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Tidal stream resource assessment in the Dover Strait (eastern English Channel)

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ABSTRACT

A methodology of tidal flow resource assessment in the Dover Strait is presented. The resource assessment is performed using surface velocity time series recorded by Very High Frequency Radars (VHFR) and ADCP velocity measurements. Following the EMEC guideline, the major parameters of tidal flow conventionally used for tidal energy site screening are estimated and mapped. The combination of two sources of data allowed to characterize the current velocity variation in three spatial dimensions and in time, which increased confidence in hydrokinetic resource assessment from the radar data. Current velocities provided by the radars show strong spatial variation and fortnightly modulation. The most energetic area was found west of the Cape Gris Nez with the peak velocity of 2.5 m/s, mean velocity of 1 m/s, and spring tide average velocity of 1.4 m/s. Velocities exceeding 1 m/s are observed more than 50% of time there. Averaged velocity profiles derived from ADCP data were obtained for different stages of the tidal cycle and then approximated by a power law function. Using velocity time series provided by the radars and the power law velocity profiles, the power density time series in the surface and bottom layers were generated. The analysis of these data show that west of the Cape Gris Nez, the mean power density attains its maximum value 0.9 kW/m^2 in the surface layer and a peak value 5 kW/m^2. In the rest of the domain, the mean power density varies from 0.1 to 0.6 kW/m^2. The power density is found three times lower in the bottom layer. A three dimensional hydrodynamic model MARS-3D is used for comparison with experimental data. The model results are in good agreement with observations thus allowing the use of the model for assessing tidal stream resource in extended area.

1. Introduction

Converting tidal current kinetic energy into electric power by in-stream tidal turbines became a real challenge since the last years. The world tidal energy potential (tidal range and tidal current) is of the order of 3 TW [1], thus offering a significant source of renewable energy. Sites with the biggest tidal stream potential are located on the northwest European shelf [2] and in particular in the English Channel [3]. Highly energetic areas such as Alderney Race, Bréhat Island region, Isle of Wight, and Dover Strait are considered as promising for tidal stream energy conversion [2]. Tidal projects are under development at several sites in France. In November 2015, the 0.5 MW Sabella D10 tidal turbine, installed in the Fromveur Strait, became the first marine current turbine to supply electricity to national power grid. In January 2016, the first of a total

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of three 0.5 MW turbine was installed at Paimpol-Bréhat demonstration site in France. Another project intends to explore in deep the French sector of Alderney Race (Raz Blanchard) and to prepare it for operational use. The Dover Strait is actually a subject of a study initiated by regional authorities in France. The new region Hauts-de-France has committed a sustainable development process with the purpose of dividing by 4 its gas emissions by 2050. Offshore wind and tidal energy represent a big potential for industrial exploitation. Tidal stream resource in the Dover Strait has been historically considered as non-negligible [3]. However there is no reliable estimate of a technically exploitable potential documented in scientific publications. The present study tends to get the knowledge on the resource available in this area.

Resource characterization is a first step toward site selection and turbine deployment planning [4]. Two approaches can be followed to quantify the tidal stream potential in the most efficient way: extensive field measurements and numerical modeling. Sometimes, both actions are combined together in order to increase the model performance or to help in interpretation of the experimental data [5,6].

The tidal flow potential can be quantified using a two-dimensional (2D) model. This is the more convenient, more simple and less expensive approach. Blunden and Bahaj [7] used the TELEMAC-2D modeling system to estimate the available resource at Portland Bill, UK. The model results were used to generate the tidal flow velocity time series over a large area and then to optimize the location of turbine arrays at the site. Xia et al. [8] used a 2D hydrodynamic model to assess the tidal current energy resource in the Severn Estuary, UK. Using a 2D finite element model (TIDE2D), Sutherland et al. [9] estimated the tidal stream potential as 1335 MW in the northwestern part of the Johnstone Strait, in Canada. Nowadays, three-dimensional (3D) models are routinely applied for tidal energy site assessment, resource quantification and studies of the impact of energy devices on local circulation and environment. Numerical simulations by Regional Ocean Modeling System (ROMS) were used to examine the tidal asymmetry in a promising site of Orkney Islands [10]. ROMS was also employed for evaluation of the wave influence on tidal stream energy resource [11] and for estimation of the tidal stream resource variability in the northwest European shelf seas [12].

Remotely sensed velocity observations or in situ velocity measurements at tidal energy sites represent a valuable alternative to modeling. The technique of field data acquisition is well established and currently used for resource characterization in many coastal ocean regions [5,13–15]. Acoustic Doppler current profiler (ADCP) is often the instrument of choice for fixed point or towed surveys. In the early studies (e.g. [16–18]), while the vessel steamed around a circuit, velocity profiles were recorded with sufficient frequency allowing to resolve the vertical structure of the tidal current and its spatial irregularities. More recently, Goddijn-Murphy et al. [5] used underway ADCP data to reconstruct the tidal flow patterns in the Inner Sound (Pentland Firth, UK). Sentchev and Yaremchuk [6] employed the optimal interpolation technique for reconstructing space–time evolution of the velocity field derived from towed ADCP surveys in the Boulogne harbour (English Channel).

But the most frequent are certainly velocity measurements by bottom mounted ADCPs – routinely used for assessing temporal variations of the tidal stream [13] and turbulent properties of the flow [19]. Turbulent kinetic energy, dissipation rate, Reynolds stress, and some other turbulent parameters can be retrieved from ADCP measurements [20,21].

In this study, a novel technique of tidal flow resource assessment is presented. It is based on the analysis of surface current velocity time series recorded by Very High Frequency Radar (VHFR) along the Opal coast, in the French sector of the Dover Strait [22]. Although the radar technology has been used in many oceanographic applications since more than 20 years (e.g. [23–25]), its efficiency for tidal energy resource assessment was demonstrated only recently [26]. The radar derived velocities were supplemented by current velocity profiles acquired by bottom mounted ADCPs in the study area. The radars allow continuous data acquisition of the surface current velocities over a large area at high spatial and time resolution. ADCP data provide information about velocity variation with depth which is fundamental for detailed tidal stream resource assessment. The knowledge of the three dimensional structure of a tidal flow in combination with the temporal variability of currents allows to assess the resource variability at a site from direct velocity measurements with a high degree of confidence. Results from the regional modeling in the Dover Strait are also used to support the estimation of the tidal stream potential derived from observations. A combination of different sources of data and numerical modeling allowed the detailed characterization of the tidal stream potential available in a region that was previously considered as promising for tidal energy conversion. The results of this research can be useful for decision makers and stakeholders for future development of renewable energy network at a regional scale.

2. Data and methods

2.1. Study site, environmental conditions and constraints

The study area is located in the Dover Strait (eastern English Channel), along the Opal coast of France (Fig. 1, right panel). The coastline is meridionally oriented with a large embayment in the central part (Boulogne harbour) and a number of small inlets and river estuaries. The water depth is less than 50 m throughout the domain. In the middle of the Dover Strait, there are sandbanks oriented in the alongshore direction.

Investigation of the physical processes which govern the circulation along the Opal coast has been performed using VHFR observations [22] and numerical modeling (e.g. [27–29]). The authors showed that the local hydrodynamics is by far dominated by tidal motions. Tidal wave propagating along the Opal coast determines the variability of the sea surface height