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A Modular Concept for Integrated Modeling of Offshore WEC Applied to Wave-Structure Coupling

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59.1 Introduction

For the development of robust and economic offshore wind energy converters, reliable design methods to perform integrated simulation of offshore wind turbines in time domain have to be improved or even developed.

In the offshore environment, we have to consider a coupled system, consisting of the support structure, the foundation, the aeroelastic system for the wind model and the hydrodynamic loads due to waves.

The achievement of an integral model suffers from the diversity of different processes and process interactions to be taken into account for the analysis of an offshore wind turbine and its associated subsystems. The models used by research teams and consulting engineers are normally heterogeneous. Therefore, a flexible structure of the integral model is the main target of current research. A well designed object-oriented and easily extendable set of models and interfaces have to be developed in order to fulfill future demands.

This paper gives an overview of the single modules which are needed for an integrated design and how they would interact. Moreover it describes the pursued strategy for the coupling procedures and the interface design. In the first step a model for fluid structure interaction is implemented.

59.2 Integrated Modeling

The numerical simulation of coupled processes (see Fig. 59.1) is essential for optimization purposes and for prediction of the breakeven performance of offshore WEC. A variety of commercial simulation tools for fluid dynamics, multibody dynamics or structural mechanics is available. Additional sophisticated tools for specific demands are being developed or self-improved. In order to serve several purposes an alternative use of different models is required in order to fulfill the a wide variety of modeling and simplification strategies.

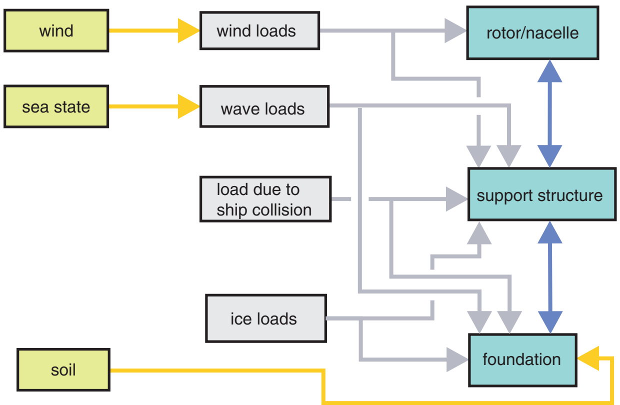

Fig. 59.1. Components of the integrated model approach: processes, loads, and subsystems

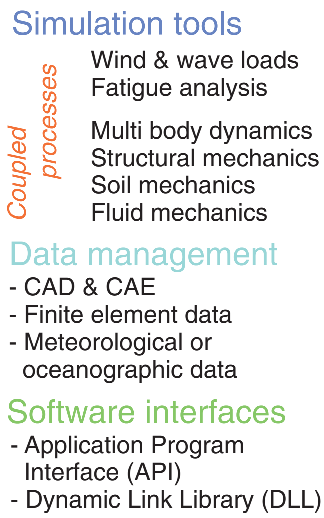

Fig. 59.2. Coupled processes and submodules of the IM

The set-up of a comprehensive model suffers from the multitude of heterogeneous modeling frameworks involved. The *integrated model* (IM), to be developed within the research activities of the *Center for Wind Energy Research* (ForWind), is supposed to reduce these shortcomings [2]. Especially, the data management and the preparation or automation of simulation sequences are important aspects (Fig. 59.2). Thus, the IM has to be developed in terms of a flexible compound of modular simulation models combined with control, data base, and interface units. These interfaces are one of the main targets as they will improve and faster interacting simulations. A modular concept will also enable independent code developments of several research teams.

59.2.1 Model Concept

The IM research work is aimed to get together the diversity of different processes and process interactions which have to be taken into account for the analysis of an offshore wind turbine and its associated subsystems. Therefore, a flexible structure of the IM is the main target of current research. A well designed object-oriented and easily extendable set of models and interfaces have to be developed in order to fulfill future demands. The current approach is depicted in Fig. 59.3.

59.2.2 Model Realization

The current status of development of the IM allows to define the geometric data, its discretization and the belonging material properties for the transformation to the load module (WeveLoads) followed by the specification of input files for a dynamic analysis using a finite element solver. Thus, the user is assisted in three ways: the geometric and material data transformation on the one hand and the transformation (global/local) of the loading data or evaluation of resulting values on the one hand. With increasing amount of integrated submodules the usefulness of having graphical modules available in the IM gets more apparent as well as the need of data format transition.

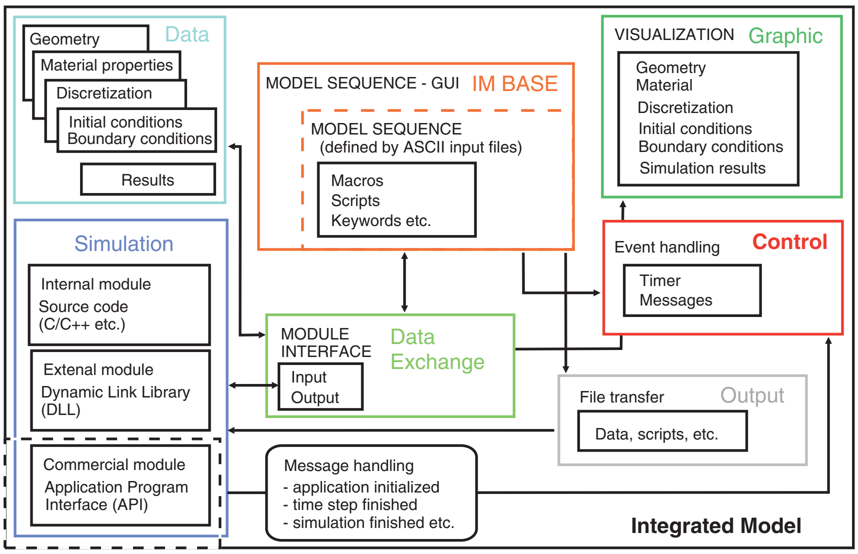

Fig. 59.3. Simulations tools and submodules in the IM frame

59.3 Modeling of Wave Loads on the Support Structure Offshore Wind Energy Turbines

During the design process of an offshore wind turbine the engineer has to consider the extreme load condition as well as the fatigue life. Following, the support structure for the WEC is modeled with a finite element approach using the program ANSYS. The hydrodynamic loads are calculated using different linear or nonlinear wave theories in combination with the Morison equation [1, 4]. Morison equation is limited to hydrodynamically transparent structures and is a summation of drag and inertia forces

$$F = \frac{1}{2}\rho C_D D \int_{-h}^{\eta} u\,|u|\,\mathrm{d}z + C_M \rho \frac{\pi D^2}{4} \int_{-h}^{\eta} \frac{\partial u}{\partial t}\mathrm{d}z \qquad (59.1)$$

where u is the water particle kinematic perpendicular to the structure axis, C_D and C_M hydrodynamic coefficients, D tube diameter and ρ fluid density.

59.3.1 Application to the Support Structure of an Offshore Wind Turbine

In the next step the structural behavior of a monopile (Fig. 59.4) loaded by irregular waves with and without directionality of the wave field is analyzed. A reduction of the loads and the structure response up to 20% can be observed, when the directionality is taken into account (Fig. 59.5) [3]. In further examinations the effect on the fatigue will be analyzed.

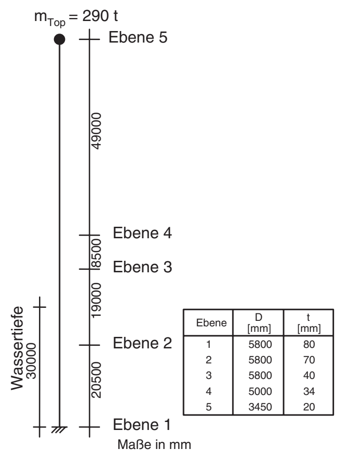

Fig. 59.4. Monopile

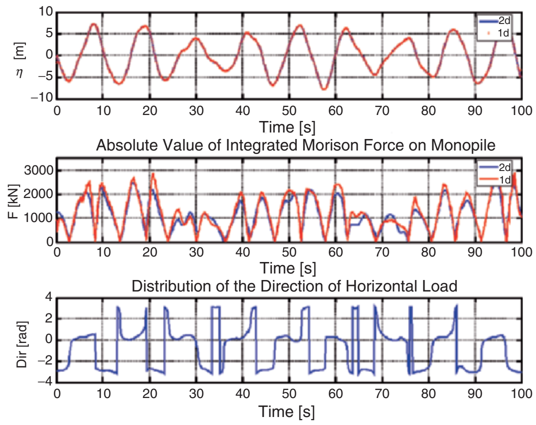

Fig. 59.5. 1D and 2D wave loads applied to monopile.

59.4 Future Demands

Future demands are not yet fully predictable, but a higher resolution of the used models also for substructures will yield in a demand for model adaptive strategies and new methods or solutions techniques.
The next milestone of the development will be the implementation of aeroelasticity model for the dynamical analysis of the structure due to combined wind and wave loads.

References

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