A survey on wind farm control and the OPWIND way forward

DeepWind 2019 – Leif Erik Andersson

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High fidelity models

• Task:
  – Solve numerically the 3D unsteady Navier-Stokes equations

• Direct Numerical Simulation (DNS)

• Large Eddy Simulations (LES)
  – e.g.:
    • Ellipsys3D (1995)
    • PALM (2001)
    • SP-Wind (2010)
    • SOWFA (2012)
Medium fidelity models

- Compromise between accuracy and computational costs
- E.g.
Medium fidelity models

- Compromise between accuracy and computational costs
- E.g.

80’s 90’s 2000’s 10’s

- Larsen
- Ainslie

- Trabucchi et al. (2016)
- Rott et al. (2017)

- WakeFarm
- 3D RANS
- WindFarmSimulator
- FAST.Farm
Engineering models

- Focus on simplicity
- Small number of parameters
- Steady-state vs dynamic
Engineering models

- Focus on simplicity
- Small number of parameters
- Steady-state vs dynamic
- E.g.

80’s  |  90’s  |  2000’s  |  10’s

Lissaman

Jensen

Vermeulen
Engineering models

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- E.g.

80's 90's 2000's 10's

Lissaman
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FLORIS
Bastankhah
Engineering models

- Focus on simplicity
- Small number of parameters
- Steady-state vs dynamic
- E.g.

- Lissaman
- Ishihara
- FLORIS
- Qian
- Jensen
- 80’s
- 90’s
- 2000’s
- 10’s
- Vermeulen
- Bastankhah
Example – centralized model-predictive control (MPC)
Control approaches

Objective function
- Mitigate loads
- Maximize energy
- Track power reference

Control concept
- Optimization-based
  - Model-based (open-loop, closed-loop)
  - Model-free
- Conventional feedback control

Control structure
- Distributed
- Decentralized
- Centralized

Control inputs
- Axial induction
- Wake steering
OPWIND

• OPerational control for WIND power plants
Objective:
- Maximize energy yield
- Minimize O&M costs
- Power system services
Thank you!
Questions?
Modifier Adaptation with Gaussian process regression

- Optimize model does not necessarily optimize plant

- Idea: Correct the model with plant measurements

\[
\mathbf{u}_{k+1}^* = \arg\min_{\mathbf{u}} \phi(\mathbf{u}) + (\mathcal{GP})_{\Phi_p - \Phi}(\mathbf{u}, \mathbf{U}_k)
\]

\[
s.t. \quad G_i(\mathbf{u}) + (\mathcal{GP})_{k}(G_{p,i} - G_i)(\mathbf{u}, \mathbf{U}_k) \leq 0, \quad i = 1, \ldots, n_g;
\]

\[
\mathbf{u} \in \mathcal{U},
\]
Example – 2 turbines & 2 control inputs

Plant objective function

Model objective function
Example – 2 turbines & 2 control inputs

Corrected objective function – after training
Example – 2 turbines & 2 control inputs

Corrected objective function – 10 iteration