Wind turbine and wind farm control: Control challenges and solutions

Jan-Willem van Wingerden*, Paul Fleming, David Schlipf***, Kathryn Johnson**,****, Lucy Pao*******

**Delft University of Technology, The Netherlands (j.w.vanwingerden@tudelft.nl).*
***National Renewable Energy Laboratory, USA*
**** Stuttgart University, Germany*
***** Colorado School of Mines, USA*
****** University of Colorado Boulder, USA*

Abstract: Controls research plays an important role in wind energy. Advances in controls are making wind turbines more efficient, more reliable, and more cost-effective. Wind turbines have evolved from passively controlled machines to actively controlled machines, and more recently, to distributed machines controlled collectively (wind farms). With this open session, we invite researchers to present their latest results in wind energy control. The attendees of these sessions will learn how controls research can make substantial contributions to wind energy, and they will also get an overview of the latest developments and open issues. Example contributions include: 'smart' rotor control, lidar-based control, control of floating turbines, wind farm control, and active power control.

Keywords: Include a list of 5-10 keywords, preferably taken from the IFAC keyword list.

1. The choice of an IFAC technical committee for evaluation

TC6.3. Power and Energy Systems

2. A detailed description of the topic:

Many early turbine designs focused on passive control solutions. A concept widely used from the 1970s until the 1990s was the 'Danish concept'. Such turbines combine constant rotor speed with stall of the flow around the rotor blades and are stable by design; increasing wind speeds automatically induce increasing drag forces that limit the produced power (this concept is also referred to as a stall turbine). In that period, all other control options were considered too complex and also the technology for variable speed control was not mature enough.

Modern commercial turbines, however, now conventionally include several active control loops. For example, full-span collective pitch control has been a major step in this field; the control of the blade pitch angle has not only led to power regulation, but also to a significantly lighter blade construction due to the lower load spectrum and a lighter gear box due to shaved torque peaks. With the introduction of Individual Pitch Control (IPC), the loads can be reduced considerably leading to even lighter or larger turbines. However, due to the increasing size of wind turbines, it is necessary to look ahead to control concepts that can impose a force profile matching the distributed nature of turbulence in order to reduce the loads and to guarantee an economic lifetime of 20 years for the new generation of large scale offshore wind turbines (with rotor diameters greater than 150 meters). So, for the next generation of wind turbines, we must seek novel control concepts that may be considered too complex at this point in time in the wind energy field, much like IPC was 20 years ago.

Research topics for this open invited track

1. Smart rotor control (novel actuators)

There are a number of concepts for the next generation of wind turbines. For many concepts, loads (both extreme and fatigue) represent critical design drivers. In current wind turbine designs, this is solved by the mechanical design and collective pitch control. In the previous section, we discussed that the current set of actuators is not a feasible solution for larger and more flexible machines, consequently more advanced concepts are required.

One advanced operational concept is to use a number of actuators that locally change the force profile on the wind turbine blade to cope with the spatial distributed nature of turbulence. This, in combination with sensors that measure the loads and a controller that manipulates the measured signals and generates an appropriate actuation signal, is defined as the 'smart' rotor concept. We invite researchers with novel control concepts to submit their paper(s) to this open invited track.

2. lidar-based control

Lidar technology allows direct measurement of the wind approaching the turbine. Because the wind is both the source of energy and the primary disturbance, this information is potentially useful for improving any control loop within the turbine. Pitch and torque control can be improved by applying a feed-forward action in response to incoming changes in wind, such as gusts. The availability of a predictive measurement of the main disturbances also enables the use of Model Predictive Control algorithms. Yaw control can be improved if the wind direction measured by the lidar is more accurate than that measured by the nacelle mounted vane. The direct measurement of the incoming wind also gives an estimate of available power for improving grid-support services. Finally, rear-facing lidars can also improve wake control. Papers covering lidar-based control are invited for this open invited track.

3. Control of floating wind turbines

By placing a wind turbine on a floating platform, large areas of high-wind resource become possible sites for large wind power plants. Additionally, such offshore turbines can be assembled at a port and towed to their locations. One of the primary difficulties of this approach is controls-related: the floating system is more dynamic and potentially closed-loop unstable. Wind turbine controllers must now, on top of their existing objectives of power production and load regulation, avoid large platform oscillations and accommodate wave disturbances. We invite papers which examine solutions to this complicated problem.

4. Wind farm control

To date, wind turbine control has been optimized at the single turbine level. However, it is known that turbines collocated in a farm interact with each other through their wakes. Recent studies have shown that because of this interaction, control strategies that are optimal for individual turbines can be sub-optimal at the wind farm level. Designing a wind farm controller, or turbine-to-turbine distributed control strategy, which can outperform individual turbine only control is the focus of research at several centers.

5. Active power control

High levels of wind penetration make it more necessary that wind plays an active role in supporting the grid through ancillary services in addition to energy production. These services include providing reactive power control, reacting automatically to frequency deviations, and following power setpoints provided by the utility operator. From the wind turbine control perspective, this adds additional objectives over the power production and load mitigation objectives presented already. However, it also represents another opportunity for controls research to contribute to the expanded application of wind energy.