Lehrstuhl Steuerung,
Regelung und Systemdynamik

Master Thesis

Theory and programming

Advanced control of large-scale onshore wind turbines for load mitigation and power optimization

Conditions:

Duration:	6 Months
Requirements:	Strong ability in MATLAB programming Strong knowledge in Control Theory
Language:	English
Target groups:	Master students

Content:

To meet the growing demand for renewable energy, wind energy generation has been increasing rapidly in recent years. This has led to continued growth in the physical dimensions and power rating of Wind Turbines (WTs). With increasing size, WTs are becoming heavier and flexible, leading to increased inertial, gyroscopic, and gravitational loading of its components during operation. Although offshore WT installations are projected to grow in the coming years, the number of onshore wind turbines will still take up a larger share of new wind turbine installations due to its comparatively lower Levelized Cost of Energy (LCOE) [1]. Spatial and temporal variation in wind, which is treated as disturbance to a wind turbine system is responsible for undesirable fatigue loading of WT components as well as variation in generated power. Figure 2 shows a generic power curve of a variable speed WT. In region I no power is generated by the WT as the aerodynamic power is not sufficient to overcome frictional losses. In region II the generator torque is controlled for maximum power capture from the incoming wind speed. In region III, blade pitch angles are controlled to regulate the rotor speed and generated power to avoid exceeding mechanical and electrical limits. In region IV, the WT is shut down for safety reasons.

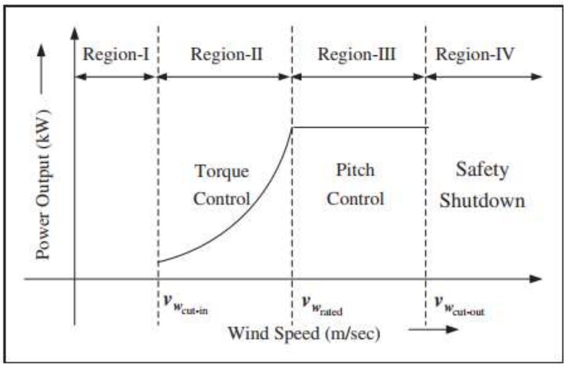

Figure 1 Operating regions of a variable speed wind turbine [2].

Modern WTs are instrumented with several sensors and actuators. This enables implementation of several objectives including, load mitigation, power optimization, and structural health monitoring. Classical PID controllers are becoming increasingly less effective in meeting the requirements of

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these Multi-Input Multi-Output (MIMO) systems. Therefore, advanced control strategies are required to meet the several control objectives.

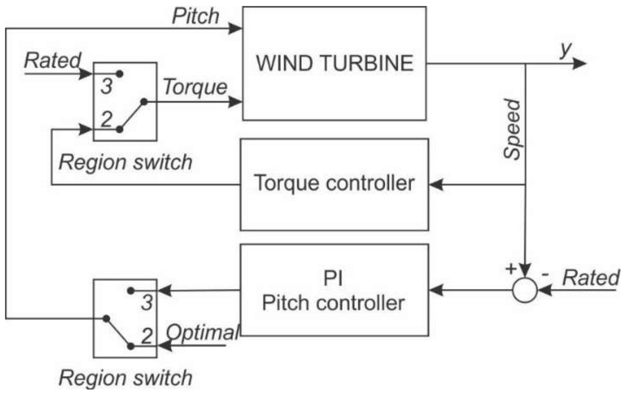

Figure 2 Baseline wind turbine control.

Along with evolution in wind turbines, state-of-the art Reference Wind Turbines (RWTs) reflecting the current and future trends in wind energy have been developed to study new technologies and advance the next generation of wind turbines [3]. These RWTs have been widely used for testing modern control techniques.

The goal of this thesis is to design and implement a Disturbance Accommodating Controller (DAC) for controlling the NREL 5 MW onshore RWT [4] to mitigate tower and rotor blade loads and regulate speed in the high wind speed regime. A gain-scheduled PI controller is to be designed as a baseline controller for evaluating the performance improvement of the developed control strategy.

The detailed goals of the thesis are as follows:

- Develop a classical gain-scheduled PI controller to serve as a baseline controller for speed regulation in region III.
- Design DAC controller to meet objectives of load mitigation and speed regulation in region III.
- Evaluate the performance of the DAC controller against the baseline controller.

The steps related to this work can be summarized as:

1) Design a gain-scheduled PI controller for speed regulation in region III.
2) Implement the PI controller in MATLAB/Simulink.
3) Simulate the RWT with the PI controller in the loop using both step and stochastic wind profiles generated from TurbSim turbulent wind simulation software.
4) Generate an appropriate linearized (reduced order) state-space model of the nonlinear (full order) model of the 5 MW RWT.
5) Design a DAC controller based on the obtained linear time-invariant model.
6) Implement the closed loop system in MATLAB/Simulink.
7) Simulate the closed loop system under step and stochastic wind conditions.
8) Compare the results obtained using the two controllers and draw conclusions.
9) Complete a detailed documentation and present the research results.

In case good results are generated, the candidate will be invited to be a co-author of a publication to be submitted to a reputable conference/journal.

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[1] J. Lee and F. Zhao, “Global Wind Report 2021,” 2021.
[2] N. Singh, B. Pratap, and A. Swarup, “Robust control design of variable speed wind turbine using quantitative feedback theory,” *J. Power Energy*, vol. 232, no. 6, pp. 691–705, 2018.
[3] J. Rinker, E. Gaertner, F. Zahle, N. Abbas, H. Bredmose, and G. Barter, “Comparison of loads from HAWC2 and OpenFAST for the IEA Wind 15 MW Reference Wind Turbine,” in *J. Phys.: Conf. Ser. 1618 052052*, 2020.
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