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Economic feasibility of floating offshore wind farms

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ABSTRACT

The aim of this paper is to develop a methodology to determine the economic feasibility of a floating offshore wind farm. The methodology proposed considers that the life-cycle cost of a floating offshore wind farm is composed of the costs of each of the phases of its life-cycle (concept and definition, design and development, manufacturing, installation, exploitation and dismantling). Moreover, they are subdivided considering their sub-costs and taking into account the five components of a floating offshore wind farm: offshore wind turbine, floating platform, mooring, anchoring and electric system. The method ends when the economic feasibility indexes are calculated. The methodology has been used to analyse an offshore location: the Galician region (North-West of Spain). Results indicate that the best economic area in the Galician region is the area located from the Ría de Pontevedra to the Ría de Ribadeo. In addition, comparing the three floating offshore wind platforms, the semisubmersible platform and the spar platform are the best options in economic terms. The method proposed can be used to determine the economic keys in order to develop a floating offshore wind farm in any location.

1. Introduction

Offshore wind energy can lead the future in terms of production of electricity using renewable energies, being one important technology for the future perspectives of low-carbon electricity production [1,2]. One of the main reasons is the fact that the European Union (EU) has established that each country of the EU should satisfy by 2020 a specific renewable energy framework [3].

However, the majority of the European countries, included Spain, have developed onshore wind energy during the last twenty years. Therefore, the best onshore wind areas are occupied by onshore wind farms, whose life-cycle indicates that they should be repowering in next years [4,5].

An other option to comply with the European objective is to use the offshore wind energy, whose use in some European areas, such as the North Sea [6], is an ordinary option in our days. In fact, the farms installed or under construction have more than 11 GW during 2015 [1]. However, the offshore wind technology taken into account in these areas is based on fixed structures: monopiles [7], tripods [8], gravity based foundations, jackets [7], etc. However, in the context of a global world, most of the offshore locations need the use of floating structures [9], because its depth is higher than 50–60 m. Therefore, these new technologies, whose research is being carried out, will lead the development of offshore wind energy.

There are several prototypes of floating offshore wind platforms. Nevertheless, all of them can be classified in three main typologies: semisubmersible platform [10,11], Tensioned Leg Platform (TLP) [12,13], and spar platform [14]. Nowadays, these platforms are in development in hydrodynamic terms [9]. The first commercial floating offshore wind test farm is scheduled to be installed in 2017 in Scotland by Statoil and it will be composed of five floating offshore spar wind platforms called Hywind, which are being constructed by Navantia shipyard in Galicia (North-West of Spain). In the future, investors should define which ones are the most economically feasible or if their development can be simultaneously carried out.

On the other hand, the average size of offshore wind turbines in the EU was 4 MW in 2012, value which is continuously increasing [15].

Nevertheless, although the floating offshore wind technology is being still developed, it is important to define its economic aspects [16]. In this sense, the objective in future years will be reduce their costs, whose value is high due to the immaturity of this new

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technology [1]. Therefore, these costs should be defined. There are several authors who indicate general economic aspects [17–19], but they do not give a specific methodology to calculate the costs involved in a floating offshore wind farm. In fact, the majority of them are only usually focused on fixed offshore wind [20].

Therefore, the purpose of this paper is to give a detailed description of a method to determine the economic feasibility of a floating offshore wind farm, which are the type of offshore wind farms whose development will be increase in future years. Costs defined in the present paper can be analysed by investors to reduce them in the future and adjust their value to the feasible electric tariff for these type of renewable energy.

In this context, the main objective of this paper is to develop a methodology to determine the economic feasibility of a floating offshore wind farm. Therefore, aspects such as the electric tariff, the energy produced and a technical study, which support the calculation of the life-cycle costs of a floating offshore wind farm have been taken into account. The methodology proposed considers that the life-cycle cost of a floating offshore wind farm is composed of the costs of each of the phases of its life-cycle (concept and definition cost, design and development cost, manufacturing cost, installation cost, exploitation cost and dismantling cost). Moreover, they are subdivide considering their sub-costs and taking into account the five components of a floating offshore wind farm: offshore wind turbine, floating platform, mooring, anchoring and electric system. The method ends when the economic feasibility indexes are calculated: Internal Rate of Return, Net Present Value, Discounted Pay-Back Period, Levelized Cost Of Energy and Cost of power ratio. The methodology has been used to analyse an offshore location: the coast of the Galician region, located in the North-West of Spain. In this sense, it is important to notice that a specific area can be economically feasible, but you can have limitations to install the floating offshore wind farm. Therefore, some restriction areas have been taken into consideration (navigation areas, seismic fault lines, etc.). All these economic issues have been introduced in a GIS (Geographic Information System) software, which creates the economic maps with restrictions. Results indicate the best economic area in the Galician region in terms of their economic feasibility. In addition, comparing the three floating offshore wind platforms taken into consideration, the semisubmersible platform and the spar platform are the best options in economic terms. The method proposed can be used to determine the economic keys in order to develop a floating offshore wind farm in any location.

2. Methodology

2.1. Procedure

The methodology proposed to determine the economic feasibility of a floating offshore wind farm is based on several inputs, which allow the user to calculate the economic outputs or indexes whose reading gives an overview of the most important economic aspects of the farm (Fig. 1).

Therefore, the inputs of the method are: electric tariff for floating offshore wind, energy generated by the floating offshore wind turbines, the technical study taken into account and the life-cycle costs of the floating offshore wind farm. Firstly, the electric tariff is dependent on the country considered in the study and its legal aspects. Secondly, the energy generated mainly depends on the offshore wind speed of the offshore farm location, the height of the tower of the offshore wind turbine, the height of the floating offshore wind platform over the sea and the nominal capacity of the wind turbine. Of course, the higher the tower the more energy it generates, but also the higher the costs of the sub-structure, which supports the offshore wind turbine.

Thirdly, the technical study, which involves the calculation of mooring and anchoring dimensions, the width of the different types of electric cable considered (depending on the voltage taken into account), the number of vessels required to transport all the components of the farm, among others, is an important part of the economic study because it allows to determine all the costs involved in the installation and manufacturing of the parts of the floating offshore wind farm [21].

Finally, the life-cycle cost of a Floating Offshore Wind Farm (FOWF) (LCS_{FOWF}) is composed of the costs of each of the phases of the life-cycle process of the farm [22,23],: concept and definition cost ($C1$), design and development cost ($C2$), manufacturing cost ($C3$), installation cost ($C4$), exploitation cost ($C5$) and dismantling cost ($C6$).

$$LCS_{FOWF} = C1 + C2 + C3 + C4 + C5 + C6 \tag{1}$$

All of them are subdivided in several sub-costs considering the five main components of a floating offshore wind farm (offshore wind turbine, floating platform, mooring, anchoring and electric system), as Fig. 2 is shown:

On the other hand, the outputs of the methodology are used to consider if the floating offshore wind farm is economically feasible or not. In this paper, five outputs have been taken into account: Internal Rate of Return (IRR), Net Present Value (NPV), Discounted Pay-Back Period (DPBP), Levelized Cost Of Energy (LCOE) and Cost of power ratio (Cpower).

The project will be economically feasible if the IRR is higher than the capital cost, the NPV is positive and the DPBP has a value less than the life-cycle time of the project. Moreover, we are looking for a low LCOE and Cpower.

2.2. Concept and definition cost

The concept and definition cost is the first stage in a floating offshore wind farm. It includes works related to the market study ($C11$), law factors ($C12$) and the entire design of the farm ($C13$), as the equation shows:

$$C1 = C11 + C12 + C13 \tag{2}$$

The market study cost is defined by the cost of the economic feasibility study (C_{em}) to know if the floating offshore wind farm will have good economic results.

$$C11 = C_{em} \tag{3}$$

The law factors are composed of the legislative costs (C_{taxes}) of the country where the floating offshore wind farm is established. They can be related to the environmental impact taxes or the authorization of installing the floating offshore wind farm. It can be dependent on the size of the floating offshore wind farm: number of floating offshore wind turbines (NWT) and their unitary power (PWT).

$$C12 = C_{taxes} \times NWT \times PWT \tag{4}$$

On the other hand, the designing of the floating offshore wind farm is mainly based on selecting its location. Therefore, its costs are composed of studying the offshore wind resource: the cost of the meteorological structure (C_{emet}), the cost of the meteorological sensors (C_{smet}) and the cost of other auxiliary meteorological aspects (C_{samet}); and the characterization of the seabed, composed of the geotechnical study cost (C_{lm}), which is also dependent on the size of the farm (based on NWT and PWT).