Fixed-Pitch Blades for Passive-Feather Power Regulation of Tidal Turbines

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Work stream x:<Power Take Off Development/Reliability/Turbulence>

Introduction

The Problem: The tidal stream industry's focus is cost and risk reduction. At present, systems regulating power captured are costly, complex and vulnerable; discussed by Burton et al [1], Hansen [2], amongst others.

The Hypothesised Solution: Power is passively regulated with mechanically simple, robust design.

Research Goal: Develop a blade design to achieve this.

In Theory

The vectors of tidal flow, U_∞, a 2D blade section's tangential velocity, Ωr, and the rotor's effect on the flow give the relative flow vector, W, and the angle of attack, α; α determines how much power is captured.

Exceeding Rated Conditions: *Figure1* shows a blade section during operation at rated conditions

Figure 1 – Rated Flow

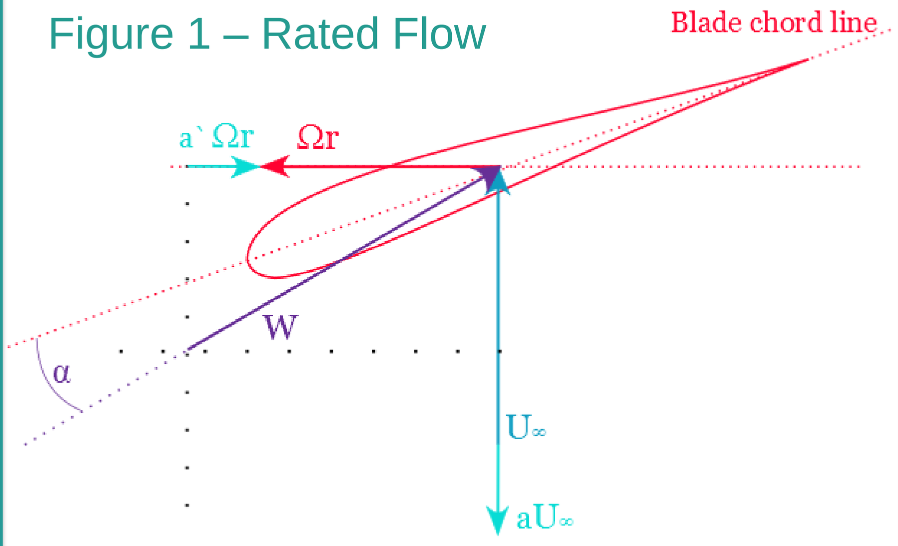
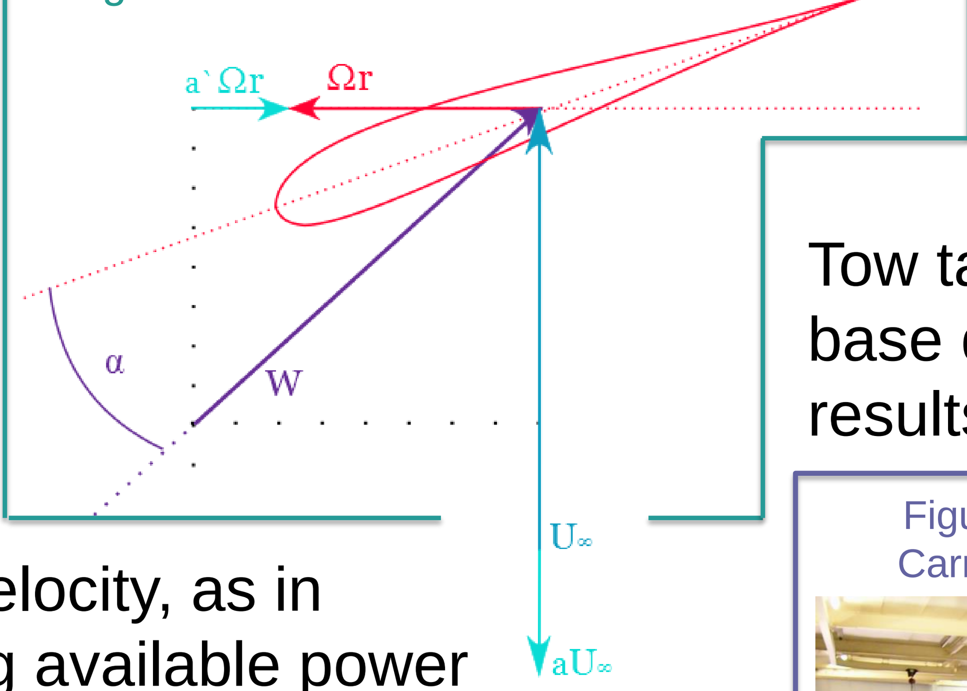
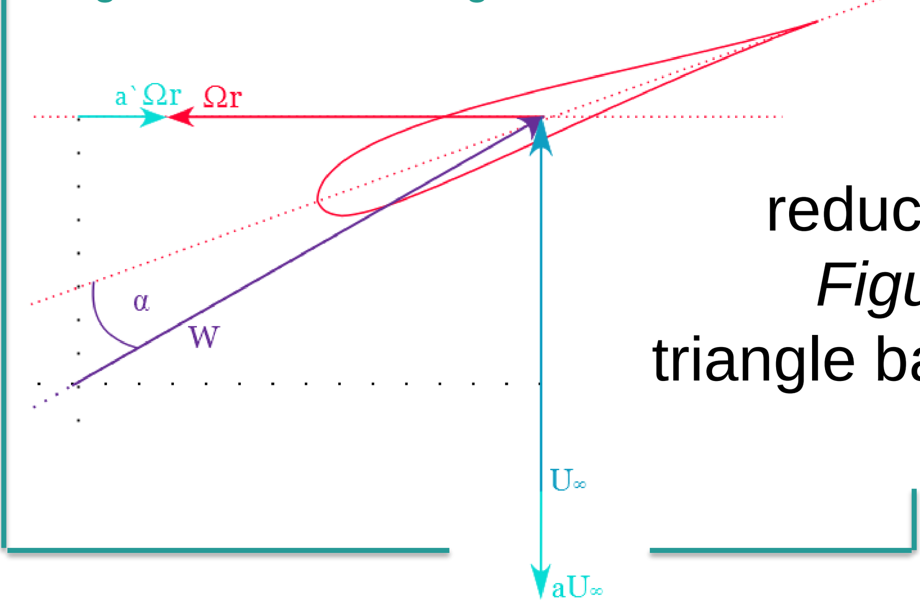


Figure 2 – Increased Tide



When the tide exceeds rated velocity, as in *Figure 2,* α increases; capturing available power would damage the system. α must be reduced.

Figure 3 – Power Regulation



Passive Feathering of α: Allowing the rotor to speed up (increasing Ω) reduces α towards feather. As in *Figure 3*, this brings the vector triangle back to rated conditions and passively regulates power.

In Practice

Controlling Ω: Wind tunnel tests showed reducing load on the generator increased Ω, which allowed λ - thus C_P - to be controlled; *Figure 4* illustrates.

Figure 4 - C_P-λ curves of the wind turbine at different flow velocities

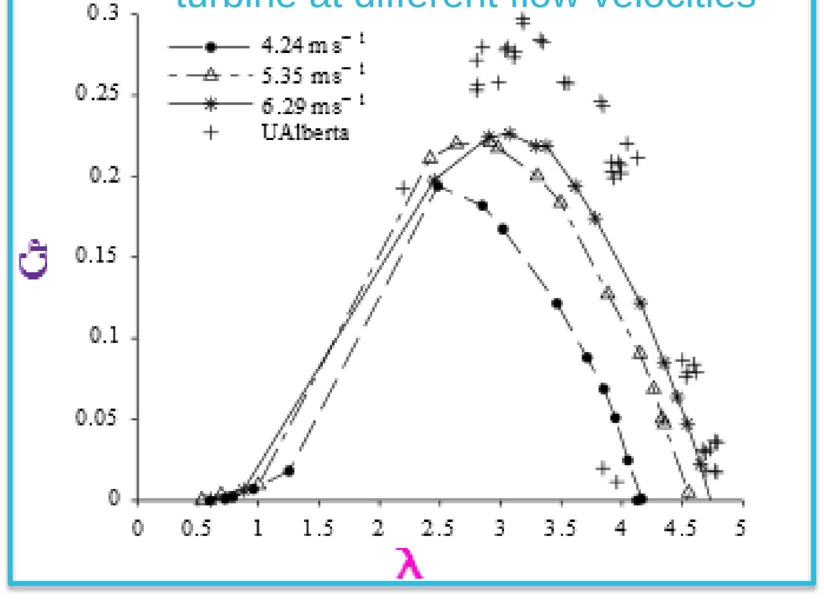
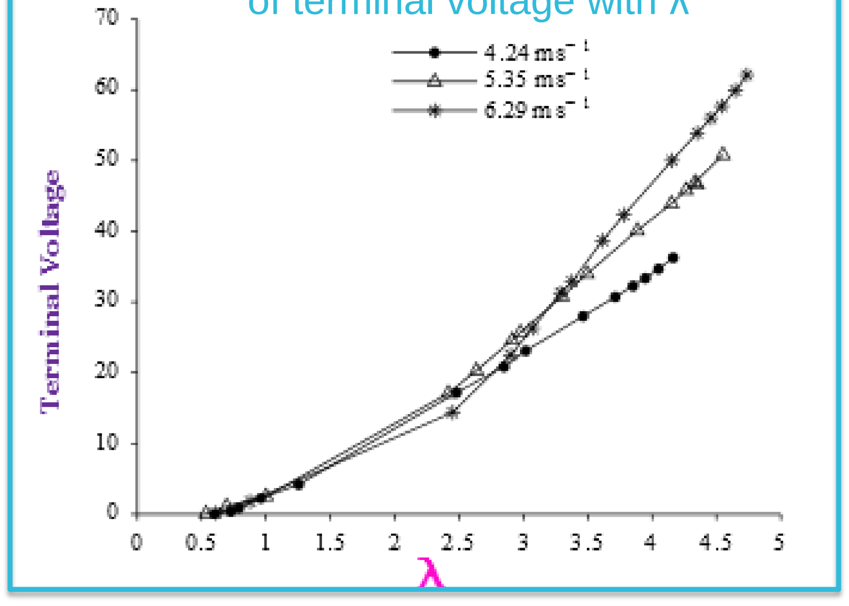


Figure 5 – Variation of terminal voltage with λ



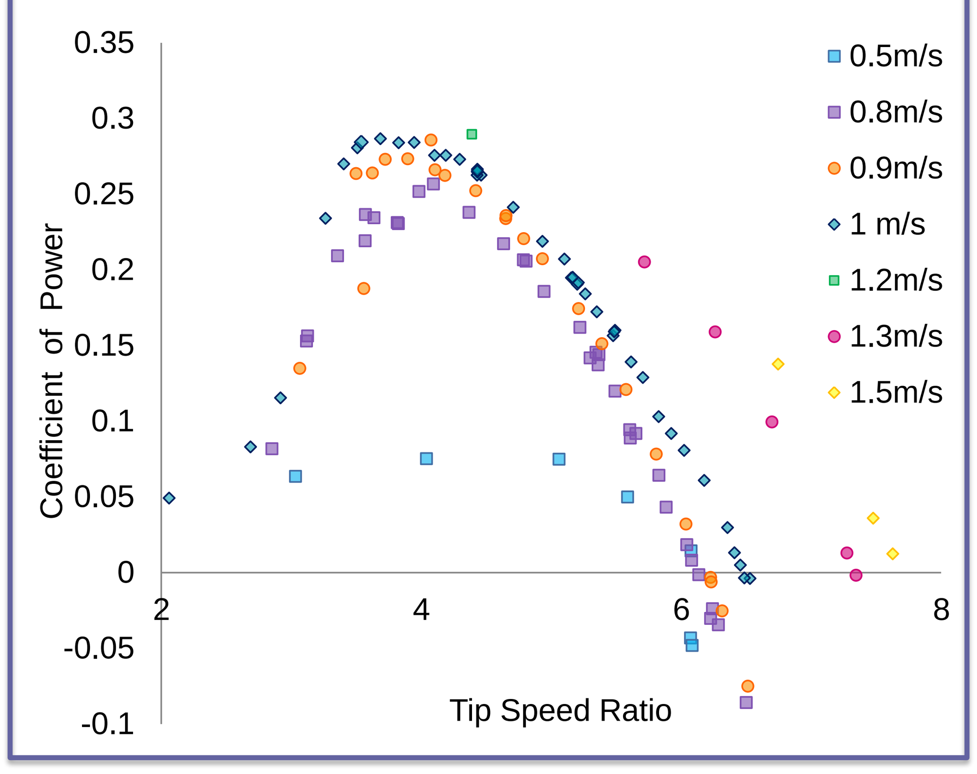
As *Figure* 5 shows, terminal voltage increased by up to 164%, suggesting the extent of increase in λ will be important in designing blade performance. The pattern of change in thrust force with λ will be a further consideration in blade design.

Base Data Set

Tow tank tests have been run (shown in *Figure 6*) to provide a base data set of tidal rotor performance. Highly repeatable results have been produced, as *Figure 7* illustrates.

Figure 6 - Test Rig installed on Tow Carriage during Testing in Tow Tank

Figure 7 - Experimentally Obtained Performance Curves



Future Work

Analysis of the electrical output of a generator under the conditions of the tested rotor will follow. The tow tank results will be used to verify a BEMT code. Alongside a Performance Design Code previously developed by the author, this will be used to inform future blade design processes so that blades can operate in passive-feather power regulation while upholding system constraints

References

[1] Burton, N. Jenkins, D. Sharpe, and E. Bossanyi, Wind energy handbook, 2001.

[2] M. Hansen, Aerodynamics of wind turbines, 2008.

Acknowledgements

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