Special Issue: Wind Turbine Modeling and Simulation

The contribution of wind to the energy mix is steadily growing: with well over 300 GW of installed wind power worldwide [1], wind energy provides today about 8% of electricity consumption in Europe [2], with peaks of up to 34% for Denmark [3], and about 4.5% in the U.S. [3], with other markets such as China and South America in rapid expansion. The growth in recent years has been remarkable; just to give an example, wind represented only 2.4% of the total installed nameplate power capacity in Europe back in the year 2000, while it was up to 14% in 2014 [2]. The penetration of wind energy has been helped not only by specific political choices favoring renewables to curb carbon emissions, but also and foremost by substantial technological advancements that have and are contributing to the reduction of the cost of energy from wind. In fact, a recent study from the U.S. Department of Energy [3] shows that the cost of electricity from wind in the U.S. is not only at an all-time low, but also appears to be competitive with the average price range of all other technologies.

Technological improvements that are enabling the progress of wind energy span a very wide range: from aerodynamics, to electromechanical conversion, to construction technology and manufacturing, to materials, to sensing and advanced controls, to operation and maintenance, and many other fields, technological innovation is helping propel wind energy into the future. Technological advancements not only contribute to the reduction of the cost of energy from wind, but also mitigate the impacts of wind turbines on the environment, the landscape, and the population. The desire to minimize impacts and increase acceptance, together with the availability of extremely substantial wind resources, is pushing a new great effort at making off-shore wind energy technically and economically viable. In particular, opening the development of deep-waters would allow an energy hungry world to tap into immense energy supply sources [4,5]. Much remains to be done to win this grand challenge, as floating off-shore technology is still in its infancy, and costs are still much higher than for on-shore installations. However, a substantial research effort is underway worldwide, with new ideas and results being reported at a fast pace.

Simulation is what makes much of all this possible. In fact, simulation is the key enabler that allows for new technological improvements to be verified, integrated into the design, and assessed for their potential benefits. In wind energy applications, simulation models are often inherently multidisciplinary as they should consider the coupled effects of dynamics, structural mechanics, aerodynamics, hydrodynamics for off-shore applications, soil mechanics, contact dynamics for the modeling of gears, servo and control elements, and other effects, depending on need. There is also a wide range of different complexity levels for simulation models: from the coarser models based on a limited number of degrees-of-freedom, all the way to the high fidelity computing-intensive models based on first principles. All these models are useful in various stages of the design and development process, and all play crucial roles: the coarser models are mostly used for the synthesis of control laws or the fast exploration of the design space, the intermediate ones for preliminary design and load assessment, while the high fidelity models are necessary for refining the design or for capturing small solution scales and local effects. Clearly, all such models need to be validated, in order to ensure and quantify their level of fidelity to the physical processes that they try to represent. Hence, model validation and verification is another activity that goes hand in hand with the advancement of simulation technology.

This wide range of coupled physical processes, scales, complexity levels and application needs makes the field of modeling and simulation of wind energy systems not only extremely challenging but also immensely interesting from a scientific point of view. The fact that simulation models are also the crucial enablers of much of the technological improvements that are helping increase the penetration of wind energy, makes this area all the more relevant and worth investigating. This special issue presents a collection of fine contributions, which illustrate well the breadth and variety of research that is nowadays conducted on wind energy simulation and modeling. Topics covered here include flexible multibody dynamics, loads and aeroelasticity, the analysis of drivetrains, off-shore wind turbines, reduced order modeling, identification and validation. The guest editor would like to thank the editor in chief of Computational and Nonlinear Dynamics for having proposed and made possible this special issue, and to all who contributed to it as authors and reviewers.

References

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