Backflow flaps as stall control elements on wind turbines

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Long Abstract

Introduction

Wind turbine blades suffer from dynamic unsteady stall effects during their normal operation. At the same time strong secondary flows (cross-flows) exist at the inner and the outermost regions of the blade. The current invention proposes a solution to the unsteady stall issues and at the same time a performance increasing element. The solution comprizes a passively actuated backflow flap positioned in span-wise or chord-wise orientation depending on the local flow characteristics.

1. Concept of Backflow Flaps

Current wind turbines have reached previously unpresidented sizes. Modern wind turbine rotors have reached diameters larger than 150m. The combination of the enormous rotor swept area, the unsteadiness and non-uniformity of the inflow wind field and the highly aeroelastic behavior of the blades leads to extrem aerodynamic and structural load complexities. Due to the large blade deflections and the unsteady inflow wind field most of the current wind turbines experience several complicated static and dynamic stall effects which increase the extreme and then fatigue loads of the whole wind turbine while reducing its performance. In order to reduce the load and thus the cost of the wind turbines of the future it is necessary to reduce or eliminate the adverse dynamic aeroelastic loads.

A solution in this direction is the use of passive backflow flaps. This concept was initially proposed by Bechert et al.[1] as a passive stall delay solution used as a landing device on aircrafts. Its initial operation was considered to be quasi- static due to the long activation time during the whole duration of the aircraft landing. As mentioned before however, the flow regimes of wind turbine blades are highly unsteady, therefore a highly adaptive and responsive passive stall control solution would be required.

The work proposes the use of aeroelastic backflow flaps strategically located at the wind turbine blade surface in order to perform optimally according to the local flow regime. Such passive aeroelastic element would be able to reduce or even eliminate the dynamic stall effects that appear on wind turbine blades of the state of the art. In addition to that the stall delay caused by the aeroelastic backflow flaps would increase the high angle of attak perfor- mance of the said blade section thus improving its overall performance while additionally reducing the aerodynamic loads caused by the transition from normal operation to stall due to angle of attack variation.

The backflow flaps were tested by means of a multi parameter wind tunnel test at the large wind tunnel facility of HFI TU Berlin and their optimal size, location and form was determined especially for wind turbine airfoil configurations.

In order to investigate the optimal location of the backflow flap elements in real life conditions the SMARTviz method, developed at the Technical University of Berlin (HFI) in collaboration with the company SMART BLADE GmbH was used. The stall phenomena of a utility scale wind turbine were analyzed and the position of backflow flaps was determined. The said rotorblade was modeled with the aerodynamic Lifting Line Code QBlade (developed at HFI TU Berlin) and the effects of backflow flaps were simulated by means of the aforementioned code.

The results of the investigations show that a significant reduction of the stall region is achieved with the use of backflow flaps. This can lead to an annual energy production increase in the range of 1%. Further investigations will be conducted for the analysis of the fatigue load reduction of the blade due to backflow flaps and its subsequent effect on effective blade lifetime.

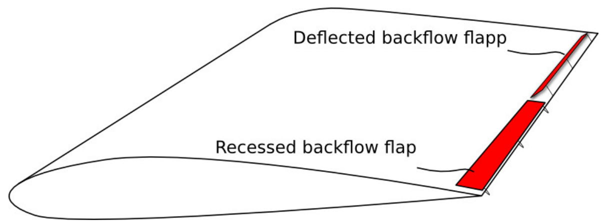

Figure 1. Basic representation of a deflected and a recessed flap on a blade section.

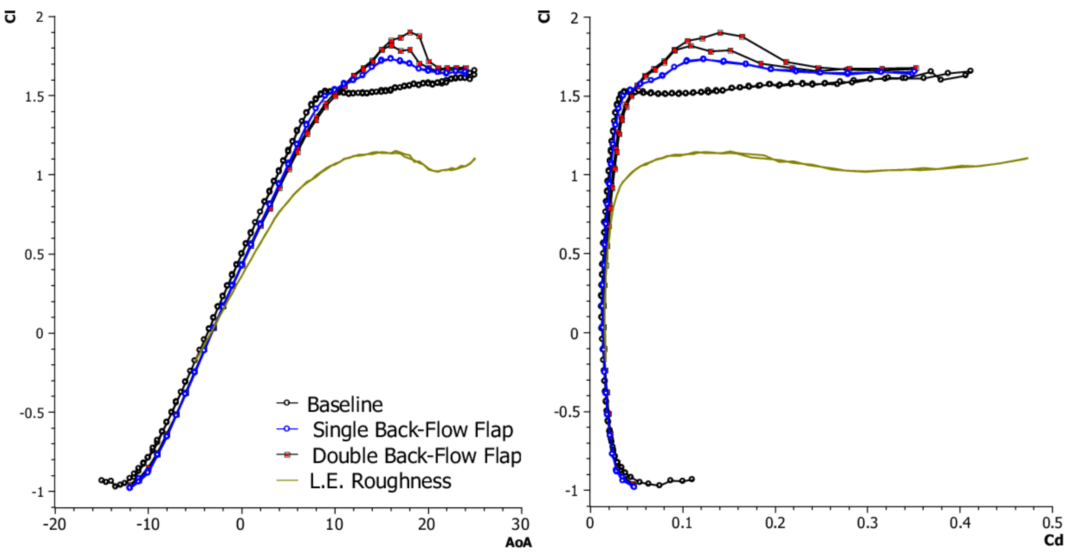

Figure 2. Wind tunnel test results of various backflow flap configurations.

References