Optimal Control of Wind Turbine Drivetrain

Mohamed L. Shaltout Dongmei Chen

THE UNIVERSITY OF TEXAS AT AUSTIN

Advanced Power Systems and Control Laboratory

INTRODUCTION

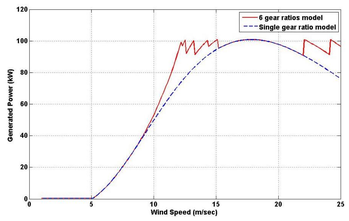
One of the most abundant renewable and clean energy sources on earth is Wind Energy. In order to increase wind energy penetration, the wind turbine installation has been dramatically increased over the past decade. Generally, the goal of design and control of wind turbines is to improve their efficiency and to enhance their reliability.

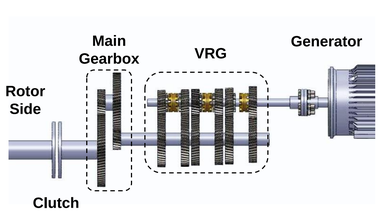
The following control designs were investigated or still under investigation,

1. Optimal Control of a Wind Turbine with a Variable Ratio Gearbox for Maximum Energy Capture and Prolonged Gear Life.
2. An Optimum Wind Turbine Control Approach for Maximum Energy Harvesting and Minimum Noise Emission.
3. Optimal Control of a Wind Farm under Wake Effect for Maximum Energy Capture and Prolonged Turbine Life.

Optimal Control of a Wind Turbine with a Variable Ratio Gearbox for Maximum Energy Capture and Prolonged Gear Life

- The employment of a variable ratio gearbox has proven to enhance the capabilities of the wind turbine to cope with wind speed variations.
- Based on a preliminary study in our group, the gear ratios of the variable ratio gearbox were carefully selected to maximize the wind energy capture.





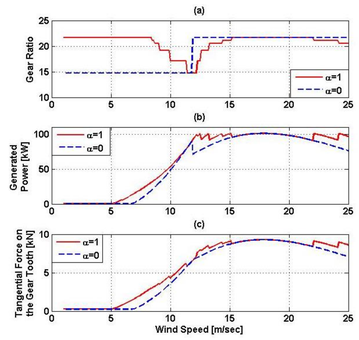
- The objective is to find the optimum shifting sequence of the variable ratio gearbox in order to maximize power generation and extend gear life through minimizing the tangential force on the gear tooth.

- The following cost function was formulated,

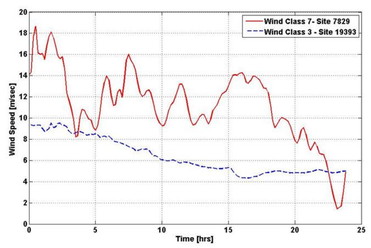
$$J = \sum_{i=1}^{N} \alpha \left[\frac{P_{g,max} - P_g(i)}{P_{g,max}}\right] + (1-\alpha)\left[\frac{F_t(i)}{F_{t,max}}\right]$$

- **Simulation Results and Conclusions:**

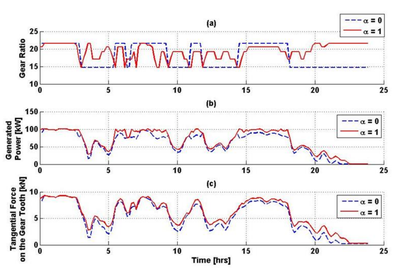
  - The results show that a bias that limits the applied gear force will generally reduce the wind energy harvesting. It also decreases the frequency of gear shifting.



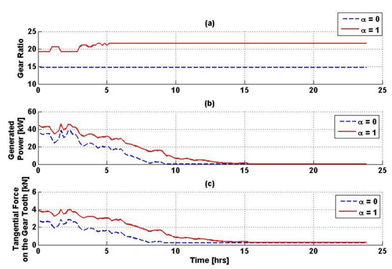
  - Using the same set of gears in each case, it was found that the effect on life is not significant for lower wind speeds. Hence, it is possible to favor the power generation over the tangential force on the gear tooth for low wind class sites.
  - For high wind class sites, the choice of the value of the weighting factor depends on the trade-off study between energy harvesting and decreasing tangential force on the gear tooth, hence, extending the gearbox life.



Wind Class 7 Site



Wind Class 3 Site



- **Publications:**

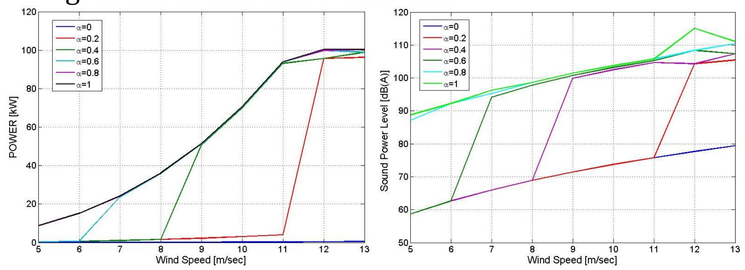
1. M. L. Shaltout, N. Zhao, J.F. Hall and D. Chen, "Wind Turbine Gearbox Control for Maximum Energy Capture and Prolonged Gear Life", in the Proceedings of the 2012 ASME Dynamic Systems and Control Conference, Ft. Lauderdale, FL, Oct. 17-19, 2012
2. M. L. Shaltout, J.F. Hall and D. Chen, "Optimal Control of a Wind Turbine with a Variable Ratio Gearbox for Maximum Energy Capture and Prolonged Gear Life", Submitted to ASME Journal of Solar Energy Engineering.

An Optimum Wind Turbine Control for Maximum Energy Harvesting and Minimum Noise Emission

- One of the challenges facing the continuous growth of wind energy industry is the noise emitted from the wind turbines.
- Generally, utility scale wind farms are built in nearly unpopulated areas, but the emitted noise can still be audible to the residents in the neighborhood of wind farms.
- This work proposes a wind turbine control approach aiming to energy harvesting maximization in addition to noise emission minimization.
- The cost function J, combines the generated power, P_g, and the noise power level, L_{WA}, as follows,

$$J = \sum_{i=1}^{N} \alpha \left[\frac{P_{g,max} - P_g(i)}{P_{g,max}}\right] + (1- \quad)\left[\frac{L_{WA}(i)}{L_{WA,max}}\right]$$

- **Preliminary Simulation Results and Conclusions:**
  - In Region 2, there is a tradeoff between power generation and noise emission.



  - In Region 3, there is no tradeoff between power generation and noise emission.

Optimal Control of a Wind Farm under Wake Effect for Maximum Energy Capture and Prolonged Turbine Life.

Cockrell School of Engineering

Mechanical engineering department