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

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A B S T R A C T

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.

Contents

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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