In order to avoid using the upper bound of disturbance D, we use adaptive algorithm to estimate the disturbance D.

Select the Lyapunov function as

$$S_3 = S_2 + \tilde{D}^2 / 2\gamma_4 \quad (35)$$

where γ is positive constant , $\hat{D}$ is the estimate of D, estimate error is $\tilde{D} = D - \hat{D}$.

The adaptive law is designed as

$$\dot{\hat{D}} = \sigma_2 f \gamma_4 \quad (36)$$

The controller can be designed as

$$u_\psi = (-M - fN - f\hat{D} + \dot{\alpha}_2 - tL_2)) / fh \quad (37)$$

where $N = \dot{x} - D - hu_\psi$, $L_2 = \sigma_2 + \varepsilon\, \mathrm{sgn}(\sigma_2)$, $M = (k_1 - 2e)\dot{\psi}$.

$$\dot{S}_3 = \dot{S}_2 - \tilde{D}\dot{\hat{D}} / \gamma_4 \quad (38)$$

$$= -z^T Q_2 z - t\varepsilon \mid \sigma_2 \mid \le 0$$

where $z^T = [z_1 \quad z_2]$, $Q_2 = \begin{bmatrix} c_2 + tk_2^2 & tk_2 - 1/2 \\ tk_2 - 1/2 & t \end{bmatrix}$

In order to restrain chattering phenomenon, the use of a relay function for obtaining the alternate control input induces unacceptable generator torque or current variations. Use of a continuous hyperbolic tangent function is a well-know method for alleviating the supplementary fatigue due to current oscillations and electromagnetic torque without greatly affecting the control law robustness.

IV. Simulation Results

To evaluate the performance of the proposed adaptive sliding mode backstepping control algorithm, the proposed sliding mode torque regulation strategy has been tested for validation using the NREL FAST and TurbSim code [11].

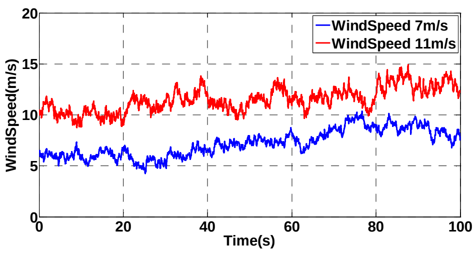

Figure 2. Wind speed profile

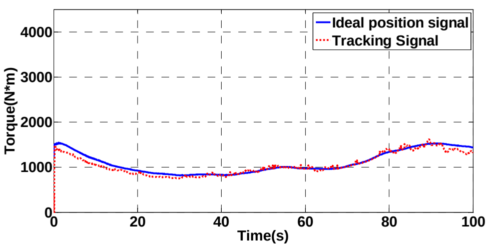

Figure. 3. Torque: reference (blue) and real (red)

Numerical validations, using FAST and TurbSim with MATLAB has been carried out on the NERL CART-3 WT. Validation tests were performed using turbulent wind data with 7 and 11 m/s wind speeds respectively see the Figure 2. As clearly shown in Figs. 3, 4, very good tracking performances are achieved in terms of DFIG torque with respect to wind fluctuations.

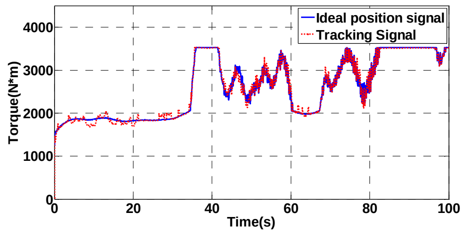

Figure 4. Torque: reference (blue) and real (red)

V. Conclusion

A model-independent control scheme based on adaptive backstepping slide control method is developed for torque tracking of DFIG system. Based on Lyapunov stability theory, we establish torque and flux tracking of proposed adaptive slide control scheme. The proposed sliding mode control strategy present attractive features such as robustness to parametric uncertainties of the turbine and the generator as well as to electric grid disturbances. The obtained results clearly show the adaptive slide control approach effectiveness in terms of power extraction maximization compared to more traditional technique.

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