

Control Co-Design of Offshore Wind Turbines

Lotte de Vries

Control Co-Design of Offshore Wind Turbines

Integrating structural design and feedback control for floating platforms

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by

Lotte Marije DE VRIES

Master of Science in Aerospace Engineering, Delft University of Technology, the Netherlands

This dissertation has been approved by the (co)promotors.

Composition of the doctoral committee:

Rector Magnificus,	chairperson
Prof.dr.ir. M.T. Hoogland	Delft University of Technology, promotor
Dr.ir. A. Janssen	Delft University of Technology, copromotor

Independent Members:

Prof.dr. S. Okafor	Delft University of Technology
Prof.dr.-Ing. M. Keller	Vertex University, Germany
Dr. E. Lindgren	Nexa Wind Research, Norway
Prof.dr.ir. R. Bos	Delft University of Technology, reserve member

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Summary

Floating platforms let wind turbines be placed in deep water, but the platform moves, and its motion couples with the rotor in ways that a controller designed for a fixed tower does not anticipate. This dissertation treats the platform geometry and the feedback controller as one design problem. It formulates a co-design optimization whose variables include ballast, column spacing and controller gains, subject to fatigue and pitch-motion limits. Solving it for a 15-megawatt reference turbine yields a platform 12% lighter than the sequentially designed baseline at equal fatigue damage.

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Contents

Summary	i
Acknowledgements	ii
1 Introduction	1
2 Background	2
3 Co-Design Formulation	3
4 Results	4
5 Conclusion	5
A Load Cases	6

List of Figures

3.1	Nested co-design: the controller is re-derived for every candidate platform.	3
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List of Tables

4.1	Sequential versus co-designed platform for a 15-megawatt turbine.	4
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Chapter 1

Introduction

Most of the world's offshore wind resource lies over water too deep for fixed foundations. Floating platforms reach it, but they introduce a new difficulty: the rotor thrust that the controller regulates also pitches the platform, and a controller tuned for a fixed tower can destabilize this motion. The usual design process fixes the platform first and then designs a controller for it. This dissertation designs both together.

Chapter 2

Background

Near an operating point the coupled turbine and platform dynamics can be linearized as

$$\dot{x} = A(p) x + B(p) u + E w, \tag{2.1}$$

where x collects platform and rotor states, u the blade pitch and generator torque, w the wind and wave disturbances, and p the platform design parameters [1]. A controller that ignores the dependence of A and B on p may be optimal for one platform and poor for another.

Chapter 3

Co-Design Formulation

We minimize platform mass over the design parameters p and controller gains K jointly, subject to limits on tower-base fatigue and platform pitch under a set of stochastic load cases. For fixed p the optimal gains come from a linear quadratic regulator, which lets the outer optimization treat $K(p)$ as a function of the platform alone.

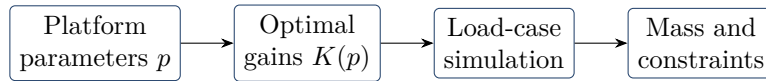


Figure 3.1: Nested co-design: the controller is re-derived for every candidate platform.

Chapter 4

Results

Table 4.1 compares the sequential and co-designed solutions for a 15-megawatt reference turbine.

Table 4.1: Sequential versus co-designed platform for a 15-megawatt turbine.

Quantity	Sequential	Co-designed
Platform mass (t)	20 900	18 400
Tower-base fatigue (normalized)	1.00	1.00
Maximum platform pitch (deg)	5.8	5.6

The co-designed platform is 12% lighter because its controller damps pitch motion that the sequential design had to resist with ballast and column spacing.

Chapter 5

Conclusion

Treating platform and controller as one design problem shifts work from steel to software. The nested formulation keeps the optimization tractable; extending it to nonlinear controllers and to farm-level wake interactions is future work.

Appendix A

Load Cases

Six load cases were used, combining mean wind speeds of 8, 12 and 18 m/s with significant wave heights of 2 and 5 m, each simulated for one hour with turbulent inflow.

Bibliography

- [1] Jason Jonkman. Definition of the floating system for phase IV of OC3. Technical Report NREL/TP-500-47535, National Renewable Energy Laboratory, 2010.