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Editorial: Development of advanced methods for offshore integrated wind-wave power generation devices

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Editorial on the Research Topic
Development of advanced methods for off shore integrated wind-wavep ower generation devices

The huge amount of offshore renewable energy resources in deep waters has attracted tremendous interest worldwide. Different technologies have reached distinct Technology Readiness Levels (TRL), so far, confirming the intensive research, but also, the industrialization. Floating wind turbine technology has been regarded as an attractive and reliable solution for deep water areas, although it inherently has a number of technological challenges, such as the high cost and severe operational conditions. Already, floating wind turbines farms are in operation successfully without large downtimes and significant problems affecting their operation.

However, compared with the offshore wind power generation, the wave energy technology has not yet been exploited in a commercialized scale. The most important inhibitors to the wave energy exploitation are both the functionality and the survivability of the energy devices subjected to the harsh ocean environmental conditions, as well as, their huge Levelized Cost of Energy (LCOE).

Many researchers have considered the idea of integrating Wave Energy Converters (WECs) with an offshore wind turbine, particularly with a floating offshore wind turbine for reducing the LCOE of both the wind and wave power generations in deep waters. In recent years, a large number of concepts and possible designs for combining WECs with a floating wind turbine have been proposed and experimentally tested, and even some demonstration projects have been carried out.

Compared to the single floating wind turbine, integrated concepts introduce new design challenges that should be modeled and accounted during the analysis, such as the multi-body dynamic coupling mechanisms (Li et al., 2021) between the WECs and floating wind turbines (e.g., hydrodynamic, aerodynamic, mechanical) (Wang et al., 2022), and the nonlinear dynamics induced by the end-stop system of WECs (Chen et al., 2021) and the utilized PTO control schemes of the WEC. In addition, those integrated concepts need to be further explored to achieve a robust and versatile design (Wang et al., 2020). Low and high fidelity numerical and testing methods (Michailides et al., 2020) are urgently needed to be developed for further exploring the potential of combined power generation, but also, for optimizing the design of such devices.

For addressing all those challenges, this Research Topic focuses on presenting latest novel and original developments of advanced numerical methodologies and testing methods for offshore integrated wind-wave power generation devices. Those methods cover various aspects of the design of offshore integrated wind-wave power generation devices, such as hydrodynamic and aerodynamic loads, structural safety and integrity, mooring safety and PTO control strategies. Emphasis is given in the efficient and correct multi-body hydrodynamic modeling, as well as, multi-body dynamic coupling modeling that result to high fidelity structural and fatigue analysis of the integrated devices. In addition, new novel designs of integrated devices are also targeted. This Research Topic brings together recent developments related to the design, analysis, testing and demonstration of the integrated wind-wave power generation devices, aiming to promote the engineering application of such new combined offshore renewable energy devices.

New novel designs of integrated wind-wave devices have been recently proposed. Based on the integrated Floating Wind-Wave generation Platform (FWWP) proposed by Chen et al. (2020), Chen M. et al. established a fully coupled model for analyzing the dynamics and power generations of the FWWP in operational sea-states where the end-stop mechanism of the PAWEC is ineffective. The analyzed FWWP consists of the DeepCwind semi-submersible floating offshore wind turbine (FOWT) and one point absorber wave energy convertor (PAWEC). The coupled motion responses and wind-wave power generation of the FWWP are compared with those that correspond to the single PAWEC and FOWT for both regular and irregular waves. The hydrodynamic interaction of the FWWP has significant effect on the hydrodynamics of the PAWEC. The effect is very large for the heave RAO response of the PAWEC in FWWP and significantly larger than that of the single PAWEC for most incident wave directions. The wave power generation of the device is greatly enhanced. The aerodynamic loads are found to have significant effect on the wave power generation of the FWWP. In addition, the existence of PAWEC is generally found to have small effect on the wind power generation of FWWP.

Chen Z. et al. proposed the integration a novel hybrid wind-wave energy platform consisting of a semi-submersible floating offshore wind turbine (FOWT) and three heaving-type WECs for improving both the overall energy production, but also, the platform dynamic responses, thus is expected to reduce the levelized cost of energy and increase their lifetime. The feasibility of reducing the FOWT dynamic responses and fatigue loads by integrating heaving-type WECs with different PTO control schemes is investigated. The active bang-bang control could effectively suppress the platform heave and pitch motion by a large amount. On the other hand, the system power production could be increased by a level of almost 6%. Therefore, it is shown that integrating heaving-type wave energy converters with bang-bang control is able to effectively reduce the dynamic responses and fatigue loads of semi-submersible FOWT, while absorbing additional wave energy.

Konispoliatis et al. presents coupled analysis results performed in frequency and time domain for the case of a multi-purpose floating structure suitable for offshore wind and wave energy sources exploitation. Such systems can represent a cost-effective engineering solution by increasing the anticipated energy extraction to production cost ratio when it is compared to the corresponding one applicable to separate exploitation. The present analysis is built to incorporate properly, the solutions of the diffraction, and the pressure- and motion-dependent radiation problems around the floating structure, the mooring lines characteristics, the PTO characteristics and the aerodynamics of the wind turbine by accounting for the aerodynamic modeling of the rotor, the elastic modeling of the turbine components. The hydrodynamic properties of the platform are presented, while its structural integrity is investigated through the determination of the ultimate and the fatigue loads expected to be imposed on it over its lifetime.

Mooring lines is a basic component of possible integrated concepts; novel types of mooring lines should be identified and analyzed. Ma et al. proposed an innovative type of a mooring system in order to resist the pitch and horizontal motions. The authors suggested dividing the fairleads into two groups at different depths. The innovative mooring system used for the case of a floating offshore wind turbine. In addition a conventional mooring system was employed and modeled for comparison and the dynamic responses of the same floating offshore wind turbine with those two mooring systems were calculated and analyzed. The motion responses and structural loads of the floating offshore wind turbine were calculated and compared. The proposed innovative mooring lines system effectively reduces the horizontal and pitch motions simultaneously of the platform. Moreover, the bending moment and shearing force at tower base were also reduced significantly.

Harsh extreme ocean conditions and specifically typhoon sea conditions have always been a challenging issue not only for the integrity of the offshore structures but also for validating the fidelity of the developed numerical analysis methods and tools. Liu et al. investigated the dynamic performance of an integrated 15MW semi-submersible floating offshore wind turbine (FOWT) under the typhoon sea condition in South China Sea and ECD wind condition. An aero-hydro-servo-chain coupled method was developed for the dynamic analysis of the 15MW FOWT. Motion responses, mooring line axial forces and internal loads of the blades and tower are examined and presented. The typhoon conditions will result to the snap tension of the mooring line several times. Second-order difference-frequency wave loads have a significant effect on the dynamic response of the 15MW FOWT under typhoon environmental conditions.

Author contributions

MC and WS: conceptualization, methodology, and writing—reviewing and editing. TF: writing—reviewing and editing. CM: writing original draft. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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