Flow-Induced Vibration Marine Current Energy Harvesting Using a Symmetrical Balanced Pair of Pivoted Cylinders

Authors : Brad Stappenbelt

Abstract : The phenomenon of vortex-induced vibration (VIV) for elastically restrained cylindrical structures in cross-flows is relatively well investigated. The utility of this mechanism in harvesting energy from marine current and tidal flows is however arguably still in its infancy. With relatively few moving components, a flow-induced vibration-based energy conversion device augers low complexity compared to the commonly employed turbine design. Despite the interest in this concept, a practical device has yet to emerge. It is desirable for optimal system performance to design for a very low mass or mass moment of inertia ratio. The device operating range, in particular, is maximized below the vortex-induced vibration critical point where an infinite resonant response region is realized. An unfortunate consequence of this requirement is large buoyancy forces that need to be mitigated by gravity-based, suction-caisson or anchor mooring systems. The focus of this paper is the testing of a novel VIV marine current energy harvesting configuration that utilizes a symmetrical and balanced pair of horizontal pivoted cylinders. The results of several years of experimental investigation, utilizing the University of Wollongong fluid mechanics laboratory towing tank, are analyzed and presented. A reduced velocity test range of 0 to 60 was covered across a large array of device configurations. In particular, power take-off damping ratios spanning from 0.044 to critical damping were examined in order to determine the optimal conditions and hence the maximum device energy conversion efficiency. The experiments conducted revealed acceptable energy conversion efficiencies of around 16% and desirable low flow-speed operating ranges when compared to traditional turbine technology. The potentially out-of-phase spanwise VIV cells on each arm of the device synchronized naturally as no decrease in amplitude response and comparable energy conversion efficiencies to the single cylinder arrangement were observed. In addition to the spatial design benefits related to the horizontal device orientation, the main advantage demonstrated by the current symmetrical horizontal configuration is to allow large velocity range resonant response conditions without the excessive buoyancy. The novel configuration proposed shows clear promise in overcoming many of the practical implementation issues related to flow-induced vibration marine current energy harvesting.

Keywords : flow-induced vibration, vortex-induced vibration, energy harvesting, tidal energy
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