COMPLIANT FLOW DESIGNS FOR OPTIMUM LIFT CONTROL OF WIND TURBINE ROTORS

Abstract

by

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An optimization approach was formulated to determine geometric designs that are most compliant to flow control devices. Single dielectric barrier discharge (SDBD) plasma actuators are used in the flow control design optimization as they are able to be incorporated into CFD simulations. An adjoint formulation was derived in order to have a numerically efficient way of calculating the shape derivatives on the surface of the geometric design.

The design of a wind turbine blade retrofit for the JIMP 25kW wind turbine at Notre Dame is used to motivate analyses that utilize the optimization approach. The CFD simulations of the existing wind turbine blade were validated against wind tunnel testing.

A one-parameter optimization was performed in order to design a trailing edge addition for the current wind turbine blade. The trailing edge addition was designed to meet a desired lift target while maximizing the lift-to-drag ratio. This analysis was performed at seven radial locations on the wind turbine blade. The new trailing edge retrofits were able to achieve the lift target for the outboard radial locations. The designed geometry has been fabricated and is currently being validated on a full-scale turbine and it is predicted to have an increase in annual energy production of 4.30%.
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The design of a trailing edge retrofit that includes the use of a SDBD plasma actuator was performed using a two-parameter optimization. The objective of this analysis was to meet the lift target and maximize the controllability of the design. The controllability is defined as the difference in lift between plasma on and plasma off cases. A trailing edge retrofit with the plasma actuator located on the pressure side was able to achieve the target passive lift increase while using plasma flow control to reduce the lift to below the original design. This design resulted in a highly compliant flow.