Combining Wind Plant Control With Systems Engineering

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Overview

• Wind plant controls research
• Combining optimization
• Case study: Princess Amalia Wind Park
• Conclusions.
Wind Plant Control

- Recent research has focused on improving wind plant performance by coordinating the control of individual turbines.

Photo from Uni-Fly A/s
One promising approach uses intentional yaw misalignment to redirect wakes away from downstream turbines.
Model Development

- Work has used high-fidelity simulation to study the control systems (Simulator for On/Offshore Wind Farm Applications, or SOWFA)

- Additionally, control-oriented engineering models have been developed for control design (FLOw Redirection and Induction in Steady-state, or FLORIS).


Model-Based Control

- Using engineering-level model:
  - Optimize yaw angles within this model.
- Test selected values in SOWFA.
Model-Based Control

Combined Optimization

• The previous work assumes a fixed plant layout, turbine design, and so on
• Perhaps the benefit of wind plant control could be amplified if accounted for during the early phase of design
• In this work, a proof-of-concept study was performed in which wind plant controls and layout were optimized.
Case Study: Princess Amalia Wind Park

- Given baseline layout of real wind plant, compare:
  - **Baseline**: fixed (original) positions, turbines all yawed in mean wind direction
  - **Optimized yaw**: fixed (original) positions, turbines optimally yawed for each wind direction
  - **Optimized location**: position optimized, turbines all yawed in mean wind direction
  - **Combined optimization**: simultaneously optimized position and yaw for each wind direction.

- Use as a proxy metric of COE the power density of the wind farm (W/m²)
- Note 1: Full paper (under review in Wind Energy) considered cable length and boundary limitations as well
- Note 2: NREL’s 5-megawatt (MW) turbines were used in place of ~2-MW turbines, making baseline spacings closer
- Note 3: All following figures from upcoming full paper.
Baseline

Power Output

- Mean power (MW): 78.86
- Area (km²): 14.53
- Power density (W/m²): 5.43

Layout
Optimized yaw angles for the 180° case
Yaw Control

Power Output

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>YawOpt</th>
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<tbody>
<tr>
<td>Mean power (MW)</td>
<td>78.86</td>
<td>84.91</td>
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<tr>
<td>Area (km²)</td>
<td>14.53</td>
<td>14.53</td>
</tr>
<tr>
<td>Power density (W/m²)</td>
<td>5.43</td>
<td>5.84</td>
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Layout Optimization

Power Output

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<tr>
<th></th>
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<td>Mean power (MW)</td>
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<td>78.86</td>
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<td>Area (km²)</td>
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<td>Power density (W/m²)</td>
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</table>
Combined Optimization

Power Output

- Mean power (MW): Baseline 78.86, YawOpt 84.91, PosOpt 78.86, Combined 78.84
- Power density (W/m²): Baseline 5.43, YawOpt 5.84, PosOpt 6.33, Combined 8.80

Layout
Results

• Coupling yaw control and position density provided a 40% increase in power density over layout optimization alone and 50% more than yaw control alone.

• Proof-of-concept study demonstrated that the potential of wind plant control can be greatly expanded if included in the design phase.

• Full paper includes optimizations for cable length and given a fixed wind plant boundary.
Future Work

• Current and future work considers:
  o Impact on loading and inclusion of loading effects in optimization
  o More realistic cost-of-energy optimization function
  o More detailed and realistic constraints
  o Improved optimization for faster convergence.
Thanks for Your Attention!

Photo by Dennis Schroeder, NREL 25915

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