A novel pitch control system for a wind turbine driven by a variable-speed pump-controlled hydraulic servo system

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1. Introduction

Wind energy is considered one of the most important green energies being developed and applied worldwide. The applications of modern wind energy have expanded in recent years. The Asian countries, such as Taiwan, China, Japan, Korea, and India, started to develop and apply wind energy for reducing CO₂ pollution. Taiwan began to develop wind energy in 1990s. The large wind turbines (2 MW) started to operate in 2006 by Taipower Company and a German company called VWind AG. Modern large wind turbines can be classified into three different types, including the constant speed type, variable pitch control type and variable speed type. The main control tasks of the constant speed wind turbine consist of an air brake, yaw control and automatic cut-out. Because the pitch angle of the blade is fixed, the electric power output is not controlled so the output power is easily influenced by larger disturbance from varying wind speeds and thus has worse electric power quality. Therefore, a variable pitch control wind turbine was developed. By controlling the variable pitch angle of the blade, the rotational speed of the wind turbine can be kept constant so rated electric power can still be produced when the wind speed is higher than the rated wind speed. However, the electric power output was still problematic when the wind speed was lower than the rated wind speed. To reduce this problem, the variable speed wind turbine combining the variable pitch control of the blade and the rotational speed control of the generator was proposed. When the wind speed is lower than the rated wind speed, the rotational speed of the wind turbine is controlled according to the variable wind speed by the rotational speed control of the generator for keeping the optimal power coefficient \( C_p \). When the wind speed is higher than the rated wind speed, the variable pitch control of the blade works as the variable pitch control wind turbine to generate the optimal electric power.

Some researches in relevant fields of wind turbines have been published in recent years. The constant speed wind turbine, which was designed with a fixed pitch angle of blades and stall control, was researched in 1980s [1]. Because the control system and the control strategies were relatively simple, the electric power output was relatively unstable and the power coefficient \( C_p \) was also lower. In 1990s, Jones and Smith [2] analyzed how to maintain the electric power output of the variable speed wind turbine. Freeman and Balas [3] made the system identification of the dynamic models of wind turbine experimentally. Idan and Lior [4] realized the variable speed wind turbine using robust control. Song et al. [5] examined the variable pitch control and variable speed wind turbine by the nonlinear and adaptive control. Rehfeldt [6] investigated the dynamic modeling and control of a horizontal axle wind turbine. Boukhezar and Siguerdidjane [7] discussed the nonlinear control of variable speed wind turbines without wind speed