Renewable and Sustainable Energy Reviews 31 (2014) 343–352

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

What economic support is needed for Arctic offshore wind power?

Olli Salo [1], Sanna Syri *

Aalto University, Department of Energy Technology, School of Engineering, P.O. Box 14100, FIN-00076 Aalto, Finland

ARTICLE INFO

Article history:
Received 5 August 2013
Received in revised form
15 November 2013
Accepted 22 November 2013
Available online 22 December 2013

Keywords:
Offshore wind
Support scheme
Finland

ABSTRACT

Wind power is increasingly being installed in cold climates and in offshore locations. It is generally recognised that installing wind power to offshore locations is more expensive than onshore. The additional challenges from Arctic conditions with annual sea icing are still poorly known. We reviewed the existing knowledge of offshore wind power costs and developed a calculation model for the economics of offshore wind turbines in Finland, including taxes and sea base rent, to obtain a base case for determining the required tariff support. The model was tested with different production and cost rates to obtain a tariff price, which would make offshore wind power on Finnish territory economically viable for the producer. The main developers of planned offshore projects in Finland were interviewed to obtain a comparison between the created model and industry expectations. The cost of erected turbines was estimated to be 2750 €/kW. With this cost of capacity, it was clear that a higher than the current tariff price (83.5 €/MWh) will be required for offshore developments. Our analysis indicated a price level of about 115 €/MWh to be required. We found that even rather small changes in cost or production rates may lead to excess profits or economic losses and further research and pilot projects are required to define a more reliable tariff level.

Contents

* Corresponding author. Tel.: +358 50 599 3022.
E-mail addresses: olli.a.salo@aalto.fi (O. Salo), sanna.syri@aalto.fi (S. Syri).
[1] Tel.: +358 44 5092976.

1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2013.11.051

1. Introduction

Wind power is increasingly being installed in cold climates and in offshore locations [1,2]. Europe is currently the leading region in offshore wind development, mainly due to the significant activities in the UK, Denmark and the Netherlands [2]. Recently, two of the world's largest offshore wind farms were opened off the UK coast, the 500 MW Greater Gabbard farm and the 630 MW London Array farm [3].

It is generally recognised that installing wind power to offshore locations is more expensive compared to onshore. However, the additional challenges and costs from Arctic conditions with annual thick sea ice, pack ice formation and icing on surfaces are still poorly known. These are the conditions in many parts of the Baltic Sea, whereas, for instance, at similarly high latitudes on the Atlantic coast the ocean rarely freezes.

At the EU level, support for renewable energy is driven by the EU RES-directive, which targets to a 20% share of renewable energy in energy end-use by the year 2020. The RES-directive has varying national goals for each member state depending on the amount of renewables already in use. The goal for Finland is a 38% share of renewable energy in end consumption, which requires an increase of over 30 TWh to annual renewable production. As a part of this goal, The Finnish Government Long term climate and energy strategy dated November 2008 specified a wind power target of 2500 MW in Finland by the year 2020 and in 2011 a feed-in tariff came into force [4]. In Finland, there is a strong interest to start developing offshore wind power in addition to onshore projects. A total of 3000 MW of offshore projects are under investigation or preparation. However, there has not been any separate offshore wind power tariff, and it is very unlikely that offshore projects would be realised without a separate, higher support.

Among the industry, different opinions can be heard of the wind goal being achievable without erecting offshore turbines. Realisation of onshore wind power has been unexpectedly slow in Finland despite the large number of projects under planning and licensing (about 320 MW realised out of total 11,000 MW under planning) [5]. Projects are delayed mainly due to slow licensing processes and the treatment of local complaints against the plans. In favour of offshore turbines is the free space over sea, where turbine noise does not disturb habitants. In the 2013 update of the Energy and Climate strategy the government reserved 20 M€ for the first offshore wind power demonstration project [6]. The main objective of this paper is to answer the question "How much subsidies the Finnish offshore wind production would require to be economically viable?"

This paper estimates the investment costs for offshore wind energy in Finland. It introduces a net present value (NPV) model to estimate the required feed-in tariff prices for generated electricity to make such developments economically attractive for investors. The paper consists of three main parts. Chapter two estimates the costs of building an offshore turbine and connecting it to the grid. Research methodology and main sources are described in chapter three. Chapter four presents the NPV calculation model and parameters used in the model. Chapter five presents the results of the calculations and sensitivity analysis for selected parameters. Chapter six presents the results of a survey made for the Finnish wind power industry about their expectations and concerns. All background data in this paper have been gathered from literature sources, from the Finnish Wind Atlas and from the Finnish Wind Power Association web pages [5,7].

For simplicity, all calculations have been made for 3 MW turbine units as a part of a wind park and the possible economies of scale for increased plant size have not been taken into consideration.

2. Costs of offshore wind energy

Offshore wind production is based on the same technology and physical principles as onshore wind. Despite that, the costs of wind developments on land and sea are very different. The main offshore components can be considered as conventional machinery and structures but the harsh environment at sea sets more strict criteria to equipment and the construction of the foundations [8].

Other challenges arise with the operation and maintenance of the turbines, especially on the northern Baltic Sea because of annual icing of the sea and winter conditions. The whole offshore industry is rather new technology and none of the large-scale offshore parks in Europe have been in use for more than a decade. Hence, there is no first-hand information available on the actual life-cycle costs including decommissioning. The cold climate of Finland creates a problem with blade icing. Icing reduces production and mitigation measures like blade heating increases the costs of the turbines and increases the internal energy use in turbine. Unfortunately no cost estimations were found and icing was excluded from calculations. All these specialties affect the cost structure and its accuracy and they are discussed in this paper.

2.1. Basic offshore wind technology

The main structures and mechanical components of an offshore wind farm are foundations, tower, blades, shafts and gearboxes. For energy conversion to electricity there are generators, converters, transformers, cables and medium-voltage gas-insulated switchgear inside the turbine unit. In a wind park other electrical structures and equipment are substations for collecting produced electricity and stepping-up voltage. Subsea transmission lines are needed to evacuate power to the mainland grid [8].

Modern onshore turbines stand on tubular towers, mostly due to aesthetic purposes. For offshore farms located over the horizon, cheaper lattice towers could also be used. For instance, based on the environmental impact analysis of Merituuli Oy for the Inkoo Raasepori project off the South Coast of Finland, there are two available tower and foundation structures to be used on the Gulf of Finland. For towers the possibilities are tubular and lattice towers. Lattice towers are lighter and therefore require less steel but on the other hand require greater foundations area and are considered "old fashioned" by their looks. Tubular towers generate