# Reduced Order Simulation Surrogate for Wind Turbine Component Design

**Robert T. Rudolf**

Flensburg University of Applied Sciences: Wind Energy Technology Institute, Schleswig-Holstein, Germany, robert.rudolf@fh-flensburg.de

## Abstract

Small changes in the structural dynamic properties of wind turbine components can have a large influence on the ultimate and fatigue loads they experience. This is due to strong coupling between the aerodynamic (aero), control-system (servo) and structural (elastic) behaviours of the wind turbine system. Therefore attempts to design these structures using algorithm-driven numerical parameter studies are more likely to lead to feasible designs when the load calculation is integrated into the optimization problem formulation. Industry-standard aero-servo-elastic (ASE) simulation codes are, however, too computationally expensive to iterate in the constraint evaluation of a highly-dimensional design optimization problem. More efficient load simulation methods are needed to make optimization algorithms practical for the structural design of major wind turbine components.

A reduced-fidelity ultimate and fatigue load approximation method is proposed as a means to conduct sizing optimization for lightweight structures. The new method, termed ROSS for reduced order load simulation surrogate, leverages FEM substructuring operations and surrogate modelling to reduce the degrees of freedom in the load simulation. This speeds computation and reduces the dimensionality of the design space (to select terms in the condensed mass and stiffness matrices). In the first step, all design load cases are simulated for each sample point in a design of experiments (DOE) on the reduced design space. Then ultimate loads and damage equivalent fatigue loads (DEL) are calculated and a metamodel is calibrated to approximate the DEL for arbitrary mass and stiffness matrices. Finally, the constraints can be analysed for the original set of design variables by a sequence of substructuring, metamodel evaluation and static FEM analysis using the approximated ultimate loads and DEL.

The additional FEM calculations and metamodel evaluations are orders of magnitude faster than the many ASE time series simulations which they replace. This enables optimization algorithms to design lightweight (flexible) turbine structures with a highly dimensional design space exhibiting a large range of natural frequencies. Uses for ROSS extend beyond constraint evaluation for frame optimization problems; the method can also be utilized to replace the static load assumption in topology optimization schemes.

.