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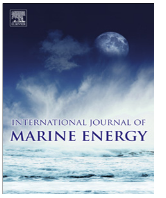

Field measurements of a full scale tidal turbine

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ABSTRACT

Field testing studies are required for tidal turbine device developers to determine the performance of their turbines in tidal flows. Full-scale testing of the SCHOTTEL tidal turbine has been conducted at Queen's University Belfast's tidal site at Strangford Lough, NI. The device was mounted on a floating barge. Testing was conducted over 48 days, for 288 h, during flood tides in daylight hours. Several instruments were deployed, resulting in an expansive data set. The performance results from this data set are presented here. The device, rated to 50 kW at 2.75 m/s was tested in flows up to 2.5 m/s, producing up to 19 kW, when time-averaged. The thrust on the turbine reached 17 kN in the maximum flow. The maximum system efficiency of the turbine in these flows reached 35%. The test campaign was very successful and further tests may be conducted at higher flow speeds in a similar tidal environment.

1. Introduction

The development of tidal energy converters and the advancement from lab-scale tests to prototype devices has accelerated in recent years. Many devices have been tank tested at model scales, such as Scotrenewables 1/40 to 1/7 scale tests [1] and Oceanflow 1/40 scale tests [2], and several have been deployed as full-scale devices; some examples of these are Andritz Hydro Hammerfest HS1000 [3],

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Nomenclature and abbreviations

ADP	Acoustic Doppler Profiler
ADV	Acoustic Doppler Velocimeter
C_T	coefficient of thrust
d	depth
d_h	hub depth
D_E	equivalent diameter
n	rotation rate
P_{el}	electrical power
PTO	power take-off
RPM	rotations per minute
STG	SCHOTTEL Tidal Generator
T	thrust
TEC	tidal energy converter
TSR	tip speed ratio
U_{in}	inflow velocity
$\eta_{system,i}$	system efficiency

Alstom TGL DeepGen [4], Marine Current Turbines SeaGen [5], Verdant Power KHPS [6], Atlantis Resources AR1000 [7] and Scotrenewables SR250kW [8]. One of the key features for device developers to understand is how their turbine performs in 'real' turbulent tidal flows compared to laboratory flows [9]. This can be assessed by deploying a medium- or full-scale device in tidal field studies.

Queen's University Belfast recently conducted a series of experiments to determine the effect of tidal flows on 1/10 scale devices [10], as well as testing the scale models of Oceanflow's Evopod device [2], and in doing so developed a tidal test centre in Strangford Lough, which has flow speeds up to 2.5 m/s. SCHOTTEL also recently conducted model scale towing tank tests as well as pushing tests of their full-scale device [11] and wished to develop their understanding of the turbine's performance in tidal flows at full-scale.

During the summer of 2014, Queen's University Belfast, SCHOTTEL and Fraunhofer IWES collaborated under the EU MaRINET project to conduct a series of field tests of a full-scale tidal turbine in highly turbulent flows in Strangford Lough, N.I. The full scale device, the SCHOTTEL Tidal Generator (STG), was designed and constructed by SCHOTTEL and deployed at the QUB tidal test facility from June through to September. The 4 m turbine, rated at 50 kW, operates from flow speeds of 0.8 m/s and reaches maximum power at 2.75 m/s, so was operational at the QUB site. The turbine characteristics, inflow conditions and loading on the structure and rotor were all measured and used to calculate the performance characteristics of the turbine.

The testing method and turbine performance characterisation were guided by the IEC62600-200 Technical Specification for Tidal Energy Converter (TEC) power performance assessment [12]. Several parts of the IEC TS standard were used for reference, particularly in terms of data processing, though there were several sections that differed from the testing performed. The TS is useful as a tool because it provides guidelines on techniques such as device placement, filtering and depth-averaging velocities, along with many testing methods. The main advantages of using the TS is that it gives a good basis for testing methods and data analysis techniques employed, and it also allows different devices to be directly compared in terms of site characteristics, turbine performance and operation. There are specific requirements for reporting the site conditions; however, this paper will focus on the turbine performance and output, rather than the site itself. Clauses of the TS used will be indentified in the text.

The key objectives of this paper are: to present a vessel-mounted testing method for field studies of medium- and full-scale tidal devices; to investigate the performance of a full-scale device in tidal flows; and to apply the IEC standards to data processing. This paper details: the tidal field site