Energy 72 (2014) 652–670

Contents lists available at ScienceDirect

Energy

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

Coastal impact assessment of a generic wave farm operating in the Romanian nearshore

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ARTICLE INFO

Article history:
Received 9 December 2013
Accepted 24 May 2014
Available online 18 June 2014

Keywords:
Wave farms
Black Sea
Romanian nearshore
SWAN
Waves
Coastal impact

ABSTRACT

The present work is focused on the evaluation of the coastal impact of a generic wave farm that would operate in the Romanian nearshore. The target area considered for analysis is located in the Black Sea, in the vicinity of the Saint George arm of the Danube River, which is a sector where the erosion processes are very high. A first perspective concerning the wave conditions close to this coastal environment is provided by analyzing the in situ measurements coming from the Gloria drilling unit. As a further step, the influence of a generic wave farm on the nearshore climate was assessed, based on some relevant scenarios which consider average, energetic and extreme wave conditions. Numerical simulations are performed with the SWAN (Simulating Waves Nearshore) spectral model, where the generic wave farm was modeled as an obstacle defined by a sequence of corner points of a line. A general perspective on the wave field evolution is provided by increasing the absorbing property of the farm, from zero (no wave farm) to a total absorption scenario. In the final part of the work, an assessment of the longshore currents was also carried out by considering a 1D surf model.

1. Introduction

Considering the current economic and population growth it is logic to anticipate that in the near future the demand for energy will increase substantially [1,2]. It has been estimated that the global population will expand with a rate of 25% during the time interval 2010–2040 reaching almost 9 billion. At this moment, a significant amount of energy is obtained from burning fossil fuels, which for example in 2009 were considered the main source of the global greenhouse gas emissions (84%) [3,4].

Although this issue can be considered a serious threat for the future, it is possible to consider new strategies in order to consolidate a sustainable energy portfolio [5–9]. One solution may be found in the use of various renewable energy sources like wind or sunlight, which are naturally replenished [10–12]. Considering only the electricity generation sector for the year 2008, the global technical potential was evaluated to be in the range of 260–2072 EJ/yr [13].

There is currently an increasing interest in the use of natural resources, the world wide capacity in 2012 exceeded 1.47 GW (up with 8.5% from 2011) mainly due to projects coming from the wind power sector (39%), hydropower and photovoltaic (with about 26% each) [14].

From this perspective, on a large scale level the marine environment promises to be an important source of energy due to the large water surface, the diversity of the resources (wind, wave or tides) and their relatively high energy density. The offshore wind industry has already become an important player in this market [15], especially on a European level, where in the first half of 2013 a total capacity of 6 GW was obtained from 58 wind farms fully grid connected [16]. From the different types of marine resources, the wave energy provides the highest energy concentration being also more predictable than solar or wind. From their generation areas, the waves can travel over large distances with very little energy loses until they arrive in the nearshore, where this energy is dissipated due to the interaction with the seabed [17].

On the other hand, the shoreline areas are highly dynamic environments which constantly change under the influence of the natural factors and the balance between erosion and accretion processes determines the stability of the coastline over various time intervals. Maybe the most important issue is represented by the action of the breaking waves, which cut into the surf and beach area and throughout mechanical abrasive processes dislocate small particles and carry them back into the sea.

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http://dx.doi.org/10.1016/j.energy.2014.05.093
0360-5442/

Another important occurrence in the coastal areas is represented by the longshore currents which are produced by the incident waves approaching the beach at a certain angle. They shift large sediment quantity along the shoreline at a constant rate, changing the aspect of different beach sectors. During high or extreme events a much larger sediment volume is dislocated and the beach is exposed to an intense degradation process [18].

On a global level, the Romanian coast is one of the most affected areas by the erosion processes [19]. The Romanian coastlines are located on the northwestern part of the Black Sea, and based on the severity of the erosion process they can be divided into two distinct regions: north and south. Previous studies indicate that the north sector (located in the vicinity of the Danube Delta) is in a critical stage, while the southern sector (with more economic facilities) is more stable [20]. Since the River Danube is the main source of sediments in this region, during the last decade the coastal degradation was accentuated due to anthropogenic factors such as: major port developments, consolidation of the navigation channels and dam constructions on the Danube [21,22].

Recent studies of the wave conditions in the Black Sea basin showed that the western part of the sea presents in general more energetic wave conditions [23]. If we also consider that this area presents a good windy climate and a shallow water area (in the north-west) with depths close to 50 m [24], it is possible that in the near future this two natural resource to be used throughout marine energetic farms [25].

The benefits of a future wave energy farm for Romania will consist in the fact that this will add a new renewable energy source to the internal market (beside hydro and wind) while since this will extract energy from the incoming waves the impact on the coastline should be greatly reduced [26,27].

In this context, the main objective of the present work is to identify the influence of a generic wave farm on wave and nearshore circulation patterns from the Romanian coastal environment and also to evaluate the performances of several types of wave energy converters considering the local wave conditions.

2. Methods and materials

2.1. Target area and in situ data

Fig. 1 presents the target area, which is located in the northern part of the Romanian nearshore, between the arms of the Danube Saint George and Sulina. In general, this region is characterized by a low relief profile created by the accumulation of the deltaic sands. In the vicinity of the Danube Delta the shelf area is much larger, being characterized by a water depth of 12–15 m and a multi-barred beach profiles with gradients of 0.003 and 0.01. The quartz sands (medium-fine sands) represent the main sediment from the region, which is transported by the littoral drift from the north of the Danube Delta [28]. The presence of the large dams on the Danube River significantly reduces the volume of alluvia from 67 mill. tons/year (during 1921–1960) to a 30–35 mill. tons/year over the last 30 years. In addition, the coastal engineering structures (ex: Sulina dams), storm conditions and the sea level rise accelerate the erosion processes from this area [29].

In order to identify the wave conditions of the target area, in situ measurements coming from the offshore Gloria drilling station (illustrated in Fig. 1) were considered for the analysis. This platform operates in the vicinity of the target area (44°31′N, 29°34′E) at about 50 m water depth and provide daily measurements available for every 6 h (01-07-13-19 UTC) covering the ten-year time period January 2000–December 2009. The wave parameters considered for the analysis are mean wave direction, significant wave height and mean wave period. Since the simulations carried out in the present work are performed based on the significant wave height (*Hs*) input, the in situ measurements, which were carried out in terms of $H_{1/10}$, were adjusted as follows [30]:

$$H_{1/10} = 1.27H_s \tag{1}$$

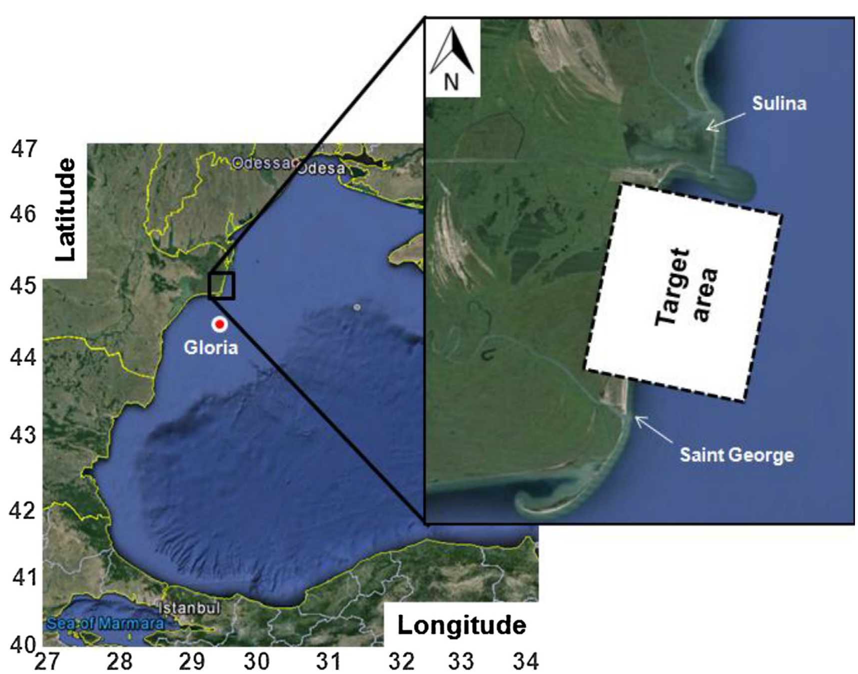

Fig. 1. Map of the target area located in the vicinity of the Saint George arm of the Danube River.