# Multi-Objective Optimization Framework for Offshore Wind Farms

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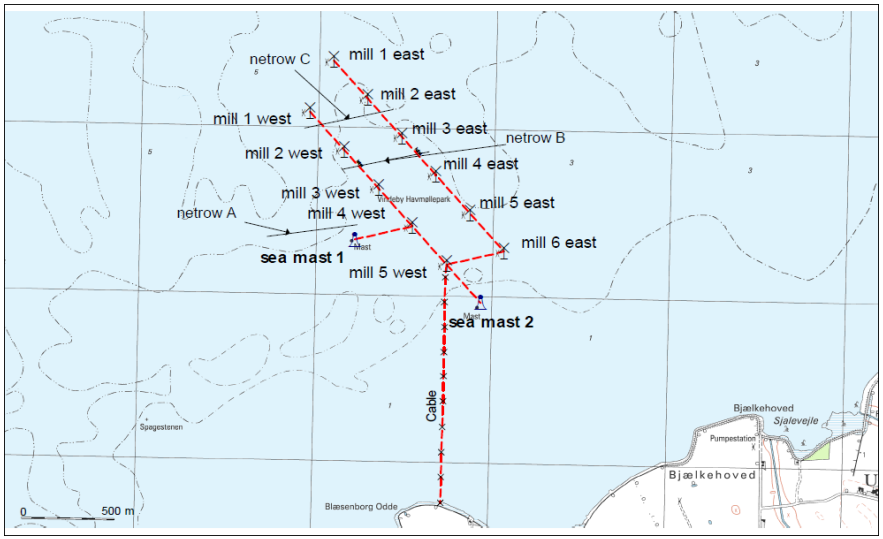
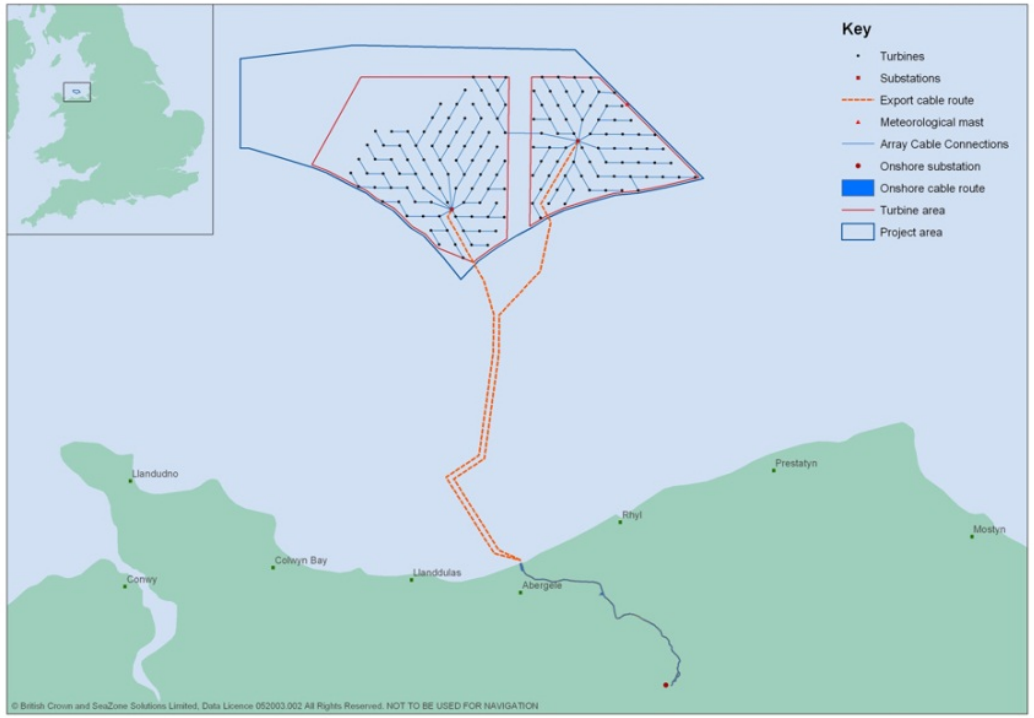
# Offshore Wind Energy




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 =/= offshore (e.g. noise, shadow flickering)
- Wind farm efficiency impact

# Selected Optimization Goals

- <u>Wind farm efficiency</u>
  - 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

- <u>Investment Costs</u>
  - Support structure costs
  - Cable costs
    - Cables with different cross sections.
  - Cable installation costs

# Selected Optimization Goals

- <u>Operation & Maintenance Costs</u>
  - 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 an installation of the OWF components are not considered.

# Discarded Optimization Goals

- Environmental Impacts

| Physical | Biological | Human |
|---|---|---|
| Suspended Solids | Birds | Visual impact |
| Scour | Seabed habitats | Shipping and navigation |
| Sediment Transport | fish & shellfish | Oil & gas |
| Waves and tides | Marine mammals | Shadow flicker |
| Water quality | Nature conservation | Tourism and recreation |
| | | Dredging and disposal areas |
| | | Archaeology |
| | | Commercial fishing |
| | | Military activity |
| | | Munitions |
| | | Aviation |
| | | Mobile communication links |
| | | Noise |

# Framework boundaries

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

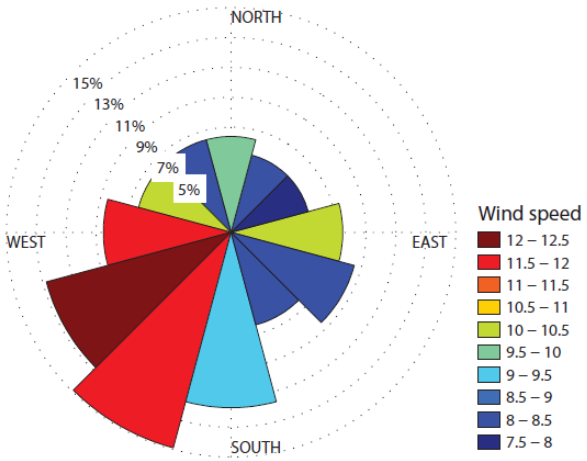
# Framework input data

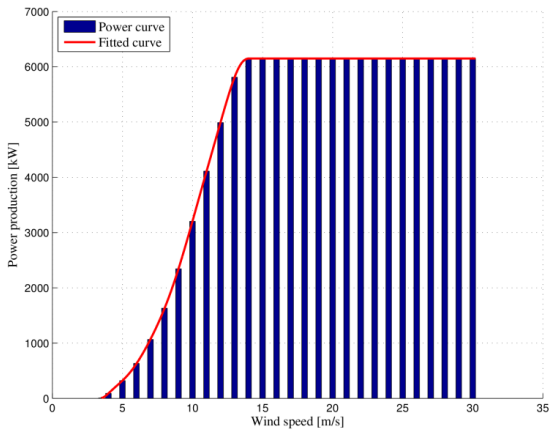
- Wind rose
- Pre-selected components data
- Wind farm and export corridor seabed information
- Location of the landfall point
- The maximum water depth for turbines, substations and cables

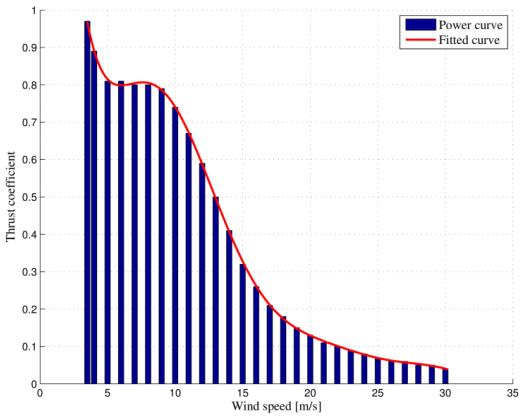
# Preliminary Results

# Case study

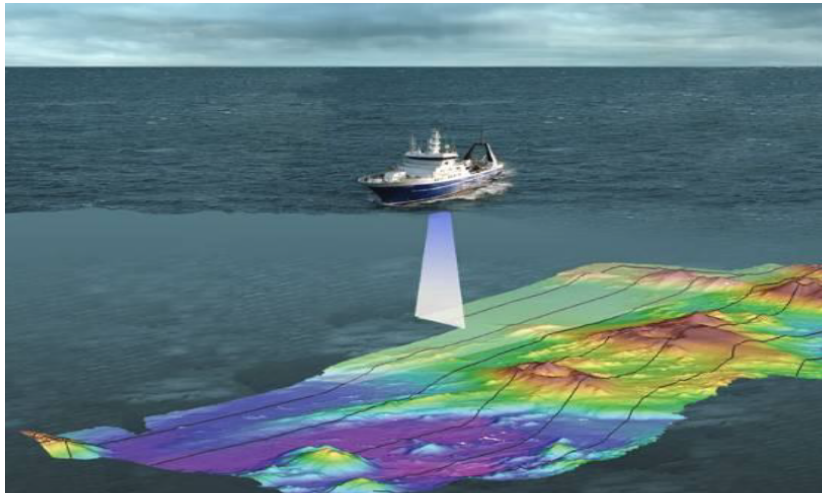
- Wind farm with a square shape: 5 km x 5 km
- 36 turbines (6.15 MW each).

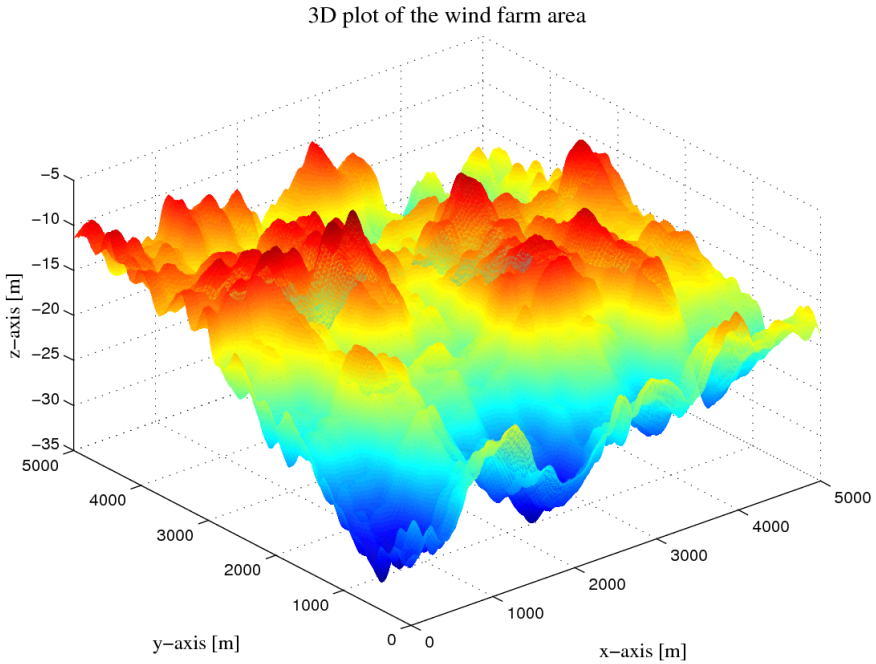


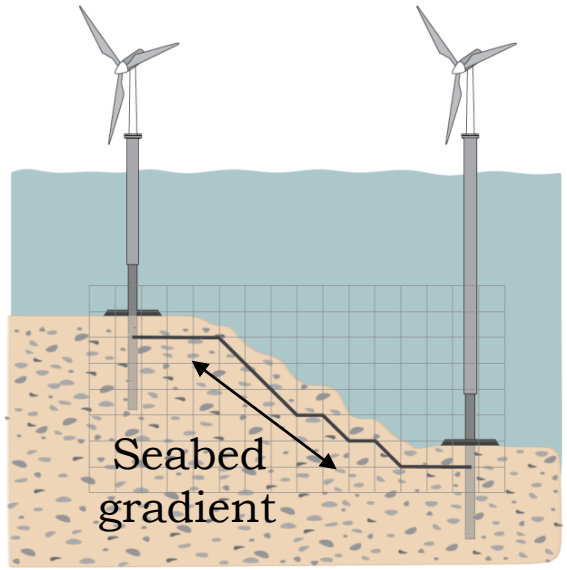



# Seabed profile

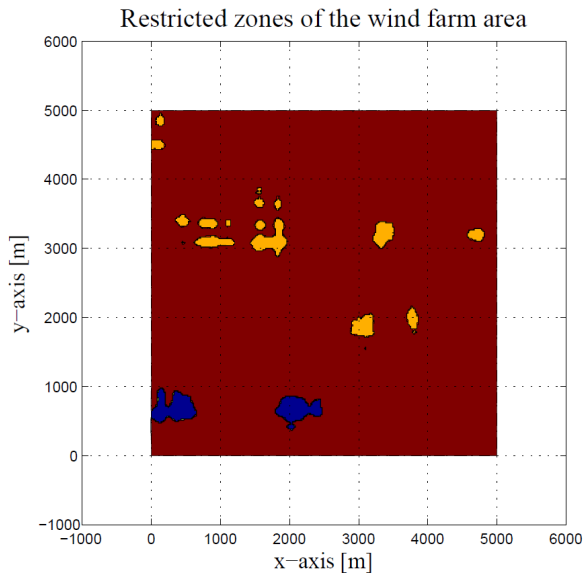


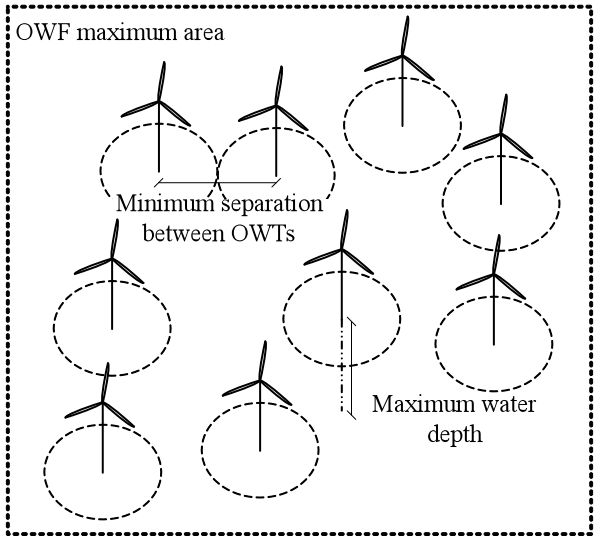


# Discretization and constraints




Seabed discretization

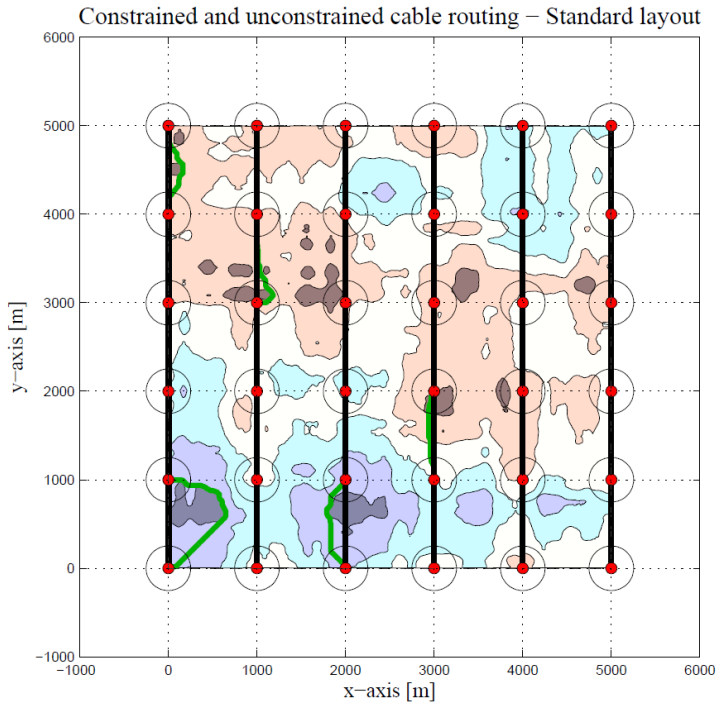


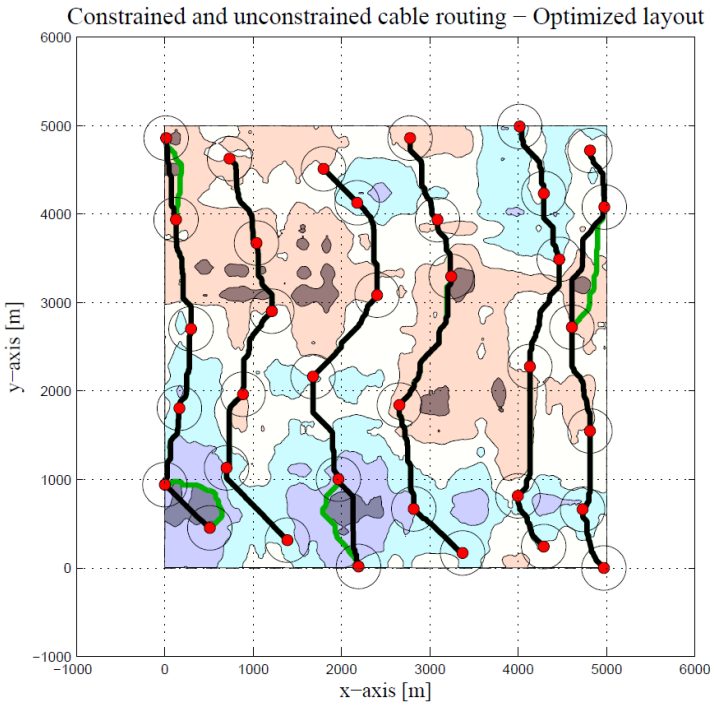




Unfeasible areas

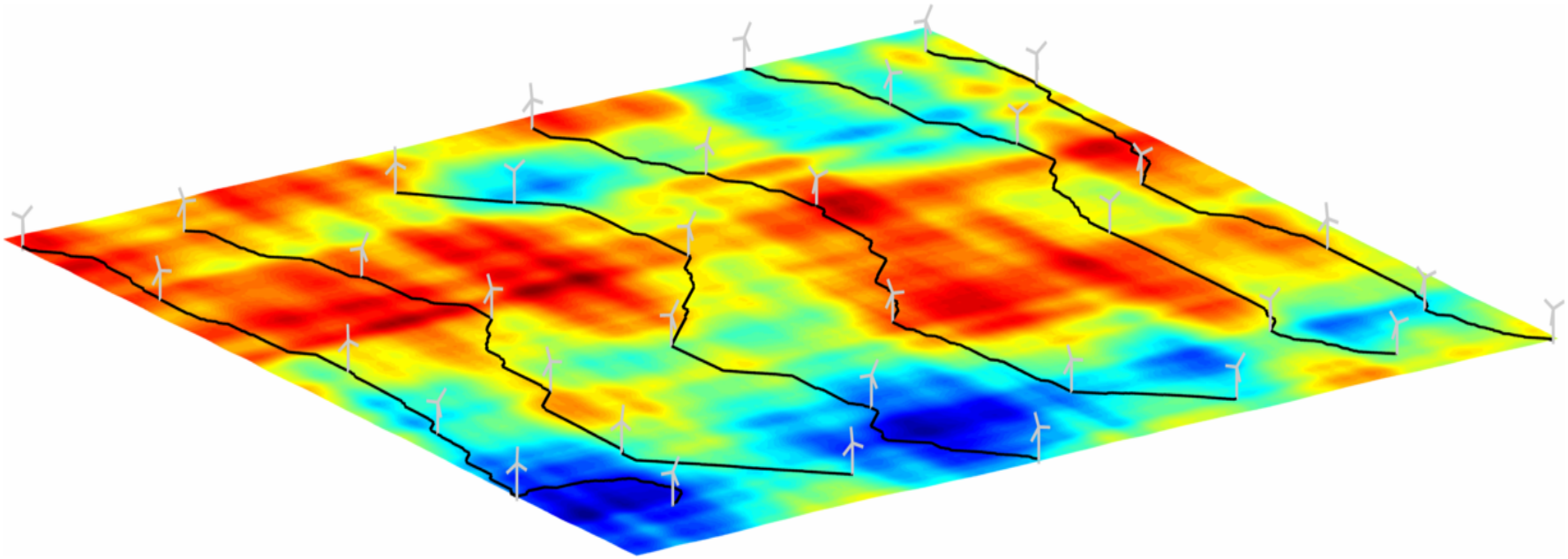
# Results

| | Standard layout | | Optimized layout | |
|---|---|---|---|---|
| | Unconstrained | Constrained | Unconstrained | Constrained |
| **Wind farm efficiency** | 80.77% | | +13.46% | |
| **Collection system cable length** | 30 km | +4.6% | +3.4% | +5.5% |



# 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?

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