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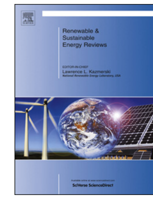

Offshore floating wind parks in the deep waters of Mediterranean Sea

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ABSTRACT

Offshore wind is mainly exploited for electricity production in Northern European countries where shallow waters exist. Although technology has been progressed to provide the offshore wind sector with many pioneering projects, there are still several interesting subjects for investigation, such as the very high costs of fixed-bottom offshore wind facilities in deep waters, constraining the implementation of offshore wind parks only in swallow waters. The exploitation of the vast wind resources in larger water depths is very significant for the offshore wind sector expansion, thus floating wind turbines are needed. This paper explores the feasibility of the, still immature, floating wind technology in deep waters, such as the Mediterranean Sea and under which conditions offshore wind farms can be implanted. The techno-economic study of the project, estimating the complete payback period, the net present value and the internal rate of return, revealed the conditions needed for its profitability. In addition, the social benefits from the floating wind park operation, which are related with the reduction of the oil imports, the savings from carbon dioxide emissions and other externalities, are compared with the applied feed in tariffs, in order to provide their break even values.

Contents

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1. Introduction

The wind power generation industry has seen significant growth during the last two decades [1–6] with the majority of wind farm installations to take place onshore [7,8]. Although this development of renewable energy sources across Europe has the support of the society and State policy, reluctance to invest and public opposition remain significant obstacles to the expansion of renewable energy sources (RES). Studies showed [9] that negative opinions regarding wind turbines are closely linked with beliefs that they are inefficient, unprofitable, noisier and more visually intrusive. Apart from issues though, such as visual and noise impacts, land space limitations, disturbance of flora and fauna habitat and constraints on natural reserved areas that were created with the onshore wind farm installations, led to the investigation of offshore site locations, where most of these issues are eliminated [10–13].

The available energy power in the European coasts, considering the Mediterranean and the Atlantic is 350 GW [14]. Europe has widely developed offshore wind parks [15–20] with the majority of installations implemented by Denmark and the United Kingdom, where shallow waters exist [21]. The experience gained from the research and the implementation of offshore wind turbines offers the opportunity to countries with deep seas, to reconsider their hesitation about developing offshore wind farms.

European countries are the leading players in the offshore wind energy market. The first offshore wind farm was installed in Denmark in 1991. The energy authorities of Denmark and the UK supported experimental projects (Vindeby and Blyth in Denmark and the UK, respectively) that proved successful and led them to utility-scale projects, through an attractive policy regime [22]. Nowadays the offshore capacity is growing with a rate of 40% per year. In the UK the projected offshore installed capacity by the year 2016 is 8 GW, while in the US 3.824 MW offshore projects are under development [6].

Currently, offshore wind farms are built primarily in shallow waters less than 30 m and close to shore [8,10,16,20,23], as offshore wind turbine foundations are considerably affected by sea floor soil properties, water depth, wave heights and currents. Although the Mediterranean Sea has high wind potential, no offshore wind farms have been implemented due to its deep waters.

Most of the conducted researches refer to wind parks that are implemented in shallow waters no more than 30 m depth. The existing challenges and opportunities in the development stages of an offshore wind farm project are discussed in [5]. Furthermore, a comparison between a high voltage direct current and high voltage alternating current transmission for integration of large scale offshore wind farm with onshore grid is also presented [5]. The work [6] researches the current situation of UK and US offshore wind industries and analyses the proper direction and pathways of the industry in India. The combination of offshore wind and wave systems is introduced in [14], based on the degree of integration between the technologies, and the type of substructure. The article [20] investigates the investment cost, employment, industry and installation of offshore wind energy in Europe and also in comparison to its onshore counterpart. A comparison between onshore and offshore wind energy is provided in [21], which also assesses whether offshore wind development potential has been exploited through further differentiation of the electricity market. In [23] the potential for development offshore wind power plant in the Croatian part of the Adriatic Sea is analyzed, with likely implication on the environment and economy of the country. In [24] an analysis of hypothetical offshore wind park scenarios in Belgium, Denmark, Germany, France, and the UK, for different water depths and distances to shore are presented, as these factors influence costs, whereas available wind resources determine the amount of electricity produced. The work [25] reviews some important factors and techniques for wind turbine installations such as the wind energy resource assessment techniques, environmental and grid integration factors, control strategies, impact of offshore wind turbines, feed-in tariff mechanism, modeling of wind turbine components including generators and performance improvement techniques. In [26] a detailed overview of the offshore wind power industry in the UK is presented, in terms of market growth, policy development and offshore wind farm costs. The work [27] provides a survey of previous regional-economic assessments of wind power projects, as well as a

Table 1
Specifications of NREL offshore 5 MW wind turbine [35].

Wind turbine characteristics	Value
Rated power	5 MW
Rotor orientation	Upwind
Control	Variable speed. Collective pitch
Drivetrain	High speed. Multiple stage gearbox
Rotor/hub diameter	126 m/3 m
Hub height	90 m above mean sea level
Cut-in; rated; cut-out wind speed	3 m/s; 11.4 m/s; 25 m/s
Cut-in; rated; rotor; generator wind speed	6.9 rpm; 12.1 rpm; 670 rpm; 1173.7 rpm
Rated tip speed	80 m/s
Overhang; shaft tilt; precone	5 m; 5°; 2.5°
Rotor mass	110 000 kg
Nacelle mass	240 000 kg
Tower mass	347 460 kg