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Optimising power transmission options for marine energy converter farms

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ABSTRACT

This paper introduces a techno-economic analysis framework to assess different transmission options for marine energy converter (MEC) farms. On the technical front, the feasibility of the transmission options considering supply quality constraints and the optimal sizing of reactive power compensation to allow maximum real power transfer capability in the subsea transmission cable have been considered. The economic viability of different transmission options are measured based on component costs and the costs associated with the transmission losses. A case study has been presented in the paper, which demonstrates the application of this techno-economic analysis framework on a range of MEC farm sizes and distances from the shore. The results characterise the performance of different transmission system options with respect to three key design parameters – distance to shore, array power and transmission voltage – and provide guidance for system design.

1. Introduction

As marine energy converter (MEC) deployment moves from single device installations to arrays and farms of devices, a concept engineering study of the electrical infrastructure is required to inform the connection of these commercial scale farms to the electricity network. Although the marine energy sector can learn from experience in the offshore wind sector, e.g. [1–3], there are a number of engineering challenges which are unique to the marine energy sector. The fact that there are potentially more subsea components in areas with stronger wave and tidal current conditions creates new design challenges for the operation and installation of electrical networks and components.

The harsher operating conditions in the marine renewable energy (MRE) environment may require the use of specialised components, which are generally more expensive than commercially available products. This can result in a higher levilised cost of energy (LCOE) – which defines the power cost per unit to break even over the project lifetime – than competing offshore generation technologies. In order to gain a market share, the LCOE of MEC arrays has to be comparable. Without subsidy, there are two general ways to achieve this: by reducing component cost or by maximising the use of existing assets. Reducing component cost will require an increase in production volume and will only happen when the industry reaches

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maturity. However, by detailed cost-benefit analysis, electrical networks can be designed to ensure maximum possible return for the available resources and network capacity.

In this paper, a techno-economic analysis framework for allowing maximum real power transfer across the transmission network is described. This is illustrated by assessing the impact of three of the most important array design parameters – the installed capacity, the export cable length and the transmission voltage – on the cost and performance of the transmission system. The boundaries of these parameters are defined with respect to the current needs of the industry, and are representative of pre-commercial and full commercial deployment. They are set to installed capacity of less than or equal to 100 MW and an export cable length of less than or equal to 50 km, respectively [4].

In this operating region, ac transmission is still the most economical solution (dc transmission may become a better solution for distances greater than 50 km and for farm sizes greater than 500 MW [5–7]). With ac transmission, the capacitance of the cables causes a charging current to flow through it. This limits the real power transfer back to shore if the transmission system is not properly designed. The fact that the cost of the export cable is high, and that it can constrain the output of the array, makes it particularly interesting for cost-benefit analysis.

The transfer capability of the ac transmission can be improved using reactive power compensation and a detailed study of the sizing of onshore and offshore reactive power compensation to utilise the transmission capacity of the export cable is presented. A case study investigates the impact of reactive power compensation on the cost and efficiency of the MEC array transmission system, highlighting the importance of the design of the transmission network to the array performance. Power losses within the intra-array network are generally small in comparison with the transmission network losses and the design of the intra-array network is a different process altogether; accordingly, the efficiency of the intra-array network is not considered in the analysis. The results presented here are part of ongoing research and will serve to highlight the sensitivity of the overall system to alternative designs, and will help to determine the prevailing parameters for optimal design of offshore networks.

The paper is structured as follows. Section 2 introduces the main subsystems present within an offshore MEC farm. The techno-economic analysis framework is defined in Section 3. Both the technical and economic aspects considered in this work are described in more detail in Sections 4 and 5, respectively. A case study is presented in Section 6. The conclusions and areas of further work are discussed in Section 7.

2. Design of marine energy converter farms

The electrical system of a MEC farm follows a hierarchical structure from production to grid connection. A generic offshore network architecture is shown in Fig. 1 which clearly identifies the subsystems within. Note that the terms MEC array and MEC farm have been used interchangeably in this paper, and have not been selected based on the rating of the development and/or the number of devices within it.

The design of the MEC farm layout depends on a multitude of factors, ranging from the site characteristics and the level of performance required from the system to the available capital cost. Some of the most important decisions which must be taken during the design can be defined as follows:

- The transmission system between the collection point and the onshore network.
- The number and type of offshore collection points.
- The intra-array network layout.

The network design will typically start with the selection of the export cable of the transmission system. Once this has been defined, the need for a collection point is then assessed, which will be performed in conjunction with decisions on the layout of and control within the intra-array network. This section presents an overview of the options that are currently

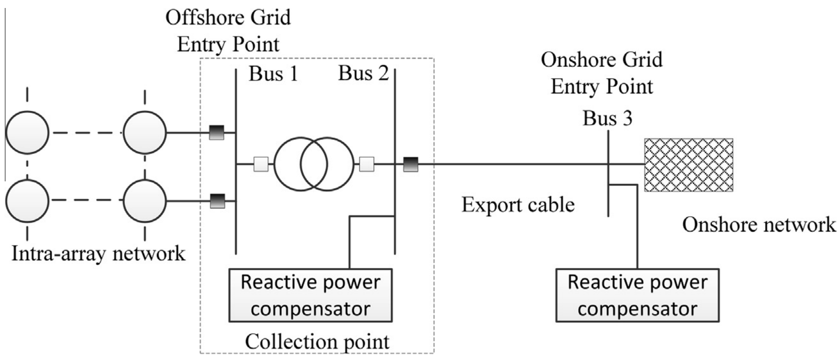

Fig. 1. Simplified generic offshore electrical network for MEC arrays.