Control design and optimization for the DOT500 hydraulic wind turbine

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BOOK OF ABSTRACTS

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Preface

Wind Energy Science Conference 2017 (WESC-2017) is held at the Technical University of Denmark in Lyngby during June 26-29, 2017. This conference is the first of a series of bi-annual conferences launched by the European Academy of Wind Energy (EAWE). The purpose of the conference is to gather leading scientists and researchers in the field of wind energy to present their latest findings. The conference aims at covering all scientific topics in wind energy, comprising from most fundamental aspects to recent applications. It provides a world-wide forum for scientists to meet each other and exchange information of all aspects of wind energy, including aerodynamics, turbulence, wind resource assessment, wind farms and wakes, aero-serve-elasticity, loads, structural mechanics, control, operation and maintenance, generator technology, grid integration, structural design and materials, new concepts, as well as community acceptance, environmental aspects, and economics.

This volume of abstracts comprises all presentations of the conference, including two plenary lectures, and nearly 370 contributed papers, presented in either oral sessions or during 13 mini symposia. The abstracts are sorted chronologically after the day of presentation, corresponding to the way they appear in the conference programme. At the end of the book you will find a list of presenting authors, listed alphabetically, and the page number where their abstract appear.

I like to thank the scientific committee and the local organizing committee for their work with the evaluation and selection process. In particular, I thank Marianne Hjorthede Arbirk for her invaluable help in preparing the conference and this book of abstracts.

Jens N. Sørensen, chairman WESC-2017
Lyngby, June 2017

Keywords: New concepts and configurations, Turbine plant control

Control design and optimization for the DOT500 hydraulic wind turbine

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The drivetrain of most wind turbines currently being deployed commercially consists of a rotor-gearbox-generator configuration in the nacelle. This abstract introduces the control system design and optimization for a wind turbine with a hydraulic drivetrain, based on the Delft Offshore Turbine (DOT) concept[1]. This concept enables the connection of multiple turbines with only a single water pump in the nacelle to drive a centralized multi-megawatt generator at sea level: simplifying maintenance, reducing the amount of components and thus has great potential in reducing the Levelized Cost of Electricity (LCOE) of offshore wind. To evaluate the practical feasibility of the concept, field tests are performed with a full-scale retrofitted Vestas V44 600 kW wind turbine, of which the drivetrain is scaled to a 500 kW hydraulic configuration. As a substitute to generator torque control used in conventional wind turbines, an alternative torque controller is designed where fluid pressure is regulated to vary the system torque. Moreover, during the field tests, a data-driven optimization technique is employed to find the unknown fine-pitch angle for maximum rotor power extraction in the below-rated region.

The system torque is controlled by varying the nozzle area with use of a spear valve, which influences the fluid pressure. In previous work[1], a hydraulic torque controller is developed, where on a laboratory test set-up it is shown that a passive torque control scheme enables the rotor to operate near maximum aerodynamic efficiency in the below-rated region. However, due to complexification of the drivetrain in the early prototype stage of the full-scale wind turbine, the passive control implementation is not yet feasible. For this reason, a grid search is performed during an indoor measurement campaign where the rotor is substituted by a 500 kW electric motor, to obtain steady-state characteristics of the hydraulic drivetrain. Fig. 1 shows the intersection between the experimentally found system torque and the $C_{p,max}$ rotor torque plane, as function of rotor speed and spear valve position. The intersection is used to construct a feedforward controller for maintaining the optimal rotor power coefficient in the below-rated region. In-field evaluation results are presented in Fig. 2, and show that the torque controller, subjected to fluctuating rotor speeds, is able to maintain the optimal tip-speed ratio (TSR) of 7.43.

As exact information on blade geometry and thus aerodynamic rotor characteristics is unavailable for the Vestas turbine, the fine-pitch angle for tracking $C_{p,max}$ is assumed to be 0 deg during the control design phase. During field tests, the data-driven optimization algorithm Extremum Seeking Control (ESC) is employed to optimize the fine-pitch angle[2], with the objective to maximize rotor power capture. Results in Fig. 3 show that the ESC implementation converges towards an optimal fine-pitch angle of -2 deg.

Future work will focus on system design and control design for a complete wind farm driven by hydraulic turbines. Moreover, in later prototype stages, the passive torque control strategy[1] will be evaluated, and online data-driven optimization techniques will be applied to actual full-scale offshore hydraulic wind turbines.

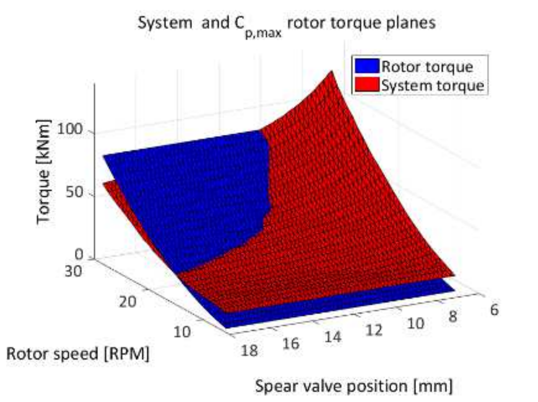

Fig. 1: Rotor and system torque intersection, used for construction of the torque controller

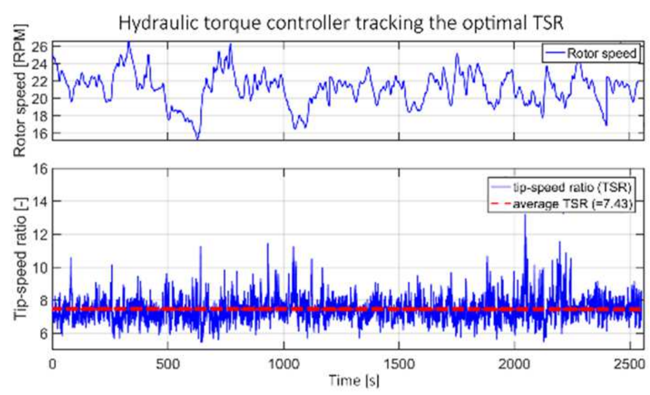

Fig. 2: Rotor speed and TSR obtained during field-tests with the hydraulic torque controller. The optimum TSR is tracked.

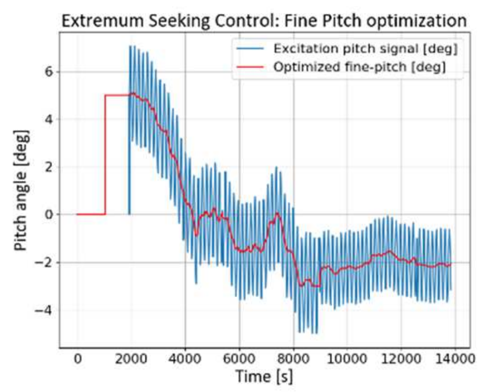

Fig. 3: ESC applied to fine-pitch converges to the optimal angle for $C_{p,max}$ tracking.

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[1] Diepeveen, Delft University of Technology, Delft, Ph. D. Thesis (2013).

[2] Y. Xiao et al., AIAA 34th Wind Energy Symposium, 1737 (2016).