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Study on offshore wind farm layout optimization based on decommissioning strategy

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Abstract

In recent years, along with the first generation of wind power reaching retirement age, the high decommissioning cost arises with more and more attention all around the word. To reduce this huge cost, an innovative offshore wind farm layout optimization method based on decommissioning strategy is presented in this paper. In the optimization method, the decommissioning strategy means that the foundations can be reused after the retirement of the first generation of wind turbines, and then smaller second-generation wind turbines will be installed on the original foundations. The optimization process is based on the Multi-Population Genetic Algorithm (MPGA). A conceptual two-dimensional (2D) wake model is adopted to calculate wind losses caused by wake effect. The Cost of Energy (COE) is regarded as the criteria to judge the effectiveness of this new method. The way to estimate costs will also be introduced in this study. Finally, a case study in Waglan sea area in Hong Kong is analyzed and discussed. From the case results, Hong Kong is an ideal region to develop the offshore wind industry, and the proposed optimization method can reduce the COE down to 1.02 HK$/kWh.

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Keywords: Offshore wind farm layout optimization; Decommissioning strategy; Multi-population genetic algorithm; Cost of energy.

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1. Introduction

With global population and economy increase annually, the demand of energy, one crucial input for socio-economic development, is also increasing dramatically [1]. Offshore wind power generation develops rapidly at moment and represents the most potential renewable energy supply to coastal cities in the future. In the year 2016, global new offshore wind capacity additions totaled 2.219 GW, which brought total offshore wind installed capacity to 14.384 GW [2].

On the other hand, as the first generation of offshore wind turbines approaches the end of their 20-year service, a new decommissioning market is emerging [3]. However, unlike onshore wind turbine decommissioning, where service providers have accumulated sufficient experience to enable them to carry out the works rapidly, decommissioning offshore wind turbines requires a much larger spatial and time scale. Thus, a new challenge may arise due to an unexpected increase in decommissioning costs.

Offshore wind turbines have a longer life expectancy than onshore turbines, which is around 25–30 years [4]. The offshore wind farm will be decommissioned in order to protect marine ecological environment after its life cycle's operation. However, the foundation is too often overdesigned [5]. To reduce the huge decommissioning cost, an original decommissioning strategy based offshore wind farm layout optimization method is presented in this paper. In the optimization method, the COE criteria is on account of two generations' energy output and total cost, the COE comparison of this innovative method and conventional method will be shown in this paper.

Nomenclature

2D	two-dimensional
COE	cost of energy
MHK$	million Hong Kong dollar
MPGA	Multi-Population Genetic Algorithm
O&M	operation and maintenance
WT	wind turbine

2. Decommissioning strategy

The decommissioning strategy presented means when the first generation offshore wind turbines are decommissioned, foundations can still be utilized after some strengthen strategies in the second generation. In this study, costs include: capital cost, operation and maintenance (O&M) cost and levelised cost. The difference between conventional strategy and decommissioning strategy lies in the capital cost, which consists of WT cost, foundation cost, installation cost and other costs (like grid connection cost and decommissioning cost). The capital costs of conventional strategy and decommissioning strategy are shown in (1) and (2) respectively.

$$Cost_{capital} = Cost_{WT} + Cost_{f} + Cost_{installation} + Cost_{decommissioning} \quad (1)$$

$$Cost_{capital} = Cost_{WT1} + Cost_{f1} + Cost_{installation} + Cost_{strengthening} + Cost_{WT2} + Cost_{installation} + Cost_{decommissioning2} \quad (2)$$

In the formulae, $Cost_{WT}$ is the WT cost, referenced from $Cost_{WT} = A_P + B_P \cdot P_{rated}$ [6]; $Cost_f$ is the foundation cost, assumed to be 6.075 MHK$ per foundation; $Cost_{installing}$ is the installation cost, assumed to be 80% of the wind turbine cost; $Cost_{decommissioning}$ is the decommissioning cost, assumed to be 60% of the installation cost; $Cost_{strengthening}$ is the strengthening cost, assumed to be 10% of the installation cost.