Available online at www.sciencedirect.com
ScienceDirect
Journal of Hydrodynamics
2016,28(6):1058-1064
DOI: 10.1016/S1001-6058(16)60711-4
www.sciencedirect.com/
science/journal/l0016058

Modelling hydrodynamic processes in tidal stream energy extraction*

Jie LIN（林杰）, Bin-liang LIN（林斌良）, Jian SUN（孙健）, Ya-ling CHEN（陈娅玲）
Department of Hydraulic Engineering, Tsinghua University, Beijing 100084, China,
E-mail: linjie13@mails.tsinghua.edu.cn

(Received June 18, 2016, Revised October 10, 2016)

Abstract: Tidal stream energy is a type of marine renewable energy which is close to commercial-scale production. Tidal stream turbine arrays are considered as the one of the most promising exploitation methods. However, compared to the relatively mature technology of single turbine design and installation, the current knowledge on the hydrodynamic processes of tidal stream turbine arrays is still limited. Coastal models with simplified turbine representations based on the shallow water equation are among the most favorable methods for studying the tidal stream energy extraction processes in realistic sites. This paper presents a review of the progress and challenges in assessing the tidal stream energy.

Key words: tidal stream energy, coastal flow field, shallow water equations, turbine parameterization

Introduction

Marine renewable-energies promise attractive, low environmental impact alternative supplements to the current energy system which highly depends on fossil and nuclear power plants[1]. Among the several forms of marine energy that are technically feasible to exploit, wave and tidal stream energy seems to be the two most promising choices, with the latter being more close to commercial-scale production because of its high predictability and relatively mature technology inherited from wind turbines. At present, a number of small or full scaled prototype tidal stream energy devices are undergoing sea tests, some of which have reached megawatt capacity and been connected to the grid[2]. Further updates of the equipment are underway, along with a number of projects on schedule[3], hopefully they will promote the tidal stream energy technology into the stage of small array exploitation in the next few years.

* Project supported by the National High-Technology Research and Development Program of China (863 Program, Grant No. 2012AA052602).
Biography: Jie LIN (1991-), Male, Ph. D. Candidate
Corresponding author: Bin-liang LIN,
E-mail: linbl@mail.tsinghua.edu.cn

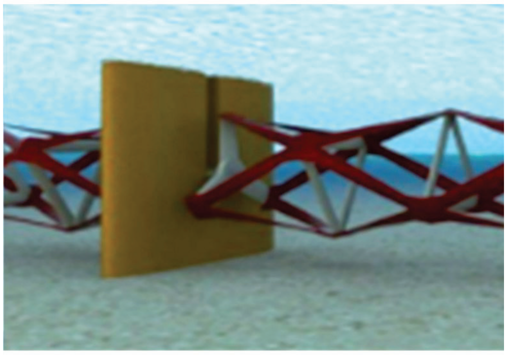
Considering the diffuse nature of tidal stream energy, the tidal turbine array is so far the most promising method for large scale tidal stream energy extraction, but whose effect on the flow field cannot be ignored as the number of turbines becomes significant. However, compared to deploying a single turbine, the knowledge on deploying a turbine array is still very limited. Problems such as turbines interaction within an array and its induced alternations in the flow field are not clear, but they may have large influences on the effectiveness of the turbine arrays and their environmental impacts. Thus, researches on the hydrodynamic processes of turbine arrays should be strengthened. Numerical modelling is so far among the best techniques for turbine array investigations. Complex turbine wakes along with their turbulent structures can be reproduced using a full 3-D model[4]. However, because of their high computational cost, such models cannot be used for simulating flows in a real tidal field, which usually has a large spatial coverage and complex bathymetry[5]. Considering the fact that the best tidal stream exploitation sites often locate in shallow coastal areas and the turbine array performance is highly site depended, the shallow water equation (SWE) based coastal models with simplified turbine representations are often employed for large scale tidal stream energy extraction modelling[6]. The predictions could provide an insight into the future scenarios of tidal stream energy exploitations.

1. Tidal stream energy conversion

1.1 *Tidal stream energy conversion devices*

To date, there are a number of tidal stream devices under development or being tested. The main designs of such devices are axial-flow turbines, cross-flow turbines, and oscillating devices[7-9]. Examples of the energy converters are presented below (see Fig.1, 2).

(a)



(b)

(c)

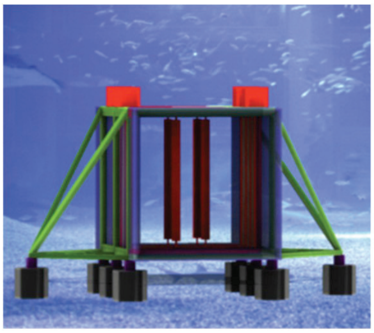
Fig.1 Examples of axial-flow turbines and cross-flow turbines[3,11-14]

An axial-flow turbine is a classical category of rotating machine which is similar to a modern wind turbine. The majority of current tidal stream converters are lift-based turbines with axial-flow design, whose blades are composed of two dimensional hydrofoil cross-sections[8]. Such turbines extract the kinetic energy from the moving water by the rotating blades, which are mounted on a horizontal hub paralleling to the incoming flow. The pressure differences across the blades result in a force component along the tangential direction of the rotor and thus provide a torque to the shaft. Examples of axial-flow turbines are SeaGen and Alstom turbines[2,10].

A cross-flow turbine is another classical category of rotating machine with its axis being normal to the incoming flow (either horizontal or vertical). In this case, the turbine works rather like the reverse of a combine harvester[7]. In a cross-flow turbine the rotor movement also relies on the pressure difference across the blades normal to the freestream[8] and the resultant rotation of the cylinder. The Kepler Energy transverse horizontal axis water turbine[11] and Gorlov helical turbine (GHT)[13] are examples of cross-flow turbines.

Two other important designs are oscillating-hydrofoil devices and vortex induced vibration devices. Among these two types of oscillating systems, oscillating-hydrofoil devices drive an arm to move with the lift force acting on a hydrofoil and converts the energy into electricity through a hydraulic system[7], see Fig.2. While vortex induced vibration devices make use of the alternating shedding vortices downstream of a bluff body exposed to the flow, which is a well-known flow induced phenomenon called Karman Street[8]. These vortices altering the pressure distribution on the body and causes periodic forces to act on a cylinder[15].

(a)



(b)

Fig.2 Examples of oscillating tidal stream energy converters[15,16]