Tower Damper

Prof. Dr.-Ing. David Schlipf

11.09.2024

Lecture #5
Controller Design for Wind Turbines and Wind Farms

Hochschule Flensburg
University of Applied Sciences

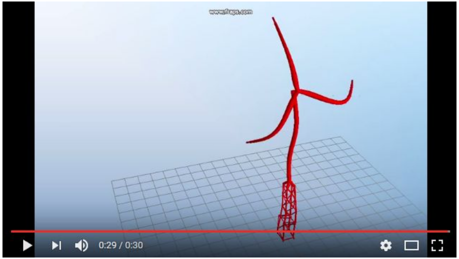
SWE Stuttgart Wind Energy
@ Institute of Aircraft Design

Wind Energy Technology Institute

Schedule

02.09.	1	Controller Design Objectives and Modeling
03.09.	2	Baseline Generator Torque Controller
04.09.	3	Collective Pitch Controller
05.09.	4	Filter Design
06.09.	7	Wind Field Generation
09.09.	10	Lidar-Assisted Control I
10.09.	11	Lidar-Assisted Control II
11.09.	5	Tower Damper
12.09.	6	Advanced Torque Controller
12.09.	8	Steady State Calculations
16.09.	9	Individual Pitch Control
17.09.	12	Wind Farm Effects
18.09.	13	Wind Farm Control
19.09.	14	Floating Wind Control I
20.09.	15	Floating Wind Control II

Filter design, tower and drive train damper



Motivation:
Wind Turbines are very flexible structures!

- modes from tower, blades, shaft...
- coupling with each other and rotation
- only rotor motion considered in baseline controller design

→ Might result in unwanted resonance!

Objectives

- How can we avoid resonance with important modes by filtering?
- How can we damp tower and drive train torsional vibrations? Tower today!

Contents

Tower vibration damping design 1/2

$$m\ddot{x}_{\mathrm{T}} + c\dot{x}_{\mathrm{T}} + kx_{\mathrm{T}} = F_{\mathrm{a}}(\Omega, \theta, v_{\mathrm{rel}}) + \Delta F_{\mathrm{a}}(\Delta\theta_{\mathrm{TD}}) \text{ with } v_{\mathrm{rel}} = v_0 - \dot{x}_{\mathrm{T}}$$

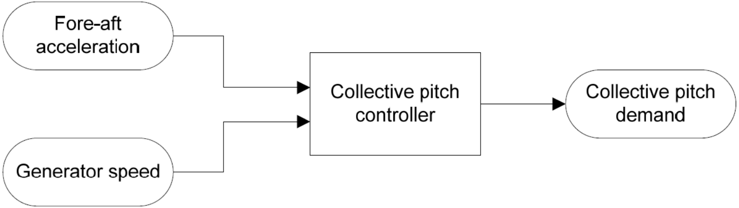
$$\text{with } \Delta F_{\mathrm{a}} = \frac{\partial F_{\mathrm{a}}}{\partial \theta}\Delta\theta_{\mathrm{TD}} = -c_{\mathrm{TD}}\,\dot{x}_{\mathrm{T}}$$

$$\rightarrow \Delta\theta_{\mathrm{TD}} = -\frac{c_{\mathrm{TD}}}{\frac{\partial F_{\mathrm{a}}}{\partial \theta}}\dot{x}_{\mathrm{T}} = g_{\mathrm{TD}}\dot{x}_{\mathrm{T}}$$

Main idea

- Tower fore-aft bending mode is very lightly damped (c small).
- Aerodynamic damping (via v_{rel}) is helpful.
- Additional damping c_{TD} can be obtained via pitch update $\Delta\theta_{\mathrm{TD}}$ [1].
- However, tower top speed $\dot{x}_{\mathrm{T}}$ not measurable, thus we need to integrate acceleration $\ddot{x}_{\mathrm{T}}$.
- Further filters are usually necessary: high pass to avoid static update, notch filter to prevent unwanted feedback from other frequencies, e.g. 3P.

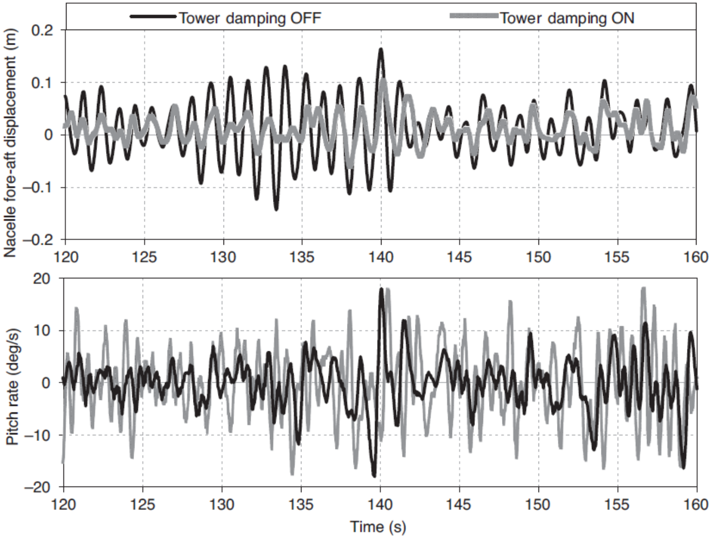
Tower vibration damping design 2/2



[2]

- Used as zero mean update.
- Can be also used in region 2. Then is ramped up with power measurement.
- Gain for tower damping g_{TD} can be found by linear analysis (see exercise).

Tower vibration damping results



[1]

Conclusion

Main questions

- How can we avoid resonance with important modes by filtering?
- How can we damp tower and drive train torsional vibrations?

With low pass and notch filters

- A low pass is usually used for filtering out noise: Trade-off filter effect vs. time delay.
- A notch filter is used for specific frequencies.

With additional SISO loops

- Tower damping is based on tower top acceleration, needs an integrator.
- Drive train damping is done with generator torque based on generator speed.
- Band pass is useful to avoid static offset and noise impact. Notch filters might be necessary.

Quick check on learning objectives

After this lectures you should be able to...

- ...design a tower damper.
- ...combine the tower damper with the baseline controller.

References

[1] T. Burton, N. Jenkins, D. Sharpe, and E. Bossanyi. *Wind Energy Handbook*. New York, USA: John Wiley & Sons, 2011.

[2] E. Bossanyi and D. Witcher. *Controller for 5 MW reference turbine*. UpWind Report 11593/BR/04. Garrad Hassan and Partners Limited, 2009.

Please let me know if you have further questions!

Prof. Dr.-Ing. David Schlipf
David.Schlipf@HS-Flensburg.de
www.hs-flensburg.de/go/WETI

Disclaimer