FLOW Final Report

Project title : **DUWIND's far offshore wind farm design**

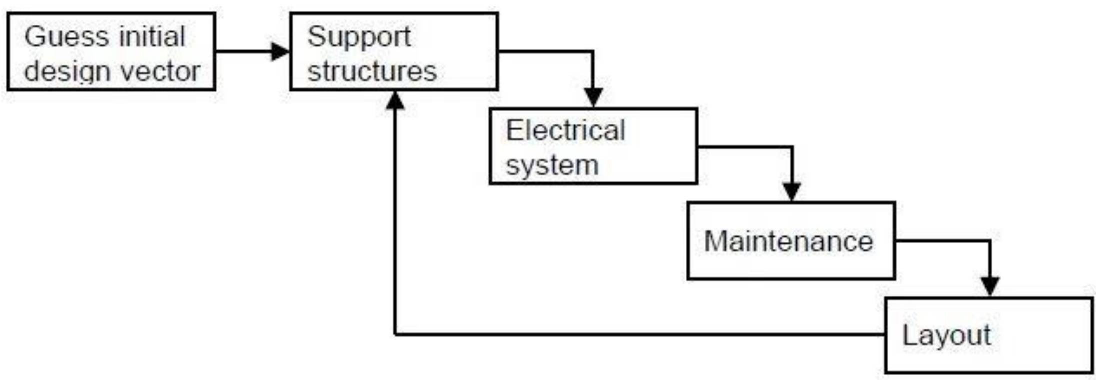
WP 5: Offhsore wind power plant conceptual design

1. Project Summary

This research addresses two challenges of making affordable electricity from offshore wind energy. The first challenge is the difficulty of optimisation, due to the multidisciplinary and multi-component nature of offshore wind farms. The second challenge is that the design of the rotor-nacelle assemblies is not performed at the same time as the design of the wind farms in which they are applied. This is the consequence of designing rotor-nacelle assemblies for many wind farms, while most of the rest of the design of the wind farm is site specific. The asynchrony between the design processes makes it difficult to optimise the rotor-nacelle assembly with respect to the cost of energy. The objective of this research is to obtain a method to support the optimisation of rotor-nacelle assemblies that will be applied in offshore wind farms.

The primary means of the method is a software tool that emulates the design processes that are outside the scope of the designer, but that affect the value of the system for which a sub component is designed. This emulation provides the means to assess the effect of sub-system design variation on the design of other parts of the system and consequentially on its value. Guidelines are developed and applied to implement the method for the optimisation of rotor-nacelle assemblies. To this end, a tool is developed that emulates the design of offshore wind farms, based on specifications of the rotor-nacelle assembly. By variation of specifications of the rotor-nacelle assembly, the designer can assess the effect on the wind farm design and on the cost of energy.

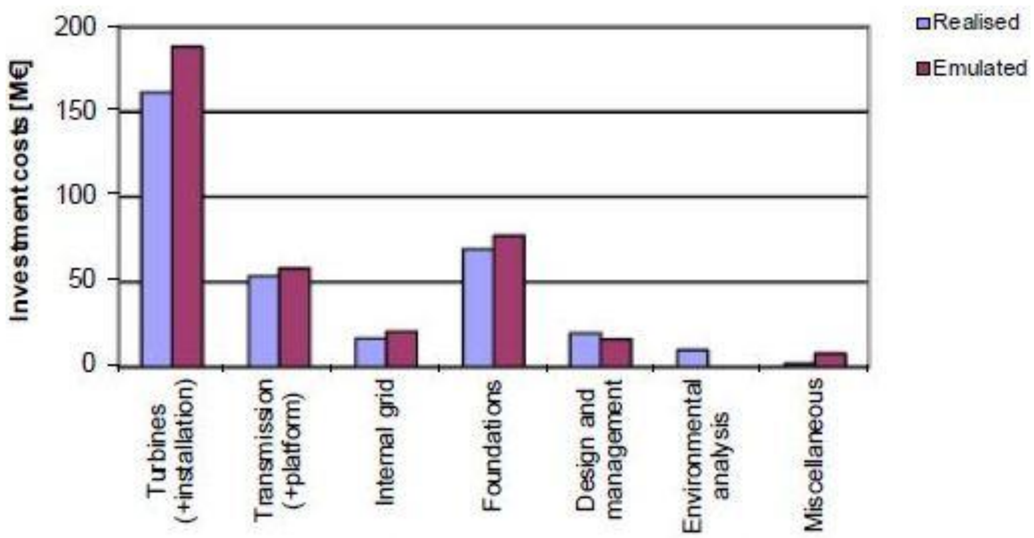
To develop the emulation of wind farm design that is implemented in the tool, a separation of this design process has been evaluated. The basis for this separation is the identification of groups of constraints in which the design variables appear. For instance, the electrical cable dimensions and the transformer voltage levels determine whether the constraint on cable temperatures and voltage breakthrough are violated, while they have no effect on the constraint on stresses in the support structure. The groups of separable constraints that were identified has led to structuring the tool as a sequential alternating formulation for optimisation of the support structure, the electrical system, the deployment of crew and equipment for maintenance and the positions of the turbines (layout). This formulation is illustrated in the next figure.



Sequence of disciplinary optimisations

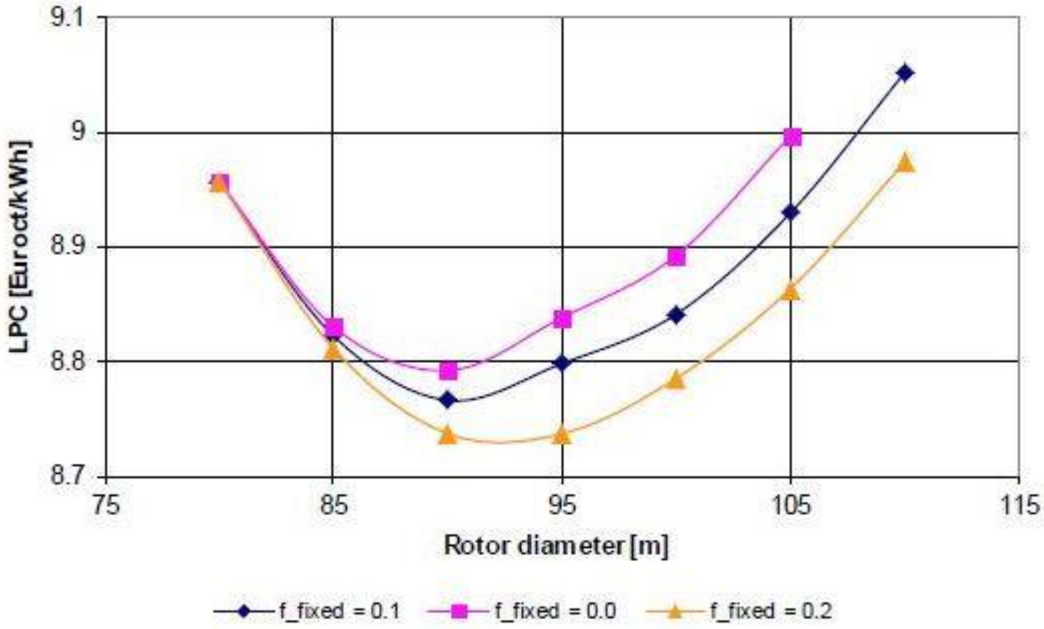
For each of the disciplinary optimisations a list of design variables is formulated. These design variables are given a value according to three principles: 1. The formulation of heuristic knowledge; 2. The evaluation of a constraint; 3. An optimisation algorithm. An example of heuristic knowledge is that the outer diameter of the transition piece is typically about 300 mm larger than outer diameter of monopile. An example of a design variable on the constraint is that the monopile penetration depth is just enough to have sufficient bearing capacity.

The quality of the emulation of offshore wind farm design is verified by comparison of emulated designs with realised designs.. The accuracy of the economic results of the emulation is found to be sufficient to support optimisation of main parameters of the rotor-nacelle assembly. Absolute accuracy of cost of energy is in the order of 20%. This is supported by the comparison of the cost components for Horns Rev, shown below. More importantly, the response of cost of energy to changes in main parameters of the rotor-nacelle assembly is found to be in agreement with expectations.



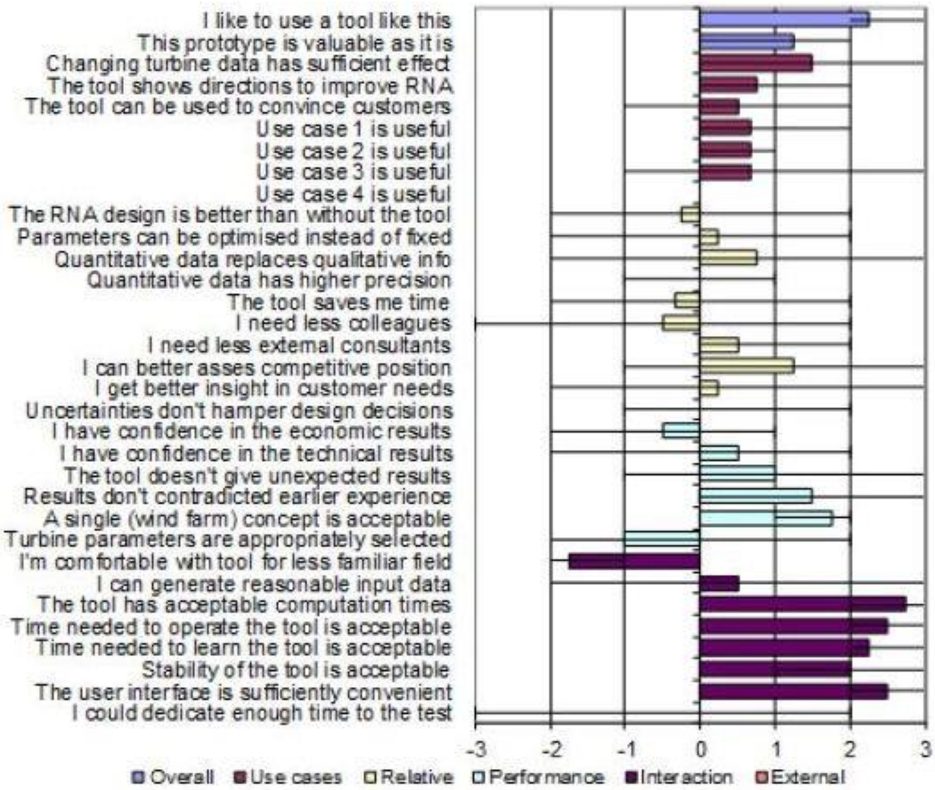
Investment cost distributions of Horns Rev

The usefulness of the method is validated by giving an informed argument, performing a controlled experiment with the tool and by holding a review of the tool by several companies. Several main parameters of the rotor-nacelle are shown to have a clear effect on the cost of energy. The magnitude of this effect and thus of the contribution of the tool to the optimisation is in the order of a few percent. Of the performed cases studies, the variation of rotor diameter resulted in the largest effect. An example of this is illustrated by the graph below, which shows variation of the rotor diameter of the V80 in Horns Rev. The reduction in Levelised Production Costs (LPC) through diameter optimisation varies between 1.8% and 2.5% for the used purchase price models in this case study.



Levelised production costs as a function of rotor diameter for three models of the RNA purchase price

Employees of the companies that have tested the emulation tool confirm the utility of the method, although several imperfections are identified for the emulation that is implemented in this project. The user satisfaction of the respondents of a questionnaire is presented in the figure below:



Average agreement to statements (-3 = disagree – +3 = agree). Error bars show the lowest and highest level of agreement of all respondents

Future prospects of the method and tool are assessed by comparison with other academic software developments and by analysis of the responses of the reviewers. Wind energy consultants are considered to be in the best position for further developments of the emulation tool, with help from engineering software developers, project developers and wind turbine companies.

The tool has been developed following guidelines that were drafted from a theoretical basis. The project demonstrates that these guidelines are relevant and can also be helpful to other or further tool developments. Nevertheless, it was found that additional guidelines are desired to fill the gap between the abstract formulations of the theory and the practical implementation of a tool.

The full report of this project can be found here.