A Numerical Study of Darrieus Water Turbine

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ABSTRACT

The aim of this paper is to compare the hydrodynamic performances and structural responses of different vertical axis hydrokinetic turbine (Darrieus water turbine). The performances were evaluated using a computational method based on the Double-Multiple Streamtube model and the structural analyses were completed using a general-purpose commercial finite element analysis software. Among the multiple plan form geometries available for Darrieus water turbines, the H-Darrieus offers some advantage over Troposkien blades on performance, but are penalized by large bending moments. Troposkien blades can withstand stronger hydrodynamic loads and are considered more suitable for large-scale applications.

KEY WORDS: Double-Multiple Streamtube model, vertical axis hydrokinetic turbine, H-Darrieus, Troposkien, rotor efficiency, structural analysis.

INTRODUCTION

In an effort to reduce greenhouse gas emissions, the search for clean and affordable electrical power from renewable energies has now reached the ocean underwater.

Water covers approximately 70% of the earth's surface and represents an enormous potential as a source of reliable energy. Hydrokinetic water turbines operate using the same principles as lift driven wind turbines, however with seawater being approximately 832 times denser than air, the amount of kinetic energy available in a 4 knots (or 2.06 m/s) ocean current is equivalent to that of a wind velocity of 19.4 m/s. In addition, ocean and tidal currents are more predictable and consistent than wind, simplifying the integration of large hydrokinetic water turbine plants to electrical networks. Moreover, hydrokinetic water turbines do not require a pressure head in the water in order to operate, thus allowing them to be used without any prior alteration to the water flow in order to build a potential difference.

In wind turbines, the loading conditions are dominated by the centrifugal force, however water turbines operate at a much lower rotational speed and in a much denser fluid, as a result hydrodynamic loads are dominant. Moreover, in such condition and for some applications, the vertical axis hydrokinetic turbine (or Darrieus water turbine) could benefit from some advantages over the horizontal axis, offering diverse possibilities in blade shapes and fixations. For example, it is possible to install a Darrieus water turbine having a greater diameter than height, enabling a larger swept area in shallow streams, hence a higher power output per turbine. Also, the electrical and mechanical components can be sited on a floating platform thanks to the vertical central shaft or tower, which provides easier maintenance and for applications in deep water, an assembly of Darrieus water turbines could be piled up along the vertical central shaft. Other advantages of Darrieus turbines are that they are less sensitive to turbulence and insensitive to flow direction. Moreover, a recent study showed that Darrieus turbines can be placed in a manner so that their mutual flow interaction increases their overall performance (Whittlesey, 2010).

Among the multiple plan form geometries available for Darrieus turbines, the straight blades geometry (or H-Darrieus) is much simpler to build and needs shorter blades for a given rotor swept area. Since all the blade sections are at the same distance to the rotation axis and have the same inclination (being parallel to the rotation axis), the flow characteristics are more uniform spanwise and the lift vectors are contained in a perpendicular plane to the rotation axis, which translates into increased hydrodynamic efficiency. On the other hand, this design usually includes a number of struts to support the blades and connect them to the central shaft. The struts disturb the flow through the rotor and their parasitic drag lowers the turbine’s torque and power output. Moreover, due to their finite span, the H-Darrieus blades behave like finite aspect ratio wings, generating induced drag that affects the rotor performance. Additionally, the blades are subjected all across their span to the same centrifugal force.