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Optimisation of Offshore Wind Farms Using a Genetic Algorithm

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A modular framework for the optimisation of an offshore wind farm using a discrete genetic algorithm is presented. This approach uses a bespoke grid generation algorithm to define the discrete positions that turbines may occupy, thereby implicitly satisfying navigational and search and rescue constraints through the wind farm. The presented methodology takes a holistic approach, optimising both the turbine placement and intra-array cable network while minimising the levelised cost of energy and satisfying real-world constraints. This tool therefore integrates models for the assessment of the energy production including wake losses, the optimisation of the intra-array cables, and the estimation of the costs of the project over the lifetime. This framework will allow alternate approaches to wake and cost modelling as well as optimisation to be benchmarked in the future.

INTRODUCTION

With the growth of the offshore wind sector and the development of large offshore wind farms in the coming years, it has become an important point to ensure that the wind farms are developed in such a way as to maximise their potential. In order to meet this need, the field of wind farm layout optimisation has been in development since the seminal paper by Mosetti et al. (1994). Though this field has been in development for the past twenty years, there still remains much work before layout optimisation displaces the industry standard rule-of-thumb approach to layout design. This paper presents a new framework that has been developed to address the layout optimisation problem, with the goal of ultimately developing a tool that would be deployed by wind farm site developers.

This framework takes a holistic approach to layout optimisation based on the objectives and constraints that would be faced by an offshore wind farm developer in the UK. This approach introduces a generalised means of discretising the wind farm area in such a way that a grid of potential turbine positions is first generated. The use of this grid ensures that the final turbine positions, which are selected from this grid, satisfy the requirement of having turbines along straight lines.

From the perspective of an offshore wind farm operator, it is important not only to maximise the energy yield from the wind farm but also to optimise the levelised cost of energy (LCOE). The full layout optimisation problem therefore represents striking a balance between maximising the energy yield and minimising the lifetime costs.

To this end, a number of projects have looked at the optimisation of wind farm layouts. This project has addressed this problem through a similar approach to previous schemes by using a genetic algorithm (GA) to minimise the LCOE (Mosetti et al., 1994; Grady et al., 2005; Elkinton, 2007; Fagerfjäll, 2010; Guillen, 2010):

$$LCOE = \frac{\sum_{t=1}^{n} C_t/(1+r)^t}{\sum_{t=1}^{n} AEP_t/(1+r)^t} \tag{1}$$

where C_t are the costs incurred in year t, n is the project lifetime time, AEP_t is the annual energy production (AEP) in year t, and r is the discount rate of the project. The LCOE measured in £/MWh effectively gives a measure of the cost effectiveness of the layout proposed and therefore acts as a means to compare the layouts under consideration on a relative basis.

Existing approaches do not apply tools and methodologies that have considered all the constraints faced by a developer, nor do

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