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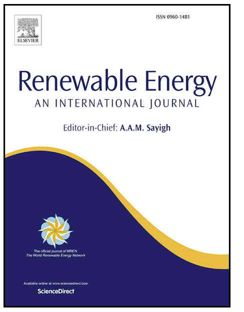

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Wind turbine blade optimisation with individual pitch and trailing edge flap control

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Abstract

Individual pitch control and trailing edge flaps have been shown to be capable of reducing flapwise fatigue loads on wind turbine blades, with research to date focusing on controller development and performance assessment. This work covers development of a blade optimisation process which integrates synthesis of individual pitch and trailing edge flap controllers to evaluate their impact on the levelised cost of energy. The optimisation process selects blade chord, twist and material distributions, along with the spar cap width, and integrates a turbine cost and mass model with existing simulation codes. Constraints based on ultimate stresses, fatigue damage, blade deflection, resonant frequency, and rotor thrust are considered. Using the NREL 5 MW reference turbine as an initial point, reductions in the levelised cost of energy of 1.05% are obtained with collective pitch control only, while the addition of individual pitch control increases this reduction to 1.17%. The use of trailing edge flaps on top of individual pitch control increases the reduction in the levelised cost of energy to 1.27%. Blade mass and material cost reductions from 13.6–16.4% and 18.1–21.5% respectively are also obtained. Optimised blade designs are driven by blade deflection, rotor thrust and ultimate stresses in the spar cap.

Keywords: individual pitch control, trailing edge flaps, cost of energy, rotor design, optimization

1. Introduction

1.1. Overview

Active load reduction methods such as individual pitch control (IPC) [1, 2] and, more recently, trailing edge flap (TEF) actuation [3, 4], have been shown to be effective in reducing blade loads on multi-megawatt wind turbines. These advanced load control methods modify the angle-of-attack, lift coefficient and corresponding lift force generated by the blade in order to reduce blade bending moment fluctuations. IPC achieves this via full span blade pitching, while localised devices such as TEFs limit the actuated region to the outer span of the blade. However, the majority of studies to date involving these load reduction methods have focused on control strategies and performance assessment in isolation to blade design.

This study is focused on blade optimisation with the addition of individual pitch and TEF control, with consideration given to a wide range of operating conditions, design constraints and variables. Advanced load control is integrated into the optimisation process through the use of a system identification and controller synthesis process in order to ensure that IPC and TEF performance is maintained and that any negative effects on the optimisation process arising from poor controller tuning are avoided. The optimisation aims to minimise the levelised cost of energy (LCOE), a key metric when considering the economic viability of wind energy. Optimisation of the LCOE on turbines with advanced load control has yet to be explored, though recent work has demonstrated that optimisation of a 10 MW turbine with TEF actuation was capable of producing a design with a lighter blade, higher annual energy production (AEP), and lower fatigue loads [5]. Reductions in the LCOE through the use of a larger rotor equipped with TEFs

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