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1 Deliverable 4.4 – Overview of the numerical models used in the consortium and their qualification

The report provides an overview of the numerical tools used by the consortium in the preliminary design and optimization of floating wind turbine substructures. A state-of-the-art review of floating wind turbine coupled modelling was conducted, with a focus on substructure modelling, highlighting current challenges in this area. Particular areas identified include nonlinear wave kinematics and force modelling on large-volume substructures; hydrodynamic viscous forcing; substructure flexibility; and, large rotor aerodynamic damping.

A questionnaire was distributed to consortium partners concerning numerical tools used during the preliminary design and optimization of floating substructure concepts, as well as initial "pre-design" methodologies employed. Consortium partners use either WAMIT or AQWA for carrying out hydrodynamic analysis, largely in the frequency domain. A range of aero-hydro-servo-elastic numerical tools are then used for carrying out coupled dynamic simulations of the floating system, with FAST being the most prevalent, followed by OrcaFlex, SIMA, Bladed, Flex5, HAWC2, Simpack Wind and SLOW.

These aero-hydro-servo-elastic numerical tools have similar engineering models implemented: variants of the momentum balance aerodynamic model; combinations of time domain hydrodynamic potential flow and Morison equations; a mixture of finite element methods, multibody formulations and shape response structural representations; and both quasi-static and dynamic mooring line models. The verification, validation and qualification of these tools are defined and presented, with the majority of tools being similarly qualified for the preliminary design and optimization of floating wind turbines.

Consortium partners use preliminary design methodologies similar to those used in the offshore oil and gas industry. Initiating with a static design constrained by a small number of design criteria and variables, designers then carry out a static analysis to evaluate static stability and equilibrium states. Dynamic analysis of the floating substructure follows, normally in the frequency domain, identifying natural frequencies and response amplitude operators. Finally, designers perform time-domain coupled simulations for a restricted set of environmental conditions. This is followed by a concept evaluation and if necessary, the process is repeated considering feedback from the previous cycle. Some partners also include intermediate concept evaluations between static design, static analysis, dynamic analysis, and coupled simulation analysis.

A number of challenges were also identified that design engineers face when going through this process and progressing to more advanced design phases. These include: automating the process of transitioning from one analysis type to the next; establishing optimal techno-economic target design criteria to accelerate the design process; mapping of loads from aero- and hydrodynamic engineering force models to more detailed structural models; and improving computational efficiency.

The results from the questionnaire responses and state-of-the-art review also provided an outlook on future numerical modelling activities and areas where model improvements are needed. The major topics of interest identified were: more efficient integrated numerical tools; integration of numerical tools within the design process; cascading of design tools from different levels of modelling; and improving the reliability of design tools.