Energy Conversion and Management 177 (2018) 43–54

Contents lists available at ScienceDirect

Energy Conversion and Management

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

Marine renewable energy potential: A global perspective for offshore wind and wave exploitation

Carlos V.C. Weiss[a,*], Raúl Guanche[a], Bárbara Ondiviela[a], Omar F. Castellanos[b], José Juanes[a]

[a] Environmental Hydraulics Institute, Universidad de Cantabria, Avda. Isabel Torres, 15, Parque Científico y Tecnológico de Cantabria, 39011 Santander, Spain
[b] Universidad Estatal Península de Santa Elena, Vía Santa Elena – La Libertad, Km 1, La Libertad, Ecuador

ARTICLE INFO

Keywords:
Offshore renewable energies
Potential zones
Structural survivability
Available resources
Logistics activities
Co-location

ABSTRACT

The global development of the offshore renewable energy sector has been driven by extensive investment and research in the utilization of offshore renewable energies, mainly at the regional level. However, for mid to long-term marine energy development planning, a comprehensive assessment of the global potential for the exploitation of the main offshore resources is required. This work developed and implemented an innovative methodological approach to identify potential zones for wind and wave energy exploitation at the global level, using long-term data series with fine spatial and temporal resolution. The proposed methodology was based on a five-step approach comprised of: (*i*) a resource assessment, to identify the zones with favorable conditions for energy exploitation; (*ii*) a structural survivability assessment, to identify feasible areas which would likely ensure the integrity and durability of the wind and wave devices; (*iii*) a logistics assessment, to evaluate the possibility of carrying out installation, operations, and maintenance activities; (*iv*) an assessment of the distance to consumer centers, to estimate the feasibility of transmission to the main urban areas; and (*v*) an estimate of the extractable power of the identified potential zones. For wind power, the United Kingdom (with 1470 TWh/month using a 10-MW turbine) and the United States (1079 TWh/month) were the countries with the highest estimated energy output of the identified potential zones. For wave energy, Brazil and New Zealand presented good opportunities for the development of the wave energy industry, with an estimated extractable power of 372 TWh/month and 286 TWh/month, respectively. The unique preliminary global analysis presented in this work provides guidelines to assist in the development of wave and offshore wind industries, in addition to supporting the management of marine spaces. Moreover, the methodologies can be replicated for other marine activities.

1. Introduction

The Marine Renewable Energies field has great potential for development, and due to technological advances that make operation in more severe met-ocean conditions possible, this sector is expanding towards the open sea [1,2,3,4]. The exploitation of renewable sources is on the rise, and there are public policies which encourage and promote this exploitation. The European Union in particular has become a global pioneer in the application of state-of-the-art renewable energy technologies, introducing a mandatory 20% share of total energy consumption for renewables by the year 2020 [5]. As an example, the European Commission's Blue Growth strategy, which fosters and promotes the development of marine sectors with high employment potential and sustainable growth, is one of the principal axes of the expansion of offshore renewables [6].

Electricity generated from marine renewable resources (tide, wave, ocean current and offshore wind) reached 42,619 GWh in 2016, with a total installed capacity of 19,252 MW. Offshore wind was the main contributor, with 41,596 GWh generated and 18,726 MW installed [7]. Wind energy stands out as one of the most promising and economically viable technologies for clean energy generation. Furthermore, interest in offshore zones has grown rapidly due to onshore limitations and the better quality of the wind resource in marine zones farther from the coast [3,8].

Although wind power dominates the current scenario in the marine environment, the exploitation of wave energy is promising, due to its high resource availability and its enormous potential for electricity production [9,10]. Wave energy is more concentrated and continuous

* Corresponding author.
E-mail addresses: c.vinicius@msn.com (C.V.C. Weiss), raul.guanche@unican.es (R. Guanche), barbara.ondiviela@unican.es (B. Ondiviela), ocastellanos@upse.edu.ec (O.F. Castellanos), juanesj@unican.es (J. Juanes).

https://doi.org/10.1016/j.enconman.2018.09.059
Received 4 July 2018; Received in revised form 17 September 2018; Accepted 18 September 2018
0196-8904/ © 2018 Elsevier Ltd. All rights reserved.

compared to wind energy, presenting good predictability [11,12]. However, wave energy harvesting is at a relatively immature stage, and although many wave energy converters (WECs) have been developed, a dominant technology has not yet emerged [13].

The availability of a good energy resource is paramount when choosing the best location for renewable energy farms. However, aspects relating to structural, logistical, energy estimation, and energy transport are indispensable to the feasibility of an offshore enterprise. Several studies have addressed the global wind (*e.g.* [3]) and wave (*e.g.* [14]) power resource. Sasaki [4] assessed the predictability of available global offshore wind and wave power. Other authors have studied the accessibility of sites for operation and maintenance (O&M) activities for wave (*e.g.* [15]) and wind farms (*e.g.* [16]) and co-located wind-wave farm [17]. However, to date, no approach has comprehensively investigated energy, structural, and logistical aspects in an integrated analysis for site-selection of wind and wave farms. Consequently, for mid-term planning of marine energy development, a holistic view of the global potential for wind and wave exploitation is required. In this context, this work aims to assess the potential zones for the exploitation of offshore wind and wave energy at the global scale, as well as co-location opportunities, simultaneously taking into consideration resource availability, structural survivability, logistics activities, distance to consumer centers, and extractable power.

2. Methodology

2.1. Overview

This study analyzed the potential zones for the exploitation of offshore wind and wave energy at the global scale, as well as the opportunities for co-location (sites which are suitable for both wind and wave energy). The proposed methodology was based on a five-step approach, comprised of: (*i*) a wind and wave energy resource assessment, to identify zones with favorable conditions for energy exploitation; (*ii*) a structural survivability assessment, to identify feasible areas likely to ensure the integrity and durability of the wind and wave devices; (*iii*) a logistics assessment, to evaluate the possibility of carrying out installation, operations, and maintenance activities; (*iv*) an assessment of the distance to consumer centers, to estimate the feasibility of transmission to the main urban areas; and *v*) an estimate of the extractable power of the identified potential zones. The suitability of the study areas (coastlines with depths of up to 500 m) was estimated using an index (Suitability Index, SI) regarding the probability of meeting favorable conditions for each evaluated aspect (1 for maximum suitability, 0 for minimum suitability). Long-term data series with fine spatial and temporal resolutions were used to evaluate the spatio-temporal dynamics of met-ocean conditions.

2.2. Data and evaluation criteria

The analyses were performed using a combination of validated statistical information and reanalysis data (32–37 years) at temporal (hourly) and spatial resolutions (0.017–0.3°), depending on the availability of homogeneous data (Table 1). The Kriging method [18] was employed to interpolate the data on a grid with 0.25° resolution.

The evaluation criteria was based on reference operating thresholds for large wind turbines, WECs, site accessibility for logistics activities, offshore standards for technical requirements, and on statistics of offshore projects available in the literature (Table 2). To cover different sea states and availability of infrastructures worldwide (*i.e.* types of vessel technologies, ports, urban areas, etc.), the most globally accepted thresholds for these activities were considered. The energy resource assessment was based on the reference operating parameters for large wind turbines [27,28,29] and wave devices [13,30,31,32]. The thresholds used for the structural survivability assessment of wind turbines and WECs were based on the Offshore Standard (DNV-OS-E301) [33] and proven experience in the TELWIND project [34]. The bathymetry threshold was based on the depths of offshore wind farms in operation, construction and planning [35,36], and in the technological advances that allow exploitation in deeper waters with floating structures. The assessments for logistic activities considered thresholds available in the literature for wind speed (*Ws*) and significant wave height (H_s) [15,16,17,37]. Based on the distances of offshore farms to shore [35,36], distances from the nearest port and urban centers were established.

Table 1
Summary of data sources, resolutions and available periods.

Variable	Sources of information	Temporal resolution	Spatial resolution	Available period
Wind	[19]	Hourly	0.3°	1979–2010
	[20]		0.2°	2011–2015
Waves	[21]	Hourly	0.25°	1979–2015
	[22]		0.25°	1979–2015
Currents	[23]	Hourly	0.25°	1979–2010
Bathymetry	[24]	Punctual	0.017°	2015
Ports	[25]	Punctual	Punctual	2012
Urban Areas	[26]	Punctual	Punctual	2015

2.3. Wind and wave energy resource

The assessment of the resource availability was based on the percentage of time during which favorable production conditions existed, and on safety measures for generic wind and wave devices (Table 2). For the wind resource, zones with time-percentage greater than 70% (0.7) in favorable conditions (Available potential (Ap) ≥ 400 W/m^2) were considered to be optimal for resource exploitation (Eq. (1)). In addition, the H_s at which turbines shut down production due to safety reasons was considered. The SI of the wind resource (SI_{WindR}) was generated by integrating the percentage of time with favorable conditions of these two elements, using the minimum value (min) (*i.e.* the value of the most limiting element prevails) (Eq. (2)).

$$Ap\left(\frac{t_{Ap}}{\bar{t}}\right)\begin{cases} 1 & for \quad \frac{t_{Ap}}{\bar{t}} \geq 0.7 \\ \frac{t_{Ap}}{\bar{t}} & for \quad \frac{t_{Ap}}{\bar{t}} < 0.7 \end{cases} \tag{1}$$

where t_{Ap} is the time, at the temporal resolution of the base variable (wind, Table 1), that the Ap remained above 400 W/m^2 (Table 2) in the whole time series, $\bar{t}$ is the total time of the data series.

$$SI_{WindR} = min\left(Ap, \frac{t_{Hs}}{\bar{t}}\right) \tag{2}$$

where t_{Hs} is the time, at the temporal resolution of the base variable (waves, Table 1), that the H_s remained below 5 m (Table 2) in the whole time series.

For the calculation of the SI of the wave resource (SI_{WaveR}), the available energy flux (Ef), peak period (T_p), and H_s were considered. The SI_{WaveR} was determined by integrating the time-percentages for each element using the weighted mean (Eq. (3)). Both, severity and energy are closely reflected because Ef depends on $H_s{}^2$. Therefore, the SI is mostly dependent on the loadEf. However, in order to integrate the benefits of moderate to high-energy sites the lined term $H_s$and T_p have been included. Consequently, the SI_{WaveR} is mainly driven by theEf.

$$SI_{WaveR} = \frac{\left(\left(\frac{t_{Ef}}{\bar{t}}*2\right) + \frac{t_{Hs}}{\bar{t}} + \frac{t_{Tp}}{\bar{t}}\right)}{4} \tag{3}$$

where t_{Ef}, t_{Hs} and t_{Tp} are related to the time, at the temporal resolution of the base variable (Table 1), that the Ef, H_s and T_p remained above or between certain thresholds (Table 2) in the whole time series.

Download English Version:

https://daneshyari.com/en/article/10226449

Download Persian Version:

https://daneshyari.com/article/10226449

Daneshyari.com