ABSTRACT

To utilize effectively tidal stream, the authors have developed a counter-rotating type tidal stream power unit composed of tandem propellers and a peculiar generator with double rotational armatures. This paper prepares a prototype power unit with a synchronous type generator with net output of 1.5 kW, where the front propeller with a diameter of 1 m has three blades and the rear propeller with a diameter of 0.95 m has five blades. The propellers start rotating and generating power at a moderate stream velocity and the unit reaches a maximum output (power generation) at a relative tip speed ratio specified in the unit design. The hydrodynamic forces acting on a pile attached to the unit are affected by the velocity in the stream direction, but the force vertical to the stream is obviously tiny as the rotational moment is counter balanced in the power unit.

KEY WORDS: Tidal stream; prototype power unit; counter-rotation; tandem propellers; double rotational armatures; output; hydrodynamic force.

INTRODUCTION

It has been requesting, for building a sustainable global civilization, to exploit clean and renewable energy resources. Tidal stream, whose power can be predicted sequentially, may be one of favorable and abundant resources (Bahaj and Myers, 2003; Bahaj, 2011), and many types of power units have been proposed to utilize effectively the stream. Beneficial data for a hydrodynamic design of horizontal axis type tidal stream turbines has been proposed by numerical simulations and experiments in a cavitation tunnel and a towing tank (Batten, Bahaj, Molland and Chaplin, 2007; Bahaj, Molland, Chaplin and Batten, 2007; Bahaj, Batten and McCannih, 2007). The cavitation, undersea noise, and wake flow of the propeller have also been investigated experimentally (Wang, Atlar and Sampson, 2007). Marine Current Turbines Ltd. had installed a two-bladed turbine at Devon coast, which is the world’s first tidal current turbine in open sea conditions without a connection to the grid system (IT Power, Seacore, Gesamthochschule Kassel, and Jahnke-Kesterman, 2005). The European Marine Energy Centre (EMEC) Ltd. established at 2003 in Orkney Island has provided test sits for developers of both wave and tidal energy converters. They are, for instance, 250 kW open centered turbine of OpenHydro in 2006, 500 kW turbine of Tidal Generation Ltd’s (TG, now Alstom) in 2010, 1 MW horizontal axis turbine AR1000 of Atlantis Resource Corporation in 2011, 1 MW pre-commercial tidal turbine of ANDRITZ HYDRO Hammerfest in 2012, 1 MW horizontal axis turbine HyTide 1000 of Voith in 2013, and so on (http://www.emec.org.uk/).

Tidal stream power units with counter-rotating type tandem propellers have also been proposed. The mechanism, where the tandem propellers drive a bevel gear connected to the traditional generator shaft, has been presented (Lee, Kim, Hyun and Lee, 2014). Professor Clarke et al. discussed how to not only install the propellers on the generator but also design the blades, and then investigated the performances (Clarke, Connor, Grant and Johnstone, 2007; Clarke, Connor, Grant, Johnstone and Mackenzie, 2007; Clarke, Connor, Grant, Johnstone and Ordonez-Sanchez, 2009). The prototype manufactured by Nautricity Limited has been provided to the Null of Kintyre in Scotland for demonstrating the power generation (Nautricity, 2013).

The authors had also developed a counter-rotating type hydroelectric unit composed of tandem runners and a peculiar generator with double rotational armatures (Kanemoto, Tanaka and Kashiwabara, 2001; Tanaka, Kanemoto and Aoki, 2006; Kasai, Usui, Nakamura, Kanemoto and Tanaka, 2009) and prototypes are available for sale in a hydropower market (Kyowa, 2016), where a field magnet/coil and an armature in the generator are correctly called the double rotational armatures in this paper. The front and the rear propellers counter-rotate directly the inner and the outer armatures, respectively. The relative rotational speed is two times faster than a single propeller/armature speed while the rotational moment is counter-balanced in the unit. The unit has promising advantages as follows (Kanemoto, 2010). (a) The induced voltage, affecting on the efficiency of the electric power transmission, is sufficiently higher while keeping the armature diameter as same as the traditional one. (b) The diameter of the armature, affecting on the unit size and weight, can be reduced while keeping the induced voltage as same as the traditional one. (c) The cavitation in the propellers affecting on material erosion, vibration and undersea noise can be suppressed well as the rotational speed can be relatively slower.