International Journal of Marine Energy 6 (2014) 1–17

Contents lists available at ScienceDirect

International Journal of Marine Energy

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

A note on the power potential of tidal currents in channels

Scott Draper [a,*], Thomas A.A. Adcock [b], Alistair G.L. Borthwick [c], Guy T. Houlsby [b]

[a] Centre for Offshore Foundation Systems, University of Western Australia, Crawley 6009, Australia
[b] Department of Engineering Science, University of Oxford, Parks Road, Oxford, OX1 3PJ, UK
[c] School of Engineering, University of Edinburgh, Kings Buildings, Edinburgh EH9 3JL, UK

A R T I C L E I N F O

Article history:
Received 1 September 2013
Revised 1 May 2014
Accepted 1 May 2014
Available online 13 May 2014

Keywords:
Tidal energy
Tidal power
Tidal resource assessment
Tidal channel

A B S T R A C T

This paper presents a set of three simple one-equation formulas that can be used for rapid initial assessment of the tidal power potential of fast moving currents in both large straits and small tidal channels (as may exist close to isolated communities). The three formulas enhance previous published theoretical estimates and are consistent with each other in that any one of them can be used depending on which two of the following three input parameters are known: (i) the variation in water level at either end of the channel (or just at the ocean end for a channel connected to an enclosed bay); (ii) the peak undisturbed natural flow rate through the channel; or (iii) the approximate channel geometry and seabed drag coefficient. The formulas are derived using an electrical analogy of the dynamics of flow through a channel. Example calculations are given and the results compare favourably with previous estimates of power potential by alternative theoretical formulas and detailed numerical models.

1. Introduction

Resource assessments of tidal stream power generation were first undertaken about 5–10 years ago, with most attention paid to the sites off the United Kingdom (e.g., [3]) and North America (e.g.,

* Corresponding author. Tel.: +61 964887400.
E-mail address: scott.draper@uwa.edu.au (S. Draper).

http://dx.doi.org/10.1016/j.ijome.2014.05.001
2214-1669/

Nomenclature

a_0	amplitude of water level difference across a channel associated with the dominant tidal constituent [m]
$a_{0,j}$	amplitude of water level difference across a channel associated with additional tidal constituents [m]
a_1	amplitude of the free surface elevation in the large water body that connects to a channel and a smaller enclosed bay. Elevation associated with dominant tidal constituent [m]
$a_{1,j}$	amplitude of the free surface elevation in the large water body that connects to a channel and a smaller enclosed bay. Elevation associated with additional tidal constituents [m]
c	parameter defining geometry of tidal channel ($c = \int_0^l A^{-1}dx$) [m^{-1}]
g	acceleration due to gravity [m/s^2]
h	mean water depth as a function of position along a tidal channel [m]
i	complex number $\sqrt{(-1)}$ [-]
l	length of tidal channel [m]
t	time [s]
x	distance along channel [m]
A_e, l_e, h_e	effective geometric parameters which may be estimated for a tidal channel [m^2,m,m]
A	cross-sectional area as a function of position along tidal channel [m^2]
C	capacitance in an analogous electrical circuit [NA]
C_d	drag coefficient parameterising seabed friction in tidal channel [-]
I	current in an analogous electrical circuit [NA]
L	inductance in an analogous electrical circuit [NA]
$\overline{P}$	power extracted by tidal turbines, averaged over a tidal cycle [Watts]
$\overline{P}_{max}$	maximum power extracted by tidal turbines, averaged over a tidal cycle [Watts]
R	resistance in an analogous electrical circuit [NA]
S	surface area of enclosed bay [m^2]
$S_{channel}$	surface area of a channel connecting to an enclosed bay [m^2]
T	period of tidal wave (=$2\pi/\omega$) [s]
V	voltage in an analogous electrical circuit [NA]
Q	flow rate through the channel [m^3/s]
$Q_{0,max}$	maximum flow rate associated with the dominant tidal constituent before turbines are installed in channel [m^3/s]
$Q_{0,max,j}$	maximum flow rate associated with additional tidal constituents before turbines are installed in channel [m^3/s]
$Q_{0,max,S/N}$	maximum flow rate before turbines are installed at Spring tidal and Neap tide, respectively [m^3/s]
Z	impedance in an analogous electrical circuit [NA]
β	non-dimensional term which defines geometry of a channel connected to an enclosed bay [-]
γ	non-dimensional term which parameterises the effects of resistance and impedance on the maximum power extraction [-]
δ_t	parameter defining resistance due to tidal turbines [m^{-4}]
δ	parameter defining resistance due to bed friction in tidal channel [m^{-4}]
λ	non-dimensional term which parameterises natural bed friction, geometry and tidal amplitude for a tidal channel connecting two large bodies of water [-]
λ_1	non-dimensional term which parameterises natural bed friction, geometry and tidal amplitude for a tidal channel connected to an enclosed bay [-]
ξ	free surface elevation above still water level [m]
ξ_0	free surface elevation difference across channel [m]
ξ_1	free surface elevation in the large water body that connects to a channel and a smaller enclosed bay [m]
ρ	density of seawater [kg/m^3]