NTNU – Trondheim
Norwegian University of Science and Technology

Model predictive control of multi-rotor wind turbine

Jørgen Urdal[1], Leif E. Andersson[1] and Lars S. Imsland[1]
jorgeur@stud.ntnu.no leif.e.andersson@ntnu.no lars.imsland@ntnu.no
[1]Department of Engineering Cybernetics, Norwegian University of Science and Technology, Trondheim, Norway

Objective and motivation

- The size of wind turbines has grown considerably due to the increasing power demand with focus on renewable energy sources. Scaling up the conventional singe-rotor turbine comes with a large increase in costs. An alternative way to reduce costs is to use the multi-rotor wind turbine.
- Vestas has developed a multi-rotor wind turbine control challenge to motivate implementation of advanced control systems [1].
- The objective is to implement model predictive control (MPC) to follow a power-reference while reducing loads on the turbine structure.

Multi-rotor wind turbine

The multi-rotor wind turbine model used for this project consist of four NREL-5MW turbines on a structure similar to the picture. Giving a total of 20MW.

Pros
- Reduced weight per MW generated
- Reduced transportation and installation costs
- Increased wake recovery

Cons
- Increased structure complexity
- Increased control system complexity

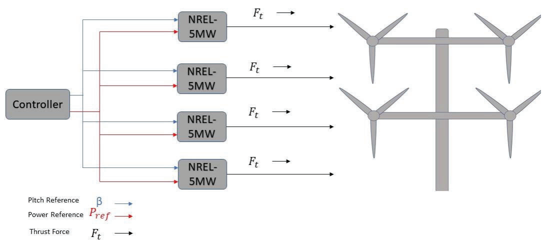

Figure 1: Overview of how the model is built up. Showing the control input signals and forces generated.

Figure 2: Vestas MRT demonstrator situated at Risø DTU in Roskilde Denmark . Image courtesy of Vestas Wind Systems A/S [2].

The mathematical model is built up by a structure model and four turbine models. With a total of 40 states and 8 control input signals
- 5 states for each turbine
- 20 states for the tower structure
- Pitch- and power-reference as input signal for each turbine

Model predictive control (MPC)

- Real time optimizing controller.
- Can handle multi-input multi-output (MIMO) systems and constraints.
- Utilizes a model of the plant to predict the output to determine the input for the next step.
- Fmincon MATLAB function used as optimizer.

$$\min_{z\in\mathbb{R}^n} f(z) = \sum_{t=0}^{N-1} q_1(P-Pref)^2 + q_2(Loads)^2$$

Objective function for the optimizer. Minimizing both the power difference from the reference and the loads on the structure.

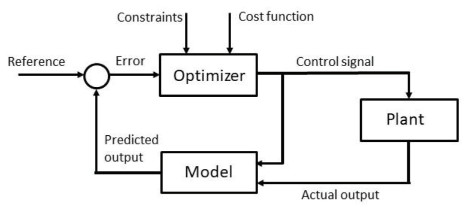

Figure 3: Overview of MPC with the plant and the model

Results

- Simulation is performed with a simple wind field with constant wind.
- Figure 4 shows the loads on the tower. The initial position of the blades gives a higher load. When the optimization starts, the loads are reduced.
- Simulations with more advanced wind fields are required to conclude that the optimization works.
- Slow run-time with Fmincon optimizer does not satisfy real-time optimizing controller.
- The upcoming master thesis will focus on improving results by:
  - Implementing CasADi to reduce run-time.
  - Simulations with more advanced wind fields.

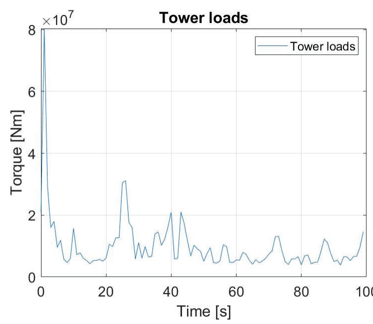

Figure 4: Plot of tower loads simulated a constant wind speed 18 m/s

Future work

- Implementation of CasADi to reduce run-time
- Implement more advanced wind fields in simulations
- Add noise to plant model to make it more realistic

References

[1] K. H. Sørensen et al. “Multi-Rotor Wind Turbine Control Challenge - A Benchmark for Advanced Control Development”. In: 2018 IEEE Conference on Control Technology and Applications (CCTA). Aug. 2018, pp. 1615–1622. doi:10.1109/CCTA. 2018.8511511
[2] https://www.facebook.com/vestas/photos/a.167902893245231/1036409796394532/?type=3&theater