COST AND UNCERTAINTY IN OVERPLANTING THE DESIGN OF OFFSHORE WIND FARMS

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Overview

To date the connection of offshore wind farms is subjected to a Maximum Export Capacity (MEC) set in their connection agreement with the Transmission System Operator (TSO). Generators can export up to their contracted MEC, with any additional generation curtailed by the TSO. However, the share of time an offshore wind farm is generating at its MEC tends to be low. Overplanting the offshore wind farm by installing a higher wind farm capacity compared to the fixed electrical infrastructure can result in better overall economics, but because wind speeds and wind farm component availabilities are uncertain, there are trade-offs between the probability of additional revenue produced by capturing more wind and higher capital costs of over-installation of turbines. Nevertheless, there is enough evidence to suggest that overplanting can lead to further cost reductions in the maturing offshore wind sector [1-2]. The percentage of time an offshore wind farm operates at its MEC is an indication of the extent to which the asset can profit from higher transmission utilisation rates. This paper provides a framework to assess overplanting when developers, policy-makers or regulatory bodies are confronted with trade-offs between cost and uncertainty. The paper sheds light onto which sites and technology-specific factors make overplanting a viable option. Finally, the findings of the paper are exemplified by an industrial case study where several offshore wind farms configurations are analysed.

Methods

The modelling approach to offshore wind cost analysis presented in this paper is based around the Offshore Wind Cost Analysis Tool (OWCAT) developed at the EDF Energy R&D UK Centre [3-7]. This cost modelling tool has been used in the past for comparative evaluation of multiple sites, detailed evaluation of specific project layouts and sensitivity studies on both design/technology choices and cost variations. The tool has been validated against cost data from the Navitus Bay, Courseulles sur Mer and Neart na Gaoithe projects and shown to be accurate within ±15% for these cases. The model consists of four main modules: a wind farm design module, a cost calculation module, a financial module and an overarching stochastic module which allows inputs to be represented by probability distribution functions.

In order to determine the optimal size of an offshore wind farm relative to its electrical infrastructure, factors such as the wind speed, wind turbine and inter-array cable availabilities, electrical losses, wake effects and the ratio of the wind turbine expenditure to the grid connection are taken into consideration. This analysis takes advantage of the stochastic capabilities of the cost modelling tool and propagates the uncertainties of the wind speed and availabilities to the financial metric via a double-loop Monte Carlo Simulation. The share of time the wind farm is producing at MEC is calculated within the Annual Energy Production module via an inner Monte Carlo simulation; uncertainties in the wind speed, electrical losses and availabilities are propagated to the AEP estimate. Furthermore, wake losses are modelled by reducing the power avaible in the wind and a degradation factor is considered by decreasing the energy produced by the wind turbines as the asset ages. The outer Monte Carlo simulation models the uncertainty of key variables such as the estimated mean wind speed, wake losses, the degradation factor and the availabilities.

Risk aversion is modelled by risk metrics originated in the financial mathematics literature such as the Value at Risk (VaR) and Conditional Value at Risk (CVaR). Whereas VaR gives the probability that a certain outcome is worse than a given threshold, CVaR gives the expected outcome given that the value is worse than VaR, providing information on the extent to which values might materialise beyond the threshold amount indicated by VaR. The risk appetite of the developer, policy-maker or regulatory body is modelled as weighted average ω of CVaR and expected value, from 0 (risk neutrality) to 1 (extreme risk aversion).

Results

Several offshore wind farm configurations are analysed in terms of its suitability to overplanting. All wind farm configurations result in economic benefits when overplanting. However, the optimal amount of overplanting is dependent on site and technology-specific factors. In addition to that, and given the fact that this problem is embedded within the global framework of uncertainty quantification, where the variable of interest is the Levelised Cost of Energy and the quantity of interest is parametrised by the risk appetite of the developer or policy-maker, different optimal levels of overplanting are obtained as a function of the risk appetite, site and technology-specific factors.

Conclusions

Overplanting a wind farm by installing a higher wind farm capacity compared to the fixed electrical infrastructure results into further optimisation of offshore wind farms despite power output being curtailed at generation's peaks. This paper has provided a framework to assess overplanting when developers, policy-makers or regulatory bodies are confronted with trade-offs between cost and uncertainty. Not only there is enough evidence that overplanting results into better overall economics to offshore wind developers but it can also provide significant cost savings for electricity consumers through the system benefits of higher transmission utilisation, lower reserve procurement and some ancillary services, and should, therefore, be taken into consideration when drafting future energy policy.

References

This research is based on work carried out at the Industrial Doctoral Centre for Offshore Renewable Energy (IDCORE), The University of Edinburgh and EDF Energy R&D UK Centre.

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