Aeroelastic stability analysis of a large wind turbine based on BEM theory

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ABSTRACT

With the continuous improvement of wind turbine generation power, the size of wind turbine blades is increasing. The blades are longer, more flexible and less rigid. This puts forward higher requirements for the stability of wind turbine under complicated and changeable working conditions. Therefore, it is very important and meaningful to analyze aeroelastic stability of large wind turbine. In this paper, the Blade-Element Momentum (BEM) theory is used to calculate the aerodynamic load of wind turbine blades. By using FAST code, the dynamic response of 5MW wind turbine under different aerodynamic loads is studied and analyzed. The results show that when the wind turbine is working, the blade root needs to bear the maximum shear force and bending moment. And the critical wind velocity which causes the blades to flutter is calculated, and the results show that the critical wind speed can be increased by increasing rotor speed and pitch angle, which means the blades less prone to stall flutter in that case.

KEY WORDS: wind turbine, Blade-Element Momentum, aeroelasticity

INTRODUCTION

Under the background of energy conservation and emission reduction, wind energy can be developed and utilized on a large scale. In order to obtain more wind energy, the design of wind turbines tends to be larger, and the blades of wind turbines are longer and longer, which leads to more and more flexible blades. This will lead to the blade may appear large elastic deformation in the working state. In addition, compared with the fixed wind turbine on land, the movement of the blade of floating wind turbine is more complicated due to the movement of the platform under wave load. What is more serious is that once aerodynamic negative damping occurs, blade flutter will occur, which will lead to blade destruction. The aerodynamic instability of wind turbines seriously affects the service life of wind turbines, so solving the aerodynamic instability of wind turbines has a very important guiding significance for the design of wind turbines. In recent years, numerical simulations have been playing an increasingly greater role in analyzing aeroelasticity problems of wind turbine. For large floating fans, there are three types of numerical methods used to calculate the aerodynamic characteristics of wind turbines: computational fluid dynamics (CFD), vortex method and Blade-Element Momentum theory (BEM). The CFD model is based on the Navier-Stocks equation. According to the mesh division of the three-dimensional flow field, the discrete difference equation is used to realize the numerical solution of the three-dimensional flow field of the wind turbine, which can accurately solve the flow field information. However, the calculation requires a more precise grid, so the calculation time is very long. The core idea of the vortex method model is to simplify the vortex distribution in the three-dimensional flow field of wind turbine into the form of concentrated linear vortex and surface vortex, and to calculate the aerodynamic performance of wind turbine by using the tail vortex model such as rigid vortex or free vortex. BEM is a combination of one-dimensional momentum theory and two-dimensional blade element theory. Due to its advantages of short calculation time and relatively accurate calculation results, BEM has been widely used in calculating the aerodynamic performance of wind turbines. It is one of the most important methods for calculating the aerodynamic performance and flow field of wind turbines.

BEM is a combination of one-dimensional momentum theory and two-dimensional blade element theory. In 1920, Betz first applied the momentum theory to the field of wind turbines, he assumed that the wind wheel of the wind turbine was an 'ideal wind wheel', which has no hubs and infinitely many blades. In this way, the energy absorbed by the wind wheel was the amount of energy reduced after the inflow passed through the wind wheel. And then Glauert added the blade element theory on this basis in 1935, thus forming a relatively complete system of blade element momentum theory. Since BEM adopts a series of simplified assumptions, it may lead to some errors in the calculation results. In order to improve the calculation accuracy of BEM, many scholars have proposed a variety of modified models based on semi-empirical formulas to make the calculation results of BEM more reliable. Prandtl proposed a tip loss