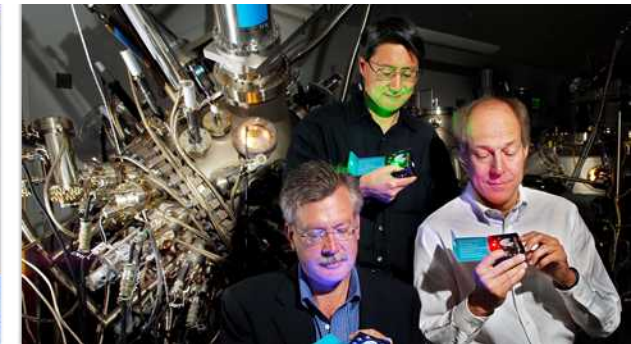


Exceptional service in the national interest



Active Aerodynamic Control of Wind Turbine Blades

Eric Anderson, PhD Student, UC Davis

Mentor: Josh Paquette



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND 2010-5138P.

My Summer

■ Turbine Interactions

- Implementing SOWFA on Red Sky
- NREL developed CFD tool can simulate groups of turbines and their interactions.
- Status: Simulation tool working. Talking to Vestas about scenarios to simulate.

■ Turbine Blade Sensors

- Install three different pressure sensors in a blade segment.
- Status: Blade segment and sensor locations chosen. Sensors arrive next week.

■ Active Aerodynamic Control

- Analyze data from Smart Rotor test.

Energy Surety of Wind Power

- Cost-effectiveness and reliability are hurdles to wind power adoption.
- Can we improve the energy surety of wind power using advanced controls and actuators?
- Yes. One method is active aerodynamic control.

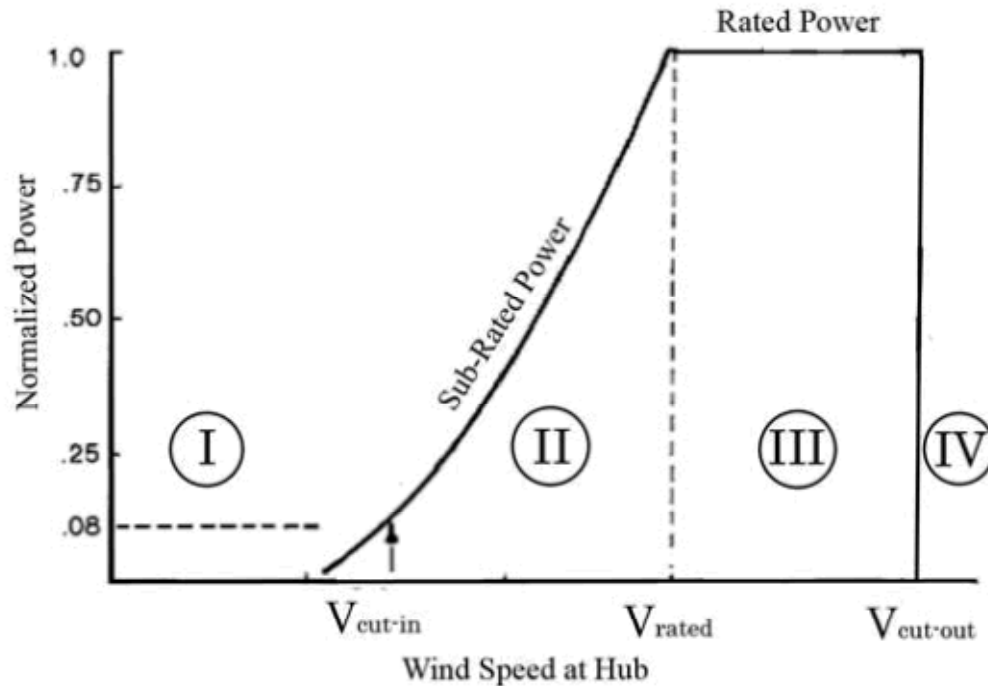


Cost of Energy

$$COE = \frac{\textit{Capital Cost} + \textit{Operation and Maintenance Cost}}{\textit{Lifetime Energy Capture}}$$

- Costs are driven by mechanical loads
 - Ultimate loads
 - Fatigue loads
- Reduce loads → Reduce cost → Reduce COE
- A 2009 Sandia report estimated a 5-9% reduction in COE for a 1.5 MW turbine using active aerodynamic control.

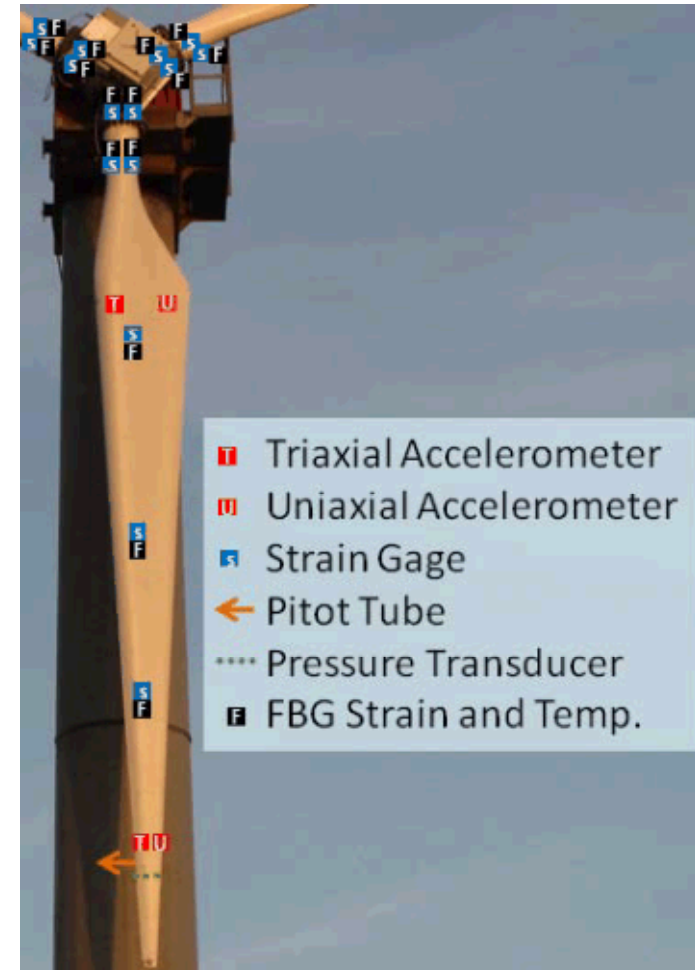
Typical Turbine Control



- Advantages
 - Simple
 - Good power capture
 - Manages loads at high wind speed
- Limitations
 - Turbulence
 - Wind gusts
 - Cyclic loads
 - Tower shadow
 - Wind shear
 - Gravity loads

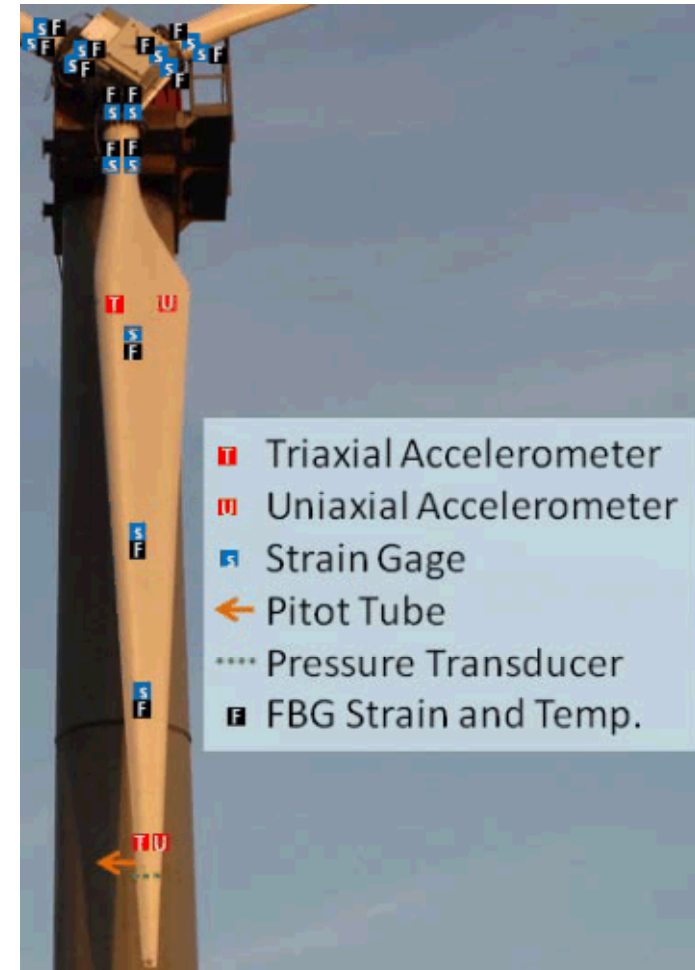
Active Aerodynamic Control

- Sensors
 - More sensors
 - More information about blade behavior
- Flow control devices
 - Small, fast devices
 - Local control of blade aerodynamics
- Controls
 - More sophisticated control



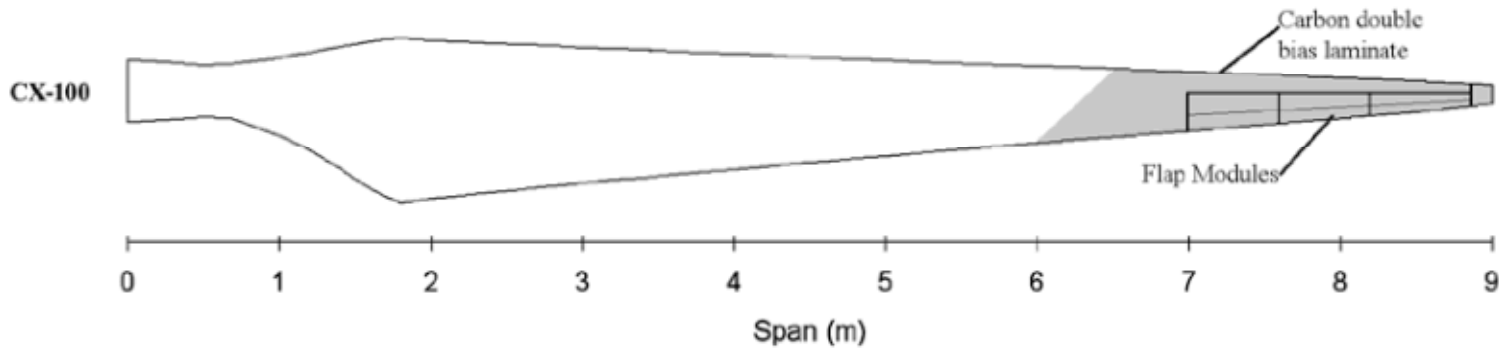
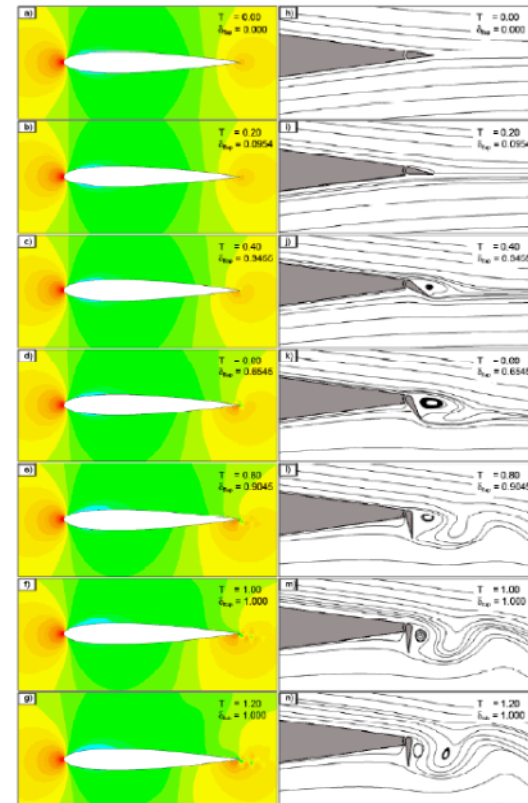
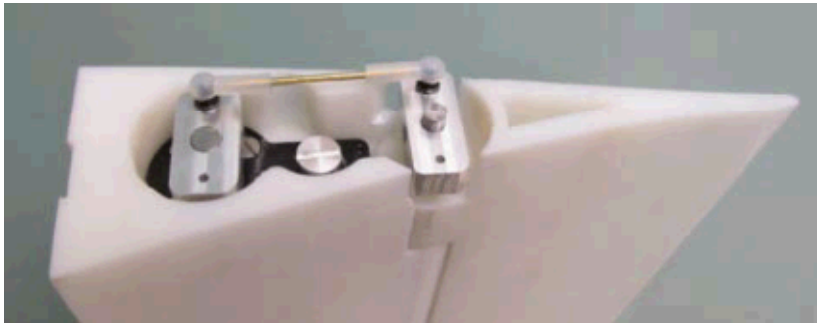
Sensors

- Accelerometer
 - Strain gauge
 - Pitot tube (pressure)
 - Pressure transducer
 - Temp sensor
 - Lidar (wind speed)
 - Upwind turbines
-
- How many?
 - Where?



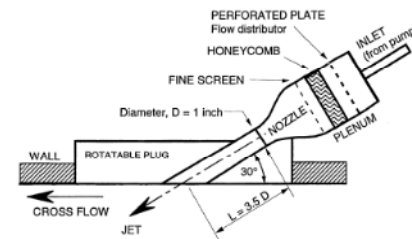
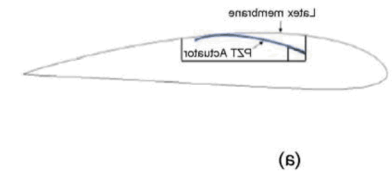
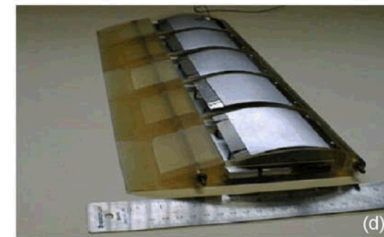
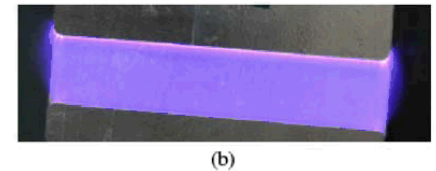
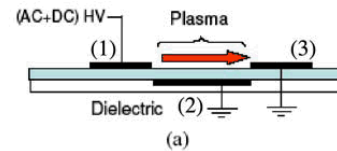
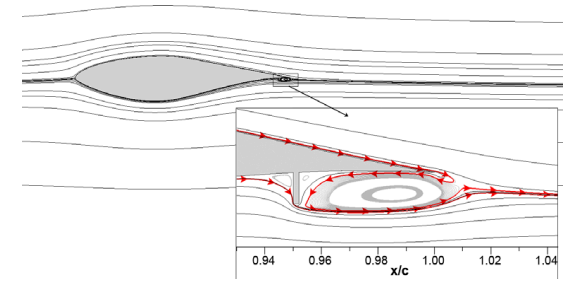
Flow Control Devices

- Trailing edge flaps



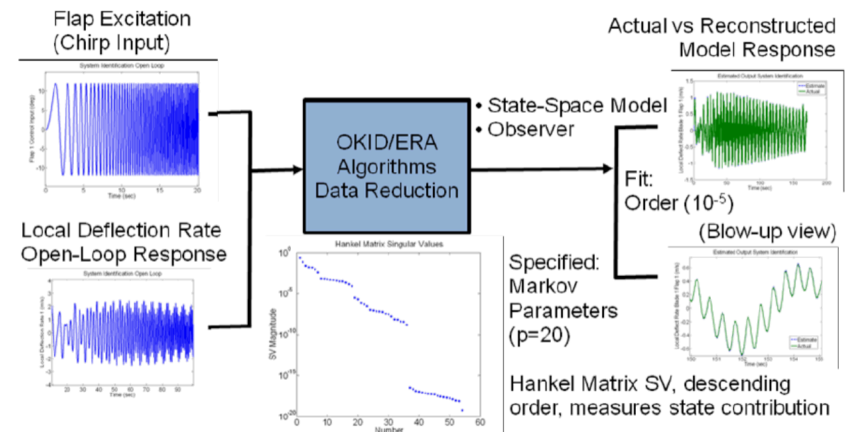
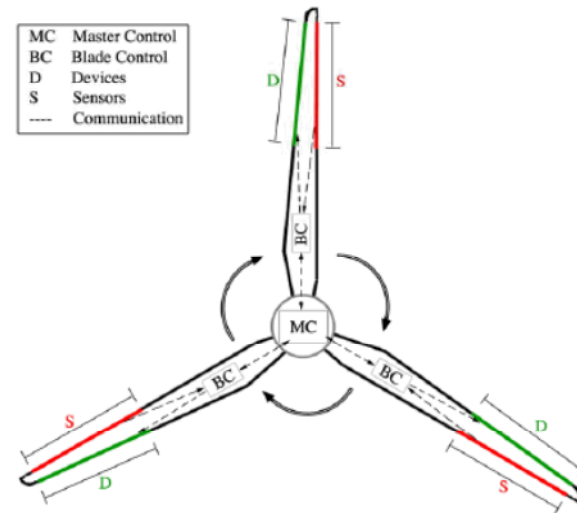
Flow Control Devices

- Micro tabs
- Plasma actuators
- Shape change airfoil
- Vortex generator jets



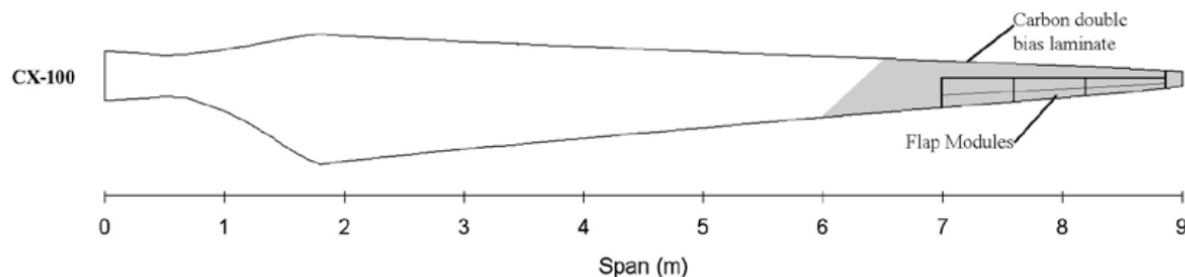
Controls

- Multi input/Multi output
- Fast response
- Non linear effects
- System identification



My Contribution

- Between February and May 2012 Sandia tested a wind turbine equipped with 9 meter blades with trailing edge flaps.
- Power production was lower than expected when trailing edge flaps were fixed.
- Air gaps around the flaps were one potential cause, so they were taped over and more data was gathered.
- I analyzed the data to determine the effect of taping over the gaps.
- I found there was no discernible difference between the taped and un-taped data.
- Other potential causes are being investigated.



Thank you.