On the development of a generic computational tool for the time-domain analysis of hybrid offshore wind and wave energy floating systems

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The efficient exploitation of the vast offshore wind and wave energy potential can contribute to reduction of CO2 emissions, economic growth and security enhancement. Although the offshore wind and the wave energy industries show, nowadays, a different level of maturity, they both share a common objective; namely, the development of sustainable solutions, satisfying energy effectiveness, cost efficiency, safety requirements, adequate resistance and durability in harsh sea environmental conditions, as well as environmental considerations. Along these lines, it may be beneficial to boost the development of synergetic systems (Hybrid Offshore Wind and Wave Energy Systems - HOWWESs) that enable the simultaneous exploitation of the offshore wind and wave energy by combining into one structure an Offshore Wind Turbine (OWT) with multiple Wave Energy Converters (WECs).

The utilization of HOWWESs can have many advantages, such as costs reduction through costs sharing, increased energy yield, smooth and highly available power output, common grid infrastructure etc. [1]. It is evident, however, that an HOWWES is characterized by high complexity due to its inherent characteristics (e.g. variability and intense interaction of components) and its operation in the complex marine environment. Hence, a key factor for advancing the HOWWES technology is the development/application of suitable integrated numerical tools enabling the efficient investigation/assessment of the performance of an HOWWES, while, supporting, at the same time, the realization of novel relevant concepts, especially in deep waters. Motivated by this, a generic computational tool within the OpenFAST environment [2] is currently being developed, capable to conduct aero-hydro-servo-elastic time-domain analysis of an HOWWES consisting of any type of moored Floating OWT (FOWT) and several WECs, which absorb wave power through oscillations at specific Degrees of Freedom (DOFs).

The whole methodology is based on the utilization of the generalized modes concept for describing the relative to the FOWT motions of the WECs, additionally to the six rigid-body modes. In this way: (a) all hydrodynamic interactions between the FOWT and the WECs and between the WECs themselves can be taken into account, while (b) the computational time of the analysis is anticipated to be reduced. The frequency-dependent exciting forces along with the hydrodynamic and the hydrostatic coefficients are initially calculated in the frequency domain using a traditional numerical model based on the boundary element /boundary integral equation method (e.g. WAMIT [3]). The required generalized mode shapes are determined through appropriate vector shape functions, derived in accordance with the WECs' working direction. As for the time-domain analysis, specific subroutines of OpenFAST are appropriately extended (e.g. extension of Cummins equation of motion for more than 6 DOFs) in order to consider the additional generalized DOFs as well as the power take-off mechanisms. The hydrodynamic coupling between the FOWT and the WECs and between the WECs themselves will be taken into account through the inclusion of non-zero non-diagonal hydrodynamic and hydrostatic coefficients in the time-domain equation of motion. Finally, the developed tool will be validated with available numerical (based on the multi-body approach) and experimental results corresponding to existing in the literature floating HOWWES concepts.

References

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