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Tidal stream characteristics on the coast of Cape Fuguei in northwestern Taiwan for a potential power generation site

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ABSTRACT

Sites of high tidal current power potential are mostly found at narrow tidal passages or channels. Not many coastal sites with unbounded ocean with high tidal current speed have been reported. The coastal sea near the Cape Fuguei in northwestern Taiwan is such a site with a high tidal power potential. The purpose of this study is to investigate the tidal current speed at this location for assessing the tidal current power potential. In-situ and remote sensing instruments were deployed simultaneously to measure the temporal and spatial distributions of tidal currents. An Acoustic Doppler Current Profiler (ADCP) was deployed at a 26 m depth site and an X-band marine radar was installed at a coastal building. Two measurements lasting over one month were done. Both instruments showed the maximum current speed at the surface was more than 3.5 m/s in the measurement period. ADCP measurements showed that the time mean speed in the upper layer (−1.7 to −6 m) was 1.5 m/s. The current speed decreased with depth slightly. It was also found from both ADCP and radar measurements that in the surface layer, the probability of duration for current speed exceeding 1 m/s was more than 70%. In addition, radar measurement showed that the average surface current speed at the area from 2 km offshore out to 4 km (radar offshore limit) was more than 1 m/s. The size of this area is more than 15 km^2.

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Our investigations indicated that this area has a high tidal power potential for current turbine deployments.

1. Introduction

The gravitational pulls of the moon and the sun cause a periodic, up and down motion of the ocean tide. If the tidal range is high, the water level difference between the high and low tides can be used to generate power. For this, a few tidal barrage schemes have been built to generate electricity. However the scheme is feasible for only a few sites with large tidal range, and these barrages may cause significant environmental concerns. On the other hand, the tide also creates periodic, back and forth, horizontal motion called tidal stream. This regular and never ceasing, tidal stream can also be used to generate electricity. The development of tidal current power generation has less environmental impact than barrages. In addition, tidal current generator can be installed incrementally to meet the increase in demand over time. Presently the tidal current energy conversion technology is still at an early stage of development, but prototypes in the UK, Norway, Canada, and elsewhere have shown promising results.

Since the power generated by the current is proportional to the third power of the speed, one basic requirement for an ideal site for tidal stream power generation is a high current speed. In most coastal seas the tidal current speed is not high enough for power generation. However, there are sites, due to their bathymetric conditions, have high current speed that suitable for kinetic energy conversion. These conditions can be an under-water ridge or a narrow tidal passage, which constricts the flow and forces the current to accelerate. In Canada, for example, extremely high tidal currents, and thus large tidal power potential [1], exist in the Minas Passage which connects the Minas Basin to the Bay of Fundy, which has the world's largest semidiurnal tidal range. The passage between the Flinders Island and the rest of Tasmania is another example of high tidal current [2]. These sites of large tidal current power potential are mostly in bounded passages. One drawback for bounded passages is that they may also be shipping lanes. Ship traffic can limit the number of tidal turbine that can be installed.

Another requirement for a good tidal current site is that the site should be large enough to accommodate a large number of power generators so that enough power is generated to be economic efficient. The northern coastal ocean of Taiwan is known to have high tidal current. Previous study on the tidal stream at the northern coast [3] focused on the Keelung Sill, which is an under-water ridge, locates outside the Keelung Harbor. The maximum tidal current measured was 2.6 m/s. However the ridge is narrow, about 2 km long and 300 m wide. The Sill is only a good site for tidal stream device testing, but not a location for a generator farm. The area this study investigated is Cape Fuguei, which located 25 km northwest of Keelung Sill. The Cape Fuguei is a headland and is the northern most point of Taiwan (Fig. 1). The sea bottom slope off Cape Fuguei is in the range of 1/50–1/150. The 20 m-depth line is only 1.5 km offshore and parallel to the coastline. The mean and maximum tidal ranges are 1.6 and 3.1 m, respectively. The tidal stream flows toward the Taiwan Strait during the flood tide and reverses its direction in ebb tide. Due to the protrusion of the cape, the tidal flow in this area is forced to accelerate. Our tidal simulation by using hydrodynamic model of MIKE 21 showed that the area with time average current speed higher than 1 m/s is as large as 34 km^2 (Fig. 2). Also, it is worthwhile to note that this coastal area does not have traffics of deep draft ocean-going vessel, since they make their turns far offshore to avoid tight turns and heavy seas, which occurs frequently in bad weather. For this reason, this coastal region can be a good tidal power generation site. Nevertheless, there have never been any tidal stream measurements done here. Therefore there is a need of field measurement at this site for the purpose assessing the tidal power potential of Cape Fuguei. Hence, the objective of this paper is to report the results of our field measurements. Two types of instruments were used: a current meter for a fixed location measurement and an X-band coastal radar system for measuring surface current in an area.