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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Introduction

The efficient exploitation of the vast offshore wind and wave energy potential can contribute to reduction of CO_2 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). Examples of HOWWES concepts are shown in Fig.1. 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.

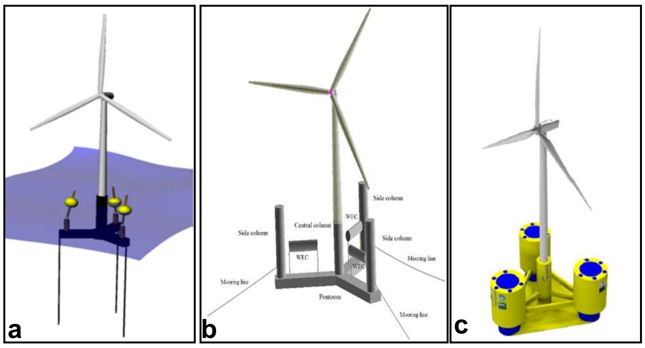

Fig. 1. HOWWES concepts of (a) Tension Leg Platform Wind Turbine “TLPWT” [2], (b) Semi-submersible Flap Combination “SFC” [3] and (c) Multi-Use Platform “MUP” [4]

Objective

A generic computational tool within the OpenFAST [5] environment 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).

Methodology

- Utilization of the generalized modes concept:
  - HOWWES’ platform is considered as single body having 6 rigid body DOFs plus additional DOFs (generalized modes) representing the relative motion of each WEC to the platform’s motion
  - Generalized modes expression: Vector shape functions
- Frequency-domain analysis of the HOWWES submerged part:
  - Use of the Boundary Integral Equation Method (BIEM) numerical model (e.g., WAMIT [6])
  - Output: Frequency-dependent exciting forces, hydrostatic and hydrodynamic coefficients of the HOWWES
- Time-domain analysis of HOWWES (whole structure) in OpenFAST:
  - Modifications (see also Fig. 2 in order to visualize the procedure):
    - Changes of OpenFAST’s source code (e.g., extending Cummins equation of motion for more than 6 DOFs)
    - Hydrodynamic coupling (i.e., non zero off-diagonal terms of the frequency dependent matrices)
    - Inclusion of WECs’ Power Take Off Mechanisms (PTO)
  - Output: Physical quantities describing HOWWES performance
  - The computational time is anticipated to be significantly reduced

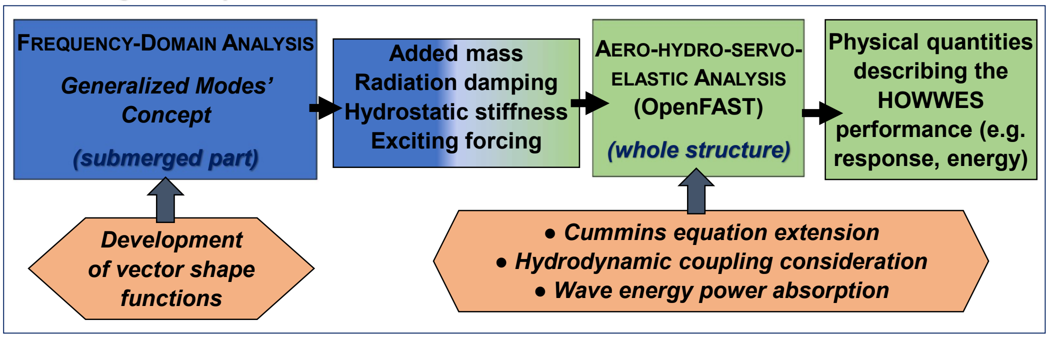

Fig. 2. Schematic layout of the proposed methodology

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