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Experimental Demonstration of Passively Pitching Blades for Tidal Turbines

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ABSTRACT

Tidal energy is a sustainable and predictable source of renewable energy. However, tidal turbines operate in hostile flow environments, leading to large unsteady forces acting on the blades which cause structural fatigue. Tidal turbines generally adopt collective pitch control, that allow the blades to adjust its pitch in accordance to the oncoming flow velocity, Bossanyi (2001). However, active pitch control systems require complex mechanisms that can increase the costs associated with survivability and maintenance. Viola et. al. (2022), first introduced the concept of a passive pitch mechanism that allows the blades to pitch freely in response to the oncoming flow. This can be done, for example, by prescribing a constant torque to the blades by means of a spring. Gambuzza et, al. (2025), demonstrated experimentally the effectiveness of passively pitching blades in maintaining rated power, while reducing the thrust loads. Previous studies have examined the effect of passive pitch systems on torque and thrust loads acting on the turbine in response to changes in tip speed ratio, flow velocity and direction. However, there are no studies reported on the effect of preload on the performance of passive pitch turbines. In the present study, we aim to address this gap by means of experiments on a $1.39\,\mathrm{m}$ diameter turbine equipped with three independently passive pitching blades and an analytical low order model using blade element momentum theory. Experiments are conducted in the University of Edinburgh's Flowave Ocean Energy Research Facility. Results indicate that at every flow velocity, we can design a spring that allow the passive pitch blades to match the performance of the rigid/fixed pitch blades. We identified an optimum preload that allows the turbine to maintain rated power, while reducing thrust fluctuations by nearly 30%. Hydrodynamic efficiency is increased significantly, to nearly 78% compared to 55% in the case of fixed pitch blades. Results from BEMT on a $24\,\mathrm{m}$ diameter full scale turbine show that a turbine equipped with passive pitch blades can maintain rated power by increasing the rotational speed marginally by 17% compared to a 280% increase required in the case of fixed pitch blades.

References

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