Multi-Objective Optimization Framework for Offshore Wind Farms

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Offshore Wind Energy

Vindeby
(1991)

Gwynt y Môr
(2014)
Offshore Wind Energy

Drawbacks

• OWFs use adapted products from other fields.
  • onshore wind turbines
  • foundations designed using oil&gas industry standards.

• Designing a large offshore wind project is a very complex task
  • Manual layout optimization and cable routing

• The design is based in a sequential approach.
  • interactions are disregarded.
  • early project decisions may become constraints in later stages.

Higher costs when compared to onshore projects with similar capacities!
Key Opportunities

- Larger turbines with improved reliability and lower operation costs;
- Greater activity at the Front End Engineering and Design (FEED);
- More use of geotechnical and geophysical surveying;
- Greater competition in key supply markets;
- Economies of scale and greater standardization;
- Optimization of installation methods;
- Products specifically designed for offshore wind environments;
- Mass produced deeper water support structures.
Increased need for FEED

- More complex and larger wind farm sites
- More wind turbines and more complex collection systems;
- Unexpected costs during the installation phase;
- The availability of a wider range of technology.
How to design a multi-objective optimization framework for offshore wind farm electrical infrastructures?
Framework Requirements

• Several requirements must be fulfilled:
  • Modularity
    • Models independency.
    • The optimization algorithm should also be easily replaced.
  • Standardization
    • The input/output of the models should be standard: plug&play.
  • Expansibility
    • New models should be included in a straightforward manner.
Optimization goals: selection criteria

- Topic Relevance
  - Onshore $\neq$ offshore (e.g. noise, shadow flickering)

- Wind farm efficiency impact
Selected Optimization Goals

• **Wind farm efficiency**
  • Wake losses

• **Electrical losses**
  • Shortest cable routings
  • Cable routing considering the sea depth / ambient temperature.
  • Location of the offshore substation.

• **Turbine**
  • Number of Wind Turbines
  • Turbine selection
Selected Optimization Goals

• **Investment Costs**
  - Support structure costs

• **Cable costs**
  - Cables with different cross sections.

• Cable installation costs
Selected Optimization Goals

- **Operation & Maintenance Costs**
  - Wind farm area
    - seabed rent
  - Fatigue loads
    - lower maintenance costs.
Discarded Optimization Goals

- Operations & maintenance
  - Construction, operational and decommissioning phases of wind projects are not considered.

- Installation methods & Logistics
  - Transportation and installation of the OWF components are not considered.
Discarded Optimization Goals

- Environmental Impacts

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<td>Noise</td>
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Framework boundaries

- A pre-selection of components was performed;
- The wind farm area is selected;
- The number of substations is defined.
Framework input data

- Wind rose
- Pre-selected components data
- Wind farm and export corridor seabed information
- Location of the landfall point
- The maximum water depth for turbines, substations and cables
Preliminary Results
Case study

- Wind farm with a square shape: 5 km x 5 km
- 36 turbines (6.15 MW each).
Seabed profile
Discretization and constraints

Seabed discretization

Unfeasible areas

Restricted zones of the wind farm area

- Seabed gradient
- Minimum separation between OWTs
- Maximum water depth
## Results

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<tr>
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<th>Standard layout</th>
<th>Optimized layout</th>
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<tbody>
<tr>
<td></td>
<td>Unconstrained</td>
<td>Constrained</td>
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<tr>
<td>Wind farm efficiency</td>
<td>80.77%</td>
<td>+13.46%</td>
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<tr>
<td>Collection system cable length</td>
<td>30 km</td>
<td>+4.6%</td>
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</tbody>
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### Diagrams

Constrained and unconstrained cable routing – Standard layout

Constrained and unconstrained cable routing – Optimized layout
3D plot
Future work

• Loss models for all the components
• Variable number of turbines
• Fatigue loads
• Collection system (different cross sections)
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Thank you
Questions?