On-Line Optimization of Wind Turbine Control Using Reinforcement Learning

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Motivation and Summary

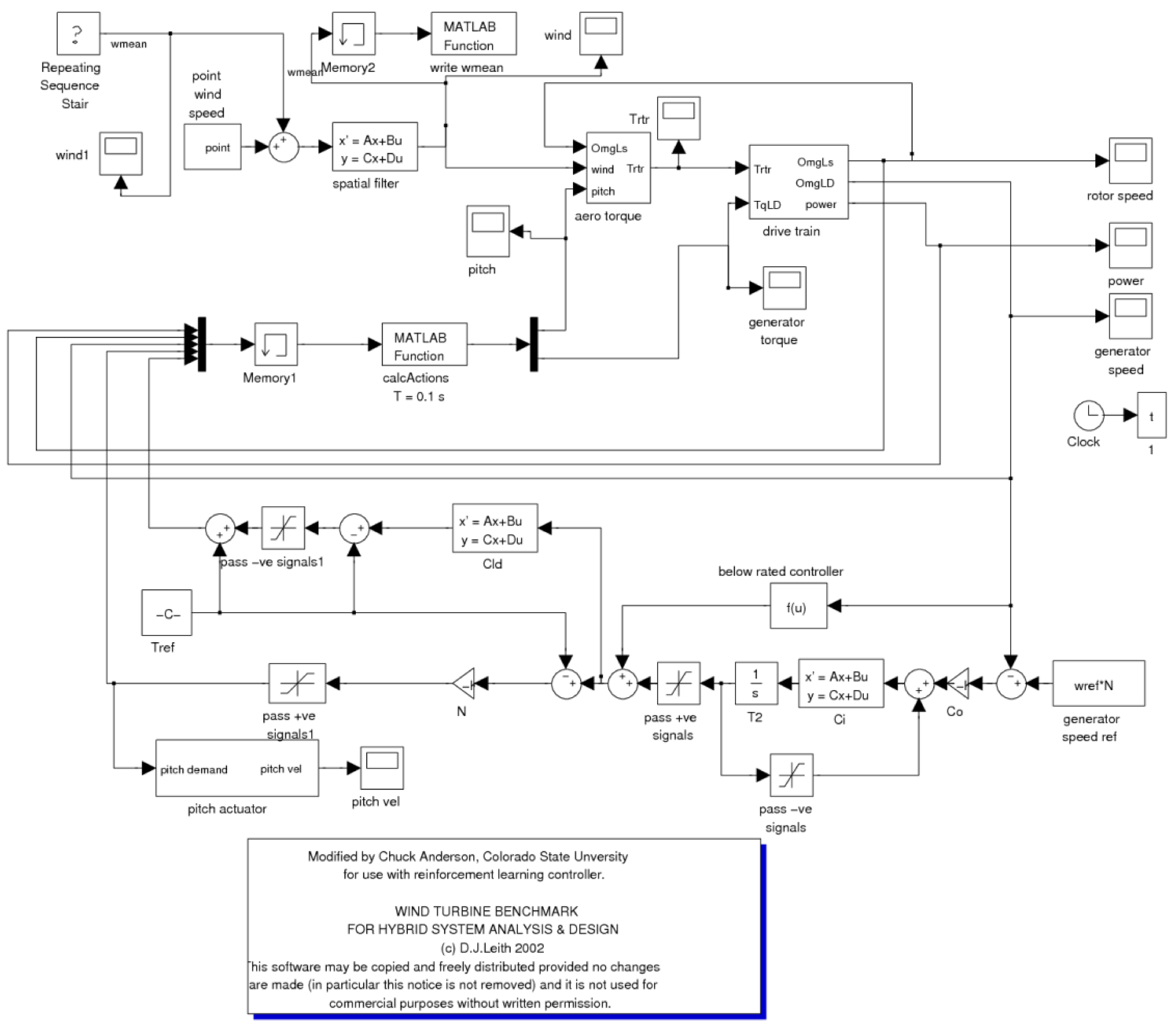
The control of wind turbines is complicated by

- variations in wind and by the complex dynamics of mechanical and electrical components of turbines,
- inaccuracies in models of the interaction of a wind turbine's blades with the air and of mechanical and electrical dynamics of the turbine lead to controllers that sacrifice efficiency and lack robustness.

Our approach to improving the performance of wind turbine control is to combine existing controllers with a reinforcement learning agent that updates the control policy with every sample of the state of the wind turbine and its environment. Results are described here of an experiment with a simulated wind turbine controlled by a nominal controller plus a reinforcement learning agent. Obtained power is increased by about 6%.

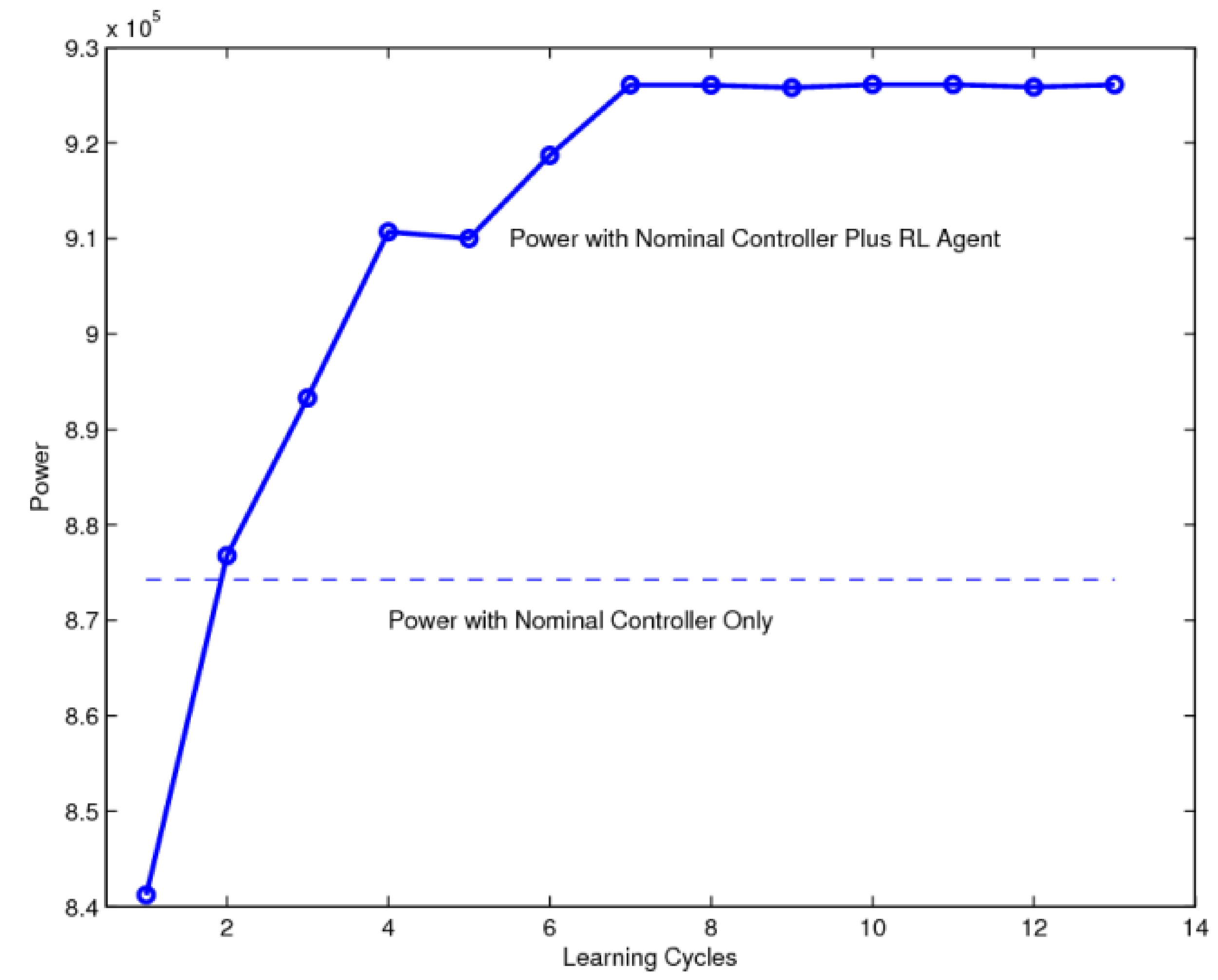
Simulation of Wind Turbine

The following Matlab Simulink simulation and nominal controller were provided by D. Leith [2, 1] at the University of Ireland, Maynooth. The top part of the diagram contains models of wind and of the wind turbine. In the middle of the diagram are reinforcement learning (RL) agent components. The bottom part of the diagram shows the nominal, fixed feedback controller.



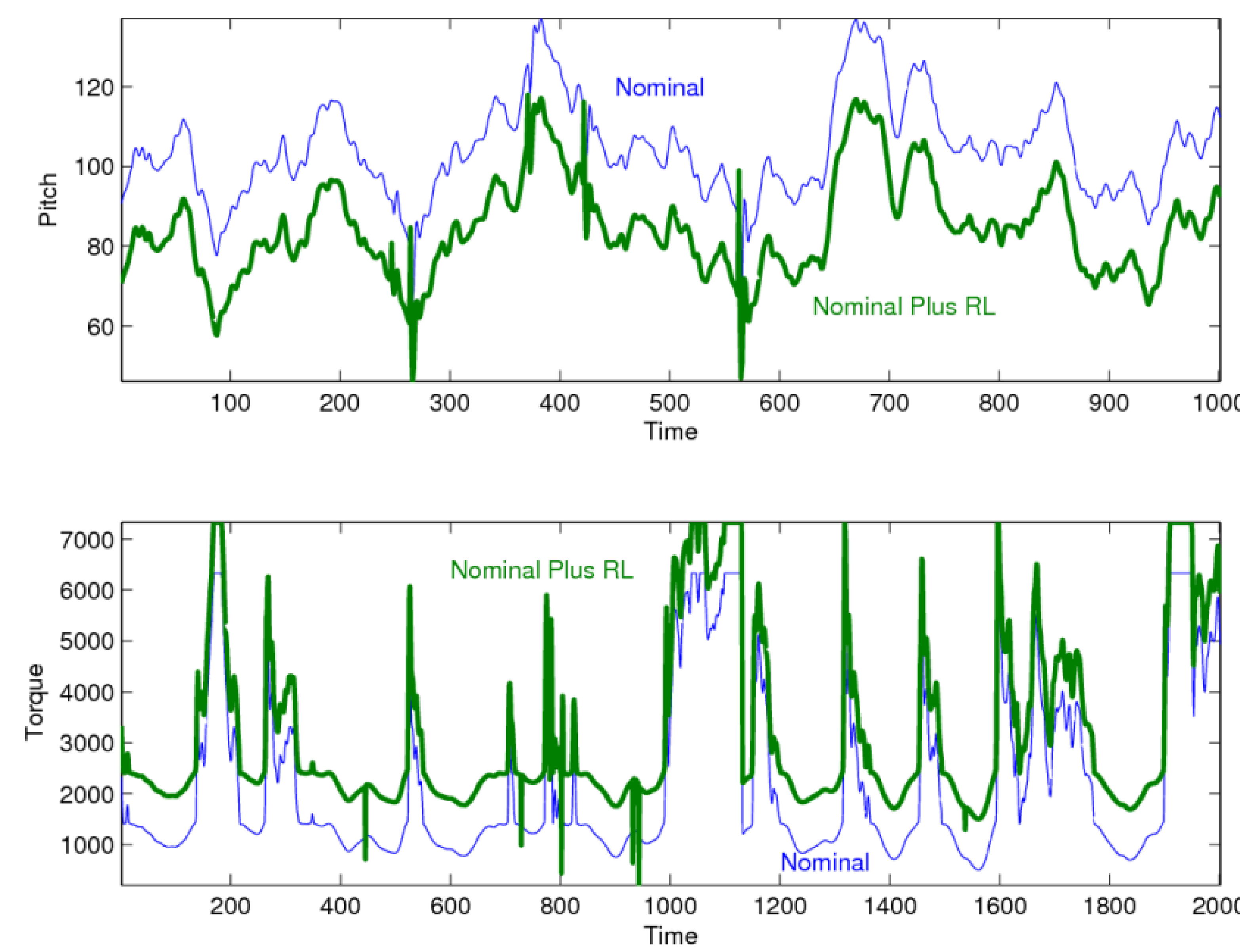
Results

The Simulink model was simulated while the mean wind speed was varied. Initially, the reinforcement learning (RL) agent selected mostly random perturbations to the controller output while it learned. The amount of randomness was slowly decreased as the RL agent converged on a policy. The power produced during these stages of learning are shown below.



The dotted line shows the power generated by the nominal controller. When the output of the reinforcement learning agent is added to the output of the nominal controller, the power shown in the solid line is produced. After two stages of learning, the hybrid nominal plus RL agent controller generates more power than the nominal system.

Control of the simulated wind turbine is accomplished by two control variables—blade pitch and generator torque. After the RL agent has converged, the difference between the nominal controller output and the combined nominal and RL output shows the effect the RL agent has. The pitch and torque control inputs to the turbine are illustrated in the following graph.



The bold lines show the combined output of the nominal and RL control, while the thin lines show the contribution of just the nominal controller. The RL agent decreases the pitch angle for most of the samples shown, though at moments it increases the angle beyond that produced by the nominal controller. The RL agent mostly increases the torque, more so at low torque levels.

References and Acknowledgments

[1] W. E. Leithead and B. Connor.
Control of variable speed wind turbines: Design task.
International Journal of Control, 73(13):1189–1212, 2000.

[2] W. E. Leithead and B. Connor.
Control of variable speed wind turbines: Dynamic models.
International Journal of Control, 73(13):1173–1188, 2000.

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For more information, see `http://www.cs.colostate.edu/~anderson`.