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Editorial

Special Issue on Offshore Wind Energy

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As the impact of fossil fuels on the planet becomes clear, the world is increasingly focusing on renewable energy sources. For instance, by 2030, the European Union aims to supply 42.5 per cent of its energy demand through renewables, followed by becoming a climate-neutral continent by 2050. These targets require mature technologies scaled to meet the demand. In this regard, wind and solar have advantages over alternatives such as wave and tidal energy.

After decades of onshore use for electricity generation, offshore wind started with the Vindeby Farm in Denmark. Eleven turbines of 450 kW with rotor diameters of 35 m were installed on monopiles in 1991. The farm stayed in service for 26 years, being decommissioned in 2017. Within those years, turbine capacities reached 15 MW, increasing by a factor of 33. While this capacity increase is also a function of efficiency, it primarily relates to larger turbine sizes due to the Betz limit.

Moving these structures into deeper waters is beneficial from both energy production and social standpoints. From an energy production perspective, a significant part of the world's wind resource is in deeper waters. The unhindered wind allows a consistent flow regime for the turbine to operate more efficiently. Regarding the social impact, turbines located farther offshore address concerns such as the visual impact. However, fixed bottom structures become economically unfeasible when operating at depths beyond 60 m. Hence, floating support structures are required, introducing their own economic and technological challenges.

The life cycle of floating wind units, consisting of design, fabrication, installation, maintenance, and decommissioning, is similar to their oil and gas counterparts. However, the turbine's presence couples the hydrodynamic and aerodynamic challenges. Thus, the design of these structures becomes a truly interdisciplinary field. Another significant difference is that the turbines must be installed in higher numbers. For example, a 500 MW wind farm would result in more than 30 turbines at a capacity of 15 MW each. Hence, the technological issues and costs multiply compared to installing one oil and gas extraction unit. Installation, operation, and maintenance planning must consider these factors, including the interaction of structures in a farm. For these reasons, while floating wind technology can borrow some of the cross-industry experience, innovation is critical in making this new technology feasible.

This Special Issue addresses the abovementioned topics through 21 papers. It starts by discussing the economics of floating wind and how the technology integrates into the current energy mix. These works are followed by evaluating the design factors to turn floating wind into a viable alternative for the future. Continuing through the order of the farm's life cycle, installation and logistics are presented, followed by topics concerning operation and maintenance.

This Special Issue opens by providing an overview of the opportunities and market needs of the floating wind industry [contribution 1]. Adopting this technology as a part of the renewable energy strategy requires political support and the right market environment.

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The assessment in the mentioned work examines the state of the art and highlights the areas for improvement.

The current grid infrastructure's fit to renewable energy sources is one of the components requiring an adaptation. Unlike consistent energy sources where the output can be set, the grid must deal with inconsistent power output from the wind resource. Evaluation of Europe [contribution 2] shows that several countries' current power systems have higher readiness levels to incorporate the incoming technology. Wind farms can easily contribute to the energy mix in these cases.

Once the contribution and integration options are clarified, economic and technical perspectives can be evaluated with the method outlined in [contribution 3]. The work provides 18 case studies for the CENTEC-TLP platform, covering three electric tariffs and the costs of capital. Beyond providing answers for a particular platform, it offers a robust approach to estimating the economics of a wind farm.

Integrating floating wind energy at a feasible cost requires suitable designs considering motion dynamics, structural safety, and reliability. The following sections cover these topics, starting with the hydrodynamic design. A SPAR platform is investigated in [contribution 4] as one of the options, providing a detailed breakdown of the design and dynamics for a 10 MW rated turbine. The numerical evaluation of motions for these platforms is sensitive to the modeling approaches [contribution 5] used in the analysis software. This case is significant for all platform types, such as barges, and the complexity increases for multi-use platforms [contribution 6].

Floating wind turbines involve handling the interaction between aerodynamics and hydrodynamics. The importance of such interaction is demonstrated in [contribution 7], highlighting how the responses of the platform can be improved through novel control strategies. Once the dynamics are covered, structural design must be performed to conform with the safety and reliability requirements, as outlined in [contribution 8]. The study evaluates a TLP-Barge hybrid platform, identifying that specific locations may need detailed attention.

Verifying a system's design, especially for newer technologies, necessitates experimental work. For floating wind turbines, the testing approaches bring topic experts together to deliver a solution for the structure's coupled dynamics, considering the points discussed in [contribution 9]. Once a suitable approach is found, testing processes are undertaken, and the results are reevaluated numerically [contribution 10]. The revision provides an opportunity to improve the numerical methods [contribution 11]. In this regard, isolating and examining each component may be necessary. For instance, mooring lines may need to be adapted to renewable energy needs [contribution 12].

Fabrication and installation follow the design stage. Accordingly, the next sections of this Special Issue focus on an overview of and solutions to installing floating wind farms. The farm layout and the complex logistics involved are covered in [contribution 13]. When installing individual units, one option is to develop novel installation vessels to ensure safety during transport and installation [contribution 14]. In most cases, the mooring lines must be pre-installed (pre-lay) for these methods to work. The pre-lay process depends on careful planning and optimization, accounting for weather windows [contribution 15]. Operation and maintenance become the primary concerns after the installation phase. At those stages, understanding and estimating the failure rates of the components [contribution 16] and prioritizing failures necessitate suitable methods [contribution 17]. Thus, preventative measures, as exemplified in [contribution 18], can be applied.

Regardless of prevention, the wind farm is subject to maintenance, where the size of the installation area, combined with the logistic setup, leads to planning challenges. Using Petri-Nets and Monte-Carlo simulations for this purpose is a solution described in [contribution 19]. Given the difficulty of working offshore within weather windows, allocating service vessels with high-efficiency methods [contribution 20] becomes another area of interest. In the case that damage occurs despite these precautions, its correct quantification [contribution 21] allows having the best approach to reducing the overall impact on the environment and the wind farm.

With these works, this Special Issue covers a significant part of a floating wind farm's life cycle. It starts with the economics and proceeds to the design and analysis processes, followed by installation logistics. The operation of the installed farm is discussed from a maintenance planning perspective. These contributions aim to provide an understanding of the developments within this novel field and contribute to its standardization and large-scale implementation. It is noted, of the 21 papers included, 15 are the result of the European project ARCWIND, which helps to provide consistency in this Special Issue.

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List of Contributions:

1. Díaz, H.; Serna, J.; Nieto, J.; Soares, C.G. Market Needs, Opportunities and Barriers for the Floating Wind Industry. *J. Mar. Sci. Eng.* **2022**, *10*, 934. https://doi.org/10.3390/jmse10070934.
2. NAmaro, N.; Egorov, A.; Glória, G. Fostering Offshore Wind Integration in Europe through Grid Connection Impact Assessment. *J. Mar. Sci. Eng.* **2022**, *10*, 463. https://doi.org/10.3390/jmse10040463.
3. Filgueira-Vizoso, A.; Castro-Santos, L.; Iglesias, D.C.; Puime-Guillén, F.; Lamas-Galdo, I.; García-Diez, A.I.; Uzunoglu, E.; Díaz, H.; Soares, C.G. The Technical and Economic Feasibility of the CENTEC Floating Offshore Wind Platform. *J. Mar. Sci. Eng.* **2022**, *10*, 1344. https://doi.org/10.3390/jmse10101344.
4. Guo, X.; Zhang, Y.; Yan, J.; Zhou, Y.; Yan, S.; Shi, W.; Li, X. Integrated Dynamics Response Analysis for IEA 10-MW Spar Floating Offshore Wind Turbine. *J. Mar. Sci. Eng.* **2022**, *10*, 542. https://doi.org/10.3390/jmse10040542.
5. Srinivas, A.; Robertson, B.; Gadasi, J.B.; Simpson, B.G.; Lomónaco, P.; Ilzarbe, J.M.B. Impact of Limited Degree of Freedom Drag Coefficients on a Floating Offshore Wind Turbine Simulation. *J. Mar. Sci. Eng.* **2023**, *11*, 139. https://doi.org/10.3390/jmse11010139.
6. Zhai, Y.; Zhao, H.; Li, X.; Shi, W. Hydrodynamic Responses of a Barge-Type Floating Offshore Wind Turbine Integrated with an Aquaculture Cage. *J. Mar. Sci. Eng.* **2022**, *10*, 854. https://doi.org/10.3390/jmse10070854.
7. Shah, S.A.A.; Gao, B.; Ahmad, I.; Ullah, H.; Ahmed, N.; Saeed, A. Adaptive Backstepping Integral Sliding Mode Control for 5DOF Barge-Type OFWT under Output Constraint. *J. Mar. Sci. Eng.* **2023**, *11*, 492. https://doi.org/10.3390/jmse11030492.
8. Zavvar, E.; Abdelwahab, H.S.; Uzunoglu, E.; Chen, B.-Q.; Soares, C.G. Stress Distribution on the Preliminary Structural Design of the CENTEC-TLP under Still Water and Wave-Induced Loads. *J. Mar. Sci. Eng.* **2023**, *11*, 951. https://doi.org/10.3390/jmse11050951.
9. Hmedi, M.; Uzunoglu, E.; Zeng, C.; Gaspar, J.F.; Soares, C.G. Experimental Challenges and Modelling Approaches of Floating Wind Turbines. *J. Mar. Sci. Eng.* **2023**, *11*, 2048. https://doi.org/10.3390/jmse11112048.
10. Hmedi, M.; Uzunoglu, E.; Medina-Manuel, A.; Mas-Soler, J.; Vittori, F.; Pires, O.; Azcona, J.; Souto-Iglesias, A.; Soares, C.G. Experimental Analysis of CENTEC-TLP Self-Stable Platform with a 10 MW Turbine. *J. Mar. Sci. Eng.* **2022**, *10*, 1910. https://doi.org/10.3390/jmse10121910.
11. Hallak, T.S.; Soares, C.G.; Sainz, O.; Hernández, S.; Arévalo, A. Hydrodynamic Analysis of the WIND-Bos Spar Floating Offshore Wind Turbine. *J. Mar. Sci. Eng.* **2022**, *10*, 1824. https://doi.org/10.3390/jmse10121824.
12. Lopez-Olocco, T.; González-Gutiérrez, L.M.; Calderon-Sanchez, J.; Loureiro, A.M.; Ynocente, L.S.; Barrio, A.B.; Valdés, N.V. Experimental and Numerical Study of the Influence of Clumped Weights on a Scaled Mooring Line. *J. Mar. Sci. Eng.* **2022**, *10*, 676. https://doi.org/10.3390/jmse10050676.
13. Díaz, H.; Soares, C.G. Approach for Installation and Logistics of a Floating Offshore Wind Farm. *J. Mar. Sci. Eng.* **2022**, *11*, 53. https://doi.org/10.3390/jmse11010053.
14. Hassan, M.; Soares, C.G. Dynamic Analysis of a Novel Installation Method of Floating Spar Wind Turbines. *J. Mar. Sci. Eng.* **2023**, *11*, 1373. https://doi.org/10.3390/jmse11071373.

15. Altuzarra, J.; Herrera, A.; Matías, O.; Urbano, J.; Romero, C.; Wang, S.; Soares, C.G. Mooring System Transport and Installation Logistics for a Floating Offshore Wind Farm in Lannion, France. *J. Mar. Sci. Eng.* **2022**, *10*, 1354. https://doi.org/10.3390/jmse10101354.
16. Li, H.; Peng, W.; Huang, C.-G.; Soares, C.G. Failure Rate Assessment for Onshore and Floating Offshore Wind Turbines. *J. Mar. Sci. Eng.* **2022**, *10*, 1965. https://doi.org/10.3390/jmse10121965.
17. Li, H.; Teixeira, A.P.; Soares, C.G. An Improved Failure Mode and Effect Analysis of Floating Offshore Wind Turbines. *J. Mar. Sci. Eng.* **2022**, *10*, 1616. https://doi.org/10.3390/jmse10111616.
18. Fu, X.; Sheng, M. Research on Structural Failure Analysis and Strengthening Design of Offshore Wind Turbine Blades. *J. Mar. Sci. Eng.* **2022**, *10*, 1661. https://doi.org/10.3390/jmse10111661.
19. Lotovskyi, E.; Teixeira, A.P.; Soares, C.G. Availability Analysis of an Offshore Wind Turbine Subjected to Age-Based Preventive Maintenance by Petri Nets. *J. Mar. Sci. Eng.* **2022**, *10*, 1000. https://doi.org/10.3390/jmse10071000.
20. Silva, L.M.R.; Li, H.; Soares, C.G. Service Operation Vessels Fleet Size and Mix Location Routing for the Maintenance of an Offshore Floating Wind Farm. *J. Mar. Sci. Eng.* **2023**, *11*, 664. https://doi.org/10.3390/jmse11030664.
21. Bashir, M.; Xu, Z.; Wang, J.; Soares, C.G. Data-Driven Damage Quantification of Floating Offshore Wind Turbine Platforms Based on Multi-Scale Encoder–Decoder with Self-Attention Mechanism. *J. Mar. Sci. Eng.* **2022**, *10*, 1830. https://doi.org/10.3390/jmse10121830.