Integrating Controls into Turbine and Plant Design Processes

In this third edition of the Wind Plant Optimization and Systems Engineering Newsletter, we are looking at the particular theme of integrating controls design with turbine and plant design and operation. Controls technologies have always been an important part of wind turbine design for a variety of purposes—mitigating against extreme loads, regulating machine power output, protecting the turbine from grid faults, and more. Recently, however, the role of controls technologies have expanded to include providing ancillary services to the grid in terms of active power control and research activities are now shifting to even look at controls strategies at the plant level rather than centered on a single turbine. From a research and development perspective, as highlighted in this newsletter, these new opportunities require that controls in be a much more integrated part of turbine and plant design processes.

News from Researchers and Practitioners

UIUC System Level Co-Design Work Evaluates Potential for Increase in Wind Turbine Energy Production

Researchers at the Engineering Systems Design Lab (ESDL) at the University of Illinois at Urbana-Champaign study and develop advanced methods for designing high-performance and high-efficiency dynamic systems. In particular, they investigate integrated design methods that capitalize on the synergy between physical system design and control system design (co-design methods). Recently they have made contributions that make possible the solution of co-design problems where significant attention is paid to detailed mechanical system design, including the use of high-fidelity multidisciplinary models [1]. The ESDL has studied a wide range of applications including wind and wave energy system design, robotics, and automotive system design.

Wind turbine system design has traditionally been performed in a sequential manner (physical system design followed by control system design), resulting in sub-optimal system designs. Only recently has co-design of wind turbines been investigated. ESDL researchers have developed novel co-design methods for wind turbine design, including completely new ways of using surrogate models in dynamic system design. Initial work [2] demonstrated an increase in power production of 7% by considering co-design in early design phases, and an order of magnitude reduction in computational expense. The team is now extending this method beyond a single turbine to farm–level co-design. Contact Prof. J. Allison for more information.

Improved Knowledge of Wind Conditions for Wind Turbine and Wind Farm Control

Detailed knowledge of wind and flow conditions can be very valuable, as it can be used for controlling individual machines or whole wind farms according to suitable strategies in order to achieve the best possible power capture, to reduce loads, to improve power quality, and to meet other desired goals. However, at the moment wind turbines are typically equipped with anemometers and wind vanes, which often provide hub-height information with a high level of noise and disturbances. Similarly, wind farms operate based on data gathered by a small number of met-masts, which do not cover the whole wind farm area.

Improved knowledge on the wind conditions on each machine and within a wind farm can be obtained directly from wind turbines, which can be used as sophisticated wind sensors. In fact, it is clear that changes in wind conditions imply changes in the wind turbine response in terms of performance and loads; therefore, by properly interpreting the wind turbine response, it is possible to measure changes in wind conditions at the wind turbine location.

The Technical University of Munich has developed wind sensing technology that can provide information in real-time at each wind turbine throughout a wind farm on wind speed, wind direction, vertical and horizontal shears, wake state (i.e. full, partial, or no wake interference) and turbulence intensity. Some of these new approaches have been tested using high fidelity simulation models, scaled wind tunnel models and field test data [1,2,3], with additional development, testing, and publication activities planned for the current year.

For information, please contact Carlo L. Bottasso, Wind Energy Institute, Technical University of Munich, Germany.


Integrating Turbine Controls into Wind Plant Analysis and Design

Researchers at NREL and TU Delft have been collaborating on the development of coordinated wind plant control systems to improve the overall performance of wind plants above what is possible with independently controlled individual turbines. To test these concepts, the high-fidelity Simulator for on/offshore wind farm applications (SOWFA) was modified to allow for the implementation of wind plant control [1]. In initial work, studies were made into using the yaw misalignment of upstream turbines for re-directing wake around downstream turbines [2]. Current research is focusing on development of control-oriented wind plant models [3,4], development of closed-loop wind plant controls, and coupling wind-plant control techniques with wind plant system optimization methods. A study looking at joint-optimization of wind-plant controls with layout design is underway. For more information, contact Paul Fleming or Pieter Gebraad.


Tuning Wind Turbine Controllers Using the OpenMDAO Optimization Framework

Integration of controllers into wind turbine design process is a subject of investigations at the department of Wind Energy of the Technical University of Denmark. To perform concurrent wind turbine aeroservoelectric design automated procedures based on numerical optimization
are required to tune the controller. Direct methods to tune loops of simple controllers are available (e.g., pole placement techniques for PI controllers). However, controllers often have additional components where no direct tuning method is available. These components are usually tuned following the designer experience aided by trial and error approaches. Therefore, there is a need to identify methods and techniques to automate these tuning procedures. Automated methods to fine tune controllers can then be included into wind turbine design procedures, where structural, aerodynamic, and controller strategies are optimized at the same time. It is believed that holistic optimization procedures will lead to an important reduction in the cost of energy.

For more information please contact Carlo Tibaldi, Department of Wind Energy, Technical University of Denmark.

Conferences and Workshops
Several upcoming conferences feature opportunities to present and attend presentations on wind plant optimization and systems engineering. To organize a meet-up for interested persons at one of the upcoming events or to notify us about relevant upcoming events, please email the Systems Engineering Initiative.

- **AWEA Windpower 2014 Conference and Exhibition**: May 5–8, 2014, in Las Vegas, Nevada. Call for abstracts closed
- **15th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference**: June 16–20, 2014 as part of the AIAA Aviation Conference in Atlanta, Georgia. Call for papers closed.
  - An **AIAA MDO Short Course** will be held the weekend before the conference.
- **AWEA Offshore Windpower 2014**: October 7–8, 2014, in Atlantic City, New Jersey. Call for abstracts open (due May 12, 2104).
- **EWEA Technology Workshop—Analysis of Operating Farms**: TBD. Call for abstracts open (due May 31, 2014).

Contribute to this Newsletter
We invite all researchers and practitioners to submit their own contributions (up to 100 words along with any weblinks) to share with the greater community. The key requirements are that the work represents a true integrated, interdisciplinary, and preferably holistic approach to wind energy research, design, engineering, and development. Contributions highlighting research, software, or technology development are all welcome. We recognize that, for our industry colleagues in particular, sharing information via this forum may be difficult. However, if there is a recent press release or publication that can be highlighted and referred to, we are happy to share that information as well. We would also like to highlight upcoming relevant conferences and workshops. Please send contributions to systems.engineering@nrel.gov.

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