analysis compared to BEMT. However, to acquire reliable result from computational method, a vast amount of computational grids are required and advanced turbulence model needs to be applied [4, 6]. High computational time for wind turbine wake calculation makes CFD based models less practical in engineering use, particularly as the evaluator module of blade design tools. CFD methods are very useful for understanding the aerodynamic characteristics of rotor blades but it consumes too much time and resources thus it is generally applied at the final performance evaluation stage after all the design process is completed [7]. On the other hand, BEMT is a simple, yet efficient method for aerodynamic analysis of rotors. BEMT-based design and analysis codes are somewhat of an industry standard. The evaluator module of almost all wind turbine blade design tools are based on this theory [8].

The accuracy of the BEMT model is in general reasonable for a wind turbine in normal operating conditions. A verification study [9] comprising the most common aero-elastic codes in Europe showed a typical difference of 5%-10% between measured and simulated mean blade loads and 5%-20% difference in dynamic blade loads. [7] Investigated both uniformly and non-uniformly loaded actuator disks and the effect of turbulent mixing to show the validity of the BEM theory. It was found that BEMT, with the application of a tip correction, gives a good correlation with the CFD results. Wiratama [10] did validation AWTSim (Aerodynamic Wind Turbine Simulation) code by comparing to WT_Perf [11]. This code based-BEMT and has been used to analyze aerodynamic performance in the optimisation design blade wind turbine [12].

In this study, developed tool based on the AWTSim code was by adding some algorithms to investigate factors affecting power produce of blade wind turbine.

LITERATURE REVIEW

In the predicting performance of wind turbines, The Blade Element Momentum Theory (BEMT) is still commonly used to analyze aerodynamic performance. Despite the fact that more sophisticated methods are available, the BEMT has significant advantages in computational speed and ease implementation. The BEMT is considered to be an effective tool during the design process to get good first order predictions of wind turbine performance under a wide range operating conditions and it can easily be implemented for the comparative studies. Furthermore, the BEMT code does

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not require large calculation resources, works with a very short calculation times and give reliable results.

BEMT combines two methods: Blade Element or Strip Theory and Momentum or Actuator Disk Theory which is used to outline the governing equations for the aerodynamic design and power prediction of a wind turbine rotor [13]. Momentum theory analyses the momentum balance on a rotating annular stream tube passing through a turbine and blade-element theory examines the forces generated by the aerofoil lift and drag coefficients at various sections along the blade. The blade-element theory assumes that the blade can be analysed as a number of independent element in span direction. Combining these theories gives a series of equations that can be solved iteratively.

For low-Mach-number flows (typically 0.2-0.25 based on blade tip speed) the density can be approximated as constant and the energy conservation law decouples from the remaining equations. Then the first four equations, conservation of mass and momentum, form a sufficient set for the velocity field vector and the pressure [4]. Air density has a significant effect on wind turbine performance. The power available in the wind is directly proportional to air density. As air density increases the available power also increases. Air density is a function of air pressure and temperature. It increases when air pressure increases or the temperature decreases. Both temperature and pressure decrease with increasing elevation. Consequently changes in elevation produce a profound effect on the generated power as a result of changing in the air density.

RESULT AND DISCUSSIONS

Figure-1 to Figure-5 show the power curves, maximum bending moment, comparing result power curve and maximum bending moment in different pitch angle for this wind turbine obtained by developing tool AWTSim as analysis aerodynamic performance .

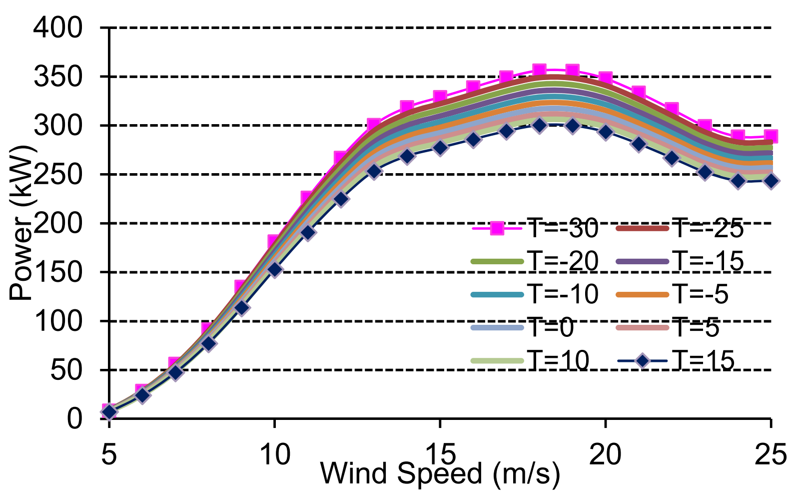

Figure-1. Power Curve generation for pitch angle -1.2 at different variation temperature.

As can be seen from Figure-1 to Figure-3, it can be observed that the different results from power curve and maximum bending moment are increase when site temperature is getting lower. From Figure-4 show that power curve at lower temperature and pitch angle reach rated power at lower wind speed (17 m/s) while higher pitch angle and temperature at 18 m/s while Figure-5 show maximum bending moment is bigger at lower temperature and pitch angle. The reasons for different results can be explained as follows. As a function of temperature density is very sensitive which means the change of density can be affecting to produce more power of wind turbine blade.

From those figure shows that the power available in the wind is directly proportional to air density. As air density increases the available power also increases. Hence, power available increases when air pressure increases or the temperature decreases therefore it shows that its parameter has a direct effect on the performance of wind turbine.

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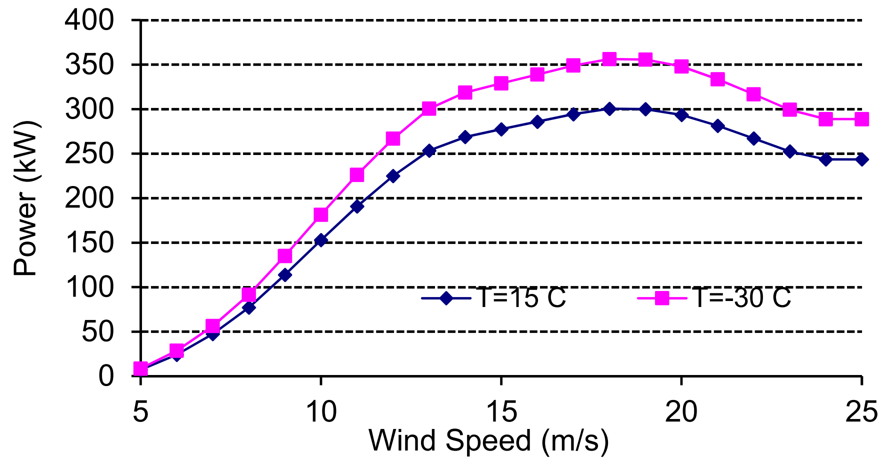

Figure-2. Comparing result power curve between temperature 15 ^{0}C and -30 ^{0}C.

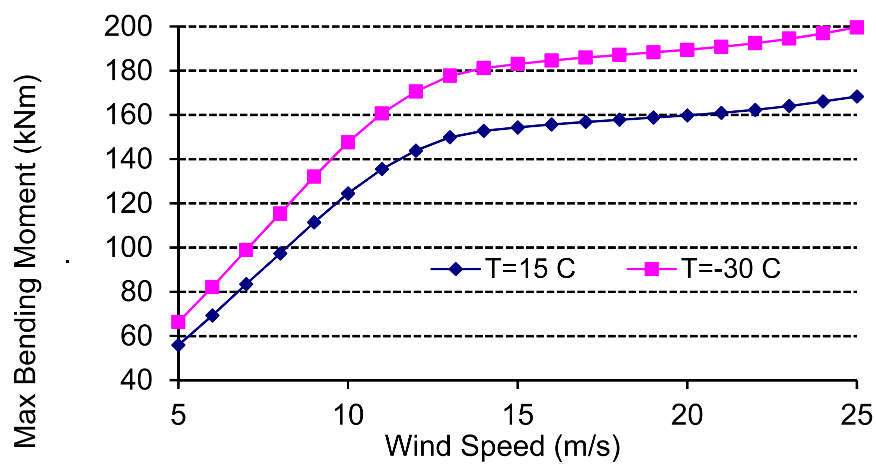

Figure-3. Comparing result of maximum bending moment at temperature 15 ^{0}C and -30 ^{0}C.

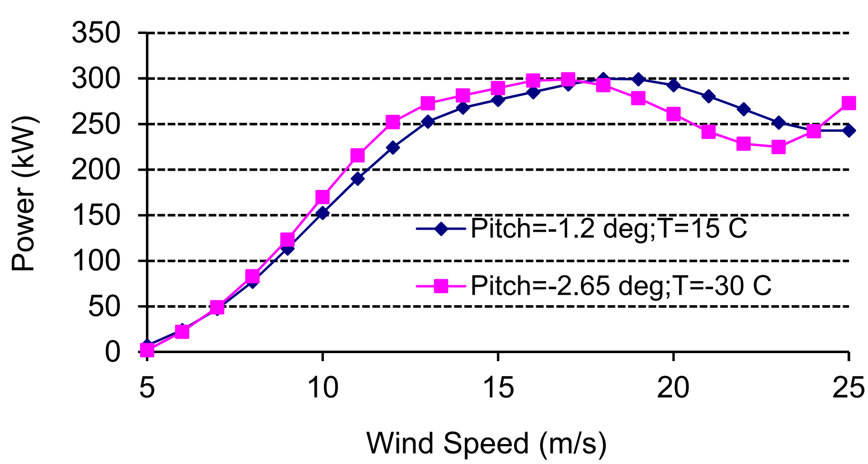

Figure-4. Power Curve in different picth angle and temperature.

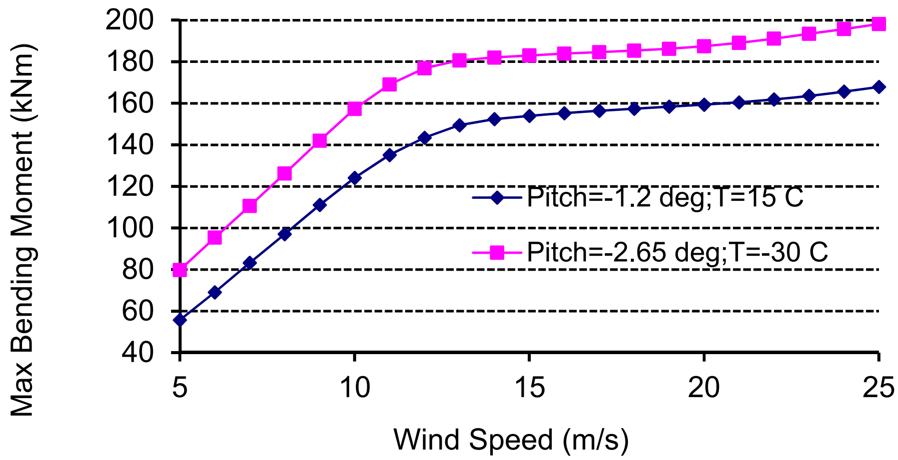

Figure-5. Maximum bending moment in different picth angle and temperature.

CONCLUSIONS

According to the above figures the following conclusion can be drawn:

1. Air density has significant effect on wind turbine performance such as producing power and maximum bending moment
2. Power curve and maximum bending moment are increase when site temperature is getting lower
3. Power curve at lower temperature and pitch angle can reach rated power at lower wind speed

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