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Stochastic Prediction of Offshore Wind Farm LCOE through an Integrated Cost Model

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Abstract

Common deterministic cost of energy models applied in offshore wind energy installations usually disregard the effect of uncertainty of key input variables – associated with OPEX, CAPEX, energy generation and other financial variables – on the calculation of levelized cost of electricity (LCOE). The present study aims at expanding a deterministic cost of energy model to systematically account for stochastic inputs. To this end, Monte Carlo simulations are performed to derive the joint probability distributions of LCOE, allowing for the estimation of probabilities of exceeding set thresholds of LCOE, determining certain confidence intervals. The results of this study stress the importance of appropriate statistical modelling of stochastic variables in order to reduce modelling uncertainties and contribute to a better informed decision making in renewable energy investments.

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Keywords: Offshore wind farm; probabilistic cost model; Monte Carlo simulation, levelised cost of electricity, stochastic inputs

1. Introduction

Sources of uncertainty affecting investment decisions for offshore wind energy projects, can be found in the amount of capital, operating, decommissioning and financing costs, as well as in technical aspects, such as the wind farm availability, aerodynamic, electrical array and other losses. Considering the continuous progress in the sector,

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these input variables are continuously updated, while they also vary significantly across different regions and water depths. These input variables can be, thus, better defined within a range and a probabilistic analysis can be employed, in order to derive probabilities of obtaining a certain amount of cost of energy.

A common measure to evaluate the life-cycle costs of generation of an energy project, as well as to compare different generation technologies is the levelized cost of electricity (LCOE), accounting for the installed capital cost, the annual operating expenses, as well as the annual energy production [1,2]. This metric allows to calculate the per unit of electricity generated cost, expressed in £/MWh. The contribution of the present study lies in the amplification of a deterministic cost of energy model of a representative offshore wind farm (OWF) [3] with the incorporation of uncertainty in key input parameters to derive representative ranges of LCOE values.

2. Costs of offshore wind farms

2.1. Capital and operating costs of an offshore wind farm

Capital expenditure comprises costs for building and commissioning of the plant, such as costs associated with the project development and consenting up to financial investment decision (FID), material and labor costs for the turbine, support structure, tower, foundations, array cables, installation, transmission build and insurance during the construction phase. Capital costs in the offshore wind energy industry have been increasing over the last decade owing to a number of reasons: installations in deeper waters and farther from shore bearing increased construction and installation costs, rise in turbine prices due to design improvements ensuring higher reliability levels (as a result of the higher awareness of technical risks), constraints in port and vessel availability, changes in global and national macroeconomic drivers, such as labor, increasing prices of commodities and energy and fluctuations in exchange rates impacting the capital cost structure. CAPEX values range across a number of sources as illustrated in Fig. 1a.

Operation and maintenance (O&M) costs account for ongoing costs needed to operate and maintain the plant. OPEX usually consists of fixed costs that do not depend on the plant uptime and variable costs that depend on the time the plant operates. Operations mostly represent activities associated to high level management of the plant, such as remote and environmental monitoring, administration, marketing, insurance, payment of the rent and other back office activities. Maintenance is the task that bears most of the effort, cost and risk, consisting of preventative (costs of proactive repairs based on condition monitoring systems) and corrective maintenance tasks (involving costs for reactive repair or replacement of equipment). A number of recent publications (Fig. 1b) have attempted to estimate ranges of operating costs for offshore wind installations either based on historical data of installed projects, or through publically available data and direct surveys of project developers [4, 5].

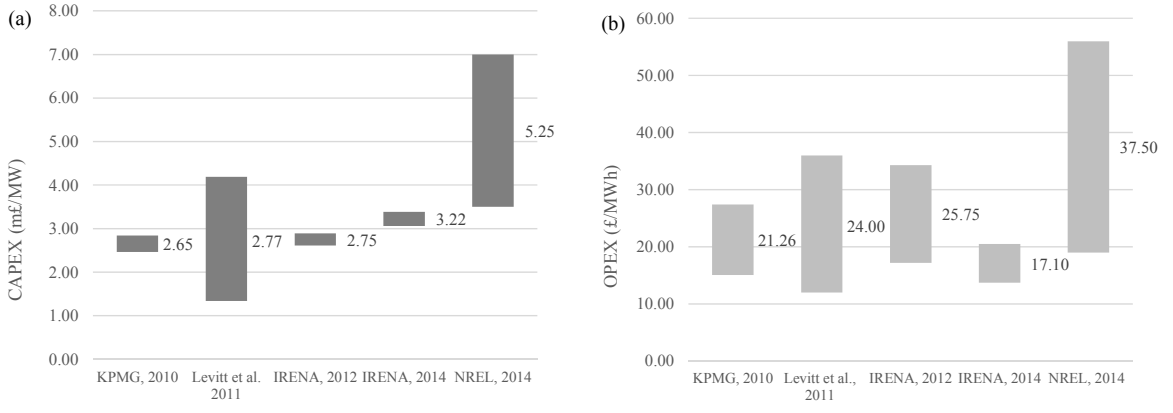

Fig. 1. (a) Range and average values of capital costs (£m/MW) in existing literature compiled and converted to 2015 £ currency; (b) Range and average values of operating costs (£/MWh) in existing literature compiled and converted to 2015 £ currency (Sources:[4–8])