WindSTAR
Wind-Energy Science, Technology, and Research
Industry/University Cooperative Research Center

NREL FAST Modeling for Blade Load Control with Plasma Actuators

Principal Investigator:
Mario Rotea, University of Texas at Dallas

Co-Principal Investigator:
Yaoyu Li, University of Texas at Dallas

Student Researcher:
Chang Liu, University of Texas at Dallas

IAB Mentors:
Neal Fine, Aquanis
Nicholas Althoff, GE Renewable Energy
Steve Nolet, TPI Composites

Reducing extreme and fatigue loads on the rotor blades of a wind turbine lowers the Levelized Cost of Energy, which is critical for future wind turbines equipped with longer and more flexible blades. With larger rotors, the span-wise variability of the wind challenges the capabilities of the blade load control strategies of current operational systems. Active flow control (AFC) has emerged as an appealing solution to fast and localized rotor control for load mitigation. Among the existing AFC devices, plasma actuators have drawn attention due to their mechanical simplicity (no moving parts), fast response time and low cost. This project developed a simulation tool for design of plasma-based AFC systems for blade load reduction. The tool is based on the industry standard NREL FAST code. The FAST module with integrated plasma actuation is demonstrated using the NREL 5-MW reference turbine model. With the feedback of blade-root flapwise bending moments, a Coleman transformation based controller is used to drive the voltage commands to the plasma actuators. Load reduction is demonstrated without noticeable penalty in turbine performance as measured by rotor speed and power errors in Region 3.

Figure 1 shows a segmented blade planform where the aerodynamics of each segment is simulated using FAST. The plasma actuators are modeled as changes in local lift coefficient ΔCL in the outer span of the blade (sections 12 to 17 in the segmented blade). The controllable lift coefficients are modulated by voltage signals (one per blade) generated by a feedback controller that measures selected blade loads to calculate the voltage commands for each blade, referred as Individual Blade Voltage Control (IBVC) in the figure. Figure 2 demonstrates the reduction of the measured loads (blade-root flap-wise bending moments) for the case with vertical shear and no turbulence. Figure 3 demonstrates the reduction of blade loads at the rotor angular frequency when both vertical shear (non-uniform flow) and turbulence (unsteady flow) are present. Damage equivalent loads (DEL) under vertical shear can be reduced from 30% (no turbulence) to 10%-15%, approximately, when turbulence intensity is increased to 15%.

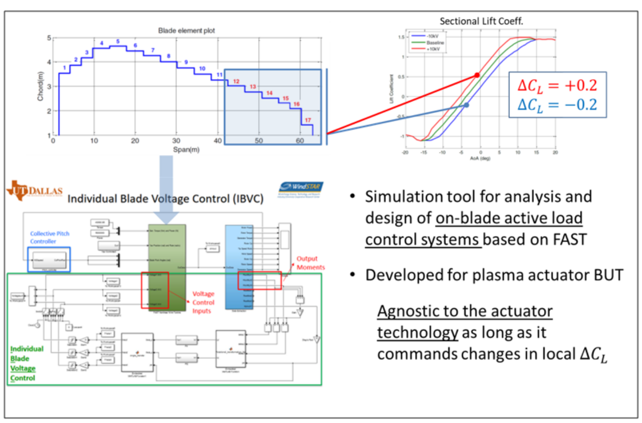

Figure 1: 5MW NREL ref turbine blade showing controllable local lift coefficients (Top). Simulink diagram of NREL FAST tool with controllable sectional lift coefficients (bottom left).

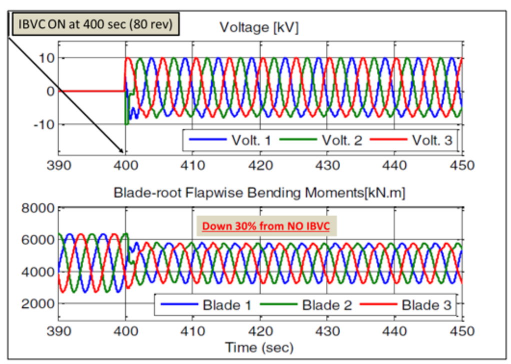

Figure 2: Time series of voltage commands to plasma actuators (one command per blade) and response of measured loads for the 5 MW NREL reference turbine at 18 m/s wind speed and with vertical wind shear.

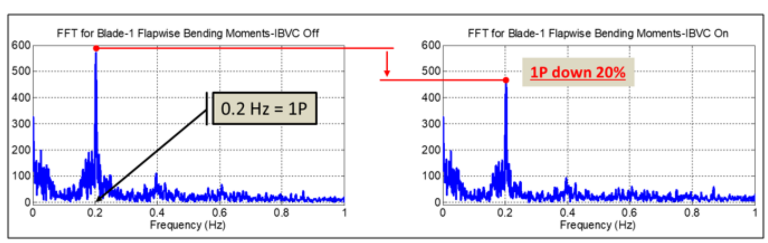

Figure 3: Frequency response of load signal with IBVC off (left) and IBVC on (right) for the 5 MW NREL reference turbine at 18 m/s wind speed, vertical wind shear and 15% turbulence intensity. Rated rotor angular speed is 12.1 rpm (1P).