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前後排列風機之氣動力負荷數值研究

Numerical Study on Aerodynamic Loading of Two Cascading Wind Turbines

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摘要

本文使用數值模擬方式進行以前後方式排列之風機氣動力負荷研究，目標風機為現役運轉於臺灣西海岸之 2MW 三葉水平軸風機，風機周圍流場模擬的風況條件為與風機排列軸線一致之額定風速以及額定轉速。三維暫態風機流場的控制方程式為連續方程式、動量方程式與 k- ϵ 紊流模型，本文使用流力分析軟體 CCM+ 求解上述非線性聯立方程組的壓力與速度耦合關係，同時流場計算空間使用數個網格加密區間以減低網格造成的離散誤差，特別是兩風機間的流場空間。經由流場模擬結果可預測前後兩風機在不同葉片位置的氣動力負荷：如葉片截距力矩、轉子轉軸力矩、機艙平擺力矩、塔柱傾倒力矩等。比較前後兩風機氣動力負荷，可了解前方風機跡流對於後方風機的氣動力負荷影響。當葉片旋轉一周時，後方風機的氣動力負荷較前方風機產生更為顯著的震盪變化，這種行為容易造成後方風機疲勞壽命的縮短以及維修需求的增加。因此適切的風場選址可提升風機運轉的穩定性與可用率。

關鍵詞：氣動力負荷、水平軸風機、前後排列、流場模擬。

Abstract

This paper investigates the aerodynamic loading of two cascading three-blade 2MW wind turbine installed on the western Taiwanese coastline under the rated wind speed via a numerical approach, where a three-dimensional flow simulation around target horizontal-axis wind turbines aligned with the wind direction and operating at rated speed is conducted. The unsteady flow field is described by the continuity and momentum equations incorporated with a k- ϵ turbulence model. The governing equations are solved by the commercial software CCM+, which employs a SIMPLE-type algorithm to decouple velocity and pressure. Several subdomains of grid refinement are embedded in the computational domain in order to reduce the diffusion error of flow field, especially those between two cascading wind turbines. The aerodynamic loadings, such the pitch moment of rotor blade, the axial moment of rotor, the yaw moment of nacelle and the overturning moments of tower, are calculated and expressed as functions of the azimuthal angle of rotor blade. Comparing the aerodynamic loadings between two wind turbines reveals the nontrivial wake influence of the first machine on the second one, where the second wind turbine clearly suffers from more significant loading variation in a complete revolution of rotor blade. This loading characteristics may lead to an unfavorable impact on the fatigue life of material, whereas the demand of frequent maintenance as well as a reduced lifetime of the system is consequently expected. The occurrence of cascading wind turbines during their operation might indicate an improper choice of siting in the wind farm design, which deteriorates the availability and stability of wind turbines in operation

Keywords: Aerodynamic loading, horizontal-axis wind turbine, cascading, flow simulation.