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Wave resource assessment for Scottish waters using a large scale North Atlantic spectral wave model

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A R T I C L E I N F O

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A B S T R A C T

This paper reports the methodology established in the application of a numerical wave model for hindcasting of wave conditions around the United Kingdom, in particular for Scottish waters, for the purpose of wave energy resource assessment at potential device development sites. The phase averaged MIKE 21 Spectral wave model has been adopted for this study and applied to the North Atlantic region bounded by latitudes 10° N–70° N and longitudes 10° E–75° W. Spatial and temporal wind speeds extracted from the European Centre for Medium Range Weather Forecast (ECMWF) have been utilised to drive the wave model. A rigorous calibration and validation of the model has been carried out by comparing model results with buoy measurements for different time periods and locations around Scotland. Significant wave height, peak wave period and peak wave direction obtained from the model correlated very well with measurements. Spatially varying statistical mean and maximum values of the significant wave height and wave power obtained based on a one-year wave hindcasting are in good agreement with the UK Marine Atlas values. The wave model can be used with high level of confidence for wave hindcasting and even forecasting of various wave parameters and wave power at any desired point locations or for regions. The wave model could also be employed for generating boundary conditions to small scale regional wave and tidal flow models.

1. Introduction

Electricity generation from ocean waves and tidal current is an active research worldwide and a number of successful technologies are now being investigated in many parts of the globe. Several of these wave/tide power converters, are either being installed and tested currently or already connected to grids (reNews [1]). According to reNews, the total wave and tidal technologies installed in Scotland alone until now sums to 6.365 MW, and the rest of the countries in the world contributed to only 6.56 MW. The Pentland Firth (see Fig. 1), which is the region between the north-east tip of Scotland and the south of Orkney Islands, is considered to be one of the best sites in the world for generating electricity from tidal stream. Fig. 1 also indicates the strategic potential sites, licensed by the Crown Estate [2], where wave and tidal energy devices will be deployed by various developers.

In Scotland, the Aquamarine Power [3] installed its Oyster 800 wave power machine at the European Marine Energy Centre (EMEC) facility in Orkney at a water depth of 13 m and commenced operational testing in June 2012. The company claims it produced the first electrical power to the grid in the same month. The company is likewise planning to deploy its next-generation machine Oyster 801 side by side, thus creating a wave farm. In addition, the Aquamarine Power now has been consented from the Scottish Government to develop a 40 MW wave farm off the north-west coast of Lewis, Scotland, which will include the deployment of 40–50 Oyster devices along the coast of Lewis.

Pelamis Wave Power [4], another wave device developer, has also deployed and tested its Pelamis P2 machine at the EMEC facility in Orkney, the Billia Croo test site, for Scottish Power Renewables. The Pelamis P2 was installed at EMEC for the first time in May 2012 at a water depth of approximately 50 m. Pelamis wave power plans to install 66 Pelamis machines for a 50 MW production off the Marwick Head in Orkney, for which the company claims to have an agreement for lease awarded by the Crown Estate. In addition to the above two, few other wave and tidal power companies, e.g., Alstom [5], Andritz Hydro Hammerfest [6], AW Energy technologies [7], Voith Hydro [8] and Wello Oy [9], have also tested their technologies at EMEC sites. Further details may be found in Ref. [10] for tidal power and [11] for wave power technologies.

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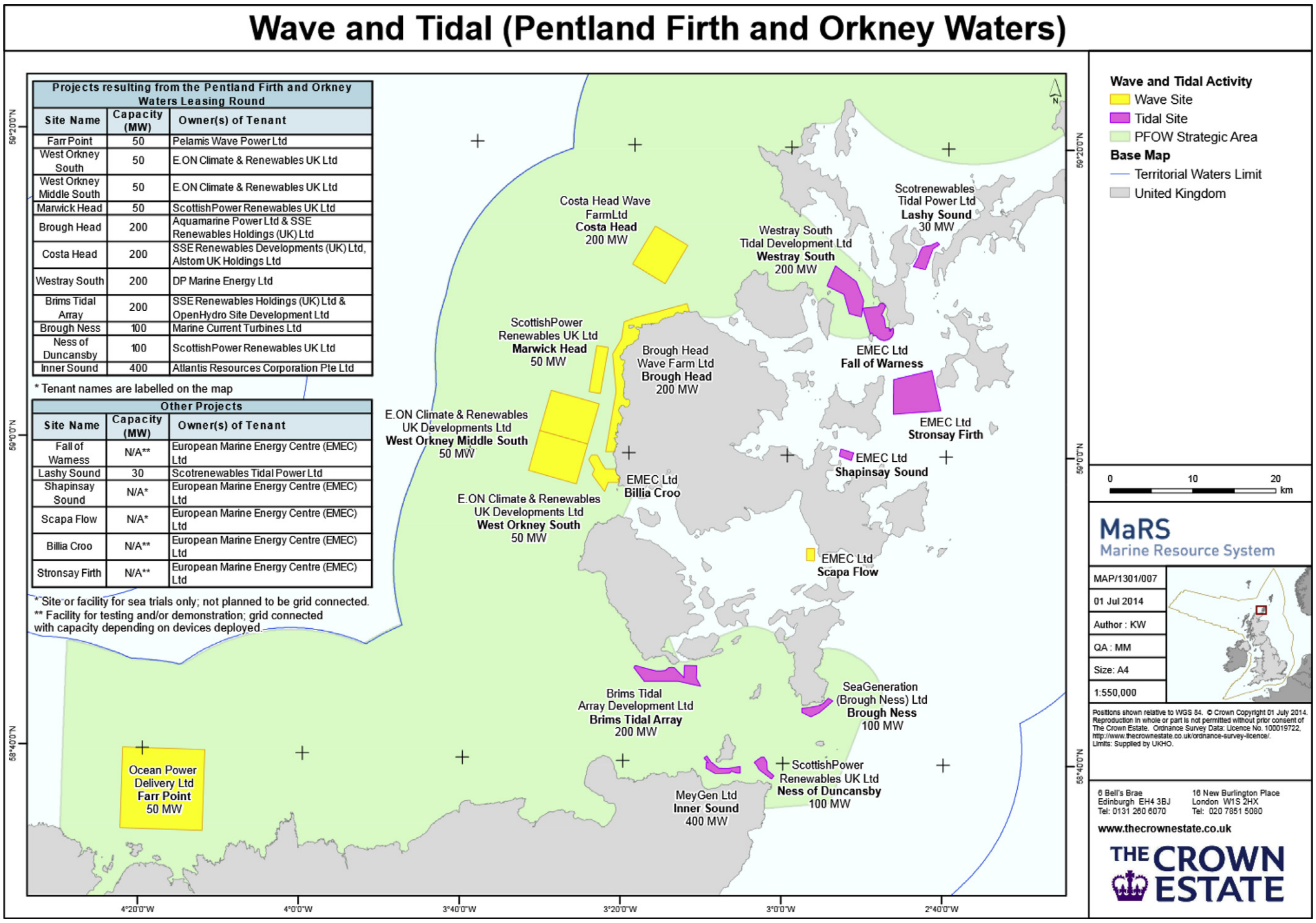

Fig. 1. Location of Pentland Firth showing wave and tidal energy leasing sites [2].

As demonstrated above, Scotland, in particular Orkney, Pentland Firth and Outer Hebrides, indeed, have become potential regions where both wave and tidal energy technologies can be successfully installed and operated. Scotland is geographically well placed on the globe where large energetic waves from the North Atlantic Ocean provide high level of sustainable wave power resources; however, harvesting these energy sources increase the number of challenges associated with it. An accurate estimation of wave conditions is essential not only for the evaluation of wave power, but also to estimate normal operational and extreme wave scenarios for assessing the survivability and economic viability of the technology and predicting any associated risks.

The UK target is to source 15% of its energy from renewables by 2020, with a commitment to target an 80% reduction in CO2 emissions by 2050. The Scottish Government has committed to the development of a successful marine renewable energy industry in Scotland and targeting to achieve 20% of European Union's energy consumption from renewable sources by the year 2020 [12]. Scotland's target is to produce up to a 25% of Europe's tidal power and 10% of its wave power from the seas around it.

To speed up these targets, several funding schemes have been developed and the UK's Engineering and Physical Sciences Research Council (EPSRC), under its SUPERGEN Marine Challenge – Accelerating the Deployment of Marine Energy (Wave and Tidal) scheme, has funded several projects one of which is the 'TeraWatt: Large Scale Interactive coupled 3D Modelling for Wave and Tidal Energy Resource and Environmental Impact' consortium. The work reported in this paper is part of the research carried out for the TeraWatt project which would concentrate on the questions: (i) what is the best way to assess the wave and tidal resource and the effects of energy extraction, (ii) what are the physical consequences of wave and tidal energy extraction and (iii) what are the ecological consequences of wave and tidal energy extraction. In order to address the above questions, an accurate wave and or tidal resource mapping must be produced for the regions where technology deployment activities are planned.

Although, there have been several wave modelling studies carried out in the past for North Atlantic and the UK seas, the purpose of them were manifold. For example, Swail et al. [13], and Swail et al. [14], investigated the longer term variation in ocean wave parameters for North Atlantic using a discrete spectral type wave model called OWI 3-G driven by the NCEP/NCAR global reanalysis wind data. Dodet et al. [15], studied the variability in the North-East Atlantic Ocean using a 57-year hindcast (1953–2009), obtained with the wave model WAVEWATCH III (Tolman [16]), which was forced with 6-h wind fields from the NCEP/NCAR Reanalysis project. The spatial resolution of the wind input used for this work was 1.875° (longitude) by 1.905° (latitude) on a Gaussian grid. Their aim was to investigate changes in significant wave height, mean wave direction and peak wave period. Galanis et al. [17] explored the characteristics of significant wave height by statistical approach for North Atlantic Ocean using satellite records and simulated records using the WAM wave model (WAMDI Group [18]). They have produced North Atlantic wide Weibull