



Towards real-time optimal control of wind farms using large-eddy simulations

Nick Janssens and Johan Meyers

KU Leuven, Department of Mechanical Engineering, Celestijnenlaan 300A, B3001 Leuven, Belgium

Correspondence: Nick Janssens (nick.janssens1@kuleuven.be)

Abstract. Large-eddy simulations (LES) are commonly considered too slow to serve as a practical wind farm control model. Using coarser grid resolutions, this study examines the feasibility of LES for real-time, receding-horizon control to optimize the overall energy extraction in wind farms. By varying the receding-horizon parameters (i.e. the optimization horizon and control update time) and spatio-temporal resolution of the LES control models, we investigate the trade-off between computational speed and controller performance. The methodology is validated on the TotalControl Reference Power Plant using a fine-grid LES model as a wind farm emulator. Analysis of the resulting power gains reveals that the performance of the controllers is primarily determined by the receding-horizon parameters, whereas the grid resolution has minor impact on the overall power extraction. By leveraging these insights, we achieve near-parity between our LES-based controller and real-time computational speed, while still maintaining competitive power gains up to 40 %.

10 1 Introduction

Turbine-wake interactions can significantly impact the efficiency of energy extraction when many turbines are clustered together in large-scale wind farms. Standard control strategies do not anticipate for the wake interactions, but maximize performance at turbine level, resulting in significant power deficits and increased loading in downstream regions. In the last decade, much research has been done into dynamic receding-horizon optimal control strategies to mitigate these effects, both through axial induction control and wake redirection (see Meyers et al. (2022) for a recent review). More recently, Goit and Meyers (2015), Goit et al. (2016) and Munters and Meyers (2017, 2018b) have developed an optimal control framework for wind farm power maximization based on high-fidelity large-eddy simulations (LES) of the wind farm boundary layer. In their latest work combining overinduction and wake redirection control, Munters and Meyers (2018b) report energy gains of up to 34 % for an aligned 4×4 wind farm. Despite its accuracy, LES is usually deemed impractical for real-time applications due to its high computational cost. In that sense, the aforementioned optimal control studies were intended as benchmarking studies, aimed at exploring the potential of LES for power optimization in wind farms.

To achieve real-time optimal control, one option is to resort to models that are less computationally intensive (compared to 3D LES). For instance, in some dynamic flow models, the vertical dimension of the flow is either disregarded or approximated to cope with the computational cost of 3D wake dynamics (see e.g., Soleimanzadeh et al., 2014; Rott et al., 2017; Boersma et al., 25 2018). This results in a 2D LES-like model suitable for online wind farm control. Instead of LES, more simplified formulations

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Table of Contents Stability Time Optimal Control Of Here

1. Understanding the eBook Stability Time Optimal Control Of Here
 - The Rise of Digital Reading Stability Time Optimal Control Of Here
 - Advantages of eBooks Over Traditional Books
2. Identifying Stability Time Optimal Control Of Here
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Stability Time Optimal Control Of Here
 - User-Friendly Interface
4. Exploring eBook Recommendations from Stability Time Optimal Control Of Here
 - Personalized Recommendations
 - Stability Time Optimal Control Of Here User Reviews and Ratings
 - Stability Time Optimal Control Of Here and Bestseller Lists
5. Accessing Stability Time Optimal Control Of Here Free and Paid eBooks

- Stability Time Optimal Control Of Here Public Domain eBooks
 - Stability Time Optimal Control Of Here eBook Subscription Services
 - Stability Time Optimal Control Of Here Budget-Friendly Options
6. Navigating Stability Time Optimal Control Of Here eBook Formats
 - ePub, PDF, MOBI, and More
 - Stability Time Optimal Control Of Here Compatibility with Devices
 - Stability Time Optimal Control Of Here Enhanced eBook Features
 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Stability Time Optimal Control Of Here
 - Highlighting and Note-Taking Stability Time Optimal Control Of Here
 - Interactive Elements Stability Time Optimal Control Of Here
 8. Staying Engaged with Stability Time Optimal Control Of Here
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Stability Time Optimal Control Of Here
 9. Balancing eBooks and Physical Books Stability Time Optimal Control Of Here
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Stability Time Optimal Control Of Here
 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
 11. Cultivating a Reading Routine Stability Time Optimal Control Of Here
 - Setting Reading Goals Stability Time Optimal Control Of Here
 - Carving Out Dedicated Reading Time
 12. Sourcing Reliable Information of Stability Time Optimal Control Of Here
 - Fact-Checking eBook Content of Stability Time Optimal Control Of Here
 - Distinguishing Credible Sources
 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development

- Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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