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Title: Performance optimization of Wind Turbine Rotors with Active Flow Control

Abstract

The continuous upscaling of wind turbines leads to significant design, manufacturing, transportation and operation problems. Some of the largest and most heavily loaded components of wind turbines are the blades. Blades suffer from extreme and fatigue loads, atmospheric turbulence, tower shadow effects etc. At the same time the existing blade pitch systems are not able to provide sufficiently fast and accurate load and power management, therefore new concepts are developed in this field. Active Flow Control (AFC) solutions are becoming very attractive since they offer distributed and fast aerodynamic response.

The paper presents the methodical investigation and evaluation of various AFC solutions by means of extensive literature research and several numerical simulations. The best performing AFC solutions are studied and evaluated in a second step experimentally with constant chord wind tunnel wing sections under steady and unsteady conditions. After these two-dimensional investigations, more realistic configurations are studied in a third phase. This phase includes the integration of the investigated AFC solutions in two different custom wind turbine blade design proposals. Each blade design proposal is simulated with an Active BEM code and their effectiveness, energy capture, load alleviation etc, are assessed in order to identify the advantages and disadvantages of each blade design. The best performing blade design proposal is virtually integrated into an AFC rotor design and compared with conventional rotor concepts (e.g. collective pitch, individual blade pitch) as well as with hybrid rotor systems (AFC and Pitch control). This comparison presents all the different rotor configurations and concludes with a rotor configuration which demonstrates the best overall performance.

In addition to the comparison of the aerodynamics and AFC designs a brief comparison is also performed in terms of the control strategies implemented for the actuation of the AFC rotors. Different control system strategies (PID, Open Loop, Neural Network etc.) are briefly analysed in order to identify their benefits and drawbacks as active flow element control systems. Wind tunnel results of each control strategy on AFC elements (tested on constant cross-section wind tunnel wings) are additionally presented in order to illustrate the effect of each control strategy on the aerodynamics.

Overall the present paper summarizes a three years research project of the authors from the wind energy group of the H.F.I/TU-Berlin. At the same time it presents the concluding results of this project by proposing complete “Smart blade” designs and their simulated performance in comparison with conventional rotors.