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Editorial

Tidal Turbines

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Tidal turbines generate energy from tidal currents. One of the major areas of interest in this renewable energy is its predictability. With this predictability, tidal turbines are ideally suited to be integrated with smart grids especially near coastal communities. The areas of interest for the installation of these devices are distributed throughout the world. They are characterized by a complex bottom morphology and flow due to currents that can be disturbed by waves, the presence of sediments, or objects transported by the flow. The design, positioning of the turbines, maintenance, and interactions must consider these aspects. Currently, the cost of tidal turbines is higher than that of technologies such as onshore and offshore wind turbines, and reducing this cost remains a challenge in aspects ranging from the design of the machine to the installation and maintenance operation. The Tidal Stream Industry Energiser Project (TIGER) is dedicated to the latter topic.

This Special Issue on "Tidal Turbines" includes twelve papers encompassing different approaches to studying tidal turbines. These include design by experimental and numerical approaches [1–3], control improvement [4,5], the use of blade flexibility to generate power [6,7], wake studies conducted by numerical simulation at the scale of a pilot tidal farm [8,9], resource characterization by regional modeling with waves [10,11], and fatigue analysis of in-site measurements [5]. Lastly, a comparison of hybrid systems has been made for a type of inland energy supply [12].

A brief summary of the content associated with each of the selected papers included in this Special Issue is included below:

In Jiang et al. [1], a methodology was developed to study the performance of tidal turbines in towing flumes with variable velocities. This methodology was based on long-term velocity measurement in the open sea, and was intended to retain the most frequent velocities by statistical analysis. A limited number of speeds were retained according to their frequency of occurrence. Then, a series of experiments was realized on several models of turbines and their performance of the turbines in a towing flume, which was measured for each flow. Afterwards, a test was carried out at sea with a turbine mounted on a floating structure to verify the results of the method. Moreover, three types of turbines were considered: a Savonius-shaped turbine based on drag force, a NACA hydrofoil turbine based on lift force, and a thin-walled foil turbine based on lift and drag forces. As for the velocity obtained in the experiment conducted at sea, the best technology appeared to be the latter.

In Jiang et al. [2], the design of a low velocity tidal turbine to be deployed in marine aquaculture was proposed. The maximum velocity in this area is 1.5 m/s, and the issue of using the lift force as conventionally employed is understandable. The new design is based on a lift–drag composite thin-plate arc turbine blade. The optimization of the blade shape was performed based on the Blade Element Momentum (BEM) theory and the fluid principles. Two turbines, one with the designed lift–drag blades and the other with a NACA shape, which used lift force, were produced and tested both in an experimental towing pool and at sea for one tidal cycle. The authors observed that the turbine equipped

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with the lift–drag composite blade provided higher-energy performances than the turbine equipped with the NACA blades based on lift force.

In Delafin et al. [3], the performance of a Darrieus Tidal Turbine with active variable pitch was analyzed on the basis of numerical simulations. This study was motivated by the vibration produced by the stall regime for the high angle of attack of blades, and the low efficiency of such a turbine. They proposed that the angle of attack be controlled by introducing some variable pitch laws. Two-dimensional blade-resolved unsteady Reynolds-averaged Navier–Stokes (URANS) simulations were used to estimate the effect of those laws on the performance of the wind turbine. The pitch laws reduced the angle of attack in the upstream half of the turbine, while no pitch correction was used in the downstream half. This demonstrated that a decrease in the angle of attack in the upstream part of the turbine induced an increase of up to 40% in the power coefficient. It also smoothed the torque along the azimuthal angle, thus reducing the maximum, increasing the minimum, and reducing the ripples. The induction factor was also reduced.

In Shen et al. [4], the control of a marine current turbine was studied in relation to current and torque disturbances. For this purpose, the author proposed a Fuzzy Adaptative Backstepping Control approach (F-C-BC) with compensation for velocity fluctuation, which permitted the use of maximum power point tracking (MPPT). Then, a fuzzy logic control approach was used to adjust the parameters of the A-BC approach in real time. The approach was compared with others (e.g., A-BC, sliding mode control, fuzzy PI control) and showed better behavior compared to the interference solicitations. Thus, the percentage error of the rotor speed was reduced by 3.5% using this approach. In addition, the F-C-BC approach facilitated the use of MPPT control, and improved the power extraction capability under variable flow speed.

Hoerner et al. [6] performed an experimental study to estimate the effect of flexibility of an oscillating hydrofoil on the performance. The foil represented one of the blades of an H-Darrieus tidal turbine. High-speed particle image velocimetry (PIV) measurements were used to capture the fluid features and the deformation of the hydrofoil. Two foils were tested: one was rigid (aluminum), and the other was made in two parts, a rigid part in aluminum (leading part) and flexible part (tail) made from silicone with a carbon–fiber composite reinforcement. A tip-speed ratio of 2 and a solidity of 1.5 were selected. With these parameters, the flow was dominated by dynamic stall. Strong fluid–structure interactions were observed in that regime, with significant structural deformations. This showed that the blade's flexibility reduced the duration of the periodic stall regime, and then exerted passive control on the flow. Moreover, it had a notable effect on wake development. This work will pave the way for studies on the flexibility of the blades of tidal turbines.

In Brousseau et al. [7] the effects of the flexibility of an oscillating hydrofoil on the power production were studied through numerical simulations at a low Reynolds number. Hydrofoil movement occurred due to a combination of forced pitching and free-heaving motions. Several materials for the hydrofoil were considered (rigid to flexible), and an analysis of the hydrodynamic loads on the structure was performed. The fluid structure interaction was accounted for by a partitioned implicit coupling approach, iteratively solving the Navier–Stokes equation by means of the Arbitrary Lagrangian–Eulerian (ALE) formulation and the elasticity equation. This study demonstrated that the flexibility of a hydrofoil impacts its hydrodynamic behavior, thus modifying the loads and improving the energy efficiency of the device. Finally, this study highlighted the use of flexible material in oscillating hydrofoil tidal turbines.

In Jégo and Guillou [8], a bi-vertical axis turbine farm was studied using numerical simulation. One advantage of a vertical axis turbine is that the production is less affected by the current orientation. The studied turbine consists of a double-level with two counter -rotating rotors developed by HYDROQUEST in the framework of project OCEANQUEST and tested at the Paimpol-Bréhat site. In the model, rotors were represented by an actuator cylinder and were implemented into a 2D stationary fluid solver. After validation with the experimental data, they applied the method to a HYDROQUEST turbine alone, then to various turbine farm arrangements under different current conditions (magnitude and direction). Finally, wake and power production were provided and discussed. For the case that used one turbine, it appears that current incidence had a slight impact on power production, and the absolute value of velocity had a small influence on velocity recovery. For the cases with several turbines within a small farm, it appears that (i) the backward flow provided better power from the farm, and (ii) the current incidence had an impact on the power and the wakes (tandem and interference configuration were found), depending on the farm's organization. This work demonstrates the need to carefully study the farm layout for each type of turbine.

In Slama et al. [9], the wake interactions of the precommercial tidal farm NEPTHYD (Normandie Energie PiloTe HYDrolien) were simulated under several ambient turbulence conditions, in both straight and yawed flows. The flow around the turbines was simulated using a three-dimensional unsteady Lagrangian vortex model with turbulence generated by the synthetic eddy method at the inlet. The turbine tested was the 18 m diameter Oceade turbine of Alstom for the NEPHYD project. The influence of the size and density of the eddies injected at the inlet was assessed. A comparison with the experimental data of Mycek et al. proved the reliability of the results. This study also demonstrated that too many eddies injected at the inlet could lead to numerical dissipation and a reduction in the wake extension. Finally, a four-tidal-turbine array of such turbines was considered, along with the arrangement of the NEPTHYD pilot farm. Two ambient turbulence intensities and two integral length scales with several yawed flows were tested. It appears that the influence of the integral length scale was not clear in this study. The incidence of the flow impacted the turbines' wakes and induced a significant shear seen by blades in the wakes of upstream turbines.

Thiébot et al. [10] proposed an evaluation of the reliability of analytical models for estimating the efficiency of a fence of tidal turbines, intending to evaluate the annual energy production. A comparison was performed using numerical simulations. Simplified approaches were developed based on assumptions such as ideal flows, depending on the induction factor. The researchers were capable of providing the first characteristics of the effects of blockage on energy production. Regional numerical models with turbines represented by actuator disks also provided an estimation of the energy available via an array. In this paper, the authors applied the three-dimensional Telemac3D model to the realistic conditions of the Alderney Race (English Channel, northwest European shelf), and compared the results to the results of three analytical models incorporating the free surface evolution and the global blockage effects. It can be observed from this analysis that efficiency estimates vary in an important manner from one model to another, and provide lower efficiency than numerical estimation. As tidal energy potential was determined based on analytical solutions, it is possible that the assumed value could be lower than the real ones, even if simulations with actuator disks are also based on assumption.

In Hardwick et al. [10], the authors proposed a method to estimate the effect of waves on the tidal turbine resources at three tidal energy sites: Alderney Race, Big Roussel (Guernsey), and PTEC (Isle of Wight). They used a commercial 2D regional coupled flow wave model (Delt D-Flow 2D and SWAN) to compare the results without the wave module and with the flow–wave interaction (two-way coupling). They observed a net difference of less than 2.5% between the two configurations. However, when the directions of the flow and the waves were aligned, the difference increased to 7%, and even to 9% when the directions were opposite. Moreover, the authors showed that the result was site-dependent by examining the effects of several mechanisms. Thus, in the case of the three tested sites, the waves seemed to have little effect on the flow power. It remains to be determined whether they could have effects on the structure loading or the conditions of maintenance and installation.

Mullings and Stallard [5] focused on determining the variation in the fatigue loading of a tidal turbine depending on the depth positions and horizontal locations within a site. They considered site data from the European Marine Energy Centre (EMEC) test facility in Scotland, and used the 18 m diameter DEEP-gen 1 MW horizontal axis turbine as a model. A blade element method combined with a synthetic turbulence inflow was used to establish the loads along the blade for five tidal cycles with a given inlet flow. The analysis was performed for two horizontal locations at two positions in the water column (close to the bottom and close to the water surface) in which velocity profiles realized with the Acoustic Doppler Current Profiler (ADCP) were available. The authors showed that the damage equivalent load (DEL) was dependent on the horizontal location due to both the turbulence characteristics and wave effects, which differed depending on the position, either near the surface or close to the bottom. Their article also clearly demonstrates the need to understand the unsteady loading conditions at multiple positions within the same tidal site.

Coles et al. [12] provided a comparison of the performance of two hybrid systems based on tidal stream (Tidal Hybrid System, THS) and wind (Wind Hybris System, WHS) turbines combined with short-term battery storage and back-up oil generators. The authors considered the case of the Alderney island's energy supply. A 3 MWh battery was also considered. Tidal power was deduced from a 2D depth-averaged model of the English Channel, and wind power was deduced from NOAA-CIRES-DOE twentieth century re-analysis data and wind measurements from Alderney airport. The results demonstrate that the energy provided is dependent upon the intermittence of tidal or wind energy. Contrarily to wind turbines, which provide energy over a long period of time depending on the wind conditions, tidal stream turbines can provide energy for four periods per day. This high-frequency power cycling allows the combination of TST with battery storage, thus improving the efficiency of this coupling method in comparison with wind turbines, as the low energy provided over long periods of time may impact the use of oil generators. By making a comparison between THS and WHS, it can be deduced that the use of THS leads to (i) an oil-generated energy reduction of 63%; (ii) an increase in the battery energy supplied to the grid by a factor of approximately 6; and (iii) curtailed turbine energy, reduced by a factor of approximately 8. Both solutions were shown to be able to drastically reduce oil-generated energy (about 5 GWH/year), but the THS was more performant.

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