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Passively morphing blades for load alleviation of tidal turbines

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Abstract

Tidal turbines are exposed to time variable loading that can lead to premature failure [1,2]. The use of passive unsteady load mitigation technology, such as bend-twist coupling, is typically limited to low frequency fluctuations and is not suitable to large blades, due to structural rigidity requirements. Active control systems, such as actuated flaps, can respond to higher frequencies than whole-blade passive devices due to their smaller size [3]. However, active systems may reduce turbine reliability. Hence there is a need to develop reliable technology that mitigates unsteady loading in a varied range of frequencies, in order to prolong the fatigue life of tidal turbines. Analytically, it is possible to cancel the unsteady loading of a tidal turbine that rotates through the ocean shear layer with a fully chordwise highly flexible blade. Here, we demonstrate that under attached flow conditions, when a blade is rigid near the leading-edge and flexible near the trailing-edge, the unsteady load mitigation is proportional to the ratio of the flexible length to the full chord of the blade. We verify this relationship experimentally with a blade that has a passively morphing trailing-edge. The morphing trailing-edge extends 25% of the chord of the blade and it allows unsteady load mitigation of up to 25%, without any variation in the mean load - thus there is no penalty in terms of power extraction. In separated flow conditions, when the length-scale of vortical structures is similar to that of the flexible part of the blade, the load mitigation is about 15%. Hence, chordwise morphing blades alleviate loads in variable flow conditions and can contribute to tidal turbine survivability in a reliable way.

References

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