Optimization of Jacket Substructures Considering Detailed Cost and Load Assumptions

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Summary
State-of-the-art jacket substructures for offshore wind turbines have substantial cost reduction potential, which may be exploited by structural optimization. This work proposes an approach that incorporates geometry and cost models, surrogate modelling for structural design code checks, and a comparison of metaheuristic optimization algorithms applied to the jacket optimization problem.

1. Introduction

To facilitate the installation of offshore wind turbines with high rated power in intermediate water depths, jacket substructures are supposed to be the most promising technology in the near future. However, the market is still dominated by monopiles, which are cost-efficient in production, transport and installation and well-established in offshore industry. Therefore, the main design objective concerning the development of jackets for offshore wind turbine is a cost optimization with respect to fatigue and ultimate limit state constraints. The structural design is commonly performed by an iterative procedure based on empirical knowledge of design experts. As the required extreme and fatigue load proofs involve thousands of simulations in time domain, the final design is usually not optimal from the economical point of view.

2. Approach

To decrease the costs of jacket substructures, the problem is described as a mathematical optimization (minimization) problem with fatigue and ultimate limit state constraints that has several minima and can be solved by meta-heuristic algorithms, for instance. Consequently, this simulation-based procedure is numerically expensive. To enable a meaningful and numerically efficient solution or jacket design, respectively, the focus of this approach is on

- the incorporation of topological design variables, while dimensions of tubes are handled in a more general way,
- the consideration of more sophisticated cost assumptions,
- a detailed load assessment the utilization of surrogate models to perform structural design code checks,
- a comparison of different optimization algorithms for performance benchmarks.

These points were handled in detail in [1].

3. Results

The improved optimization approach yields manifold findings that can be used for the design of jackets. For turbines with a rated power of 5 MW, North Sea environmental conditions, and intermediate water depths, three-legged structures are most likely preferable to four-legged ones, being about 5% cheaper according to the cost model utilized in this work. Moreover, it turns out that, for the given problem, Particle Swarm Optimization is the most efficient among some considered metaheuristic optimization algorithms [2].

4. Conclusion

Structural design optimization can render substantial financial benefits to prospective offshore wind farm projects with jacket substructures. This may be a key factor to reduce levelized costs of energy.

References

[1] Häfele J, Damiani R, King R, Gebhardt CG, Rolfes R: A Systematic Approach to Offshore Wind Turbine Jacket Pre-Design and Optimization: Geometry, Cost, and Surrogate Structural Code Check Models. To be released in Wind Energy Science, 2018.
[2] Häfele J, Gebhardt CG, Rolfes R: An Optimization Approach for Latticed Offshore Wind Turbine Substructures Considering Topology, Costs, and Scattering Environmental Conditions. To be released in Structural and Multidisciplinary Optimization, 2018.