

Frequency Weighted Model Predictive Control of Wind Turbine



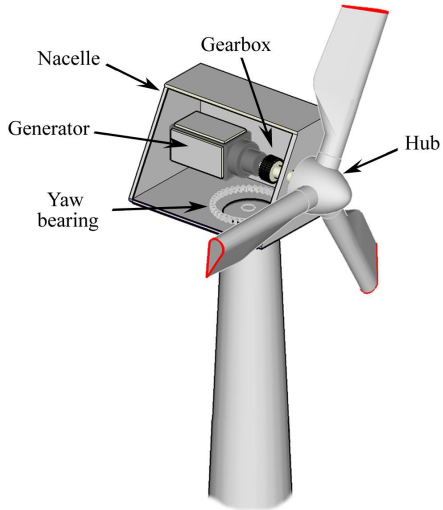
Martin Klauco

Slovak University of Technology

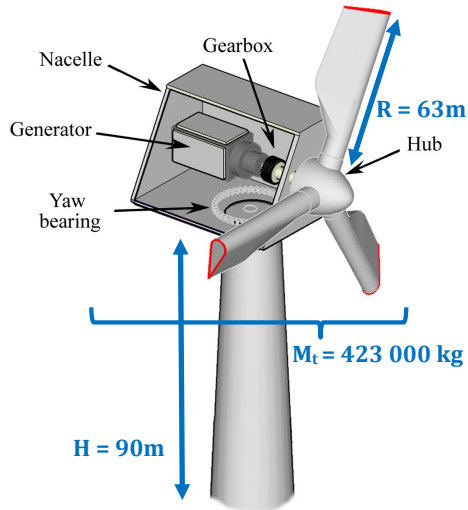
Niels Kjølstad Poulsen, Hans Henrik Niemann, Mahmood Mirzaei
Denmark University of Technology



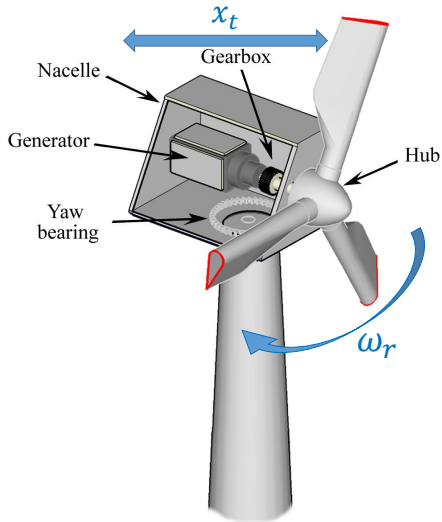
Wind Turbine



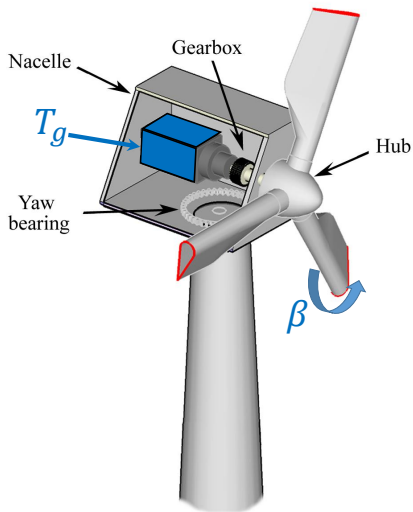
Wind Turbine - Static properties



Wind Turbine - Dynamic properties



Wind Turbine - Control actions



Wind Turbine model

$$J\dot{\omega}_r = \frac{P_r}{\omega_r} - NT_g$$

$$F_t = M_t\ddot{x}_t + D_t\dot{x}_t + K_tx_t$$

Wind Turbine model

$$J\dot{\omega}_r = \frac{P_r}{\omega_r} - NT_g$$

$$F_t = M_t\ddot{x}_t + D_t\dot{x}_t + K_tx_t$$

$$P_r = f(\omega_r, \beta, v)$$

$$F_t = f(\omega_r, \beta, v)$$

Wind Turbine model

$$J\dot{\omega}_r = \frac{P_r}{\omega_r} - NT_g$$

$$F_t = M_t\ddot{x}_t + D_t\dot{x}_t + K_tx_t$$

$$P_r = f(\omega_r, \beta, v)$$

$$F_t = f(\omega_r, \beta, v)$$

$$v = \frac{k(v_m)}{(p_1(v_m)s + 1)(p_2(v_m)s + 1)} e_t + v_m \quad e_t \in N_{iid}(0, 1)$$

Wind Turbine model

States:

ω_r	angular velocity of rotor
x_t	tower fore-aft displacement
$\dot{x}_t$	tower fore-aft speed of displacement

Control actions:

β	pitch angle
T_g	generator torque

Measurements:

ω_r	angular velocity of rotor
P_e	generated electrical power
$\dot{x}_t$	tower fore-aft speed of displacement

Control objectives

Generate electrical power

Prolong turbine operation life

Control objectives

Generate electrical power



Keep peak performance

Prolong turbine operation life



Decrease oscillations

Control objectives

Generate electrical power



Keep peak performance



Prolong turbine operation life

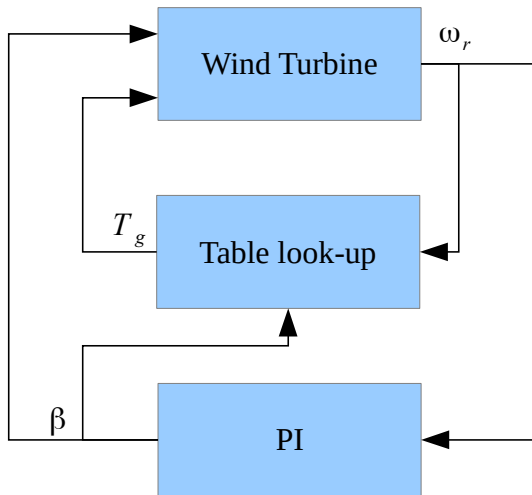


Decrease oscillations

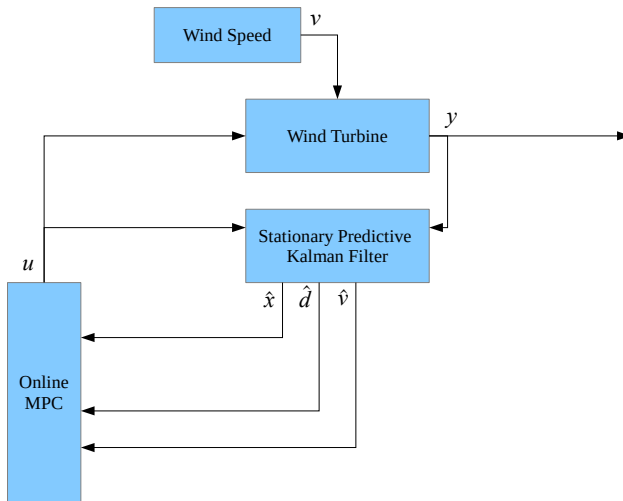


Model predictive control with frequency weighting

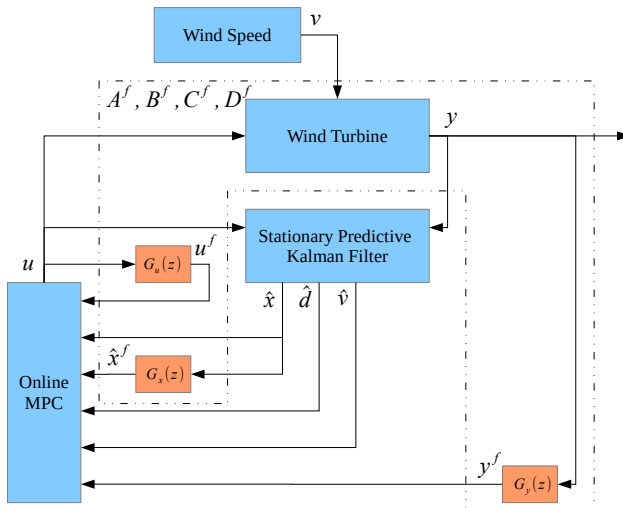
Current control approach



MPC



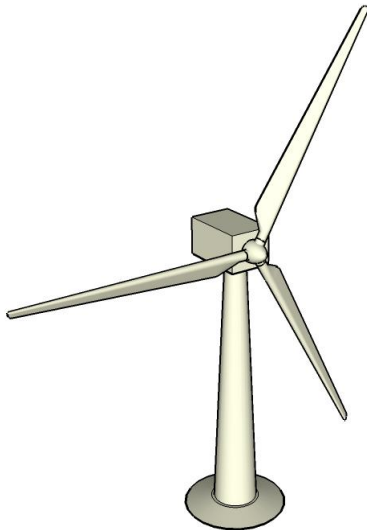
Frequency weighted MPC



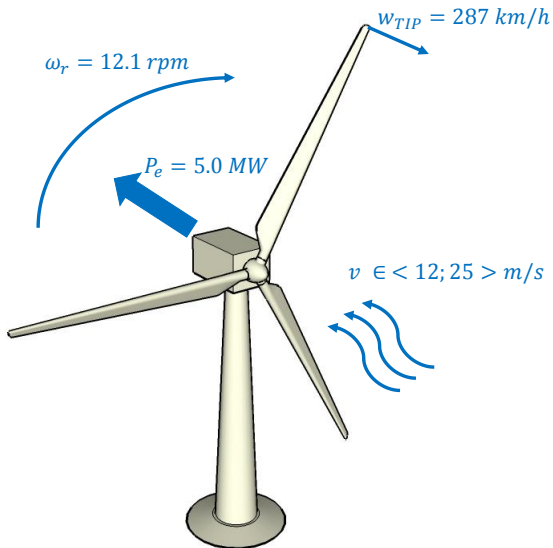
Online MPC

$$\begin{aligned}
\Phi &= \min_{u_k} \left(\sum_{k=1}^N \|r_k - y_k\|_Q^2 + \sum_{k=1}^N \|\Delta u_k\|_R^2 \right) \\
s.t. \quad &x_{k+1} = Ax_k + Bu_k + Ed_k \\
&y_k = Cx_k + Du_k + Fd_k \\
&u \in \mathbb{U} \\
&x \in \mathbb{X} \\
&y \in \mathbb{Y}
\end{aligned}$$

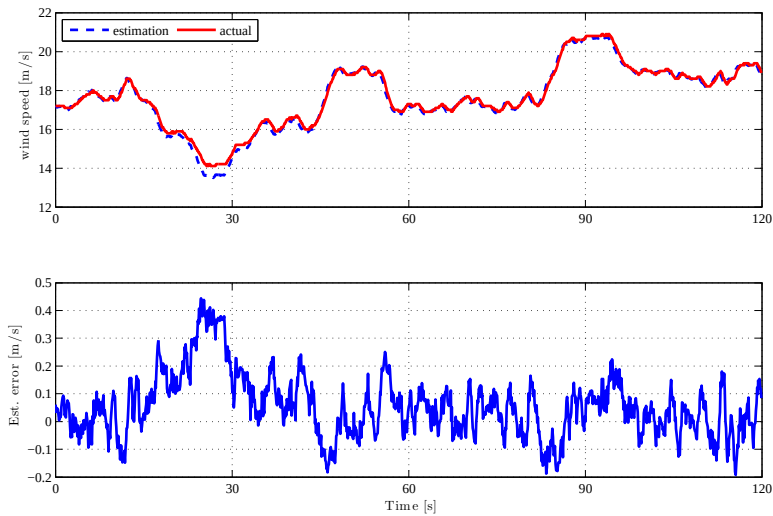
Controlled Process



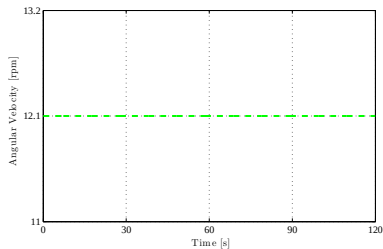
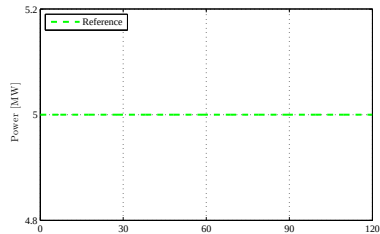
Controlled Process



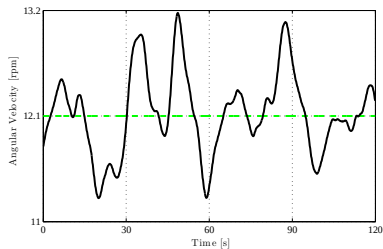
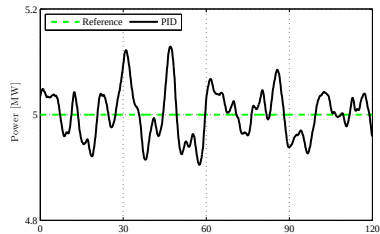
Wind speed profile



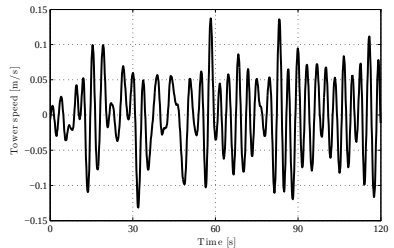
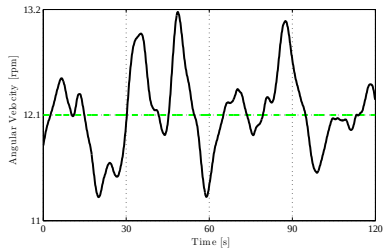
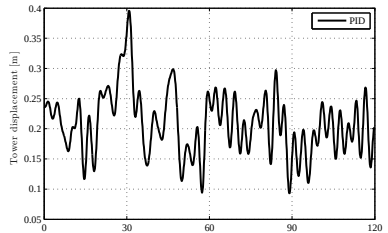
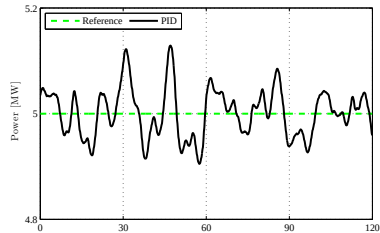
Measurements



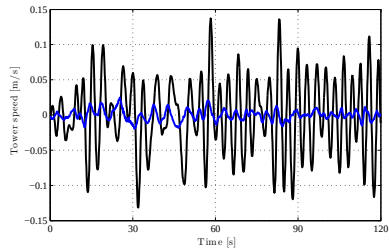
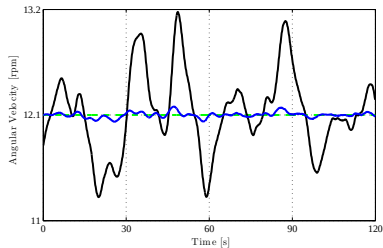
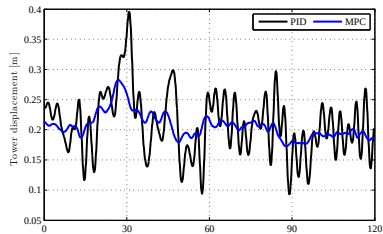
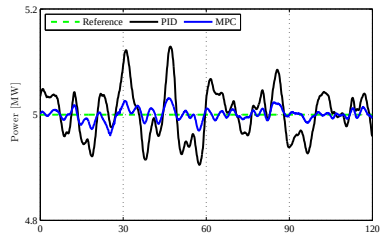
Measurements



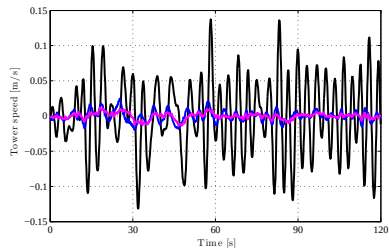
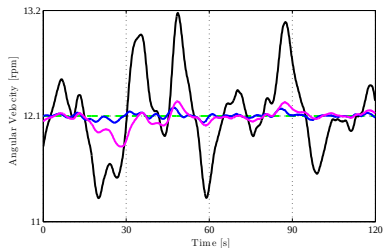
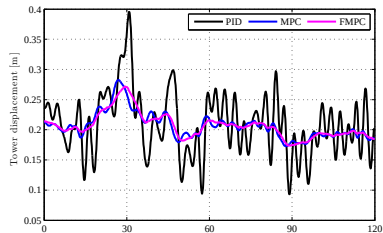
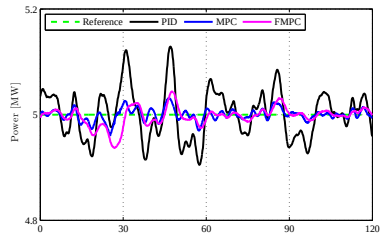
Measurements



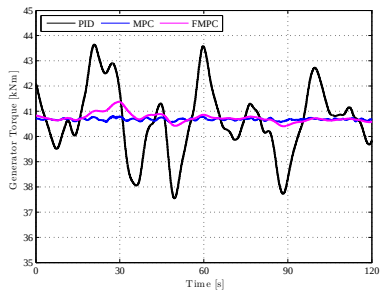
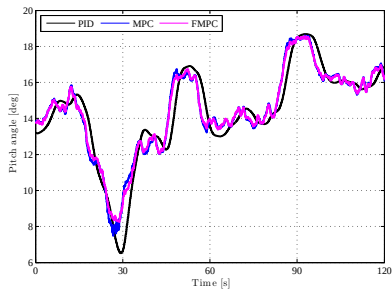
Measurements



Measurements



Control Actions



Conclusions

- Decreased variance of all signals
- Penalized certain frequency content

Conclusions

