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Multi-objective optimization of wind farm layouts – Complexity, constraint handling and scalability

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ABSTRACT

Currently, Offshore Wind Farms (OWFs) are designed to achieve high turbine density so as to reduce costs. However, due to wake interferences, densely packing turbines reduces energy production. Having insight into optimized trade-offs between energy production, capital investment and operational costs would be valuable to OWFs designers. To obtain this insight, the design of OWFs should be formulated as a multi-objective optimization problem. How to best solve a Multi-Objective Wind Farm Layout Optimization Problem (MOWFLOP) is however still largely an open question. It is however known that evolutionary algorithms (EAs) are among the state-of-the-art for solving multi-objective optimization problems. This work studies the different features that an MO Evolutionary Algorithm (MOEA) should have and which Constraint-Handling Techniques (CHTs) are suitable for solving MOWFLOP. We also investigate the relation between problem dimensionality/complexity and the degrees of freedom offered by different turbine-placement grid resolutions. Finally, the influence of problem size on algorithm performance is studied. The performance of two variants of the recently introduced Multi-Objective Gene-pool Optimal Mixing Evolutionary Algorithm (MOGOMEA) is compared with a traditional and a novel version of the Nondominated Sorting Genetic Algorithm II (NSGA-II). Five CHTs were used to assess which technique provides the best results. Results on a case study with different OWF areas demonstrate that one variant of MOGOMEA outperforms the NSGA-II for all tested problem sizes and CHTs.

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Contents

1. Introduction	588
1.1. What characteristics should an optimization algorithm have to present optimized layouts?	590
1.2. What is the best constraint-handling technique to ensure feasibility of the OWF layouts?	590
1.3. How does the problem complexity scale with the number of design variables?	590
1.4. What is the relation between problem dimensionality/complexity and the degrees of freedom offered by different turbine-placement grid resolutions?	590
2. Multi-objective wind farm layout optimization problem	591
2.1. Wake losses	591
2.1.1. Katic-Jensen wake model	592
2.1.2. Assumptions	592
2.2. Constraint-handling	592
2.2.1. No constraints	593
2.2.2. Resample	593
2.2.3. Penalty term	593
2.2.4. Constraint domination	593
2.2.5. Repair mechanism	593
2.2.6. Extra optimization goal	593
2.3. Domain of optimization variables	593

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2.3.1.	Real-coded	593
2.3.2.	Mixed-integer	593
2.3.3.	Discrete	594
3.	Optimization algorithms for the multi-objective wind farm layout optimization problem	594
3.1.	Definitions for MO optimization	594
3.2.	Characteristics	594
3.2.1.	Clustering	594
3.2.2.	Single-objective optimization	594
3.2.3.	Problem structure exploitation	594
3.3.	MOGOMEA	595
3.3.1.	Population initialization	595
3.3.2.	<i>k</i> -leaders	595
3.3.3.	Clustering	595
3.3.4.	Linkage learning	595
3.3.5.	MO Gene-pool Optimal Mixing	595
3.3.6.	Survivor selection and automated population sizing	596
3.3.7.	Elitist archive	596
3.4.	o-MOGOMEA	597
3.5.	NSGA-II	597
3.5.1.	Population initialization	597
3.5.2.	Ranking and crowding	597
3.5.3.	Parents selection	597
3.5.4.	Sampling	597
3.5.5.	Ranking and crowding	597
3.5.6.	Selection	598
3.5.7.	Elitist archive	598
3.6.	c-NSGA-II	598
3.7.	Overview of the algorithms	598
4.	Case study	598
4.1.	Turbine and wind resource	598
4.2.	Wind farms	598
4.3.	Optimization goals	599
4.3.1.	Energy production	599
4.3.2.	Efficiency	599
4.4.	Constraint-handling approaches	599
4.4.1.	No constraints	600
4.4.2.	Constraint domination	600
4.4.3.	Penalty term	600
4.4.4.	Repair mechanism	600
4.4.5.	Resample	600
4.5.	MOEAs	600
4.5.1.	MOGOMEA and o-MOGOMEA	600
4.5.2.	NSGA-II and c-NSGA-II	600
4.6.	Measuring performance	600
5.	Results	600
5.1.	What characteristics should an optimization algorithm have to present optimized layouts?	600
5.1.1.	Clustering	603
5.1.2.	SO Optimization	603
5.1.3.	Problem internal structure	603
5.2.	What is the best constraint-handling technique to ensure feasibility of the OWF layouts?	603
5.3.	How does the problem complexity scale with the number of design variables?	603
5.4.	What is the relation between problem dimensionality/complexity and the degrees of freedom offered by different turbine-placement grid resolutions?	603
5.5.	Multi-resolution	605
5.6.	Wind farm layouts	605
6.	Conclusions	605
	Acknowledgements	607
	References	607

1. Introduction

In 2007, the European Union (EU) targeted to generate 20% of its energy consumption through renewable sources and to improve the energy efficiency by 20% compared to 1990 levels, by 2020 [1]. Renewable energy sources are anticipated to help Europe meet these challenging targets. Among other renewable sources, such as hydro, solar and onshore wind, the northern European countries have been investing in Offshore Wind Farms (OWFs) for

more than two decades due to higher and steadier mean wind speeds offshore compared to onshore and lower visual impact [2,3].

The EU and the European Wind Energy Association (EWEA) estimated that the joint installed capacity of European OWFs will be 40 GW by 2020 and 150 GW by 2030 [1,4,5]. These predictions require a yearly increase rate of the offshore installed capacity of 29.6% and 19.1% to be satisfied, respectively [6]. Fig. 1 shows that these predictions may represent plausible scenarios since the

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