Study on Power Input Model for Active Blade Pitch Control of A Vertical-axis Tidal Current Turbine

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ABSTRACT

On the basis of optimization results developed by previous work of variable pitch turbine, this paper studies the influence of power input on the active pitch control turbine performance. A mathematical model is proposed by using the D’Alembert principle to help solve force equilibrium formula of single blade, then calculation of the power input that make the turbine blade pitch obey certain laws is obtained. The commercial software STAR-CCM+ is used to simulate the net output power of blade pitch turbine. The net power output of the turbine is figured out and the results of different tip speed ratio (TSR) are compared. Results of two models show that for low TSR, the net power coefficient of the active blade pitch turbine obviously lower than power coefficient owing to high angular velocity; for high TSR, the difference between net power coefficient and power coefficients of the active control pitch turbine is dominated by input momentum. It is concluded that the impact of power input on active pitch control turbine should not be ignored in some operating conditions.

KEY WORDS: Tidal current energy; vertical-axis turbine; variable pitch; power input; net power output

INTRODUCTION

Tidal current turbine is an important marine energy conversion device. Compared with vertical axis turbine, horizontal axis turbine has higher energy utilization efficiency, lower starting torque and more stable dynamic load. However, the vertical axis turbine attracts widespread attention, because of its abilities that spontaneously adapt to changes in the incoming flow direction and has a simple structure. Some studies have shown that the power efficiency of vertical axis turbines can be effectively improved by variable blade pitch technology. Variable pitch technology can change blade deflection angle with turbine azimuthal angle variation to make the angle of attack (AOA) under blade stall angle, reducing and delay flow separation. The pitch law determines blade deflection angle changing rule with azimuthal angle.

Kirke (2011) discussed in detail the inherent shortcomings of fixed-pitch vertical axis wind turbines that are difficult to overcome by changing the size, airfoil and some geometry parameters, including poor starting performance, limited energy efficiency, and impeller impact, fluctuation load and so on. As early as 1970, some scholars proposed that cycloidal turbines can improve starting torque and efficiency by delaying stall. In recent years, as the research on active controlled variable pitch turbines has been gradually developed, most of the research has focused on the exploration of the blade motion law, startup performance, energy utilization efficiency and force characteristics of variable pitch turbines. A cycloidal wind turbine is proposed (Hwang, 2006; Hwang, 2009) to study optimal deflection angle of the position angle. It was found that the energy efficiency was improved by 60% compared to the fixed blade wind turbine by numerical simulation. Under different operating conditions, the parameters of the optimal power coefficient were also obtained. The results showed that the performance was improved by 70%. Schonborn (2007) designed a variable pitch turbine that controlled blade motion through the combination of a swash plate mechanism and a hydraulic device, 20% improvement in power efficiency had been obtained by model tests. Adams and Chen (2018) used a novel flux-line theory method to optimize the cycloidal vertical axis wind turbine, and conducted model tests to verify the optimization results. The power coefficient of optimized turbine is significantly improved at a wide speed ratio range, especially at low speed ratios, and the efficiency is improved by 30%. Sagharichi (2019) performed CFD numerical simulation of a vertical axis wind turbine applied different amplitude sinusoidal function pitch laws, and the comparison analysis indicated that it was within a certain range that the power coefficient of the turbine is related to the amplitude of the blade deflection function. Jiang (2019) used DMST method combined with a genetic algorithm to establish blade deflection optimization algorithm of vertical axis wind turbine, and obtained optimization pitch function of tip speed ratio and azimuthal angle. In addition, CFD numerical simulation is performed, result shows that the optimized peak turbine power coefficient is 56.4% higher than fixed pitch turbine. Yi-Xin Peng (2019) combined a DMST model and a dynamic stall model to establish a hybrid double-disc multi-stream tube