A practical Optimization for Offshore Wind Farm Layout

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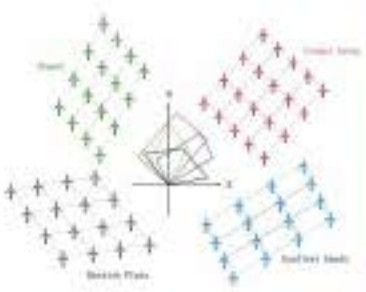
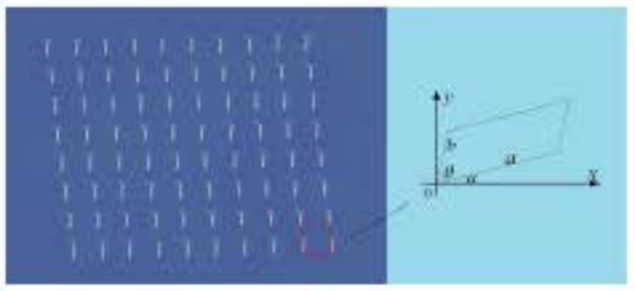
Abstract

The evenly distributed offshore wind resource calls for regular placement of wind turbines which is adopted in most offshore wind farms. An optimization for regular turbine layout and its case studies are presented to show the effectiveness and its potential for offshore wind power engineering application.

Objectives

A common practice for offshore wind farm layout is the regular arrangement of wind turbines, such as Horns Rev, London array, etc. However, given the similar wind resource, what is the optimal layout for London array and its neighboring offshore wind farms as following graph?





Upon the regular arrange of wind turbine, a windpower maximization strategy (WindMax) features uniform parallelogram arrangement for wind turbine location presented to maximize energy production.

Methods

A uniform layout of wind farm with staggered equally-spaced wind turbines arrangement can be described with parameters of a parallelogram, namely the two adjacent sides a and b, the angle θ between them, and the orientation angle of α. With each vertex standing for a wind turbine, the turbine position for row m+1 and column n+1 can be expressed with following formula under polar coordinate system.

$$\begin{cases} \rho_{mn} = \sqrt{(ma)^2 + (nb)^2 + 2mnab\cos\theta} \\ \gamma_{mn} = \arctan\dfrac{nb\sin\theta}{ma + nb\cos\theta} + \alpha \end{cases}, (m, n \in Z)$$

With such scheme, WindMax translates the layout optimization into geometry optimal value finding.

Aiming at wake loss minimization, WindMax performs an explicit enumeration of all admissible solution within various parallelogram parameters space to find the optimal layout, as shown on right side. The Jensen-Katic wake model is used to determine the wake loss with respect to 360 degree directions while maintain computing efficiency. The merged wakes are considered in WindMax by the sum of kinetic energy deficits of all turbines with full and partial wakes.

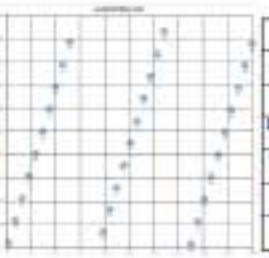
Case studies

The widely cited 3 case studies by Mosetti and Grady were used to show the effectiveness of WindMax . In such case, a wind farm with area of 2Km*2Km was divided into 10*10 square cells, the width of which is equal to 5 rotor diameter and the center of which can be placed with wind turbine.

Three cases with different wind resource: (a)uniform wind direction with a speed 12m/s; (b) 36-direction evenly distributed wind with a speed 12m/s; (c) 36-direction distributed wind with varied probabilityof the speeds 8, 12, and 17m/s as following:

Case (a) wind rose

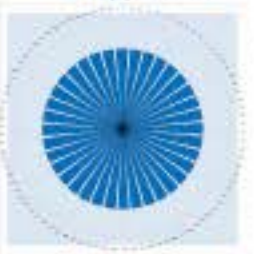
Grady layout



WindMax layout

Case (a)		
	Grady result	WindMax result
Turbine number	30	30
Mean wind speed (m/s)	12	
Wind speed after wake(m/s)	11.40	12
Production (MWh)	115169	134236
Layout efficiency(%)	94.68	100

calculation results



Case (b) wind rose

Grady layout

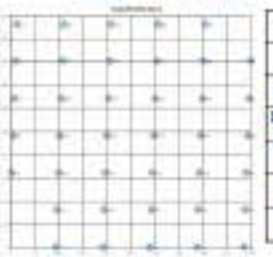
WindMax layout

Case (b)		
	Grady result	WindMax result
Turbine number	30	30
Mean wind speed (m/s)	12	
Wind speed after wake(m/s)	11.23	11.37
Production (MWh)	147121	152257
Layout efficiency(%)	93.66	95.97

calculation results

Case (c) wind rose

Grady layout



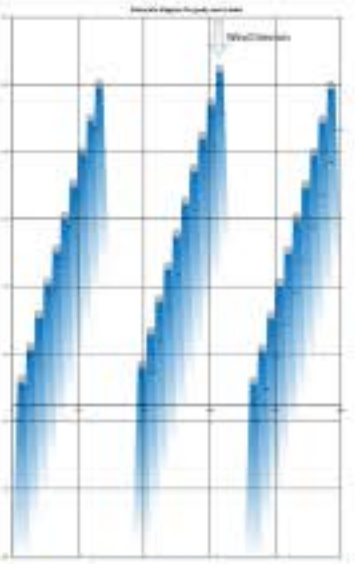
WindMax layout

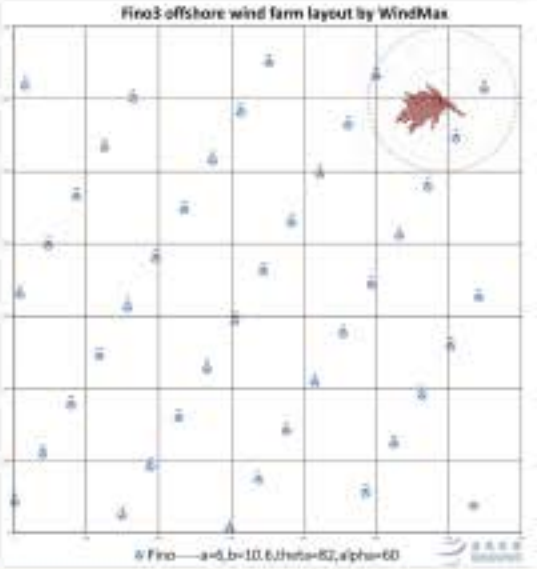
Case (c)		
	Grady result	WindMax result
Turbine number	30	30
Mean wind speed (m/s)	13.89	
Wind speed after wake(m/s)	13.02	13.17
Production (MWh)	165755	167360
Layout efficiency(%)	93.24	94.56

calculation results

Conclusions and Learning objectives

Case studies have shown WindMax advantages, although more case studies, especially real wind power projects, should be conducted to consolidate the conclusion. Additional explanatory graph for case(a) and an example for real offshore (Fino3) based on Dx wind mesoscale model data are shown below for interests.





References

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