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Reducing Turbine Mechanical Loads Using Flow Model-Based Wind Farm Controller

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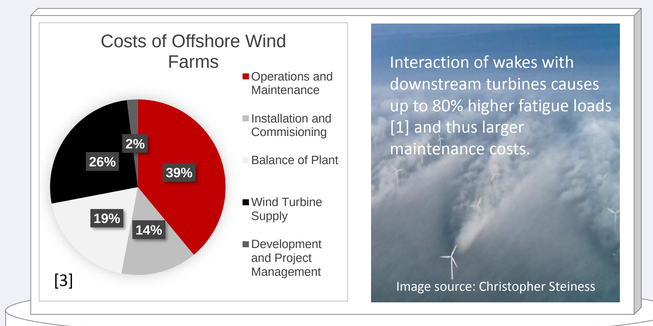
Abstract

Cumulated O&M costs of offshore wind farms are comparable with wind turbine CAPEX of such wind farm. In wind farms, wake effects can result in up to 80% higher fatigue loads at downstream wind turbines [1] and consequently larger O&M costs. The present work therefore investigates to reduce these loads during the provision of grid balancing services using optimal model-based wind farm control. Wind farm controllers coordinate the operating point of wind turbines in a wind farm in order to achieve a given objective. The investigated objective of the control in this work is to follow a total wind farm power reference while reducing the tower bending moments of the turbines in the wind farm. The wind farm controller is tested on a 8 turbine array, which is representative of a typical offshore wind farm. The operation of the wind farm is simulated using the dynamic wind farm simulation tool SimWindFarm [2]. SimWindFarm allows for the simultaneous simulation of the turbulent hub height flow field in the wind farm, the turbine dynamics and the wind farm control. The tests show a reduction of loads when compared to other optimal wind farm control approaches. Future work shall enhance the controller with more advanced turbine fatigue models in order to further improve the controller's performance.

Motivation



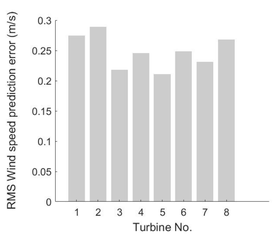
Objectives

- Compare total power reference following wind farm controllers
- Perform controller comparison using dynamic simulation tool
- Reduce turbine mechanical loading using flow model-based wind farm controller

Flow model-based optimal wind farm controller

Control approach
- Optimal turbine operation set-point is derived using model predictive control (MPC)
- Controller uses linear, dynamic, time-variant wind farm operation model
- Wind farm model is based on engineering models

Comparison of linear flow model with SimWindFarm



- Wind speed prediction error is below 3.5% of mean wind speed

DTU Wind Farm Control Framework
- DTU wind farm controller framework [4] is used for testing of different wind farm controllers
- DTU wind farm controller framework is an interface for
  - Wind farm controllers
  - Wind farm operation models
  - Online SCADA data processing procedures

Simulation Tool – SimWindFarm
- dynamic simulation of wind, turbine operation and wind farm controller
- Ambient wind field is modelled as hub height, turbulent wind flow advected with mean wind speed under assumption of Taylor's frozen turbulence

Simulated wind farm consists of
- 8 turbine row with 5D spacing
- NREL 5MW turbine model is used

Wind → 1 2 3 4 5 6 7 8

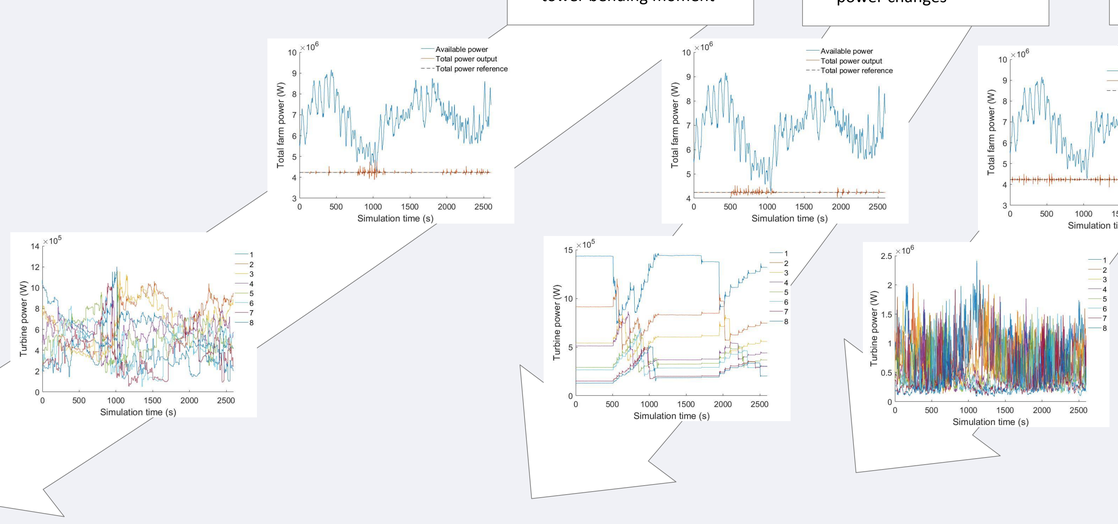
Simulated wind conditions are
- Wind direction along turbine row
- Wind speed = 8m/s
- Turbulence intensity = 8%

Methods

Flow model-based WFC – Load Optimiser
- MPC controller used with linear flow model
- Objective is reduction of tower bending moment

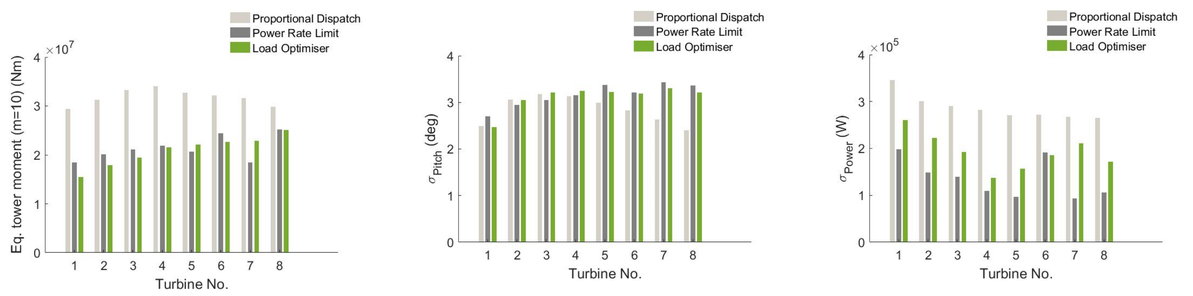
Flow model-based WFC – Power rate limiter
- MPC controller used with linear flow model
- Objective is limitation of power changes

Proportional Dispatch WFC
- Turbine set-points are proportional to turbine available power



Results

- Load optimiser reduces equivalent tower moment compared to other considered optimal wind farm control approaches
- Pitching activity is comparable between power rate limiting controller and load optimiser
- Power rate limiting controller shows lowest power activity



Conclusions

This work presents a case study of a newly developed, optimal wind farm controller. The objective of the control is to follow a power reference while reducing the loads of wind turbines in the wind farm. Simulation tests of the controller show a reduction of fatigue loading at downstream turbines when compared to other optimal wind farm control approaches. Future work shall enhance the controller with more advanced turbine fatigue models in order to further improve the controller's performance.

Acknowledgements & References

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