Fuzzy Model Predictive Pitch Control of Flexible Wind Turbine Blade

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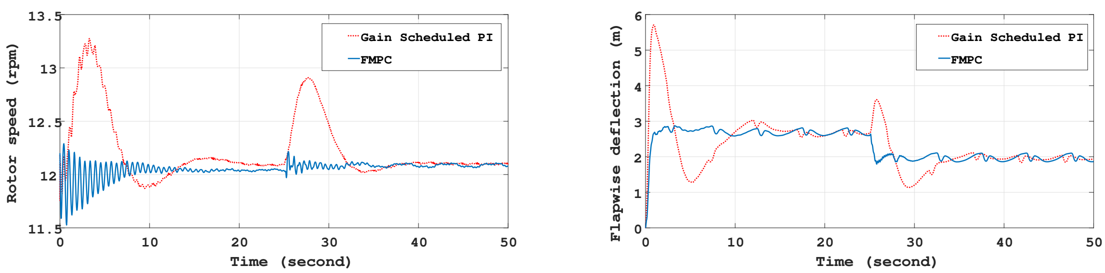
Abstract. This work presents fuzzy model predictive pitch control (FMPC) of 5-MW NREL (National Renewable Energy Laboratory) wind turbine in region 3. The controller regulates the performance of the wind turbine and minimizes the flapwise deflections and moments on the blades by maintaining the turbine rated rotor speed through blade active pitch control. The turbine nonlinear model is represented as a parameter varying Takagi-Sugeno (T-S) model with time-varying constraints. The (T-S) prediction model takes into account the flapwise bending mode of the blades. The control algorithm is investigated and compared to the baseline Gain-Scheduled Proportional Integral (GSPI) controller under the steady wind, turbulent Von Karman wind profile, and conditions that induce flutter instability as well. FMPC showed improvements in terms of speed and power regulation and flapwise deflections reduction. In addition, the controller succeeded in suppressing flutter as it minimizes the flapwise deflections through feedback. This was done even though an explicit model for the blades coupled flapwise and torsional deflections were not included in the MPC prediction model.

Introduction

Wind turbines are considered a sustainable, cost-effective, and clean source of energy; thus, they have gained recently a high research interest. Significant challenges are being investigated throughout the research to guarantee the energy sustainability of wind turbines. One of the most complex challenges is the turbine model because of its highly nonlinear nature. The problem gets more complicated when the deflections of the blades are taken into consideration in the model that makes the control algorithm very challenging. Furthermore, region three rotor over-speed scenario represents another major challenge regarding the pitch-regulated wind turbines. Thus, it experiences the risk of flutter instability due to the interaction of the elastic vibrations and the unsteady aerodynamic forces on the blades[1]. Model Predictive Control is an approach of interest to handle such challenges due to its capability to handle complex models and system constraints. The authors in [2] implemented multiple MPC where the operational region is divided into various sub-regions according to the wind speed; computation complexity is the main drawback for such an approach. Lasheen et al. [3] implemented Fuzzy MPC using a reduced 2DOF prediction model for regulating the turbine performance. The control approaches in the literature investigating wind turbine behavior. Regulating wind turbine performance and reducing mechanical loads was the common objective throughout the literature. None of them took the flapwise deflection as a control objective to be minimized through feedback.

Simulation results

The simulations include investigating the two controllers on the NREL 5MW wind turbine [4] under steady, turbulent wind speeds and under conditions inducing flutter instability adopted from the case study on the NREL 5MW turbine in [1]. The proposed controller showed improvements in terms of turbine performance regulation under steady and turbulent wind profiles as shown in Figure 1. Moreover, it succeeded in suppressing flutter instability, contrary to the baseline gain-scheduled PI controller failed to handle the instability.



(a) Rotor speed response. (b) Blade flapwise deflection response.

Figure 1: Comparison between the FMPC and GSPI controller under steady wind profile.

References

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