Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 137 (2017) 26–37

Energy Procedia

www.elsevier.com/locate/procedia

14th Deep Sea Offshore Wind R&D Conference, EERA DeepWind'2017, 18-20 January 2017, Trondheim, Norway

Can a Wind Turbine Learn to Operate Itself? Evaluation of the potential of a heuristic, data-driven self-optimizing control system for a 5MW offshore wind turbine

Stefan Gueorguiev Iordanov[a], Maurizio Collu[a,*], Yi Cao[a]

[a]*Cranfield University, Cranfield, Bedfordshire MK43 0AL, United Kingdom*

Abstract

Larger and more expensive offshore wind turbines, subject to more complex loads, operating in larger wind farms, could substantially benefit from more advanced control strategies. Nonetheless, the wind industry is reluctant to adopt such advanced, more efficient solutions, since this is perceived linked to a lower reliability. Here, a relatively simple self-optimizing control strategy, capable to "learn" (data-driven) which is the optimum control strategy depending on the objective defined, is presented. It is proved that it "re-discovers", model-free, the optimum strategy adopted by commercial wind turbine in region 2. This methodology has the potential to achieve advanced control performance without compromising its simplicity and reliability.

Peer-review under responsibility of SINTEF Energi AS.

Keywords: wind turbines; advanced control systems; data-driven; self-optimising control

1. Introduction

Due to the high costs of offshore wind turbines, their reliability is a key parameter, driving the cost of the energy delivered to the grid. Consequently, the wind industry is, in general, reluctant to adopt more advanced control strategies, and relies on simpler control structures: it is difficult to develop a control algorithm delivering both efficiency and reliability, since in general the two aspects involve conflicting objectives [1].

* Corresponding author. Tel.: +44 (0)1234 75 4779
E-mail address: maurizio.collu@cranfield.ac.uk

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of SINTEF Energi AS.
10.1016/j.egypro.2017.10.332

On the other hand, larger and more expensive wind turbines (WT), subject to more complex aero-hydro-servo-elastic dynamics, operating in larger wind farms (more complex turbine-to-turbine interactions), could substantially benefit from more advanced control strategies [1]. Another important aspect is that modern WTs, through their monitoring systems, have already access to a large amount of sensor signals – but the large majority is not used for controlling the wind turbine, only to monitor the operational status for maintenance purposes. This is because the simpler control strategies adopted cannot handle a large number of sensor signals without compromising their simplicity and/or reliability, missing an opportunity to improve the wind turbine performance.

The ideal control system would be able to consider a large number of measurements, to optimally control the wind turbine, without escalating its complexity and therefore compromising its reliability, to be ease of use, and having low maintenance costs. This is the aim of the data-driven self-optimizing control strategy proposed.

1.1. Brief overview of advanced control systems for wind turbines

Some advanced control approaches, used to maximize the power output between the cut-in and the rated wind speed (region 2), rely on the wind speed as input. Johnson [2] proposes an adaptive controller which uses a simple gain adaptation law, designed to track the optimal gain. However, using wind speed as a direct input is technically challenging, e.g. it is difficult to obtain a representative wind speed measurement, and the performance of the control system is closely related to the quality of the sensor signal [3]. Thus, various approaches representing the wind speed not as a sensor signal but as a disturbance have been developed, as the Takagi–Sugeno–Kang model [5], where an adaptive fuzzy controller is proposed, which can continuously optimize its internal parameters to achieve optimal operation. Iyasere [6] presents a nonlinear controller, with blade pitch and tip speed ratio regulation optimized to track the maximum power coefficient operating point. Despite all the advantages, they are seldom used in industry, as they are perceived as too complex and costly to implement and to maintain. A comprehensive review of advanced control systems for wind turbines is presented in [1].

Nomenclature

AHSE	Aero-Hydro-Servo-Elastic (coupled model of dynamics)
WT	Wind Turbine
C_P	Coefficient of Power
CV	Controlled Variable
NREL	National Renewable Energy Laboratory (USA)
gSOC	generalised Self-Optimising Control
TSR	Tip Speed Ratio
NCO	Necessary Conditions for Optimality
P	Power (generator)

2. Generalised Self-Optimising Control: theory and application to wind turbines

Self-optimizing control (SOC) consists of defining functions of the process variables such that, when held constant, optimal operation is achieved, despite varying disturbances [4]. These controlled variables (CVs) are selected such that the system operates minimizing the loss of optimality with respect to a given cost function, generally related to the system economic performance [7]. By considering the effect of the transient response to the disturbance on the cost (objective) function negligible [5], the objective function J depends on the value of the manipulated variables (u), measurements (y), and disturbances (d) as in Eq. (1).