Modular Approach for the Optimal Wind Turbine Micro Siting Problem through CMA-ES Algorithm [1]

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Abstract

Although, only in recent years, northern European countries started to install large offshore wind farms, it is expected that by 2020, several dozens of far and large offshore wind farms (FLOWFs) will be built. These FLOWFs will be constituted of a considerable amount of wind turbines (WTs) packed together, leading to an energy density increase. However, due to shadowing effects between WTs, power production is reduced, resulting in a revenues decrease. Therefore, when FLOWFs are considered, wake losses reduction is an important optimization goal. This work presents a modular approach to optimize the energy yield of FLOWFs through an evolutionary algorithm. The method consists of a modular strategy where the site wind rose information is used in different steps, which accelerates the calculation of the wake losses. The main contribution of this paper is the use of surrogate models to optimize the layout of offshore wind farms. Although, the surrogates models do not make use of the entire wind information set, they preserve the main problem trend. At the end, the results obtained are tested for their sensitivity regarding the wind data and the turbine locations.

1 Introduction

According to the European Commission, offshore wind will have a substantial contribution in helping the European Union to meet its energy policy objectives. Hence, a substantial increase in the offshore wind installed capacity is expected in the coming years [1]. In order to reduce costs, e.g. internal collection system cost, turbines tend to be packed in WFs. However, the installation of wind turbines (WTs) close to each other causes interferences such as shadowing effects. For example, the efficiency of the Danish Horns Rev offshore wind farm is 11% lower when compared to what the same turbines would produce if installed alone [4]. Optimizing the WT micro siting is one possible strategy to reduce wake losses. In this work, the wake growth model used was proposed in [3].

2 Optimization Approach

The covariance matrix adaptation evolution strategy (CMA-ES) is the algorithm used. It is one of the most powerful evolutionary algorithms for real-valued single-objective optimization of non-linear and non-convex functions [2]. The optimization goal in this paper is to maximize the wind farm efficiency.

[1]The full paper has been published in *Proceeding of the fifteenth annual conference companion on Genetic and evolutionary computation conference companion*, pages 1561–1568, 2013.

The proposed optimization scheme is composed of three steps. The first step makes use of only the main wind direction to optimize the WTs siting problem. In this phase, the main wind sector is considered. In the third stage, the entire wind rose is now used. Hence, the wake losses model is slower but it offers maximum accuracy. The proposed approach is compared with a standard optimization method, where the offshore WF layout is optimized using the complete wind rose information during the entire optimization process.

3 Results

Figure 1 shows the best fitness values during both optimizations. For the proposed method the wind farm efficiency was recalculated in order to considered the entire wind rose (green curve). The blue curve represents the wind farm efficiency seen by the algorithm during the optimization. During the second step of the proposed method, it can be seen that the same curve shape can be found in the blue and green curves. For this wind rose, it can be concluded that, even though only 25% of the wind information is being used, the wake losses are, to some extent, representative for the entire wind rose.

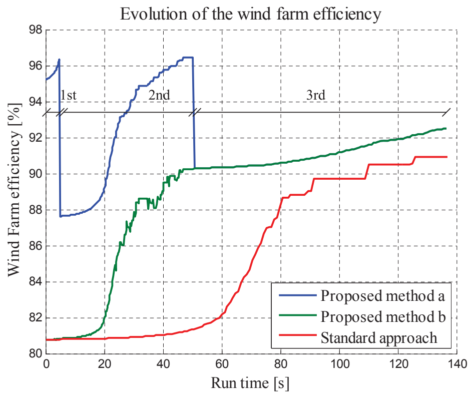

Figure 1: Best found fitness values during optimization for both strategies.

4 Conclusions

The proposed approach is able to obtain better layouts while requiring lower computational power, since the surrogates used are able to preserve the main problem trend without using the entire wind rose. Due to the lower computational complexity, the algorithm convergence to improved layouts is speeded up since more wake losses evaluations are performed within the same calculation time of the standard optimization approach.

References

[1] European Commission. [Last accessed 1st March 2013], 2008.

[2] N. Hansen and S. Kern. Evaluating the CMA Evolution Strategy on Multimodal Test Functions. In *Parallel Problem Solving from Nature*, volume 3242, pages 282–291. Springer, 2004.

[3] N. Jensen. A note on wind generator interaction. Technical report, Risø National Laboratory, 1983.

[4] Thomas Sorensen, Morten Lybech Thogersen, and Per Nielsen. Adapting and calibration of existing wake models to meet the conditions inside offshore wind farms. Technical report, EMD International A/S, 2008.