NUMERICAL DESIGN OF A WIND OBSERVER AND FEEDFORWARD CONTROL OF WIND TURBINES

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INTRODUCTION

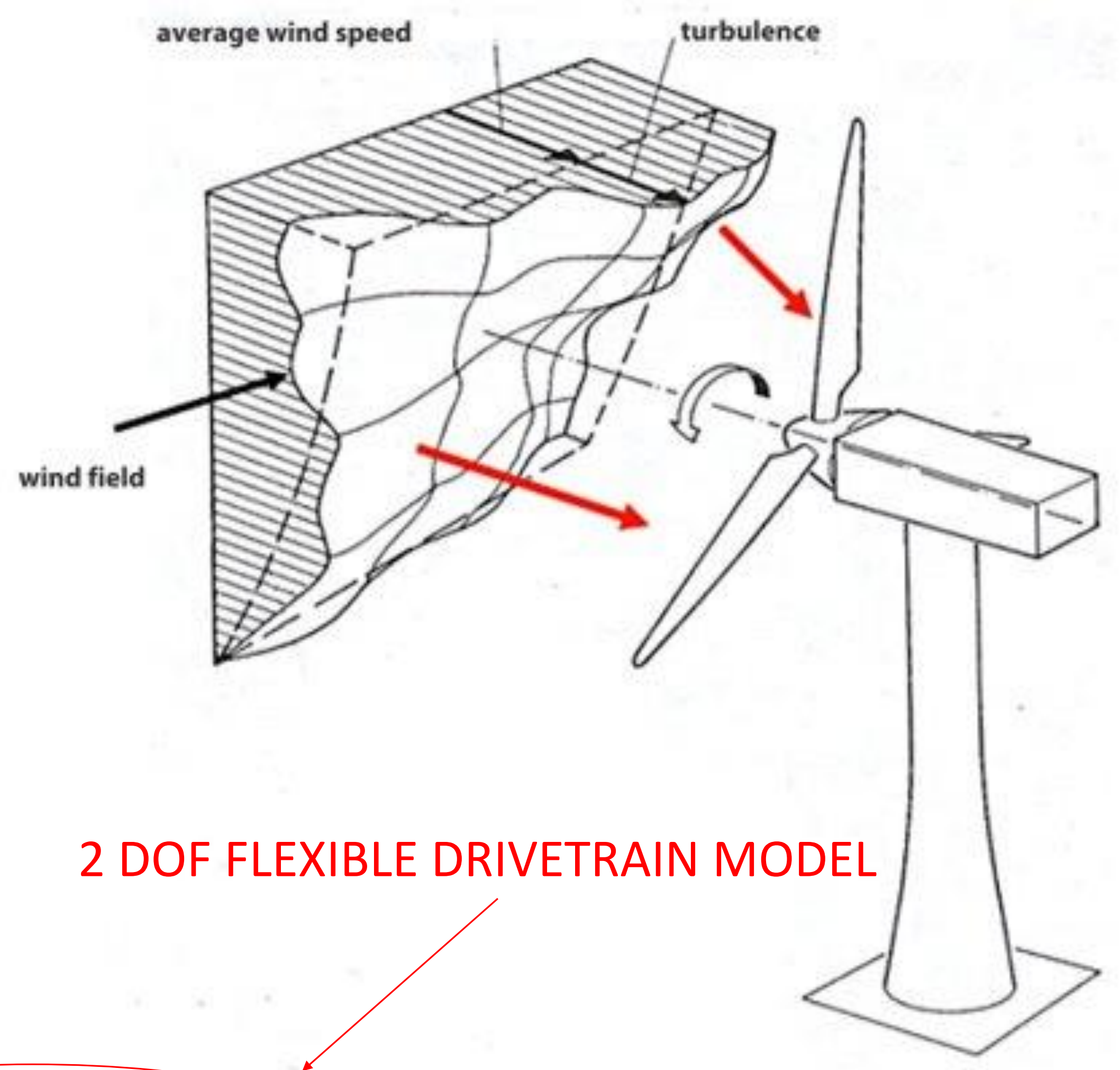
A safe and robust operation of multi-MW wind turbines requires the design of accurate control logics, with the aim of delivering high quality power to the grid and enhancing the fatigue life of crucial machine components. This work reports the numerical design of a wind observer for the estimation of the Effective Wind Speed and the subsequent implementation of a feedforward control logic. Presented techniques are tested on the 10 MW DTU reference wind turbine.

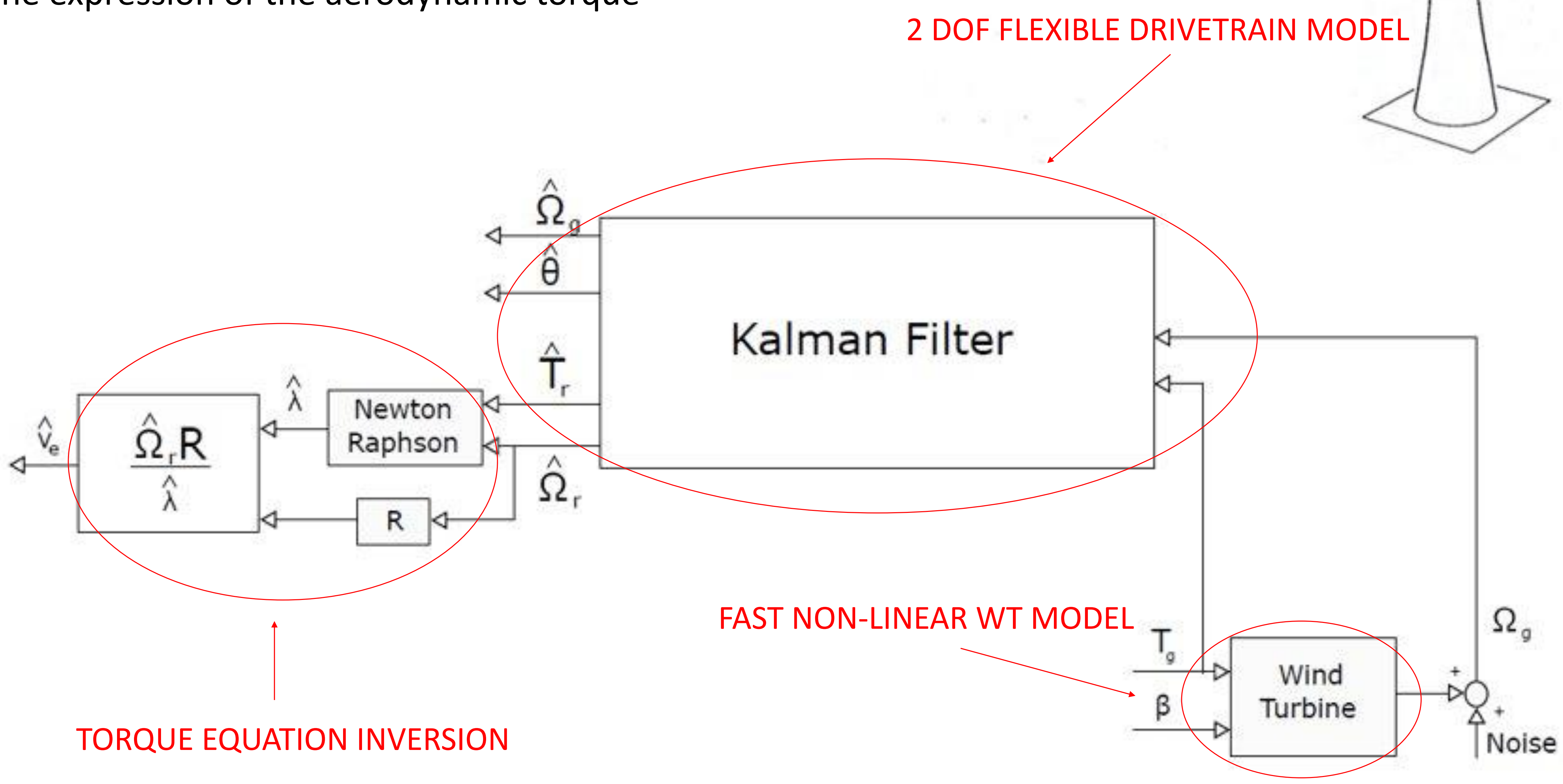
EFFECTIVE WIND SPEED OBSERVER

EWS: equivalent wind speed yielding the same aerodynamic torque of the complex, 3-D wind field crossing the rotor swept area:

$$T_r = \frac{1}{2}\rho\pi R^3 \frac{C_P}{\lambda}(\lambda,\beta)v_e^2$$

The aerodynamic torque is estimated through a Kalman –Bucy filter relying on a 2-DOF model of the drivetrain. The EWS is then derived from the expression of the aerodynamic torque





FEEDFORWARD PITCH CONTROL ACTION

The obtained EWS is exploited to generate a feedforward pitch control action for above-rated conditions:

RATED POWER
$$P_r = \frac{1}{2}\rho\pi R^2 C_P(\hat{\lambda},\beta_{ff})\hat{v}_e^3$$

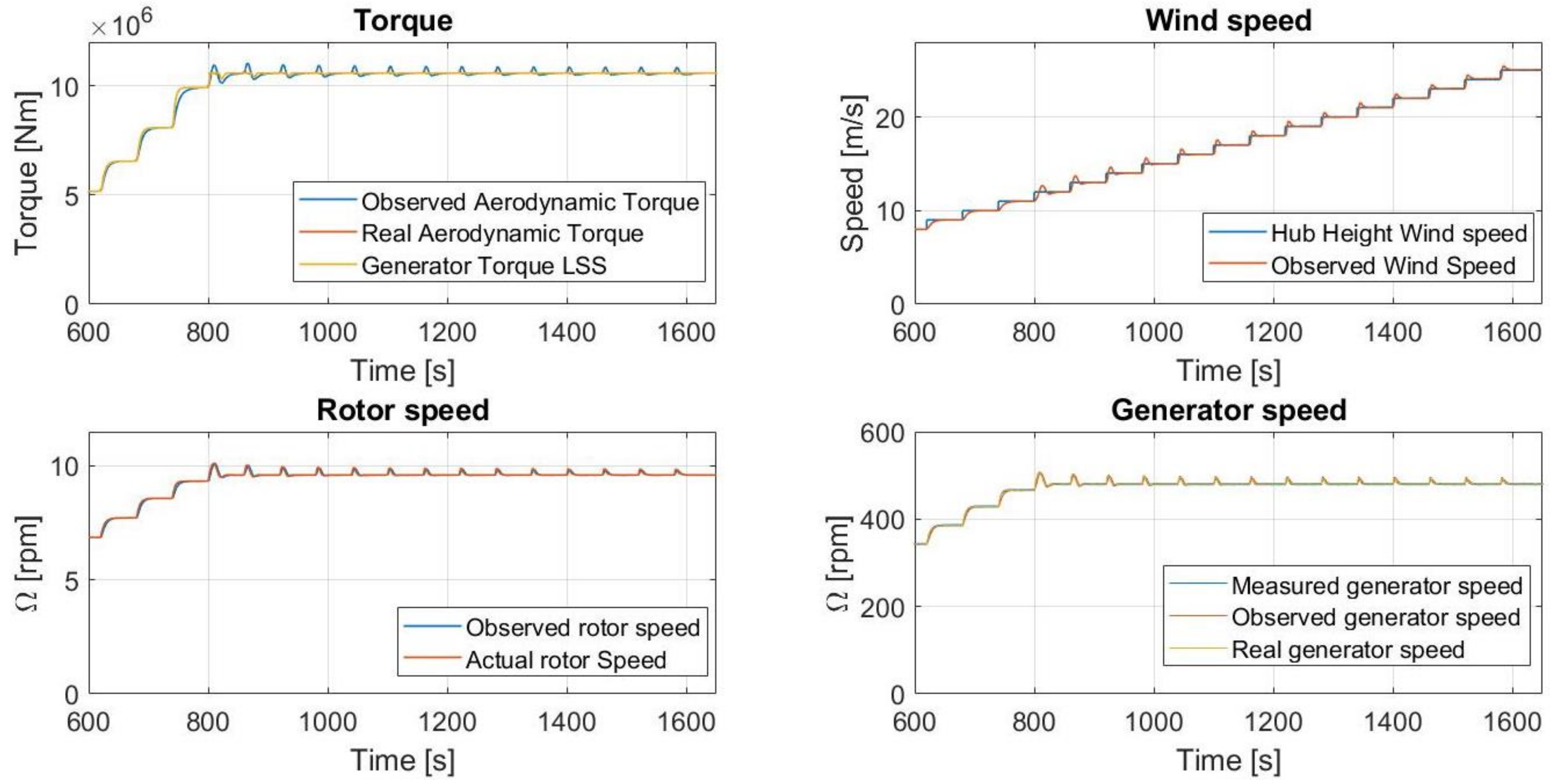
→ $C_p$curve → β_{ff}

$$\beta_{ref}(s) = \underbrace{\left(K_P^{\Omega} + \frac{K_I^{\Omega}}{s}\right)e_{\Omega}(s) + \left(K_P^{P} + \frac{K_I^{P}}{s}\right)e_P(s)}_{\text{Feedback loop}} + \underbrace{\beta_{ff,\Delta}}_{\text{Feedforward}}$$

RESULTS

The presented techniques have been implemented on the **10 MW DTU reference wind turbine** and tried in different wind conditions. Results are displayed in terms of observer performances in the tracking of relevant quantities, in the fatigue loads reduction on crucial turbine components and in the improvement of power quality.

- **Observer performances**



- **Loads reduction: Damage Equivalent Loading**

✓M_{yt} tower base bending moment

✓F_{xp} rotor thrust force

✓M_{yb} blade root bending moment

	14 m/s	16 m/s	18 m/s
M_{yt}	6.08 %	3.48 %	2.09 %
F_{xp}	6.27 %	2.45 %	1.19 %
M_{yb}	1.99 %	4.93 %	1.34 %

- **Power, speed and torque fluctuations reduction**

✓I_{Pr} rotor power fluctuation intensity

✓I_{Tr} rotor torque fluctuation intensity

✓$I_{\Omega r}$ rotor speed fluctuation intensity

	14 m/s	16 m/s	18 m/s
I_{Pr}	24.23 %	26.59 %	22.85 %
I_{Tr}	23.76 %	26.58 %	23.93 %
$I_{\Omega r}$	25.22 %	26.80 %	21.06 %

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