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FarmWise:

innovating to boost offshore wind

Index

1 Introduction

The design of offshore wind farms requires complex optimization.

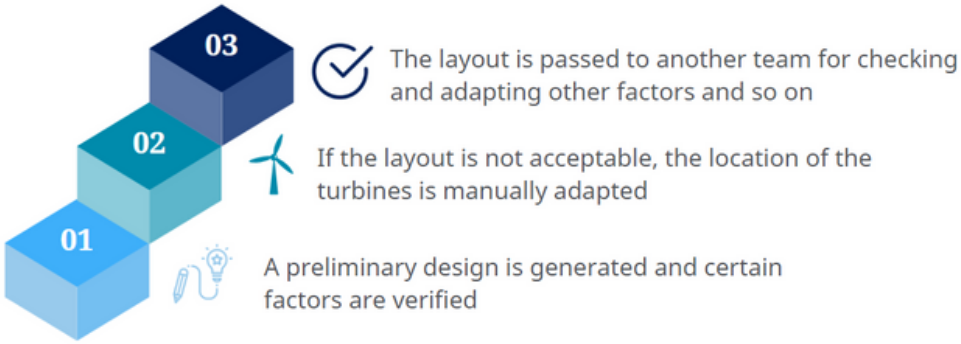
The problem

This must take into account numerous factors such as:

- the direction of the wind
- the depth
- bottom bathymetry
- exclusion zones
- anchor line costs
- physical obstacles
- types of cables
- electrical losses
- wake losses

Many of these parameters are specific to the marine environment and are not taken into account in their entirety by existing commercial software tools.

The current wind farm design process is cumbersome and can take weeks.



The overall process involves many people, is time-consuming, and the results are not optimal.

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The proposal - Farmwise

The tool

multivariable optimization of offshore wind farm implementations.

Software

for the automatic layout of wind turbines, substations and cable laying, based on generative design.

Product development

Our product stands out exceptionally in today's market thanks to our deep understanding of essential functionalities, developed in-house by an expert team. Our adaptable approach ensures an agile and effective response to changing market demands.

Iterative discoveries

Starting from our initial vision and through careful iterations, we have revealed and satisfied market needs that, until now, were unknown. This process has allowed us to uniquely fine-tune our approach, providing tailored solutions that exceed client expectations.

Benefits

- Reduce your costs: Optimize the cost of your wind farm.
- Increases production: Boosts energy generation effectively.
- Save millions of euros: Achieve significant total profits.
- Maximum profitability: Maximize your income with efficient solutions.

2 Market exploration

We believe that large utilities have small developed tools but perhaps not multivariable ones. We see sense in Farmwise even in the very initial phases of the project

As such, there is no integrative multivariable optimization tool that analyzes a large number of possible implementations, that takes into account all the information that an optimization of this type entails and that takes into account the interaction between farms.

Your tool must be included in the solutions portfolio

I find FarmWise very useful in the early stages to evaluate a large number of sites that have the same precision of information

The design of moorings can be an important point for the optimization of designs, and FarmWise can be useful for this

LCOE optimization is something that is of increasing concern, multi-criteria optimization is becoming more and more internalized. We consider that offshore energy is going to explode and that these tools will be very necessary

A priori FarmWise has many advantages, it is surprising that it has not been developed before, is there a reason we are missing?

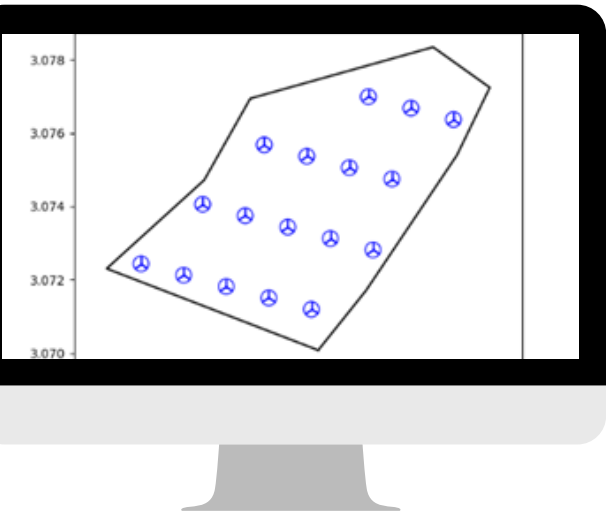
It is important to include all factors when designing: export cable, distance to port, sea floor conditions...

We have internally developed tools to evaluate each of the elements of a farm separately. Having several tools creates an integration problem between them, which makes us waste more time in "translating" results rather than in reaching them.

The leap in computing is very important from PV to offshore wind. We have previously tried to do something similar in terms of automating certain design processes but we have not come up with anything really useful

Fine optimization may become increasingly relevant as wind farms lose premiums and enter pool prices, or as the UK begins to charge an annual fee for "rental" of the plot to the State. All this can distance the ROI over time, driving the interest in this type of optimizations

3 FarmWise Scheme



Parameters: inputs	
Climatic parameters	• Air density. • Reference height. • Weibull distribution of wind speed as a function of wind direction. • Turbulence model. • Heterogeneous wind resource model. • Wind rose. • Wind directions rose.
Farm configuration	• Number of wind turbines. • Types of cables. • Power evacuation points. • Known or initial position of the wind turbines.
Wind turbine parameters	• Power. • Hub diameter. • Hub height. • Power curve. • Thrust curve. • Minimum initial speed (Vin). • Nominal speed (Vr). • Cutting speed (Vout).

Models

Optimization models

- Wind turbines arranged on a regular mesh.
- Wind turbines arranged on farm outline and regular mesh inside.
- Wind turbines arranged starting from regular mesh to optimization in irregular mesh.

Wakes

Cables

Wake-wires

Restrictions

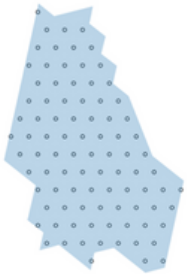
- Wind farm contours.
- Other geometric limitations (exclusion zones, seabed, etc.)
- Interconnecting cables must not be crossed.
- Minimum distance between evacuation cables.
- Minimum distance between wind turbines.
- Possible connection node in each wind turbine. Possible number of cables in each input and output of the node.
- Maximum number of evacuation points in the optimization.
- Maximum number of cables in optimization.

Results

- Optimal farm distribution.
- AEP result (GWh/year) for optimal distribution.
- Result of wake loss (%) for the optimal distribution.
- Result of electrical losses (%) for optimal distribution.
- Result of wake losses (%) for any predetermined distribution.
- Result of electrical losses (%) for any predetermined distribution.
- Distribution of AEP depending on wind direction.
- Wake loss model used.
- Optimal interconnection layout.
- Result of electrical losses.
- LCOE Result

4 Optimization model

Wakes models

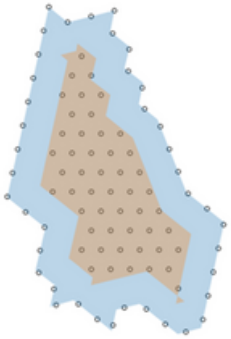


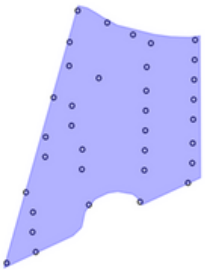
Wind turbine layout

Turbines are efficiently arranged in rows and columns by optimizing key parameters. These include the distance between rows, the spacing between columns, the strategic offset between adjacent rows, and the precise orientation of the mesh. With this meticulous layout, we seek to maximize the efficiency of the farm, ensuring optimal and sustainable renewable energy generation.

Farm contour and regular mesh inside

Some turbines are strategically distributed along the outer contour of the farm, while the others are arranged in a smaller inner contour, following a regular mesh. This design strategy, supported by recommendations in various specialized publications, has been demonstrated as an efficient choice to optimize energy generation in wind farms.



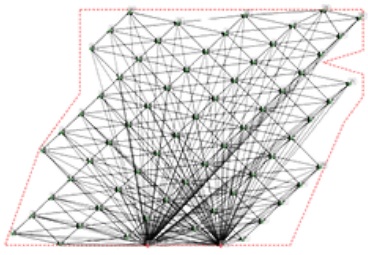


Irregular mesh optimization

Through an advanced optimization algorithm, without restrictions regarding the distribution of the wind turbines within the farm area, it seeks to maximize the efficiency and performance of each component, thus guaranteeing an optimal layout that maximizes the generation of renewable energy.

Cable model

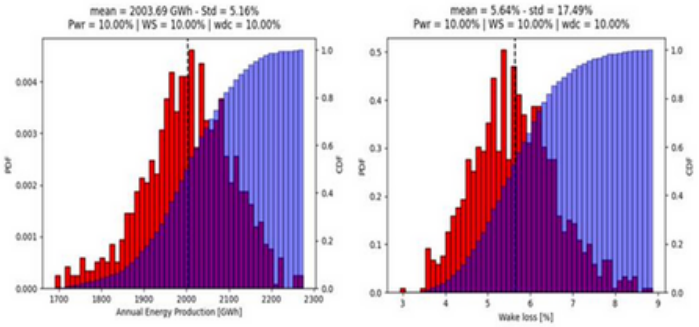
- Allows you to select catalog cables.
- Allows you to select different power evacuation points in the farm.

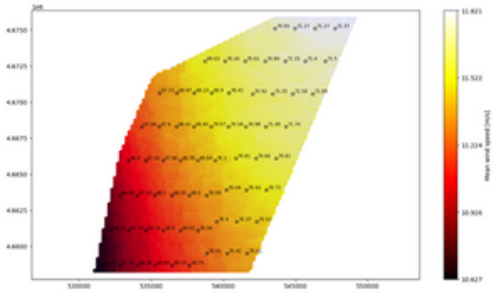


5 Functionalities

Study of sensitivity to loss parameters

Analysis of the sensitivity of the AEP and Wake Loss using the Monte Carlo method. This method has been included in the FarmWise AEP calculation module.



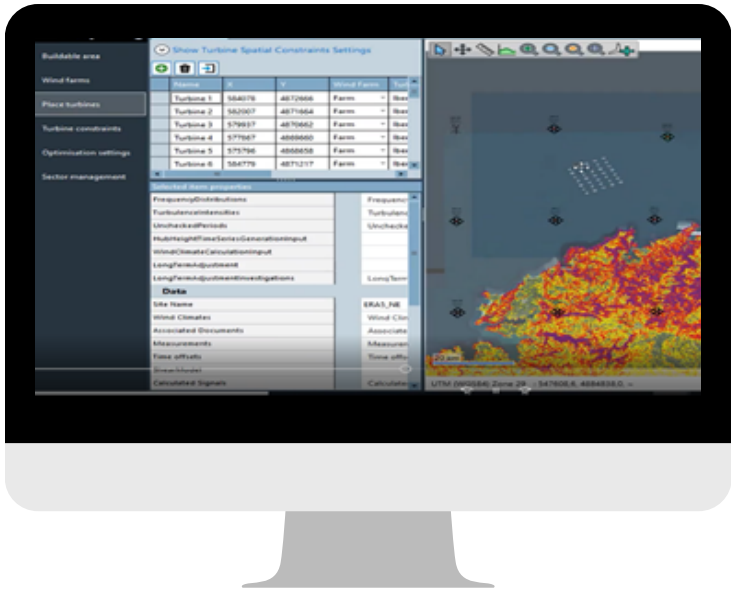


Heterogeneous climate reader

Reading WRG files, created with WAsP with Weibull distributions at different points on the map.

Compatible with WindFarmer

The user can choose the wake loss calculation method: Floris (NREL), PyWake (DTU), WindFarmer (DNV)



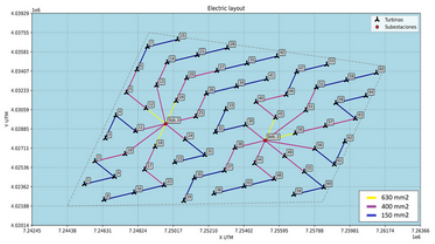
Optimization following different strategies and constraints

The user can choose the type of plant to optimize and the objective function (AEP or LCOE). Restrictions can be included in the optimization, such as minimum distance between turbines, minimum distance to the contour, exclusion zones, evacuation points, etc.

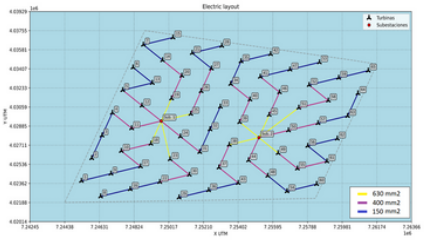
Minimum number of turbines per array

A number of functionalities have been developed for the FarmWise cable optimizer module.

- The first is a restriction of the solution: possibility of imposing a minimum number of turbines for each array of the farm.



Minimum of 3 turbines per array Total cable length = 135.3 km



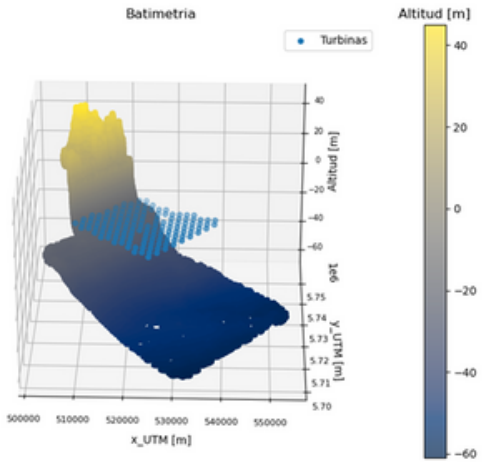
Minimum of 4 turbines per array Total cable length = 137.1 km

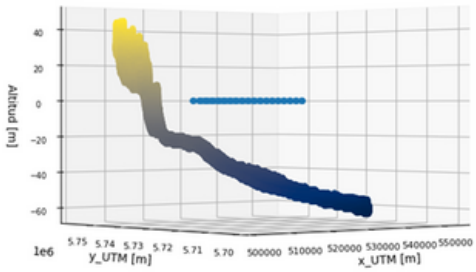
Actual cable length

FarmWise considers the actual length of the cable depending on the type of technology:

1. Fixed solution: Takes into account the bathymetry of the seabed. The cable length takes into account the depth of each turbine
2. Floating solution: Takes into account the bathymetry and formulates the **lazy wave** in each case. A distinction is made between static cable and dynamic cable (lazy wave) to take it into account at the cost level.

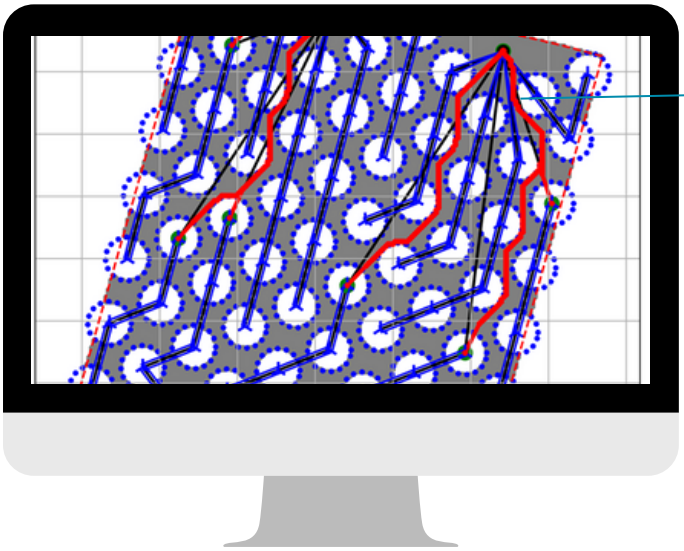
FarmWise considers site bathymetry



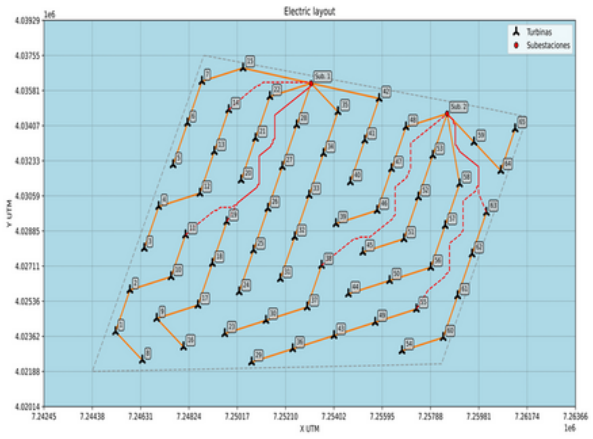


Detection and resolution of intersections

1.Detection: Both the cables that cut with other cables and those that cut with the exclusion radii around the turbines along the mooring lines are considered intersections.
2.Resolution: The most economical routing is obtained through a highly efficient algorithm.



Cable routing in wind turbine exclusion zones



The image above shows the substations in the north of the faand they are defined as exclusion zones:

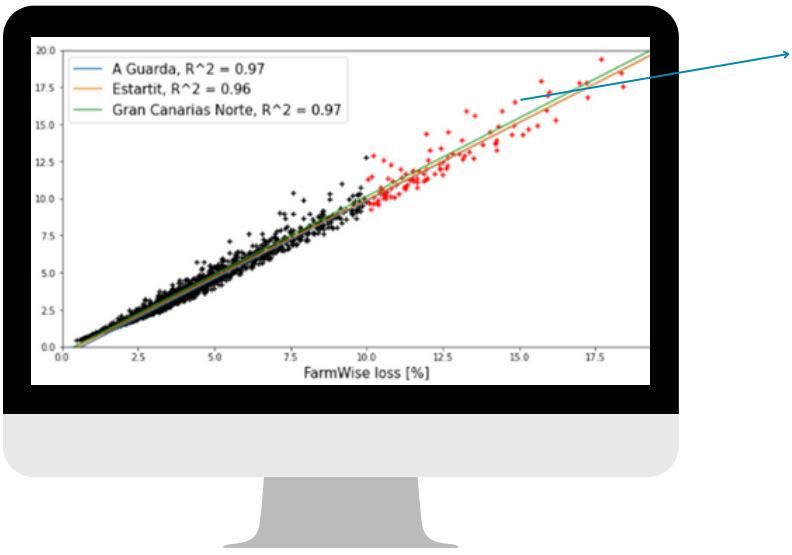
- ***a radius of 60 m around each wind turbine***
- ***a distance of 10 m to the cables***

6 Validation

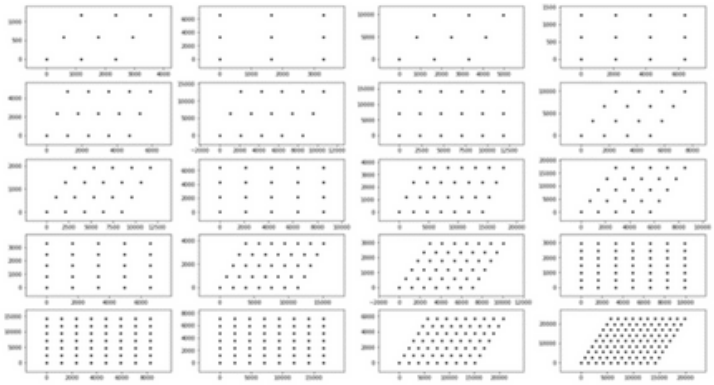
- 1620 simulated cases in FarmWise and WindFarmer, with 3 different climates for each farm:
- FarmWise calculates net AEP values very much in line with WindFarmer (average deviation of 0.66%).
- There are 2 sources of difference: gross AEP calculation (mean deviation of 0.86%) and loss calculation (mean deviation of 0.50%).
- The smaller the distance between turbines, the greater the wake losses and the greater the deviation in the loss calculation between WindFarmer and FarmWise.

Average difference in loss calculation:

- A Guarda: 0.51%
- Costa Brava: 0.42%
- Gran Canaria: 0.57%



Simulated farms in 3 different climates



For each of the 1620 farms and 3 climates, net production is calculated with FarmWise and WindFarmer, resulting in very similar results.

Send us your farm layout so we can analyse it and propose optimisations.

Contact: offshoreWind@sener.es

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