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Flexible and efficient site constraint handling for wind farm layout optimization

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Publication date
2019

Citation (APA)
Quaeghebeur, E. (2019). *Flexible and efficient site constraint handling for wind farm layout optimization*. Abstract from Wind Energy Science Conference, Cork, Ireland.
https://zenodo.org/communities/wesc2019/?page=1&size=20

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Keywords: wind farm, site constraint, layout optimization, computational efficiency.

Flexible and efficient site constraint handling for wind farm layout optimization

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Wind farm sites can have complex, disconnected shapes and may encompass exclusion zones. Even offshore this is the case, due to sea lanes, underwater pipelines and cables, wrecks, and unidentified buried objects. An example is Borssele Wind Farm Site IV[1] (BWFS IV), which is pictured in Figure 1[1] as the collection of green-colored parcels. Within BWFS IV, as shown in Figure 2[1], there is an archaeologically significant wreck—red boat—and multiple magnetic anomalies—green dots—that indicate buried objects. Furthermore, regulations require turbines to be placed a certain safety distance—one rotor radius—inside the parcels.

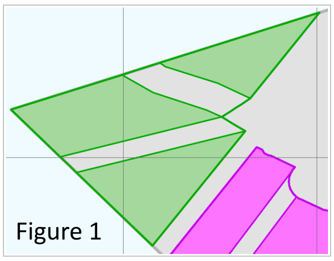
Figure 1

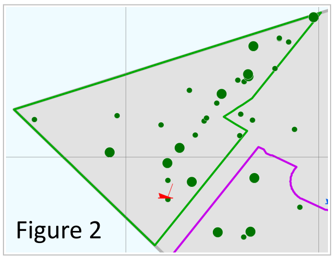
Figure 2

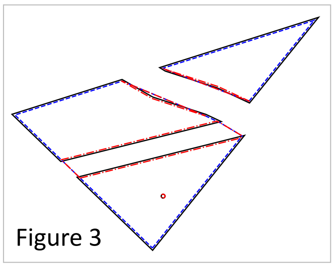
Figure 3

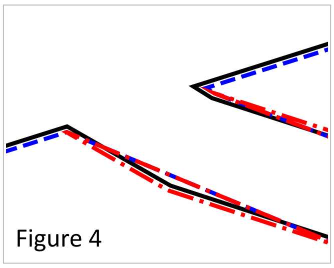
Figure 4

We present a structured site specification format that can flexibly represent such complex cases. We also present efficient algorithms based on this format (i) for checking whether a turbine is located inside the site's parcels and (ii) for finding the closest point on the parcel borders for turbines located outside. These algorithms can be used in wind farm layout optimization for checking and correcting layouts.

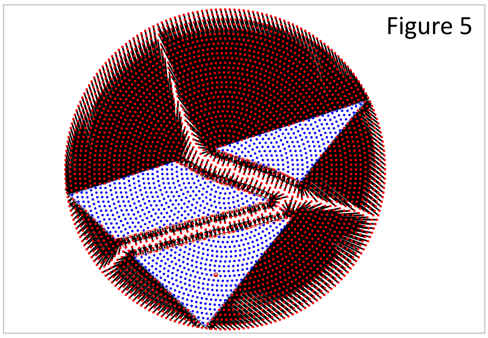
Figure 5

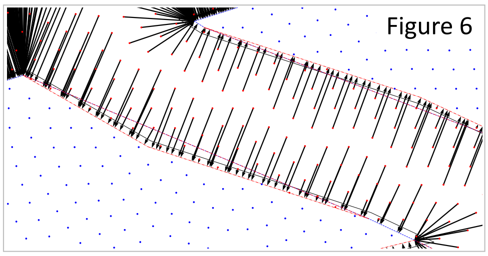
Figure 6

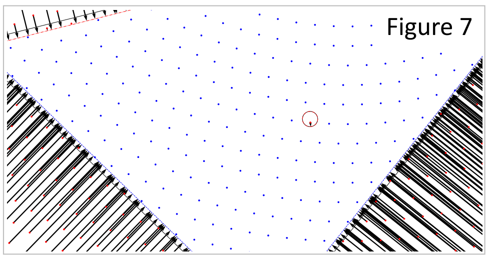
Figure 7

The flexible structured site specification format is built up of convex polygons—represented as sets of linear constraints—and discs—using circular constraints—, either of which can be used for specifying parcels or exclusion zones. Both parcels and exclusion zones can contain multiple exclusion zones or parcels, respectively. This nesting can be arbitrarily deep. Safety distance requirements can be specified at the individual constraint level.

Figure 3 shows the possible structure for BWFS IV: boundaries for safety distance-inclusive parcels are blue and those for exclusion zones are red; the boundaries specified in the site's documentation[1] are black. Figure 4 zooms in on part of two parcels, each with a thin concavity-filling exclusion zone.

The algorithms are recursive and make use of the nested site specification to avoid doing work for turbines not around or inside a parcel or exclusion zone. They make use of pre-computed information to calculate turbine-to-constraint distances and vectors using only dot products, multiplications, and—for circles—square roots. Both the work avoidance and pre-computation techniques contribute to the high computational efficiency.

Figure 5 shows the result of the algorithms when applied to 3660 turbines placed in a disc centered on BWFS IV: those inside are blue dots and those outside are red dots. It also shows the vectors towards the closest border points, which is visible in more detail in the zoomed-in areas in Figures 6 and 7. Note especially the turbine in the wreck exclusion zone in Figure 7.

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[1] RVO. *Borssele Wind Farm Zone, Wind Farm Sites III and IV*. (2016) https://offshorewind.rvo.nl/file/download/44692942.