ITERATIVE OPTIMIZATION APPROACH FOR THE DESIGN OF FULL-HEIGHT LATTICE TOWERS FOR OFFSHORE WIND TURBINES

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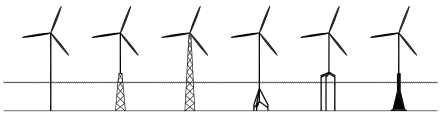
SUPPORT STRUCTURE CONCEPTS

Installations of bottom-fixed offshore wind farms in intermediate water depth are until now based on more or less the same construction idea: the support structure of the rotor nacelle assembly (RNA) is a combination of a multi-member (jacket, tripile, tripod), tubular (monopile) or gravity based substructure with a tubular tower. The latter is known from onshore wind turbines. A transition piece located at a certain level above the water surface is connecting the two structural parts.

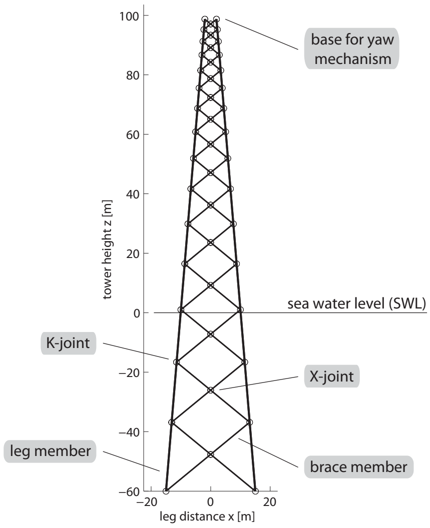


Bottom-fixed support structure concepts for intermediate water depth

A new design approach of a full-height lattice tower has been developed by the Department of Civil and Transport Engineering at NTNU, in which the traditional tubular tower is replaced by a space frame structure going all the way from seabed to RNA. The aims of this approach are a reduction in steel weight and a simplification of the installation, and thereby a reduction of total cost of the support structure, compared with known solutions.

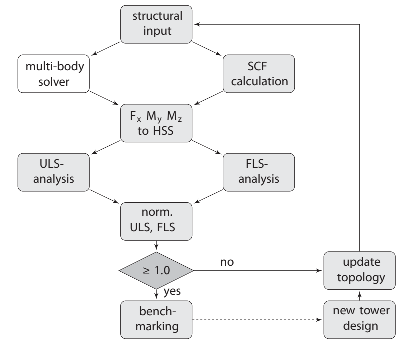
FULL-HEIGHT LATTICE TOWER DESIGN

The design of a full-height lattice tower presented here, provides directly support for the turbine nacelle, without transition to a tubular tower. The structure is characterised by leg and brace members, welded together in K- and X-joints.



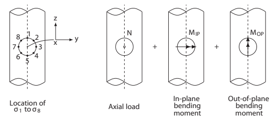
	constant dimensions	optimized design
tower height [m]	158.70	158.70
leg/brace		
diameter [m]	1.6/0.8	1.6/0.8
thickness [mm]	73/34	49..63/20..34
number of sections	15	15
tower weight [t]	3082	2283

ITERATIVE OPTIMIZATION APPROACH

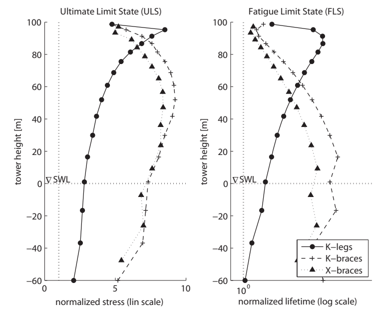


The iterative optimization approach is based on two main steps. First the analysis of a specific tower design with a multi-body solver, and second the post-processing of calculated time series of forces and moments for each member and joint. Each tower model is analysed for the ultimate limit state (ULS) and the fatigue limit state (FLS). The analysis includes the calculation of stress concentration factors (SCF) to determine hot spot stresses (HSS) in the joints of the lattice tower.

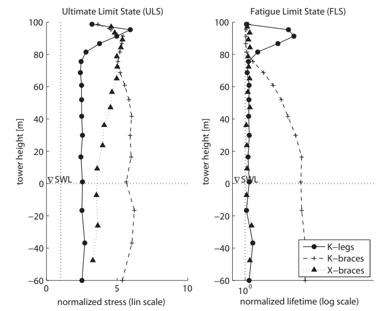
Superposition of stresses for tubular joints (DNV-RP-C203)



OPTIMIZATION RESULTS



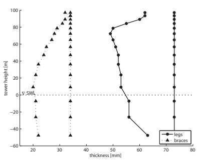
constant member dimensions over tower height



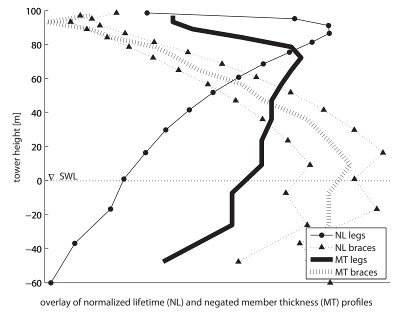
optimized member dimensions according to loads

STRUCTURAL BEHAVIOR OF OPTIMIZED DESIGN

Members were changed section-wise with constant dimension in each section. This leads to dependencies between parameters that are optimized, since legs and braces are physically connected in K-joints and the variation of one of these members results in a changed behavior for the connected member, too.



Adjusting brace dimensions leads to changes in both K- and X-joints for brace elements. This limits the possibility to optimize leg and brace members for both K- and X-joints at the same time.



comparing lifetime and thickness profiles

10MW NOWITECH REFERENCE TURBINE

A full-height lattice tower for the installation of the proposed 10MW NOWITECH reference turbine in 60m water depth was chosen as case. The rotor has a diameter of 141m and the concept is a horizontal axis three bladed offshore wind turbine.
Simulation runs with 13.5m/s turbulent wind (16% turbulence intensity) and an irregular sea state with JONSWAP spectrum (H_S=4m, T_P=9s) were performed for aligned wind and wave direction to provide initial load conditions. The model was build in FEDEM Windpower with a bottom-fixed foundation.

SUMMARY

Since several design parameters lead to significant changes in the tower topology of a full-height lattice tower and time-domain analyses are time consuming and expensive, an effective optimization approach is needed to be able to reduce the number of necessary simulation runs.
An approach was presented, where results from the analysis of a design with constant member dimensions over tower height were analysed and translated into an expectation of the member dimension profile over tower height for an optimized design.