

Special Issue on Dynamics and Control of Offshore and Onshore Wind Turbine Structures

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Renewable energies, particularly wind energy, play a decisive role in helping to meet the global energy demand while maintaining an eco-friendly and clean environment. Along with the well-established status of onshore wind, offshore wind turbines (both floating and fixed in the seabed) have emerged as a favorable solution for countries with deep-sea waters. However, wind turbine structures are subject to large loads and undesirable vibrations caused by strong, prolonged winds; sea currents; and large waves, which may reduce energy efficiency and cause damage (in addition to shortening the useful life of the turbine). Hence, reducing the impact load on these land-based and marine structures is a fundamental challenge to increase reliability and possibly reduce maintenance. Wind turbine control methods should be enhanced, thus ultimately optimizing energy extraction.

In this Special Issue of *Energies*, different related issues are addressed, from identifying computational models that can represent these strongly nonlinear systems to the various control aspects involved in the performance of these renewable energy solutions. The final goal is to improve the energy extraction efficiency and reduce vibration, the latter may decrease O&M costs.

A short review of the contributions of this Special Issue follows.

1. Improving the Performance of Controllers for Wind Turbines on Semi-Submersible Offshore Platforms: Fuzzy Supervisor Control

In this paper, the authors use an artificial intelligence technique, fuzzy logic, as a promising alternative to deal with the control issues that offshore floating wind turbines (FOWT) present. Specifically, interactions of the wind turbine and the platform movements make the dynamics of these floating systems quite complex. This work develops a methodology that combines fuzzy and PI controllers for FOWT and describes its application to enhance the results and the control of large-scale wind turbines in semi-submersible offshore platforms. The methodology of this study was based on implementing an integrated simulation tool and the definition of three indexes that describe the control system's performance in the overall platform behavior. Using this tool, an anti-wind-up algorithm was designed to improve the behavior of the conventional controller and is presented and evaluated along with a fuzzy supervisor controller. In this configuration, the fuzzy controller modifies the values of the PI controller. Finally, a comparison of the performance using the reference PI and the improved PI, in both cases with a fuzzy supervisor controller modifying their values, is presented and discussed [1].

2. Nonlinear Optimal-Based Vibration Control of a Wind Turbine Tower Using Hybrid vs. Magnetorheologically Tuned Vibration Absorber

This paper presents an implementation of a nonlinear, optimal-based wind turbine tower vibration control method. An NREL 5.0 MW tower-nacelle model with a hybrid tuned vibration absorber (HTVA) is analyzed against a magnetorheological TVA (MRTVA) model. For control purposes, a 3 kN active actuator in parallel with a passive TVA is used in the HTVA system, while an MR damper is built in the MRTVA instead of a viscous damper as in a standard TVA. All actuator force constraints are embedded in the implemented nonlinear control techniques. By employing the Pontryagin maximum



Citation: Santos, M. Special Issue on Dynamics and Control of Offshore and Onshore Wind Turbine Structures. *Energies* **2022**, *15*, 2782. <https://doi.org/10.3390/en15082782>

Received: 28 March 2022

Accepted: 8 April 2022

Published: 11 April 2022

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principle, the nonlinear optimal HTVA control proposition was derived along with its simplified revisions to avoid a high computational load during real-time control. The advantage of HTVA over MRTVA in vibration attenuation is evident within the first tower bending frequency neighborhood, with HTVA also requiring less working space. Furthermore, using the appropriate optimization fields enabled an eight-fold reduction in HTVA energy demand along with a (further) 29% reduction in its working space while maintaining a significant advantage of HTVA over the passive TVA. The obtained results are encouraging for the assumed mass ratio and actuator force limitations, proving the effectiveness and validity of the proposed approaches [2].

3. General Methodology for the Identification of Reduced Dynamic Models of Barge-Type Floating Wind Turbines

Floating offshore wind turbines (FOWT) are designed to overcome some of the limitations of offshore, fixed-bottom ones. The development of computational models to simulate the structure and turbine behavior is key to understanding the wind energy system and demonstrating its feasibility. In this work, a general methodology for identifying reduced dynamic models of barge-type FOWTs is presented. The method is described together with an example of developing a dynamic model of a 5 MW floating offshore wind turbine. The novelty of the proposed identification methodology lies in the iterative loop relationship between the identification and validation processes. Diversified datasets select the best-fitting identified parameters by cross-evaluating every set among all validating conditions. The dataset is generated for different initial FOWT operating conditions. Indeed, an optimal initial condition for platform pitch was found to be far enough from the system at rest to allow the dynamics to be characterized well but not so far that the unmodeled system nonlinearities were so large that they significantly affected the accuracy of the model. The model was successfully applied to structural control research to reduce fatigue on a barge-type FOWT [3].

4. Analysis of the Effects of the Location of Passive Control Devices on the Platform of a Floating Wind Turbine

Floating offshore wind turbines (FOWT) are subjected to strong loads, mainly due to wind and waves. These disturbances cause undesirable vibrations that affect the structure of these devices, thus increasing fatigue and reducing their energy efficiency. Among others, a possible way to enhance the performance of these wind energy devices installed in deep waters is to combine them with other marine energy systems, which may, in addition, improve their stability. This work aims to analyze the effects of installing some devices on the platform of a barge-type wind turbine, particularly the vibrations of the structure. To achieve this, two TMD (Tuned Mass Damper) passive control devices are installed on the platform of the floating device with different positions and orientations. TMDs are usually installed in the nacelle or in the tower, which imposes space, weight, and size hard constraints. An analysis is carried out using the FAST software model of the NREL-5MW FOWT. The suppression rate of the tower top displacement and the platform pitch are obtained for different locations of the structural control devices and compared with a system without TMD. In conclusion, these passive devices can improve the stability of the FOWT and reduce the vibrations of the marine turbine. However, it is indispensable to carry out a previous analysis to find the optimal orientation and position of the TMDs on the platform [4].

5. Review of Vibration Control Methods for Wind Turbines

The installation of wind energy increased in the last twenty years as its cost decreased, contributing to reducing GHG emissions. A race toward gigantism characterizes wind turbine development, primarily driven by offshore projects. Larger wind turbines face higher loads, and the imperatives of mass reduction make them more flexible. Increasing the size of wind turbines results in higher structural vibrations that reduce the lifetime of the components (blades, main shaft, bearings, generator, gearbox, etc.) and can lead to

failure or destruction. This paper aims to detail the problems associated with wind turbine vibration and provide a thorough literature review of the different mitigation solutions. It explores the advantages, drawbacks, and challenges of wind turbines' existing vibration control systems. These systems can be grouped into six main categories according to the physical principles used and how they operate to mitigate vibrations. This paper offers a multi-criteria analysis of many systems in different phases of development, ranging from full-scale testing to the prototype stage, experiments, research, and ideas [5].

6. Conclusions and Identified Gaps for Future Works

In conclusion, we can see a growing interest in large-size wind turbines, both in maximizing energy production with different control techniques and reducing vibrations with different structural control solutions. Some of the papers in this Special Issue deal with the more recent floating offshore wind turbines. This paradigm shift is due to the fact that until recently, the use of sea wind energy was restricted by the limited availability of suitable sites in shallow water. To overcome this challenge, wind turbines located in deep sea areas with different foundations appear as a valuable option, as they also allow the exploitation of other resources, such as wave energy or aquaculture. Nevertheless, the literature addressing the issues related to these more complex and challenging wind devices is scarce.

Proof of this unstoppable interest is the high number of views of the papers published in this Special Issue. This foreshadows that this field of research may contribute to extending the state of the art of controllers for large-scale wind turbines, specifically for large, floating offshore turbines.

Conflicts of Interest: The author declares no conflict of interest.

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