NTNU Trondheim
Norwegian University of Science and Technology
Faculty of Engineering Science and Technology
*Department of MarineTechnology*

# MASTER THESIS IN MARINE TECHNOLOGY

## SPRING 2013

## FOR

## Even Rosenlund

## Nonlinear Hydrodynamic Effects for Bottom-Fixed Wind Turbines

(Ikkelinære hydrodynamiske effekter på bunnfaste offshore vindturbiner)

The need for alternative and greener energy is pushing toward greater investment on offshore wind turbines. Bottom-fixed wind turbines and floating wind turbines on spar, semi-submersible, and tension leg platforms represent relevant concepts and involve important challenges. Several arrangements for intermediate and deeper water depths are presently being examined. Aero-hydro-elastic coupling is in general of great concern. For bottom-fixed wind turbines in shallow water conditions a well recognized challenge in terms of safety and efficiency is represented by the interaction with very steep waves, especially when impacting as breaking waves against the cylindrical part of the platform. An important consequence could be ringing excitation, i.e. global transient elastic resonance oscillations of the structure. In the project, the hydrodynamic challenges connected with the general concept of offshore wind turbines were examined with focus on the concept of bottom-fixed platforms and their interaction with waves.

**Objective**

The aim of the thesis is to investigate the relevance of nonlinear wave loads on a bottom-fixed wind turbine. This will be done for the platform selected in the project thesis and within the FAST open-source solver. Both the influence of nonlinear effects in the wave-load formulas and in the incident waves will be examined.

The work should be carried out in steps as follows:

1. Summarize major findings from the project thesis in the context of bottom-fixed wind turbines highlighting the nonlinear wave induced-load effects relevant for the structure.
2. Select one or more improved wave-load models examined in the project thesis and implement them in FAST. Assume linear incident waves and compare the resulting loads against those obtained using the classical Morison equations for relevant operational conditions of the platform.
3. Use an available fully nonlinear incident wave solution, and/or a weakly-nonlinear incident wave solution, as input for the implemented wave loads and check the relevance of nonlinear effects in the sea.
4. Using the improved incident-wave and wave-load models, investigate occurrence and features of ringing for the selected platform.
5. Assess the improved solver by comparing with results from fully-nonlinear numerical solvers or experiments on a circular cylinder.

The work may show to be more extensive than anticipated. Some topics may therefore be left out after discussion with the supervisor without any negative influence on the grading.

The candidate should in her report give a personal contribution to the solution of the problem formulated in this text. All assumptions and conclusions must be supported by mathematical models and/or references to physical effects in a logical manner.

The candidate should apply all available sources to find relevant literature and information on the actual problem.

The thesis should be organised in a rational manner to give a clear presentation of the work in terms of exposition of results, assessments, and conclusions. It is important that the text is well written and that tables and figures are used to support the verbal presentation. The thesis should be complete, but still as short as possible. In particular, the text should be brief and to the point, with a clear language. Telegraphic language should be avoided.

The thesis must contain the following elements: the text defining the scope (i.e. this text), preface (outlining project-work steps and acknowledgements), abstract (providing the summary), table of contents, main body of thesis, conclusions with recommendations for further work, list of symbols and acronyms, references and (optional) appendices. All figures, tables and equations shall be numerated.

The supervisor may require that the candidate, in an early stage of the work, present a written plan for the completion of the work. The plan should include budget for the use of computer and laboratory resources that will be charged to the department. Overruns shall be reported to the supervisor.

From the thesis it should be possible to identify the work carried out by the candidate and what has been found in the available literature. It is important to give references to the original source for theories and experimental results.

The thesis shall be submitted in two copies:
- The copies must be signed by the candidate.
- This text, defining the scope, must be included.
- The report must appear in a bound volume or a binder.
- Drawings and/or computer prints that cannot be included in the main volume should be organised in a separate folder.
- The bound volume shall be accompanied by a CD or DVD containing the written thesis in World or PDF format. In case computer programs have been made as part of the thesis work, the source codes shall be included. In case of experimental work, the experimental results shall be included in a suitable electronic format.

Supervisor :Marilena Greco
Submitted :16 January 2013
Deadline :10 June 2013

Marilena Greco
Supervisor