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

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ABSTRACT

The paper aims to develop a novel pitch control system for a large wind turbine driven by a variable-speed pump-controlled hydraulic servo system. To perform practical pitch control experiments, a full-scale test rig of the hydraulic pitch control system for a 2 MW wind turbine's blade, including a novel pitch control mechanism, a variable-speed pump-controlled hydraulic servo system, a disturbance system and a PC-based control system, is designed and set up. The variable-speed pump-controlled hydraulic servo system, containing an AC servo motor, a constant displacement hydraulic piston pump two differential hydraulic cylinders and hydraulic circuits, achieved high response and high energy efficiency, so it is suitable for wind turbine applications. Besides, to implement the pitch control in the proposed novel pitch control system, an adaptive fuzzy controller with self-tuning fuzzy sliding-mode compensation (AFC-STFSMC) is developed to design the pitch controller. Finally, the developed variable-speed pump-controlled hydraulic servo system was built and verified for the path tracking control and path-positioning control of the pitch control of the wind turbines by practical experiments in a full-scale test rig under different path profiles, load torques, and random wind speeds.

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 CO_2 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

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