Shutdown Controller Design for a 13 MW Segmented Ultralight Morphing Rotor Wind Turbine

Sepideh Kianbakht* and Kathryn Johnson**

* Sepideh Kianbakht is a Graduate Research Assistant at Colorado School of Mines, Department of Electrical Engineering Golden, CO 80401 USA, Email: skianbak@mines.edu

**Kathryn Johnson is Associate Professor at Colorado School of Mines, Department of Electrical Engineering, and Joint Appointee at NREL, Golden, CO 80401 USA, Email: kjohnson@mines.edu

Abstract

Wind turbine reliability and safety play important roles in the levelized cost of energy (LCOE) from wind [1]. The goal of this research is to design an overspeed and high load shutdown controller that seeks to prevent damage to the wind turbine. The turbine is a 13.2 MW, downwind, 2-bladed turbine with a Segmented Ultra-light Morphing Rotor (SUMR).

Keywords: *safety, shutdown, overspeed, ultimate load, blade bending moment*

Introduction

The main goal of a wind turbine control system is to ensure highly efficient conversion of wind energy to electrical energy while at the same time keeping the wind turbine safe, especially by limiting turbine loads. As turbines become larger and more complicated, load reduction becomes more complicated as well [2]. Transient loads that occur during start up and shutdown depend on machine and control system characteristic [3], but shutdown procedures especially can result in high loads that must be prevented from exceeding ultimate design limits. It is important to shut down the turbine only when necessary in order to prevent reductions in annual energy production, which requires a robust mechanism to determine when to trigger a shut down. In this research, an initial overspeed shutdown controller is developed for a 13-MW SUMR turbine designed by a team of researchers with expertise in turbine aerodynamics, structural dynamics, control systems, and turbine design and testing. This controller is implemented in NREL's FAST software [4] and compared to the baseline default controller, which was originally designed for a much smaller scale, 5 MW turbine.

Methods

The SUMR wind turbine must meet the requirements given in the IEC 61400-1 [5] and GL [6] standards. According to the GL and IEC the control system should be able to shut down the wind turbine if the rotor speed exceeds its design operating range, among other conditions. The shutdown controller presented in this research measures the rotor speed and blade bending moment and automatically triggers a shut down when a pre-set overspeed or blade bending moment value is reached. As part of the performance test, blade bending moments are measured during the shutdown and compared to the default shutdown case simulated using the ServoDyn routine in FAST that pitches the blades to pitch to 90 deg at a pre-set time. The new shutdown controller measures the rotor speed and blade bending moment in Matlab's ® Simulink® platform and then commands the pitch to 90 deg from the Simulink environment, creating a foundation for more sophisticated shut down control research.

Two limits has been define for over speed When the first (lower) overspeed limit "OL1" is reached, the blades pitch collectively to 90 degrees at a rate of 4 deg/s and if over speed reached limit2 it would pitch with faster rate and remain at 90 degree for the rest of the simulation. Details of the shutdown controller will be provided in the presentation but are omitted here for space considerations.

Simulation and Result

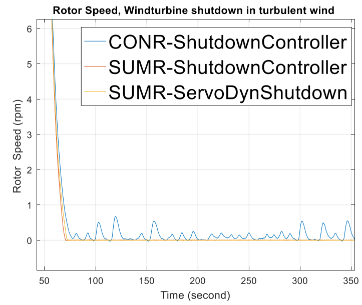

Figure 1.Rotor speed comparison before and after shutdown

Figure (1) shows the rotor speed versus time for three cases: the SUMR turbine using both the baseline Servo-Dyn based shutdown strategy and the Simulink-based overspeed shutdown case for both the SUMR turbine and a conventional 3-bladed, upwind 13 MW rotor (CONR) designed by our team.
As shown in Figure 2, the Simulink-implemented collective pitch shutdown controller 'SUMR-Shutdown Controller'results in smaller (absolute value) peak blade bending moments compared to ServoDyn shutdown for both blades 1 and 2 during the *shutdown* procedure (50 s), with more significant reductions for bending ab out the y axis.

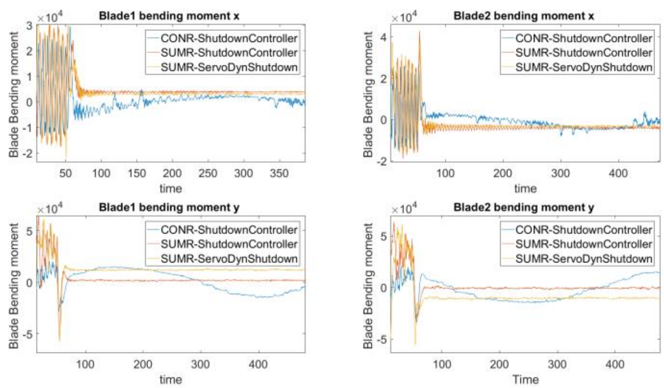

Figure 2. Blade bending moments before and after shutdown

Conclusion

A shutdown controller that causes the turbine to stop by pitching the blades to 90 deg based on a check for overspeed and high blade root bending moments has been implemented in Simulink for SUMR. This shutdown controller results in lower maximum absolute blade root bending moments compared to the FAST-based ServoDyn routine in the cases presented and provides a foundation for additional shutdown conditions and procedures.

References

1. Blanco, María Isabel. "The economics of wind energy." Renewable and Sustainable Energy Reviews 13.6 (2009): 1372-1382.
2. Pedersen, Andreas Søndergaard, and Christian Sigge Steiniche. "Safe operation and emergency shutdown of wind turbines." Aalborg University(2012).
3. Ragheb, M "Dynamics and structural loading in wind turbines". http://mragheb.com/NPRE%20475%20Wind%20Power%20Systems/Dynamics%20and%20Structural%20Loading%20in%20Wind%20Turbines.pdf:12/30/2008
4. Jonkman, Jason Mark, and Marshall L. Buhl Jr. FAST User's Guide-Updated August 2005. No. NREL/TP-500-38230. National Renewable Energy Laboratory (NREL), Golden, CO., 2005.
5. International Electrotechnical Commission. "IEC 61400-1: Wind turbines part 1: Design requirements." International Electrotechnical Commission (2005).
6. WindEnergie, Germanischer Lloyd. "Guideline for the Certification of Offshore Wind Turbines." Germanischer Lloyd Rules and Guidelines, IV—Industrial Services, Part (2005).