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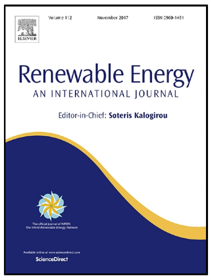

Blade-pitch system for tidal current turbines with reduced variation pitch control strategy based on tidal current velocity preview

Ya-jing Gu, Yong-gang Lin, Quan-kun Xu, Hong-wei Liu, Wei Li

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Blade-pitch system for tidal current turbines with reduced variation pitch control strategy based on tidal current velocity preview

Ya-jing Gu, Yong-gang Lin*, Quan-kun Xu, Hong-wei Liu, Wei Li
State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University, Zheda Rd.38, 310027 Hangzhou, PR China

Abstract

A collective pitch control system is designed using a rack and pinion gear set and hydraulic drive to provide an available blade pitch angle from 0° to 180°. This response accounts for the tidal current bi-directionality caused by flood and ebb under the moon's gravitational force. A front-installed hydraulic cylinder drives the rack-and-pinion system to synchronously turn the blades. Mechanisms are designed to overcome the difficulties of an outer hydraulic oil being deposited into the rotary hub and the pitch angle detection in a rotary hub. This simple and compact structure in a narrow hub reduces current blocking. Experimental results demonstrate that the pitch system has excellent dynamic characteristics. A tidal current velocity preview (CVP) method is proposed to overcome the difficulty of current velocity detection at the rotary impeller. Sealing is important for these underwater conditions. Hence, a reduced variation pitch control strategy is proposed based on CVP to reduce pitch action, which decreases mechanical wear of the sealing structure while extending the tidal current turbine's working life. Comparative results are obtained by using both an approximate sinusoidal current velocity data set simulating periods of real flow and a sea trial measured data set containing highly-turbulent and velocity-sheared flow in a semi-physical test. This test validated the significant reduction of pitch action and relatively high efficiency for energy generation.

Keywords: Tidal current turbine, Blade-pitch system, Current velocity preview (CVP), Reduced variation pitch control strategy, Pitch action reduction.

1. Introduction

The energy crisis and environmental pollution have become the major challenges for human survival and development. To create a sustainable environment, researchers and developers have started the journey of researching potential renewable energy resources and trying to harness those energy sources for electricity generation through the development of innovative technologies [1]. Among the many types of renewable energy, tidal current energy, which is caused by flood and ebb due to the gravitational force of the moon, is highly predictable and reliable [2] and hence is considered one of the most promising energy resources [3]. A tidal current turbine developed from a wind turbine and marine propeller is attracting increasingly more attention because of its higher energy density, stability and longer uninterrupted working time compared with a wind turbine, and low cost and environmental friendliness compared with traditional damming-based tidal power generation [4, 5]. At present, tidal current turbines are being developed toward megawatt class scales, and multi-megawatt farms are being constructed for large-scale commercial utilization [6, 7].

The pitch control system in a tidal current turbine plays three roles. The first is to pitch the blades from 0° to 180° to make full use of the bi-directional current. The second is to keep the captured power at its rated value above the rated current velocity. The third is to stop the turbine through the pitching the blades downstream to protect it during strong flows [8]. Existing pitch control systems of a tidal current turbine are mostly of electrical types that are driven by electromotors [9, 10]. In Ref. [11], a DC motor with a reducer installed in hub is achieved to drive 3 blades for a horizontal axis tidal current turbine. However, the electrical blade-pitch system requires a dry working environment. Once the water flows into the hub, it will soon fail. Plus, electromotors are a questionable solution because of the large sea flow blade loading.

A sealing structure at the blade roots is of high importance. In the present control strategy, a continuous pitch action is necessary to track the variation of the tidal current velocity for maintaining the generator power when above the rated current velocity. In Ref. [12], the way of limiting output power and shedding mechanical load at high flow speeds for tidal stream turbines is to force the rotating speed of the permanent magnet synchronous generator to track a reference value. Since the pitch system is an actuator, an inner-loop pitch angle control method was adopted. Simulation was undertaken in Tidal Bladed and MATLAB. The result was

* Corresponding author. Tel.: +86 15990197966; fax: +86 0571 87951941.
E-mail address: yglin@zju.edu.cn