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Experiences with Model Predictive Control for the W2E-120/3.0fc

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Abstract

This contribution presents a Model Predictive Controller (MPC) with move-blocking strategy for combined power leveling and load alleviation in wind turbine operation. The controller is designed for a 3 MW wind turbine developed by W2E Wind to Energy GmbH and compared to a baseline controller, using classic control schemes, which currently operates the wind turbine. All simulations are carried out using a detailed multibody simulation turbine model implemented in alaska/Wind.

The performance of the controllers is compared using a 50-year Extreme Operation Gust event, since it is one of the main design drivers for the wind turbine considered in this work. The implemented MPC is able to level electrical output power and reduce mechanical loads at the same time. Without derating the achievable control results, the move-blocking strategy reduces the computational burden by more than 50 % compared to a baseline MPC and allows to run the MPC on a state of the art Programmable Logic Controller (PLC).

Objectives

- Application of Model Predictive Control algorithms on an existing wind turbine
- Maximizing power output and reduction of the mechanical loads at the same time
- Testing realtime capabilities of the algorithms on a standard PLC unit

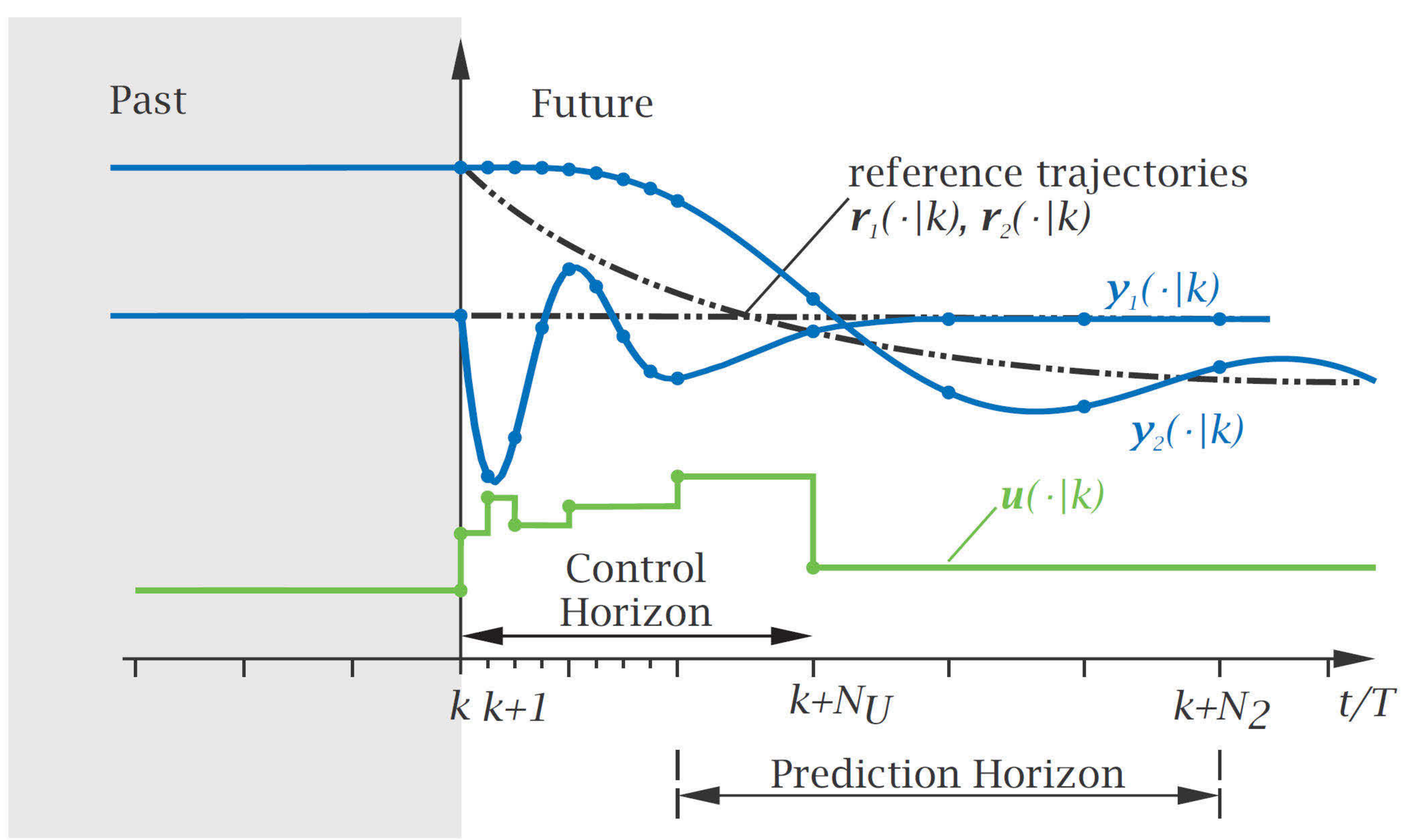
Methods

Simplified Controller Model

- A reduced-order model required for the Extended Kalman Filter and the Model Predictive Controller is introduced
- The relevant dynamics are compared to validated MBS models [1]
- The reduced-order wind turbine model includes a flexible drivetrain model and features the first tower eigenfrequency and a collective first flap-wise rotor eigenfrequency

Model Predictive Control with a Move-Blocking

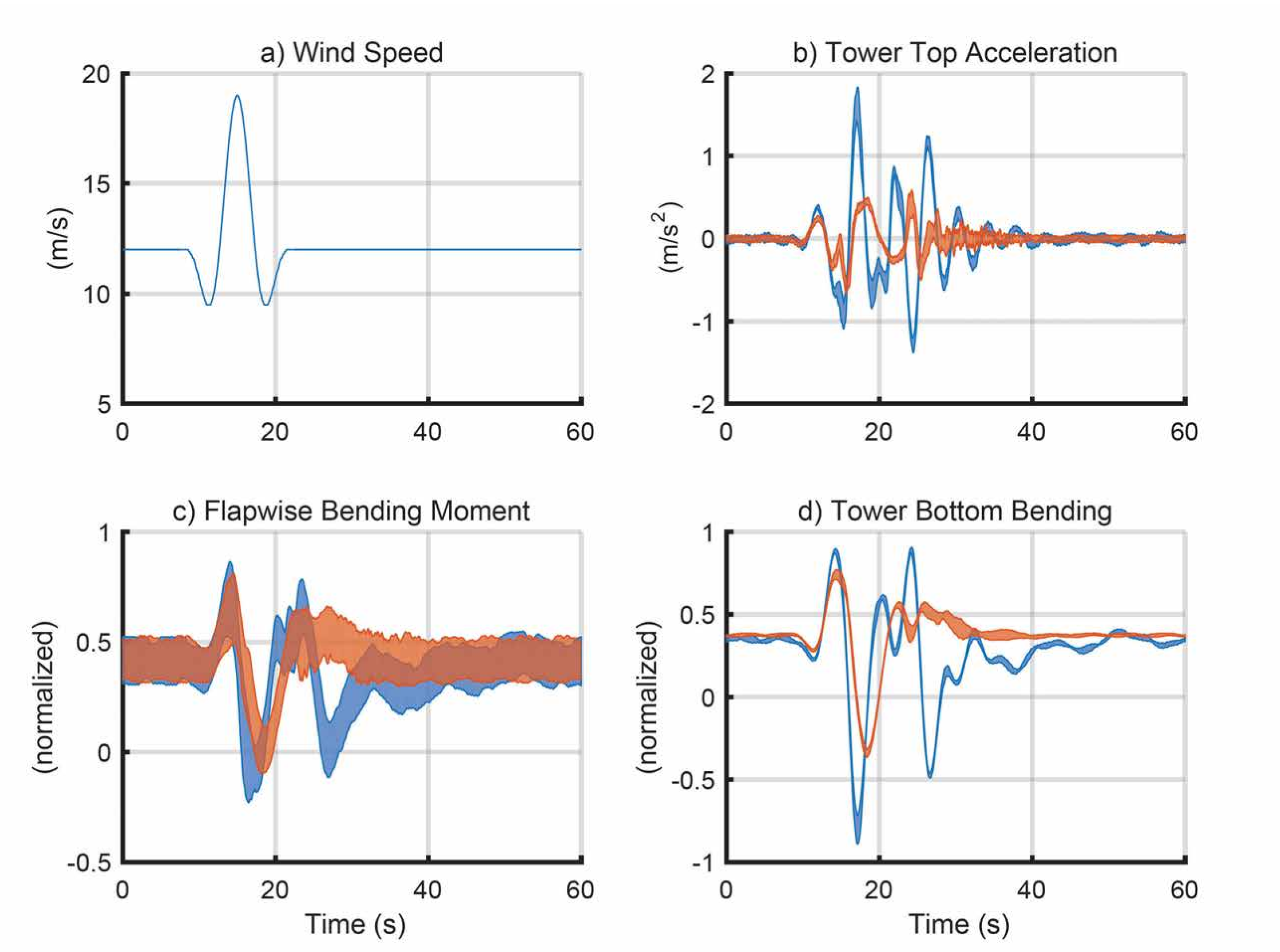
- For the linear MPC, the reduced-order model introduced described above is linearized and discretized at each time step
- Here the model is not linearized at an equilibrium point, defined by the wind speed, which is advantageous especially during extreme operation gust
- A MPC with move-blocking strategy is used in order to reduce computational burden [2]



Results

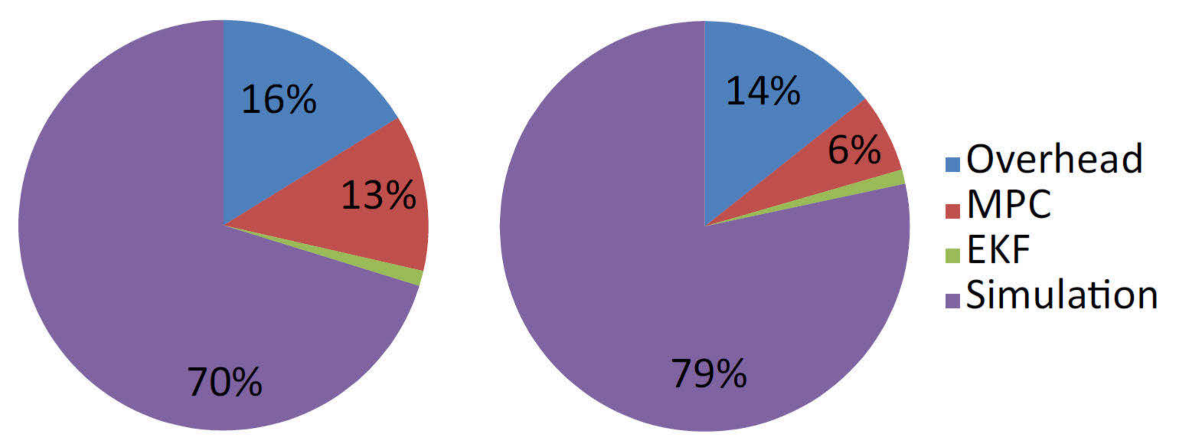
Simulation Results

- As shown below **tower top acceleration can be reduced by more than 50 %** when the MPC is used compared to the baseline controller.
- Maximum flapwise bending moment and the tower bottom bending moment are reduced by 5 % and 10 % , respectively



Computational Results

- Without derating the control results, a MPC with move-blocking strategy can **reduce the computational burden from 13% to 6% compared with a baseline MPC, so a reduction of 50 % is achieved**



Conclusions

We presented a MPC for load reduction and power leveling which in general showed good results for the EOG50 load. The blade root bending moments are reduced as much as desired. The move-blocking strategy has proved to be a suitable tool to significantly reduce computational burden caused by the MPC, while at the same time control results are not derated.

Since the whole code for the MPC, model composition and linearization is not optimized yet, the authors expect further time savings in future. Next steps will involve further code optimization in order to allow for real-time Hardware-in-the-Loop tests.

The structure of such a Hardware-in-the-Loop test rig incorporating with the general purpose multibody program alaska has been presented by [3]. Building the test rig around a general purpose MBS software allows for almost any desired expansion of the model, such as a fully represented main gearbox and nonlinear rotor blades.

References

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3. *Zierath J, Jassmann U, Dickler S, Abel D 2016 Testing Model Predictive Control Algorithms for Wind Turbine Control by Means of a Hardware-in-the-Loop Test Rig, Proceedings of the 4th IMSD, Montréal, Canada*

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