Technical University of Denmark

Integrated Individual Flap and Pitch Control for active load alleviation

Bergami, Leonardo; Hansen, Morten Hartvig; Tibaldi, Carlo

Publication date:
2014

Citation (APA):
Bergami, L., Hansen, M. H., & Tibaldi, C. (2014). Integrated Individual Flap and Pitch Control for active load alleviation. Poster session presented at Conference on Energy and Environment for the Future, Copenhagen, Denmark.

DTU Wind Energy
Department of Wind Energy

Track: Wind Power
Project: OffWindChina - Research and development of optimal wind turbine rotors under offshore wind conditions in China

DTU

Integrated Individual Flap and Pitch Control for active load alleviation

Leonardo Bergami (leob@dtu.dk) , Morten H. Hansen, Carlo Tibaldi

Abstract: This work present the development and application of an high-fidelity linear model of the aero-servo-elastic response of a smart rotor wind turbine with Individual Flap Control (IFC). The linear model allows for a rapid evaluation of the smart rotor response, and is here applied to design and tune the flap control system. The performance of the Individual Flap Control is then evaluated with non-linear time marching simulations; the non-linear simulations confirm the load alleviation potential of the IFC smart rotor configuration

Keywords: Smart rotor; active load control; flaps; linear aero-servo-elastic modelling

Introduction and motivation:

Both on-shore and off-shore wind turbines experience largely **fluctuating forces**, caused for instance by: atmospheric turbulence, wind shear, tower shadow effect, interaction with wakes from others turbines.

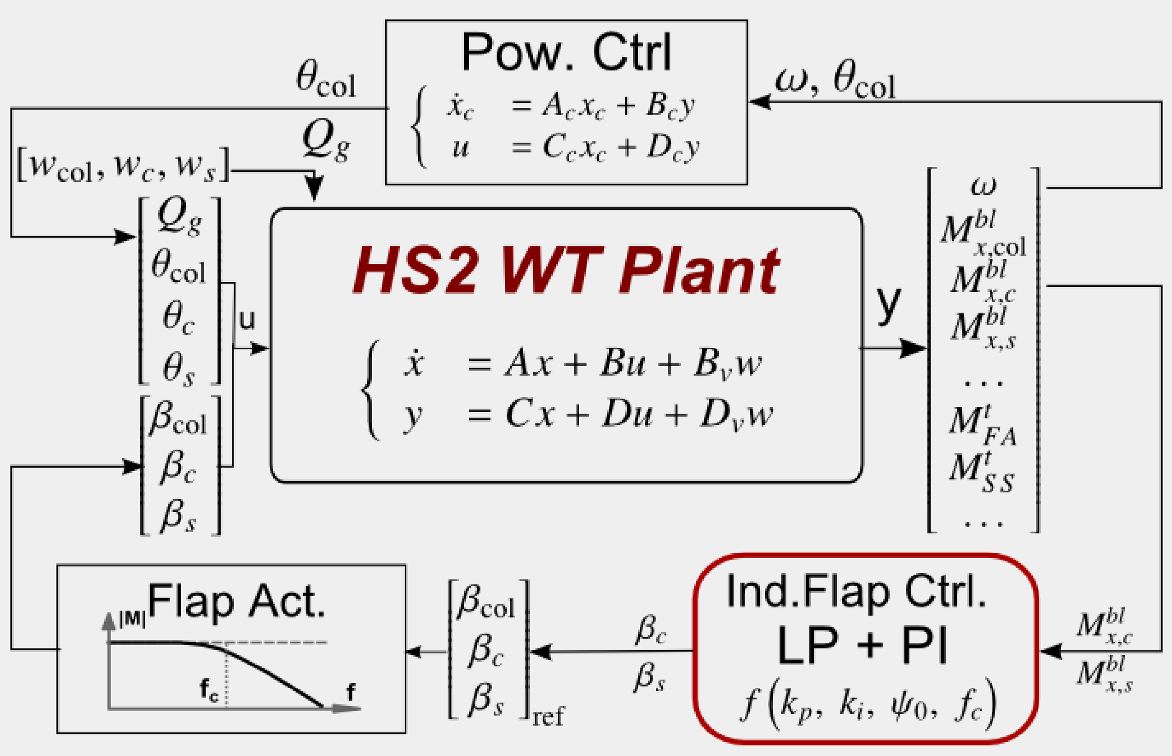
Such forces often results in **fatigue and ultimate loads** that drive the design of the wind turbine components, and hence its cost.

Smart Rotors, with a combination of sensors, control units, and actuators, are able to actively alleviate the loads the turbine experiences, thus lowering the design loads, and possibly leading to a **reduction of the Cost of Energy** [1,2,3].

Method:

1) HAWCStab2 with Flaps: high-fidelity linear modelling tool [4,5].

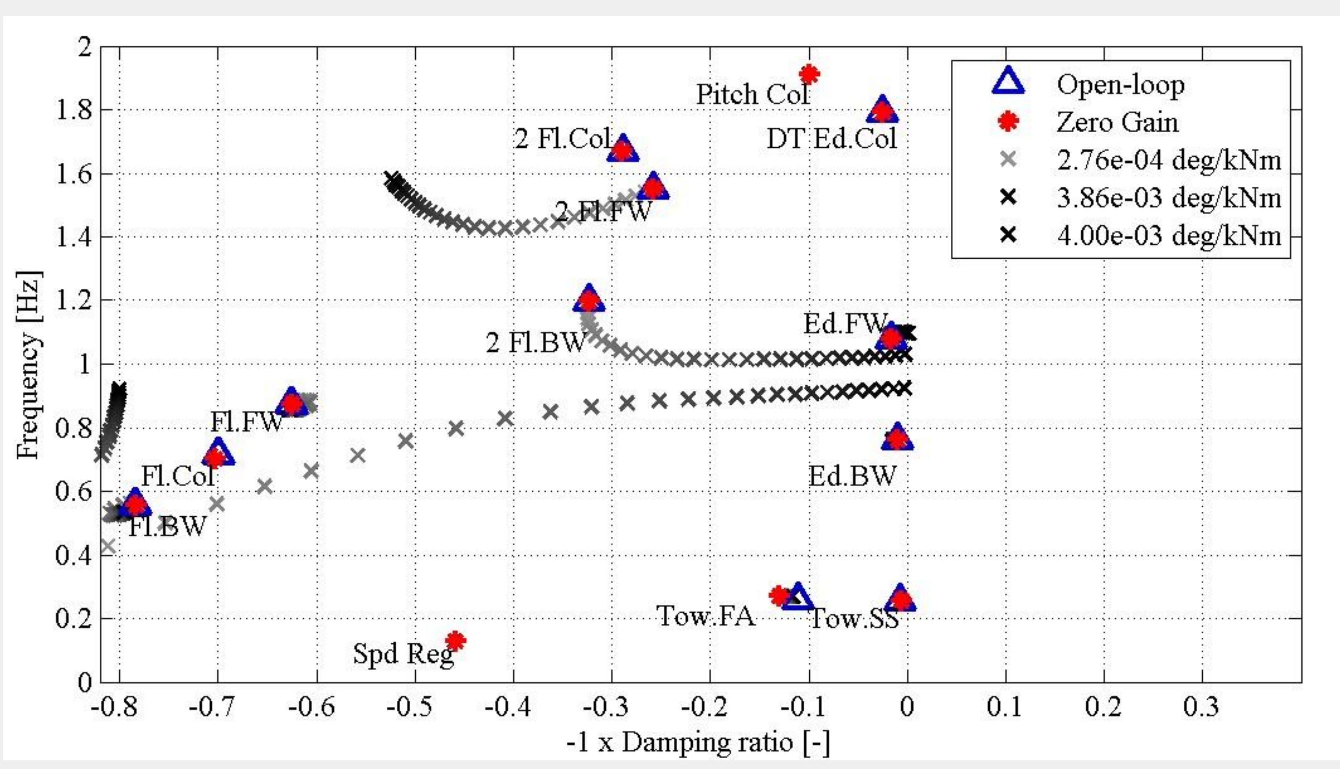
2) Linear aero-servo-elastic model of a smart rotor: Modelling: Wind turbine + Pitch and Generator power regulation + Flap Actuator.



3) Individual Flap Control (IFC): PI control on Low Pass filtered measurements of root bending moments.

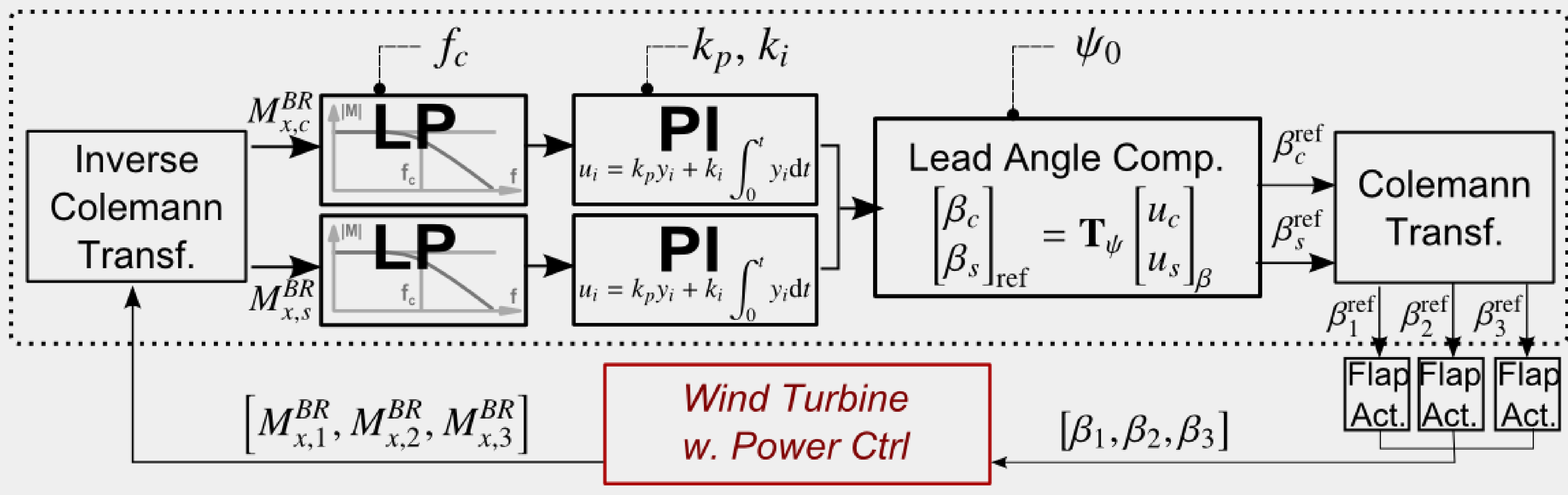
4) Closed-Loop aero-servo-elastic system: System characteristics (poles) depend on IFC tuning.

5) Ziegler-Nichols tuning of IFC control parameters:

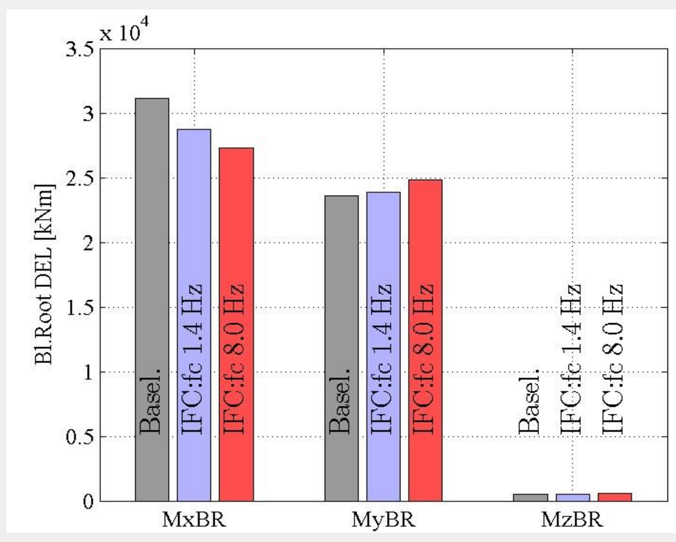


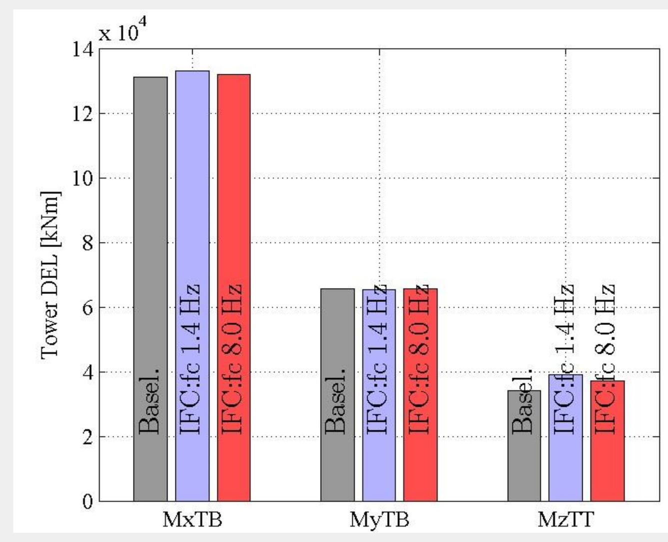
Application and results:

DTU 10 MW Reference wind turbine [6]: pitch control for power limitation, **flaps on 30 %** of the blade span, **Individual Flap Control** above rated wind speed, with two configurations: LP freq. of 1.4 Hz and 8.0 Hz.

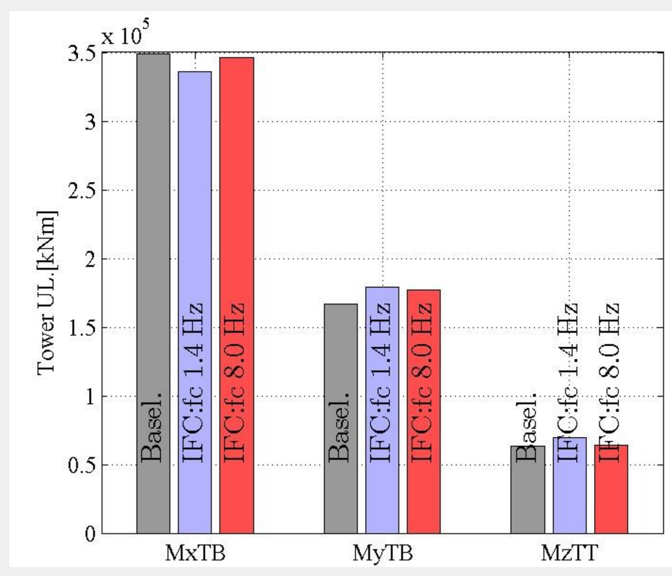


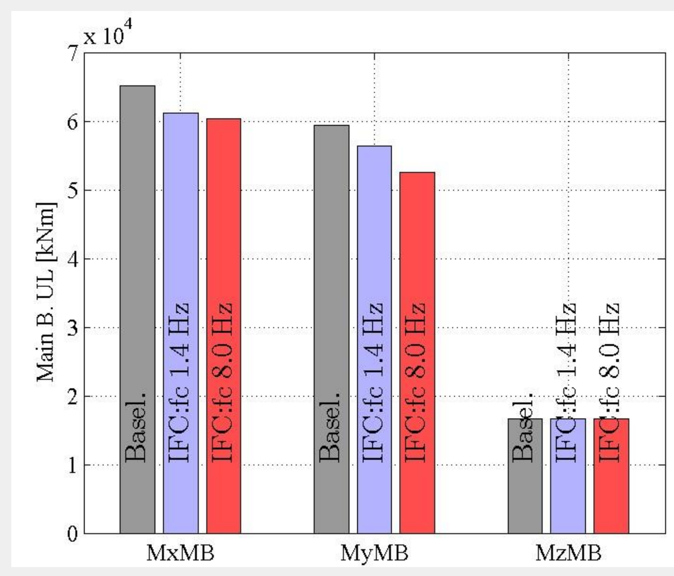
The smart rotor performance is evaluated with non-linear HAWC2 aeroelastic simulations, following the IEC standard [7] prescriptions for a class A turbine.





A reduction of **lifetime fatigue Damage Equivalent Loads** on blade root flapwise moment (ctrl. objective) is reported, together with a slight increase in blade and tower torsion DEL, and a slight decrease of the **ultimate loads** on the tower, and main bearing (extreme loads in DLC 1.x [7]).





Conclusion and future work:

- An high-fidelity linear modelling tool for smart rotor with flaps was developed. The tool can be used for rapid evaluation of the smart rotor design, as well as for design and tuning of its control system.
- An individual flap control configuration was proposed and tuned with the linear model. Non-linear time marching simulations confirmed the load alleviation potential of the smart rotor with IFC; better performances are reported for the IFC with higher corner frequency of the LP filter (8 Hz)
- To achieve an higher alleviation potential, future application of the linear tool might include: integration of individual flap and pitch control, design of model based control algorithm, integration of smart rotor configurations in concurrent design and optimization methods.

Acknowledgment: It is gratefully acknowledged that the work is partly founded by ***Innovation Found Denmark***, under the project OffWindChina – Research and development of optimal wind turbine rotors under offshore wind conditions in China

References: [1] Barlas, T. K., and G. van Kuik. “State of the Art and Prospectives of Smart Rotor Control for Wind Turbines.” *Journal of Physics: Conference Series* 75, no. 1 (2007): 012080 (20 pp.). [2] Bossanyi, E. A. “Individual Blade Pitch Control for Load Reduction.” *Wind Energy* 6, no. 2 (2003): 119–28. [3] Bergami, L. “Adaptive Trailing Edge Flaps for Active Load Alleviation in a Smart Rotor Configuration.” Ph.D. Thesis, DTU Wind Energy PhD-0020(EN), 2013. [4] HAWCStab2 Website: http://hawcstab2.vindenergi.dtu.dk/ [5] Hansen, M. H. “Aeroelastic Properties of Backward Swept Blades.” In *9th AIAA Aerospace Sciences Meeting*, Vol. 2011–260. Orlando, FL: AIAA, 2011. [6] Bak, C., F. Zahle, R. Bitsche, T. Kim, A. Yde, L. Henriksen, A. Natarajan, and M. H. Hansen. *Description of the DTU 10 MW Reference Wind Turbine*. Submitted to Wind Energy, July 2013. [7] International Electrotechnical Commission. *Standard IEC 61400-1: Wind Turbines Part 1: Design Requirements*. Rev. 3, 2005.