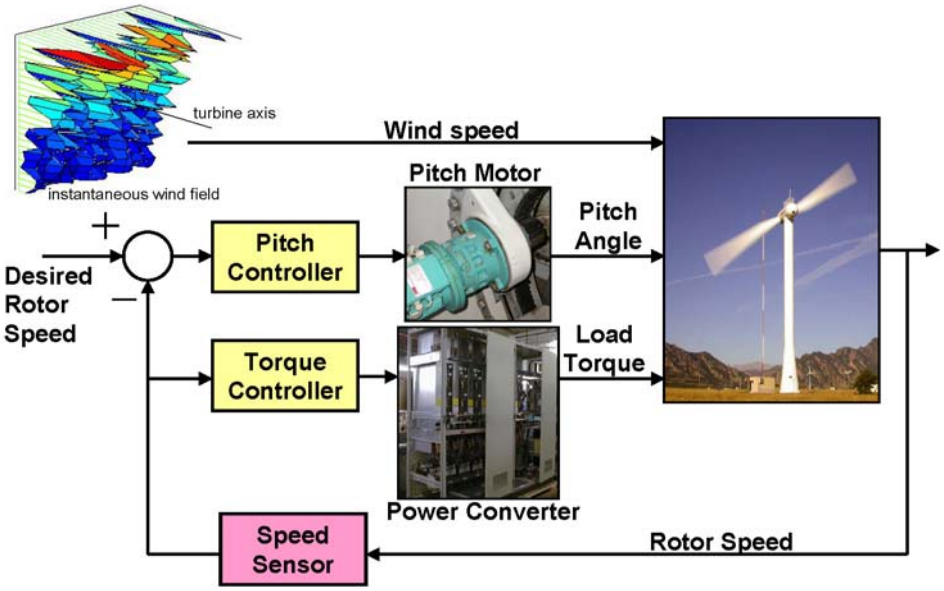
ThA02: A Tutorial on the Control of Wind Turbines and Wind Farms



Wind Turbine Control Loop

A Wind Turbine Control Block Diagram. The diagram shows that the speed of the wind that hits the turbine can vary significantly across the rotor plane. Rotor speed measurements are usually the only measurements used in the feedback loops for both generator torque and blade pitch control. [Photos courtesy of Lee Jay Fingersh]

Wind is recognized worldwide as a cost-effective, environmentally friendly solution to energy shortages, and wind energy is currently the fastest-growing energy source in the world. Despite the amazing growth in the installed capacity of wind turbines in recent years, engineering and science challenges still exist. These large, flexible structures operate in uncertain environments and lend themselves nicely to advanced control solutions. Advanced controllers can help achieve the overall goal of decreasing the cost of wind energy by increasing the efficiency, and thus the energy capture, or by reducing structural loading and increasing the lifetimes of the components and turbine structures. This session will introduce the controls community to a number of issues in wind power, and will outline many open problems in the areas of modeling and control of wind turbines.

Structure of the Tutorial Session

The tutorial session consists of 4 talks:

- **ThA02.1 (60 min):** ***A Tutorial on the Dynamics and Control of Wind Turbines and Wind Farms*****,** by Dr. Lucy Pao of the University of Colorado at Boulder and Dr. Kathryn Johnson of the Colorado School of Mines. This talk will provide a broad overview of wind energy systems. We will describe the main components of wind turbines, the sensors and actuators, the different operating regions, and we will outline the current state of the art in wind turbine modeling and control. We will also highlight growing areas of importance and areas of future work, including combined feedforward and feedback control of wind turbines using novel sensing technologies, wind turbine wake modeling and coordinated control of arrays of turbines on wind farms, and modeling and control of floating offshore wind turbines.

Image courtesy of Vestas Wind Systems A/S

Wind flow field on a wind farm. As wind turbines extract energy from the wind, wakes are created, and the inflow conditions change for wind turbines that are further downstream. Better understanding and modeling of wake interactions and coordinated control of multiple wind turbines on a wind farm can both improve overall energy capture and reduce structural loading on the turbines.

- **ThA02.2 (20 min):** ***Wind Turbine Modeling Overview for Control Engineers,*** by Dr. Pat Moriarty and Dr. Sandy Butterfield of the National Renewable Energy Laboratory. This talk will describe the major areas of wind turbine modeling, including turbulent inflow, aerodynamics, hydrodynamics (for offshore turbines), foundation dynamics, and structural dynamics. Coupling across these areas will also be discussed, and challenging design goals for control engineers will be outlined.

- **ThA02.3 (20 min):** ***Control of Wind Turbines: Past, Present, and Future,*** by Jason Laks and Dr. Lucy Pao of the University of Colorado at Boulder. After reviewing the standard control methods used in the different operating regions, this presentation will discuss a number of recent advanced control techniques that have been applied in the control of individual wind turbines. We will also outline a few control approaches that are being explored in on-going and future work.

- **ThA02.4 (20 min):** ***Wind Farm Control: Addressing the Aerodynamic Interaction among Wind Turbines,*** by Dr. Kathryn Johnson and Naveen Thomas of the Colorado School of Mines. The talk will describe the challenges in modeling the wind inflow within a wind farm and propose control strategies to mitigate problems stemming from those challenges.