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Grid parity in tidal stream energy projects: An assessment of financial, technological and economic LCOE input parameters

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Abstract

Assessments in electricity production technologies are usually supported by a levelised cost of energy (LCOE) analysis. Such cost analyses are riddled with uncertainty, with LCOE values depending on a number of financial, technical and economic variables. When it comes to minimising LCOE, the question arises as to which parameters have a greater bearing — especially if the current grid parity gap between tidal stream energy and conventional sources is to be narrowed. The aim of this study is to investigate the independent effects of the input variables on LCOE values, in order to determine the main drivers in closing the grid parity gap between tidal stream energy costs and traditional grid-power costs. The assessment features six tidal stream farms, in which different numbers of turbines, rows and spacing are considered. Not only are the device interactions of each configuration considered (by means of numerical modelling) but also the impacts of the financial and economic variables. In addition to individual variable sensitivity, a multivariable scenario analysis estimates the combined effect on the projected LCOE of varying an entire set of inputs simultaneously. As a result, it is found that the power coefficient is one of the inputs with the greatest bearing on the LCOE, closely followed by the discount rate and the capital costs (CAPEX). On this basis, a LCOE best-case scenario is constructed, which characterises tidal stream energy projects in terms of economic viability over a variety of conditions in four countries.

Introduction

If future sustainable energy needs are to be fulfilled, there is an urge for reducing reliance on fossil fuels and placing a greater emphasis on renewable energy sources (Azzellino et al., 2013, Masini and Menichetti, 2013). A number of viable renewable energies could be exploited to achieve this goal, among which marine energies are receiving increased attention (Jeffrey et al., 2014, Vazquez et al., 2014), i.e. offshore wind energy (Astariz et al., 2015a, Pérez-Collazo et al., 2015, Veigas et al., 2014, Veigas and Iglesias, 2014), wave energy (Abanades et al., 2015a, Abanades et al., 2015b, Carballo et al., 2015, Carballo et al., 2014, Vicinanza et al., 2013) and tidal stream energy (Garrett and Cummins, 2005, Ramos et al., 2014a, Ramos et al., 2013, Ramos and Iglesias, 2013, Robins et al., 2014, Sanchez et al., 2014a, Sanchez et al., 2014b, Sanchez et al., 2014c). The latter, which taps the kinetic energy of the currents caused by the tide, presents significant advantages with respect to the others: abundant resource in a number of places worldwide (Fairley et al., 2013, Neill et al., 2014, Ramos et al., 2014b), predictable character (Pacheco et al., 2014, Robins et al., 2014, Willis et al., 2010), public acceptance and positive associated externalities (i.e. social benefits) (Vazquez and Iglesias, 2015a). Despite these advantages and the demand for more sustainable forms of energy, tidal stream energy has not become a major energy supply contributor so far (IRENA, 2014). As an indicative example, the UK has around 50% of Europe's tidal energy resource (DECC, 2013a), but the participation of this renewable in the national energy mix represents less than 5% (DECC, 2013b). Several reasons could explain this scarcity (Ouedraogo et al., 2015), from a need for technological developments to the existence of policy barriers; however, it is generally agreed that the economic disadvantage of this new sector has the greatest bearing on such a low number of operational projects (Jeffrey et al., 2014, MacGillivray et al., 2014, Verbruggen et al., 2010). When it comes to selecting an energy option for a given application, the decision lies on its economic feasibility (Astariz and Iglesias, 2015): if tidal stream energy projects are to succeed, their cost needs to be competitive in the current electricity market.

The cost-competitiveness of an energy project is typically assessed on the basis of the levelised cost of energy (LCOE) (Lucheroni and Mari, 2014), a fundamental economic parameter defined as: “the ratio of total lifetime expenses versus total expected outputs, expressed in terms of the present value equivalent” (i.e. by discounting future flows of both costs and energy back to the present) (IEA, 2005). According to this definition, three main types of inputs can be distinguished: (1) economic (both capital and operational expenditures, CAPEX and OPEX, respectively), (2) technical (efficiency and device interactions),[1] and (3) financial (required for applying the Net Present Value technique) (Fig. 1) (Vazquez and Iglesias, 2015b). A number of LCOE estimates for different technologies, including tidal stream energy, have been recently published (e.g. Astariz et al., 2015b, Mills, 2015). For the specific case of tidal stream energy, LCOE values range from £125 MWh^{-1} (189 \$ MWh^{-1}) to £558 MWh^{-1} (844 \$ MWh^{-1})[2] (Mills, 2015). This ample uncertainty is caused by the variability of the different parameters involved in the LCOE estimation (CAPEX and OPEX estimates, farm size, etc.) which is affected by market risk, technological development, available resource, etc. The spatial variation of LCOE, estimated at ~15%, was found to stem primarily from differences in the available tidal energy resource (Vazquez and Iglesias, 2015c). A thorough study of the device interaction effects on the available tidal resource and hence, on LCOE values, concluded that such interactions could increase the LCOE value by up to £0.221 per kWh, and suggested the adjustment of the farm parameters (array size, spacing, etc.) as a way to reduce the overall cost (Vazquez and Iglesias, 2015c).

The work of Vazquez and Iglesias (2015c) constitutes a good basis on which future economic studies can be performed, yet it studies only the influence of one of the LCOE input parameters, i.e. changes in the available resource due to device interactions. Not only resource-related variables but any circumstance that could affect LCOE values is of interest, and this includes also financial contingencies. In addition, beyond the LCOE estimates themselves – which indeed come with ample uncertainty and should be understood in a specific context of assumptions – the bottom line is what drives cost variations and in which proportion these variations affect the LCOE results, a requirement to focus the actions towards a narrower LCOE estimation and an optimal cost scenario. This is the main motivation of the present work, which aims to assess and compare the relative impacts of various financial, technological and economic variables on the LCOE of a typical tidal stream project. In addition to individual variable sensitivity, a multivariate scenario analysis estimates the combined effect of varying an entire set of input simultaneously on the projected LCOE. Resulting LCOE values for tidal stream energy are compared with traditional grid power costs and the grid parity gap (difference between tidal stream costs and grid power costs) is determined. Finally, we assess the potential to bridge such gap with electricity tariffs for renewable energy in several places, in particular, with feed-in tariffs (FIT) (Squatrito et al., 2014). This investigation is conducted through a case study in a promising tidal stream location: Lynmouth, north Devon (UK), a tidal stream site located from 3.5 km to 10 km offshore in an area where the world's first tidal prototype, MCT's Seaflow, was tested (Fig. 2). The site offers sufficient water depth (20 m), high tidal stream energy currents (above 1.5 $m s^{-1}$) and a nearby potential grid connection. Part of the South West Marine Energy Park (South West Marine Energy Park, n.d.), it has been recently established as one of the three leased Crown Estate Demonstration Zones operated by WaveHub (Wave Hub Ltd., n.d.) — a testimony to the potential of this area as a future tidal stream energy site.

The main contribution of this work lies on taking into account a wide range of sensitivity parameters on the LCOE estimation, some of them considered here for the first time (such as the array configuration effects). Also, the grid parity gap in tidal stream energy is firstly assessed as such in the present paper. The grid parity concept constitutes a “milestone” in the tidal stream industry, since its attainment will bring the take-off of the sector.

This work is structured as follows. Section 2 deals with the materials and methods used in the study. Section 3 includes the analysis and discussion of the results. Finally, conclusions are drawn in Section 4.

Section snippets

LCOE method

The economic feasibility of a given technology can be evaluated with various metrics, but the levelised cost of energy (LCOE) is often used for comparing electricity generation technologies or considering potential grid parity for emerging technologies such as tidal stream energy (Karakaya et al., 2015, Munoz et al., 2014, Squatrito et al., 2014). It constitutes an assessment of the lifetime energy cost and lifetime energy production (Darling et al., 2011), and can be viewed as the average…

Individual variable sensitiveness

For the sensitivity analysis of the LCOE, each variable was modified in turns (Table 2). The results are presented on the basis of the main LCOE input groups, i.e. technical, financial and economic parameters (Fig. 1).…

Conclusions

While tidal stream energy is being actively developed, there are still some challenges to be addressed. The higher cost of this energy (if compared to its competitors) and the need to close the existing grid parity gap are two of such. This work contributes to addressing these issues by assessing the main drivers in reducing the cost of tidal stream energy farms, from a LCOE assessment perspective.

To this aim a numerical model was implemented in Lynmouth (UK), an area with great potential for…

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Prof Gregorio Iglesias (GI) is a Professor of Coastal Engineering at Plymouth University and Leader of the COAST (Coastal, Ocean And Sediment Transport) Research Group. He has over 20years experience in numerical and physical modelling applied to Coastal and Port Engineering, including the modelling of the tidal resource and tidal energy farms, the coastal effects of wave farms, and wave–structure interaction. He participated in the design and laboratory tests of numerous coastal structures,…

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> …Returning to our case, a 35 kW turbine, with a capacity factor of 29%, costs ~9019 €/kW. In order understand this value, two aspects should be taken into account: larger scale devices tend to present smaller costs per kW [29,30]; and also, the turbine pertaining to this project is a floatable structure, opposing to the one in Ref. [6] and the array in Ref. [11]. By inspecting Table 3, one sees that not only is the turbine itself driving the costs high, but also the necessary equipment to anchor it to the seabed is quite expensive.…

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Angela Vazquez MEng is a PhD student at the University of Santiago de Compostela in Spain (Department of Hydraulic Engineering) researching the characterisation of tidal stream energy resource under different constraints, functional, technical, economic and social. So far, her PhD was focused on investigating social and economic issues in developing tidal stream energy systems (four published articles on this topic).

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